MAKING MODERN LIVING POSSIBLE

Design Guide
VLT® HVAC Basic Drive FC 101

THE REAL DRIVE

Contents

1 Introduction

1.1 Purpose of the Manual

This design guide provides information on how to select, commission and order a frequency converter. It provides information about mechanical and electrical installation.

The design guide is intended for use by qualified personnel.
Read and follow the design guide to use the frequency converter safely and professionally, and pay particular attention to the safety instructions and general warnings.

1.2 Document and Software Version

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

Edition	Remarks	Software version
MG18C5xx	Replaces MG18C4xx	2.51

Table 1.1 Document and Software Version

1.3 Safety Symbols

The following symbols are used in this document.

WARNING

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

CAUTION

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

NOTICE

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

1.4 Abbreviations

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

Table 1.2 Abbreviations

1.5 Additional Resources

- *VLT® HVAC Basic Drive FC 101 Quick Guide*
- *VLT® HVAC Basic Drive FC 101 Programming Guide* provides information on how to programme and includes complete parameter descriptions.
- *VLT® HVAC Basic Drive FC 101 Design Guide* entails all technical information about the frequency converter and customer design and applications.
- *MCT 10 Set-up Software* enables the user to configure the frequency converter from a Windows™ based PC environment.
- Danfoss VLT®

  ® Energy Box Software allows energy consumption comparisons of HVAC fans and pumps driven by Danfoss frequency converters and alternative methods of flow control. This tool may be used to project, as accurately as possible, the costs, savings, and payback of using Danfoss frequency converters on HVAC fans and pumps.

1.6 Definitions

Frequency Converter

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

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

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

Input

The connected motor can start and stop with LCP and the digital inputs. Functions are divided into 2 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 1.3 Control Commands

Motor

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

f_M
The motor frequency.

f_{MAX}
The maximum motor frequency.

f_{MIN}
The minimum motor frequency.

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

I_M
The motor current.

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

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

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

U_M
The instantaneous motor voltage.

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

Break-away torque

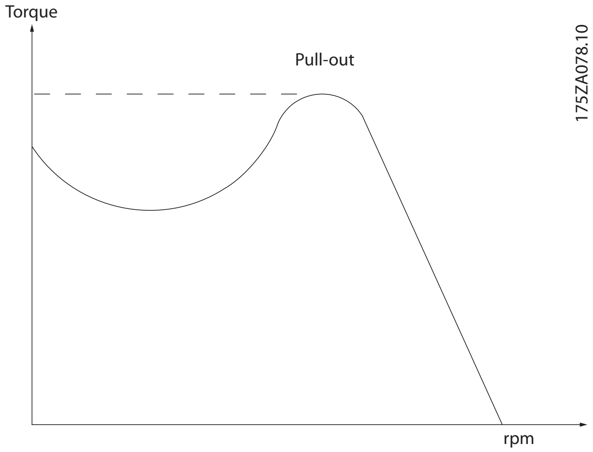


Illustration 1.1 Break-away Torque

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

Start-disable command
A stop command belonging to the group 1 control commands, see *Table 1.3*.

Stop command
See Control commands.

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

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

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

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

Analog inputs
The analog inputs are used for controlling various functions of the frequency converter.
There are 2 types of analog inputs:
Current input, 0-20 mA and 4-20 mA
Voltage input, 0-10 V DC.

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

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

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

Digital outputs
The frequency converter features 2 Solid State outputs that can supply a 24 V DC (max. 40 mA) signal.

Relay outputs
The frequency converter features 2 programmable Relay Outputs.

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

Initialising
If initialising is carried out (*14-22 Operation Mode*), the programmable parameters of the frequency converter return to their default settings.
Initialising; *14-22 Operation Mode* does not initialise communication parameters.

Intermittent duty cycle
An intermittent duty rating refers to a sequence of duty cycles. Each cycle consists of an on-load and an off-load period. The operation can be either periodic duty or none-periodic duty.

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

lsb
Least significant bit.

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

msb
Most significant bit.

On-line/Off-line parameters
Changes to on-line parameters are activated immediately after the data value is changed. Press [OK] to activate off-line parameters.

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

RCD
Residual Current Device.

Set-up
Parameter settings in 2 set-ups can be saved. Change between the 2 parameter set-ups and edit one set-up, while another set-up is active.

Slip compensation
The frequency converter compensates for the motor slip by giving the frequency a supplement that follows the measured motor load keeping the motor speed almost constant.

Smart Logic Control (SLC)
The SLC is a sequence of user defined actions executed when the associated user defined events are evaluated as true by the SLC.

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

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, for example, 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 locked 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.

1.7 Power Factor

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

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

The power factor for 3-phase control:

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

The power factor indicates to 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.
The frequency converters built-in DC coils produce a high power factor, which minimizes the imposed load on the mains supply.

2 Product Overview

2.1 Safety

2.1.1 Safety Note

WARNING

DANGEROUS VOLTAGE

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. Disconnect the frequency converter from mains, if repair work is to be carried out. Check that the mains supply has been disconnected and that the necessary time has passed before removing motor and mains plugs.
2. The [Off/Reset] key does not disconnect the equipment from mains and is thus not to be used as a safety switch.
3. Correct protective earthing of the equipment must be established, 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 currents are higher than 3.5 mA.
5. Protection against motor overload is set by *1-90 Motor Thermal Protection*. If this function is desired, set *1-90 Motor Thermal Protection* to data value *[4], [6], [8], [10] ETR trip]* or data value *[3], [5], [7], [9]ETR warning*.
Note: The function is initialised at 1.16 x rated motor current and rated motor frequency. For the North American market: The ETR functions provide class 20 motor overload protection in accordance with NEC.
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. Check that all voltage inputs have been disconnected and that the necessary time has elapsed before commencing repair work.

Installation at high altitudes

CAUTION

At altitudes above 2 km, contact Danfoss regarding PELV.

WARNING

UNINTENDED START

1. **The motor can be brought to a stop with digital commands, bus commands, references or a local stop, while the frequency converter is connected to mains. These stop functions are not sufficient to avoid unintended start and thus prevent personal injury.**
2. **While parameters are being changed, the motor may start. Consequently, always activate the stop key [Off/Reset] before modifying data.**
3. **A motor that has been stopped may start if faults occur in the electronics of the frequency converter, or if a temporary overload or a fault in the supply mains or the motor connection ceases.**

WARNING

HIGH VOLTAGE

Frequency converters contain high voltage when connected to AC mains input power. Installation, start up, and maintenance should be performed by qualified personnel only. Failure to perform installation, start up, and maintenance by qualified personnel could result in death or serious injury.

WARNING

UNINTENDED START

When the frequency converter is connected to AC mains, the motor may start at any time. The frequency converter, motor, and any driven equipment must be in operational readiness. Failure to be in operational readiness when the frequency converter is connected to AC mains could result in death, serious injury, equipment, or property damage.

WARNING

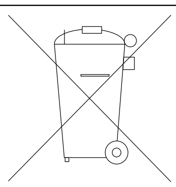
DISCHARGE TIME

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 [V]	Power range [kW]	Minimum waiting time [min]
3x200	0.25–3.7	4
3x200	5.5–45	15
3x400	0.37–7.5	4
3x400	11–90	15
3x600	2.2–7.5	4
3x600	11–90	15

Table 2.1 Discharge Time

2.1.2 Disposal Instruction



Equipment containing electrical components may not be disposed of together with domestic waste.
It must be separately collected with electrical and electronic waste according to local and currently valid legislation.

2.2 CE Labeling

2.2.1 CE Conformity and Labeling

What is CE Conformity and Labeling?
The purpose of CE labeling 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 three EU directives:
The machinery directive (98/37/EEC)
All machines with critical moving parts are covered by the machinery directive of January 1, 1995. Since a frequency converter is largely electrical, it does 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. Danfoss do this by means of a manufacturer's declaration.
The low-voltage directive (73/23/EEC)
Frequency converters must be CE labeled 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 (89/336/EEC)
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 the instructions in this Design Guide. In addition, Danfossspecifies which standards our products comply with. Danfossoffers 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.

2.2.2 What is Covered

The EU "*Guidelines on the Application of Council Directive 89/336/EEC*" outline three typical situations of using a frequency converter. See *2.2.3 Danfoss Frequency Converter and CE Labeling* for EMC coverage and CE labeling.

1. The frequency converter is sold directly to the end-consumer. The frequency converter is for example sold to a DIY market. The end-consumer is a layman. He installs the frequency converter himself for use with a hobby machine, a kitchen appliance, etc. For such applications, the frequency converter must be CE labeled in accordance with the EMC directive.
2. The frequency converter is sold for installation in a plant. The plant is built up by professionals of the trade. It could be a production plant or a heating/ventilation plant designed and installed by professionals of the trade. Neither the frequency converter nor the finished plant has to be CE labeled under the EMC directive. However, the unit must comply with the basic EMC requirements of the directive. This is ensured by using components, appliances, and systems that are CE labeled under the EMC directive.

3. The frequency converter is sold as part of a complete system. The system is being marketed as complete and could for example, be an air-conditioning system. The complete system must be CE labeled in accordance with the EMC directive. The manufacturer can ensure CE labeling under the EMC directive either by using CE labeled components or by testing the EMC of the system. If only CE labeled components are chosen, the entire system does not have to be tested.

2.2.3 Danfoss Frequency Converter and CE Labeling

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

However, CE labeling may cover many different specifications. Check what a given CE label specifically covers.

The covered specifications can be very different and a CE label may therefore give the installer a false feeling of security when using a frequency converter as a component in a system or an appliance.

Danfoss CE labels the frequency converters in accordance with the low-voltage directive. This means 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 labeling in accordance with the low-voltage directive.

The CE label also applies to the EMC directive provided that 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.

The Design Guide offers detailed instructions for installation to ensure EMC-correct installation. Furthermore, Danfoss specifies which our different products comply with.

Danfoss provides other types of assistance that can help to obtain the best EMC result.

2.2.4 Compliance with EMC Directive 89/336/EEC

As mentioned, the frequency converter is mostly 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. 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, if the EMC-correct instructions for installation are followed.

2.3 Air Humidity

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

2.4 Aggressive Environments

A frequency converter contains many 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.

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 IP54. As an extra protection, coated printed circuit boards can be ordered as an option. (Standard on some power sizes.)

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 dusty environments, use equipment with enclosure rating IP54 or a cabinet for IP20/TYPE 1 equipment.

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

Such chemical reactions rapidly affects and damages 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.

2

NOTICE

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

Before installing the frequency converter, check the ambient air for liquids, particles, and gases. 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.

2.5 Vibration and Shock

The frequency converter has been tested according to the procedure based on the shown standards, *Table 2.3*

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

Table 2.2 Standards

2.6 Advantages

2.6.1 Why use a Frequency Converter for Controlling Fans and Pumps?

A frequency converter takes advantage of the fact that centrifugal fans and pumps follow the laws of proportionality for such fans and pumps. For further information see *2.6.3 Example of Energy Savings*.

2.6.2 The Clear Advantage - Energy Savings

The clear advantage of using a frequency converter for controlling the speed of fans or pumps lies in the electricity savings.
When comparing with alternative control systems and technologies, a frequency converter is the optimum energy control system for controlling fan and pump systems.

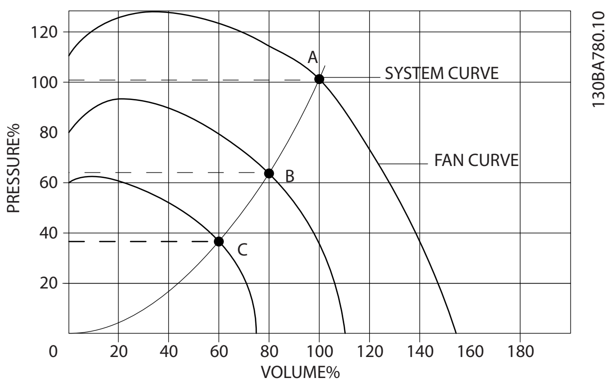


Illustration 2.1 Fan Curves (A, B, and C) for Reduced Fan Volumes

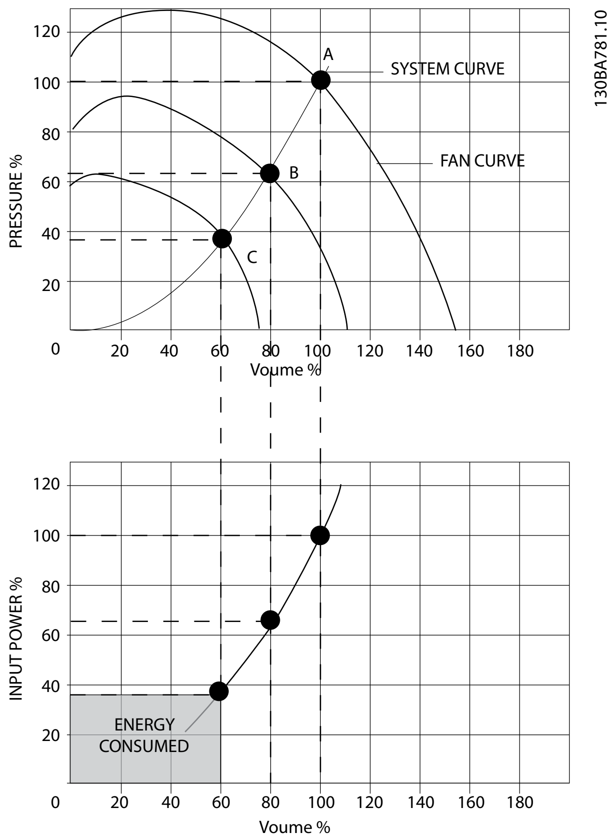


Illustration 2.2 When using a frequency converter to reduce fan capacity to 60% - more than 50% energy savings may be obtained in typical applications.

2.6.3 Example of Energy Savings

As shown in *Illustration 2.3*, the flow is controlled by changing the RPM. By reducing the speed only 20% from the rated speed, the flow is also reduced by 20%. This is because the flow is directly proportional to the RPM. The consumption of electricity, however, is reduced by 50%.
If the system in question only needs to be able to supply a flow that corresponds to 100% a few days in a year, while the average is below 80% of the rated flow for the remainder of the year, the amount of energy saved is even more than 50%.

Illustration 2.3 describes the dependence of flow, pressure and power consumption on RPM.	
Q=Flow	P=Power
Q_1=Rated flow	P_1=Rated power
Q_2=Reduced flow	P_2=Reduced power
H=Pressure	n=Speed regulation
H_1=Rated pressure	n_1=Rated speed
H_2=Reduced pressure	n_2=Reduced speed

Table 2.3 The Laws of Proportionality

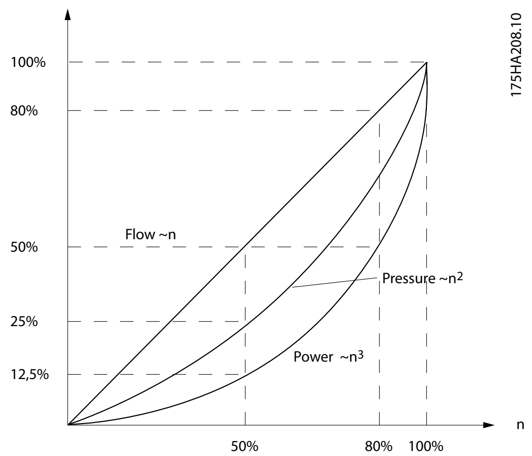


Illustration 2.3 Laws of Proportionally

$$Flow: \frac{Q_1}{Q_2} = \frac{n_1}{n_2}$$

$$Pressure: \frac{H_1}{H_2} = \left(\frac{n_1}{n_2}\right)^2$$

$$Power: \frac{P_1}{P_2} = \left(\frac{n_1}{n_2}\right)^3$$

2.6.4 Comparison of Energy Savings

The Danfoss frequency converter solution offers major savings compared with traditional energy saving solutions. This is because the frequency converter is able to control fan speed according to thermal load on the system and the fact that the frequency converter has a built-in facility that enables the frequency converter to function as a Building Management System, BMS.

Illustration 2.5 shows typical energy savings obtainable with 3 well-known solutions when fan volume is reduced to i.e. 60%.
As the graph shows, more than 50% energy savings can be achieved in typical applications.

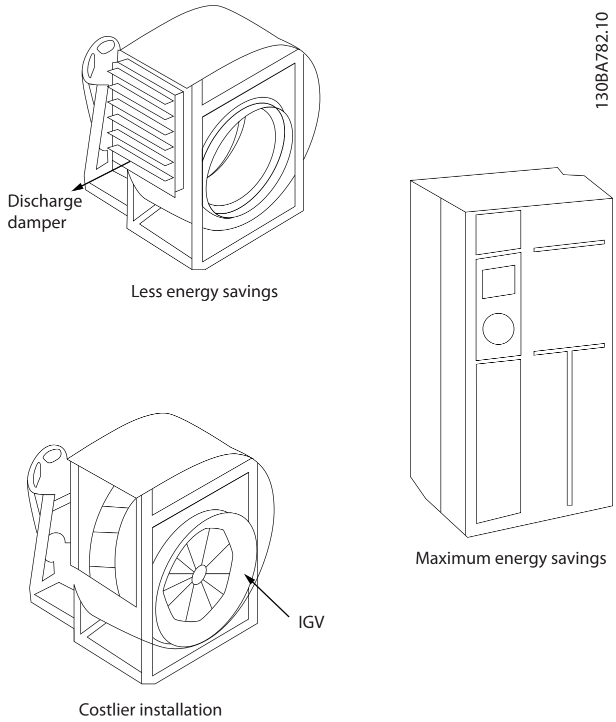


Illustration 2.4 The 3 Common Energy Saving Systems

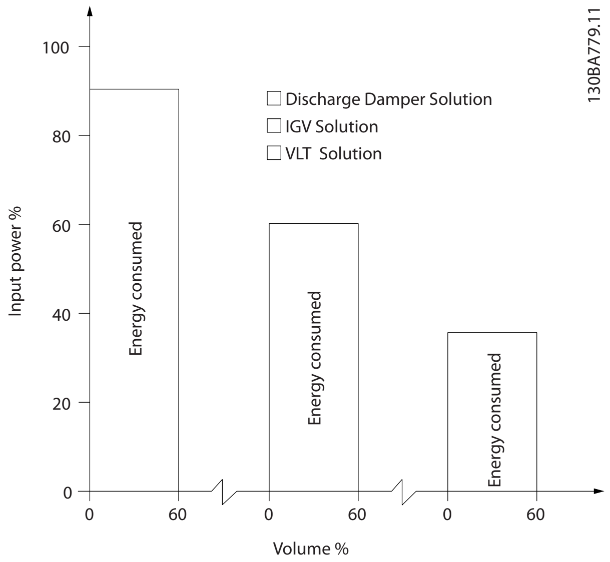


Illustration 2.5 Energy Savings

Discharge dampers reduce power consumption somewhat. Inlet Guide Vans offer a 40% reduction but are expensive to install. The Danfoss frequency converter solution reduces energy consumption with more than 50% and is easy to install.

2.6.5 Example with Varying Flow over 1 Year

This example is calculated based on pump characteristics obtained from a pump datasheet.
The result obtained shows energy savings in excess of 50% at the given flow distribution over a year. The pay back period depends on the price per kWh and price of frequency converter. In this example it is less than a year when compared with valves and constant speed.

Energy savings

$P_{shaft}=P_{shaft\ output}$

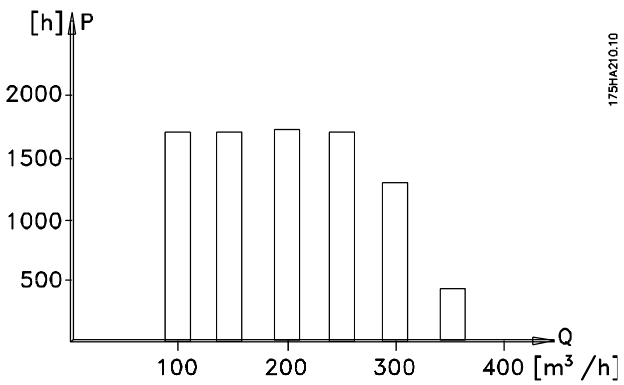


Illustration 2.6 Flow Distribution over 1 Year

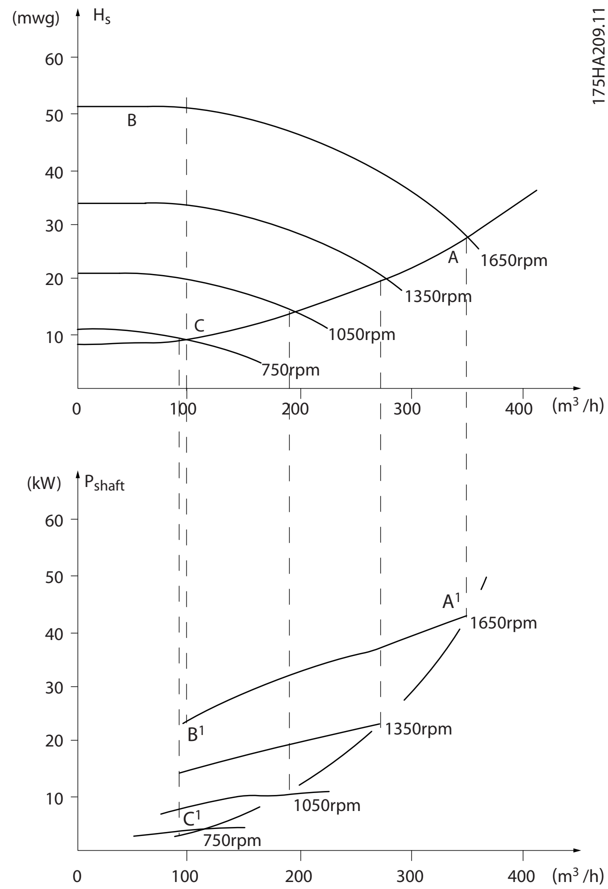


Illustration 2.7 Energy

m³/h	Distri-bution		Valve regulation		Frequency converter control	
	%	Hours	Power	Consump-tion	Power	Consump-tion
			A_1 - B_1	kWh	A_1 - C_1	kWh
350	5	438	42.5	18.615	42.5	18.615
300	15	1314	38.5	50.589	29.0	38.106
250	20	1752	35.0	61.320	18.5	32.412
200	20	1752	31.5	55.188	11.5	20.148
150	20	1752	28.0	49.056	6.5	11.388
100	20	1752	23.0	40.296	3.5	6.132
Σ	100	8760		275.064		26.801

Table 2.4 Result

2.6.6 Better Control

If a frequency converter is used for controlling the flow or pressure of a system, improved control is obtained.
A frequency converter can vary the speed of the fan or pump, obtaining variable control of flow and pressure.
Furthermore, a frequency converter can quickly adapt the speed of the fan or pump to new flow or pressure conditions in the system.
Simple control of process (Flow, Level or Pressure) utilising the built-in PI control.

2.6.7 Star/Delta Starter or Soft Starter not Required

When larger motors are started, it is necessary in many countries to use equipment that limits the start-up current. In more traditional systems, a star/delta starter or soft starter is widely used. Such motor starters are not required if a frequency converter is used.

As illustrated in *Illustration 2.8*, a frequency converter does not consume more than rated current.

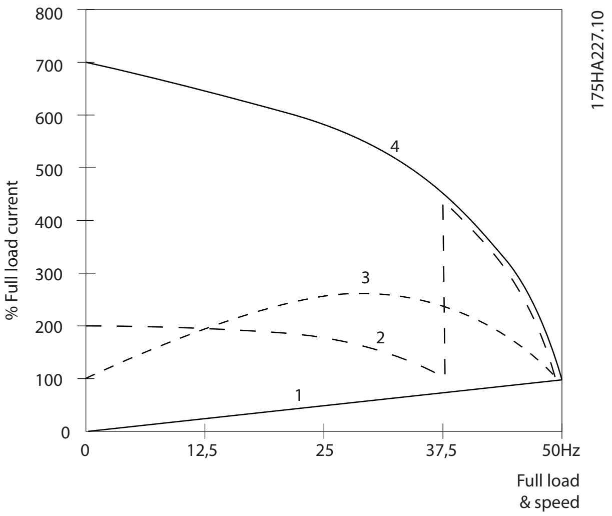


Illustration 2.8 Start-up Current

1	VLT® HVAC Basic Drive FC 101
2	Star/delta starter
3	Soft-starter
4	Start directly on mains

Table 2.5 Legend to *Illustration 2.8*

2.6.8 Using a Frequency Converter Saves Money

Example *2.6.9 Without a Frequency Converter* shows that a lot of equipment is not required when a frequency converter is used. It is possible to calculate the cost of installing the 2 different systems. In the example, the 2 systems can be established at roughly the same price.

2.6.9 Without a Frequency Converter

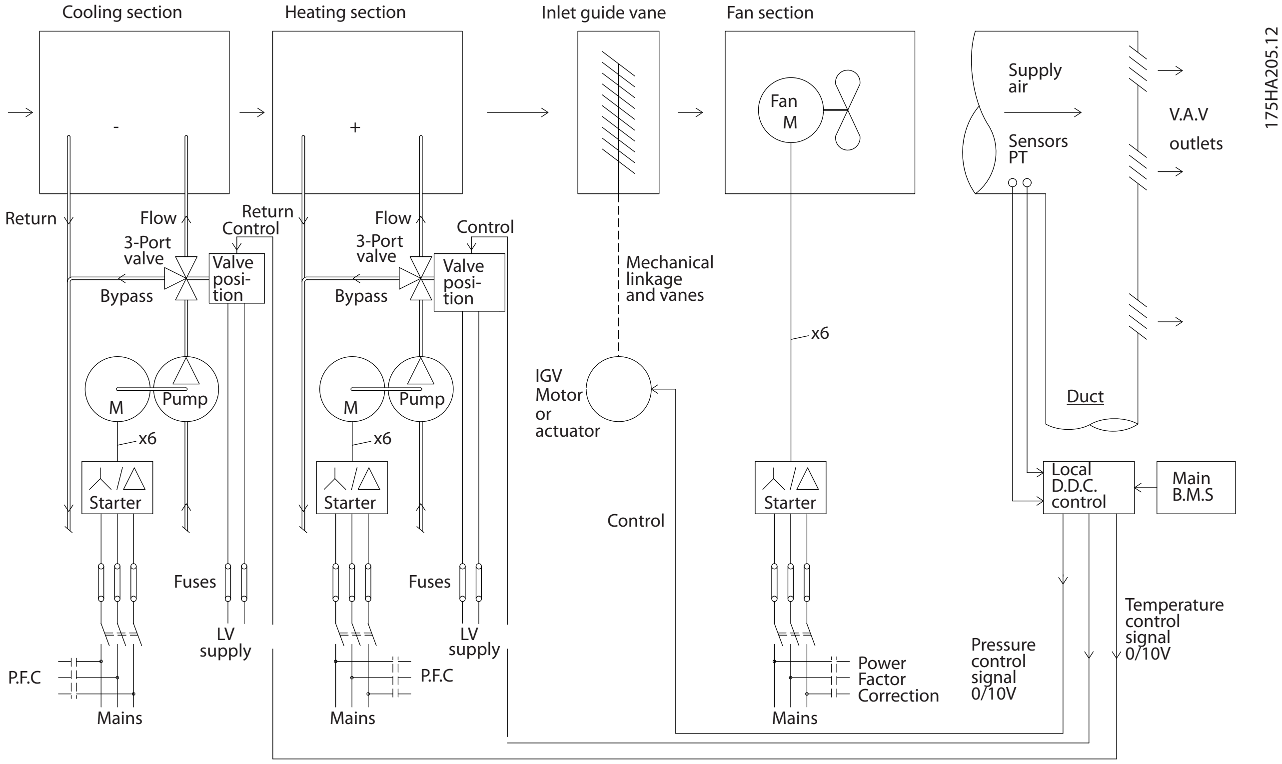


Illustration 2.9 Traditional Fan System

D.D.C.	Direct Digital Control
E.M.S.	Energy Management system
V.A.V.	Variable Air Volume
Sensor P	Pressure
Sensor T	Temperature

Table 2.6 Abbreviations used in *Illustration 2.9*

D.D.C.	Direct Digital Control
E.M.S.	Energy Management system
V.A.V.	Variable Air Volume
Sensor P	Pressure
Sensor T	Temperature

Table 2.7 Abbreviations used in *Illustration 2.10*

2.6.10 With a Frequency Converter

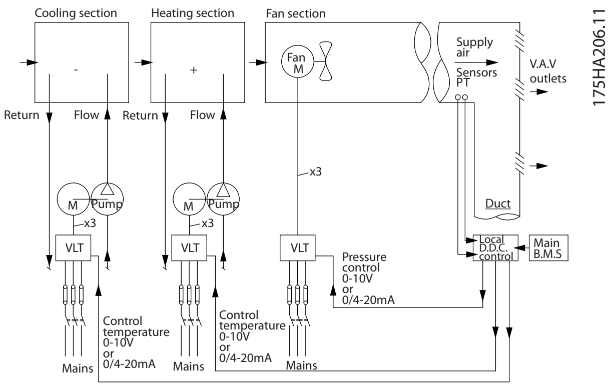


Illustration 2.10 Fan System Controlled by Frequency Converters

2.6.11 Application Examples

The next pages provide typical examples of applications within HVAC.
For further information about a given application, ask the Danfoss supplier for an information sheet that gives a full description of the application.

Variable Air Volume
Ask for *The Drive to...Improving Variable Air Volume Ventilation Systems, MN60A*.

Constant Air Volume
Ask for *The Drive to...Improving Constant Air Volume Ventilation Systems, MN60B*.

Cooling Tower Fan
Ask for *The Drive to...Improving fan control on cooling towers, MN60C*.

Condenser pumps
Ask for *The Drive to...Improving condenser water pumping systems, MN60F*.

Primary pumps
Ask for *The Drive to...Improve your primary pumping in primary/secondary pumping systems, MN60D*.

Secondary pumps
Ask for *The Drive to...Improve your secondary pumping in primary/secondary pumping systems, MN60E*.

2.6.12 Variable Air Volume

VAV, or Variable Air Volume systems, control both the ventilation and temperature to satisfy the requirements of a building. Central VAV systems are considered to be the most energy efficient method to air condition buildings. By designing central systems instead of distributed systems, a greater efficiency can be obtained.
The efficiency comes from utilising larger fans and larger chillers which have much higher efficiencies than small motors and distributed air-cooled chillers. Savings are also seen from the decreased maintenance requirements.

2.6.13 The VLT Solution

While dampers and IGVs work to maintain a constant pressure in the ductwork, a frequency converter solution saves much more energy and reduces the complexity of the installation. Instead of creating an artificial pressure drop or causing a decrease in fan efficiency, the frequency converter decreases the speed of the fan to provide the flow and pressure required by the system.
Centrifugal devices such as fans behave according to the centrifugal laws. This means the fans decrease the pressure and flow they produce as their speed is reduced. Their power consumption is thereby significantly reduced.
The PI controller of the VLT® HVAC Basic Drive can be used to eliminate the need for additional controllers.

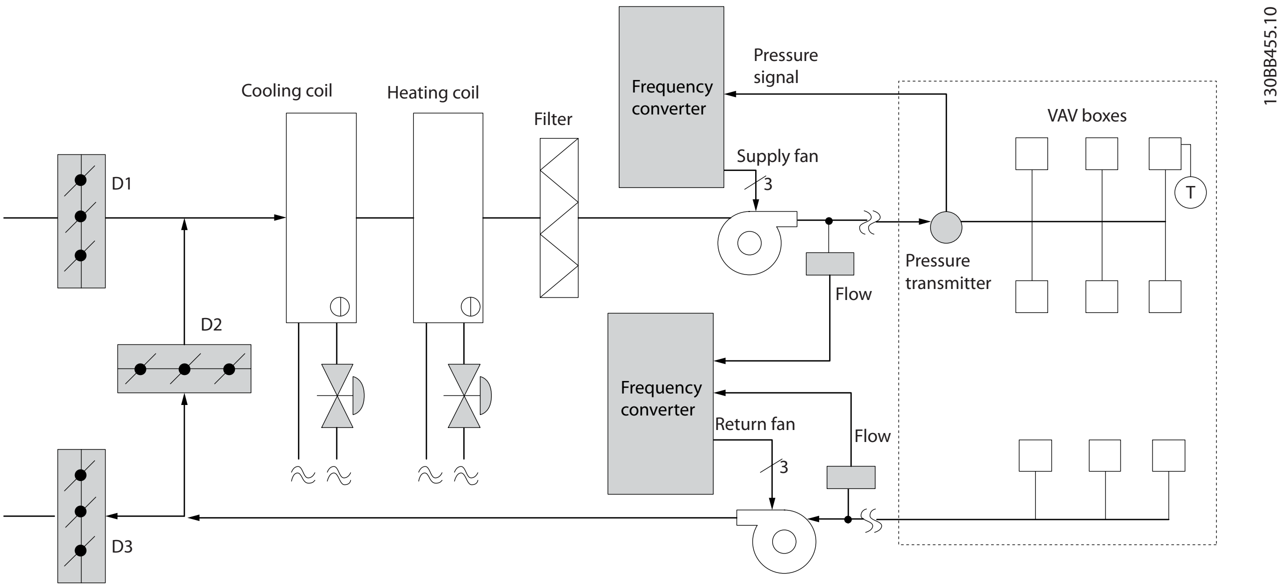


Illustration 2.11 Variable Air Volume

2.6.14 Constant Air Volume

CAV, or Constant Air Volume systems, are central ventilation systems usually used to supply large common zones with the minimum amounts of fresh tempered air. They preceded VAV systems and are therefore found in older multi-zoned commercial buildings as well. These systems preheat amounts of fresh air utilising Air Handling Units (AHUs) with a heating coil, and many are also used to air condition buildings and have a cooling coil. Fan coil units are frequently used to assist in the heating and cooling requirements in the individual zones.

2.6.15 The VLT Solution

With a frequency converter, significant energy savings can be obtained while maintaining decent control of the building. Temperature sensors or CO_2 sensors can be used as feedback signals to frequency converters. Whether controlling temperature, air quality, or both, a CAV system can be controlled to operate based on actual building conditions. As the number of people in the controlled area decreases, the need for fresh air decreases. The CO_2 sensor detects lower levels and decreases the supply fans speed. The return fan modulates to maintain a static pressure setpoint or fixed difference between the supply and return air flows.

With temperature control, especially used in air conditioning systems, as the outside temperature varies as well as the number of people in the controlled zone changes, different cooling requirements exist. As the temperature decreases below the set-point, the supply fan can decrease its speed. The return fan modulates to maintain a static pressure set-point. By decreasing the air flow, energy used to heat or cool the fresh air is also reduced, adding further savings.
Several features of the Danfoss HVAC dedicated frequency converter can be utilised to improve the performance of the CAV system. One concern of controlling a ventilation system is poor air quality. The programmable minimum frequency can be set to maintain a minimum amount of supply air regardless of the feedback or reference signal. The frequency converter also includes one PI controller, which allows monitoring both temperature and air quality. Even if the temperature requirement is satisfied, the frequency converter maintains enough supply air to satisfy the air quality sensor. The controller is capable of monitoring and comparing 2 feedback signals to control the return fan by maintaining a fixed differential air flow between the supply and return ducts as well.

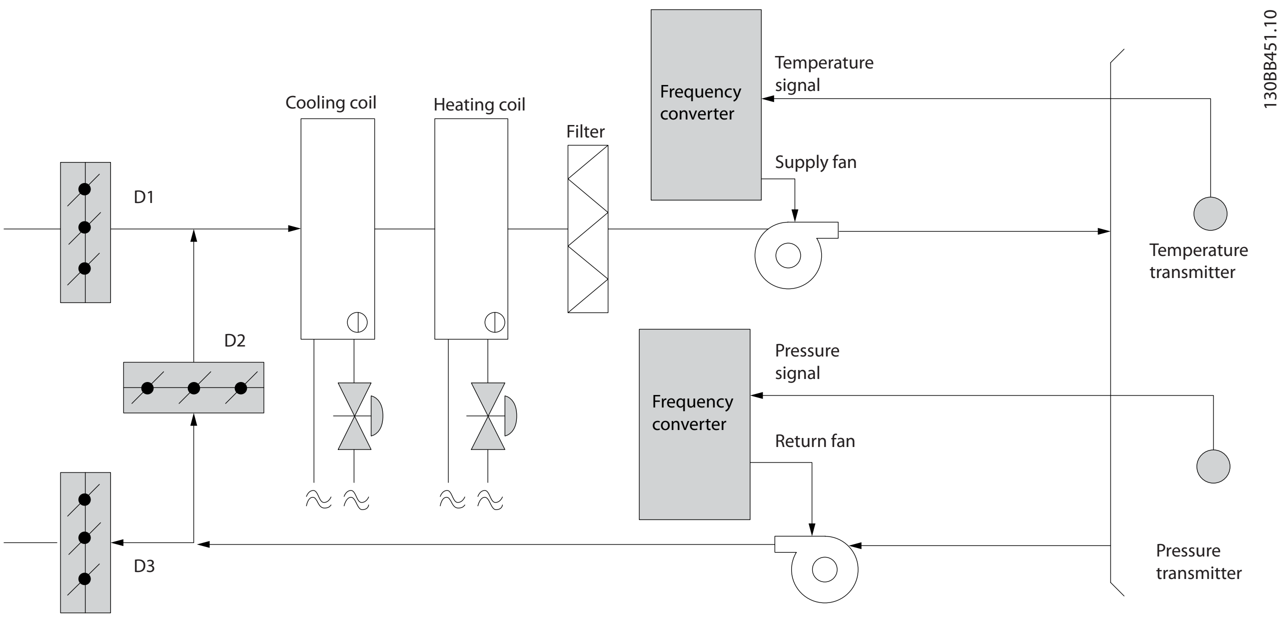


Illustration 2.12 Constant Air Volume

2

2.6.16 Cooling Tower Fan

Cooling Tower Fans cool condenser water in water cooled chiller systems. Water cooled chillers provide the most efficient means of creating chilled water. They are as much as 20% more efficient than air cooled chillers. Depending on climate, cooling towers are often the most energy efficient method of cooling the condenser water from chillers.
They cool the condenser water by evaporation.
The condenser water is sprayed into the cooling tower until the cooling towers "fill" to increase its surface area. The tower fan blows air through the fill and sprayed water to aid in the evaporation. Evaporation removes energy from the water dropping its temperature. The cooled water collects in the cooling towers basin where it is pumped back into the chillers condenser and the cycle is repeated.

2.6.17 The VLT Solution

With a frequency converter, the cooling towers fans can be controlled to the required speed to maintain the condenser water temperature. The frequency converters can also be used to turn the fan on and off as needed.

Several features of the Danfoss HVAC dedicated frequency converter, the HVAC frequency converter can be utilised to improve the performance of cooling tower fans applications. As the cooling tower fans drop below a certain speed, the effect the fan has on cooling the water becomes small. Also, when utilising a gear-box to frequency control the tower fan, a minimum speed of 40-50% may be required.
The customer programmable minimum frequency setting is available to maintain this minimum frequency even as the feedback or speed reference calls for lower speeds.

Also as a standard feature, the frequency converter can be programmed to enter a "sleep" mode and stop the fan until a higher speed is required. Additionally, some cooling tower fans have undesireable frequencies that may cause vibrations. These frequencies can easily be avoided by programming the bypass frequency ranges in the frequency converter.

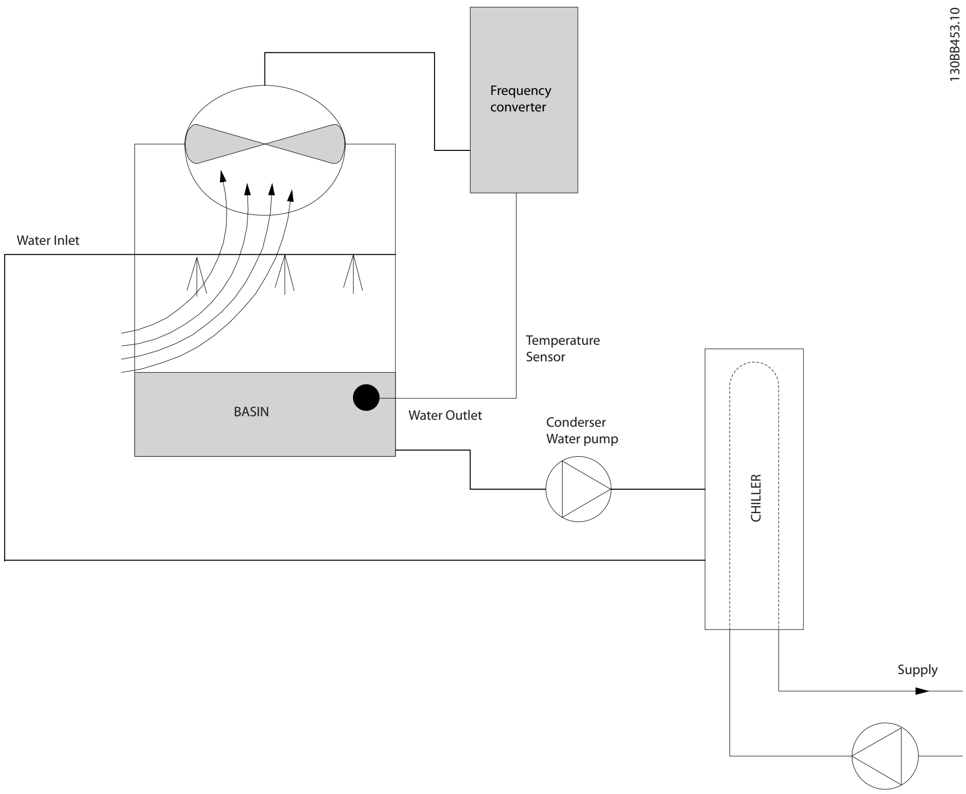


Illustration 2.13 Cooling Tower Fan

2.6.18 Condenser Pumps

Condenser water pumps are primarily used to circulate water through the condenser section of water cooled chillers and their associated cooling tower. The condenser water absorbs the heat from the chiller's condenser section and releases it into the atmosphere in the cooling tower. These systems are used to provide the most efficient means of creating chilled water, they are as much as 20% more efficient than air cooled chillers.

2.6.19 The VLT Solution

Frequency converters can be added to condenser water pumps instead of balancing the pumps with a throttling valve or trimming the pump impeller.

Using a frequency converter instead of a throttling valve simply saves the energy that would have been absorbed by the valve. This can amount to savings of 15-20% or more. Trimming the pump impeller is irreversible, thus if the conditions change and higher flow is required the impeller must be replaced.

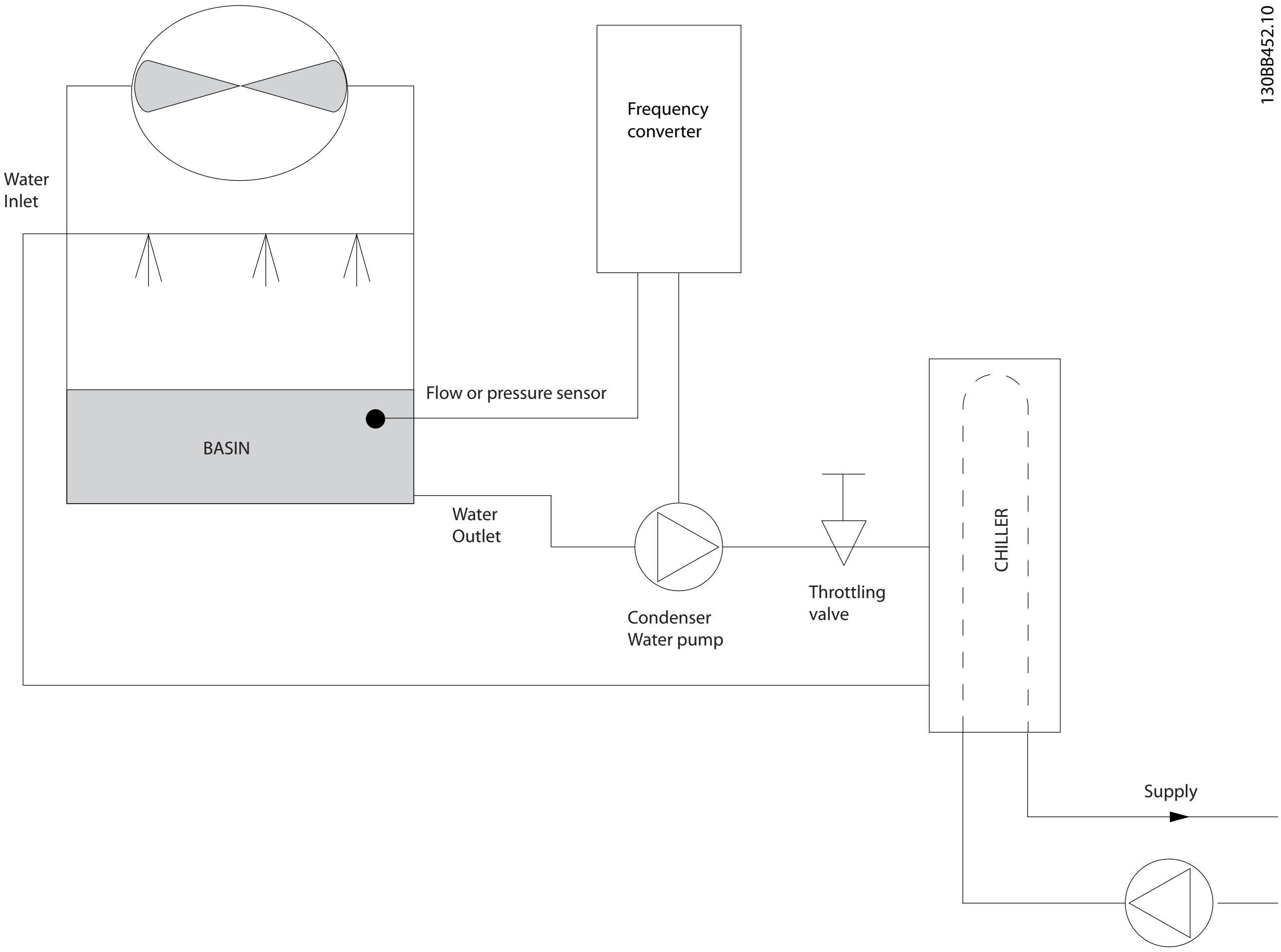


Illustration 2.14 Condenser Pumps

2.6.20 Primary Pumps

Primary pumps in a primary/secondary pumping system can be used to maintain a constant flow through devices that encounter operation or control difficulties when exposed to variable flow. The primary/secondary pumping technique decouples the “primary” production loop from the “secondary” distribution loop. This allows devices such as chillers to obtain constant design flow and operate properly while allowing the rest of the system to vary in flow.

As the evaporator flow rate decreases in a chiller, the chilled water begins to become over-chilled. As this happens, the chiller attempts to decrease its cooling capacity. If the flow rate drops far enough, or too quickly, the chiller cannot shed its load sufficiently and the chiller’s safety trips the chiller requiring a manual reset. This situation is common in large installations especially when 2 or more chillers in parallel are installed if primary/ secondary pumping is not utilised.

2.6.21 The VLT Solution

Depending on the size of the system and the size of the primary loop, the energy consumption of the primary loop can become substantial.
A frequency converter can be added to the primary system, to replace the throttling valve and/or trimming of the impellers, leading to reduced operating expenses. Two control methods are common:

Flow meter
Because the desired flow rate is known and is constant, a flow meter installed at the discharge of each chiller, can be used to control the pump directly. Using the built-in PI controller, the frequency converter always maintains the appropriate flow rate, even compensating for the changing resistance in the primary piping loop as chillers and their pumps are staged on and off.

Local speed determination
The operator simply decreases the output frequency until the design flow rate is achieved.
Using a frequency converter to decrease the pump speed is very similar to trimming the pump impeller, except it does not require any labor and the pump efficiency remains higher. The balancing contractor simply decreases the speed of the pump until the proper flow rate is achieved and leaves the speed fixed. The pump operates at this speed any time the chiller is staged on. Because the primary loop does not have control valves or other devices that can cause the system curve to change and the variance due to staging pumps and chillers on and off is usually small, this fixed speed remains appropriate. In the event the flow rate needs to be increased later in the systems life, the frequency convertercan simply increase the pump speed instead of requiring a new pump impeller.

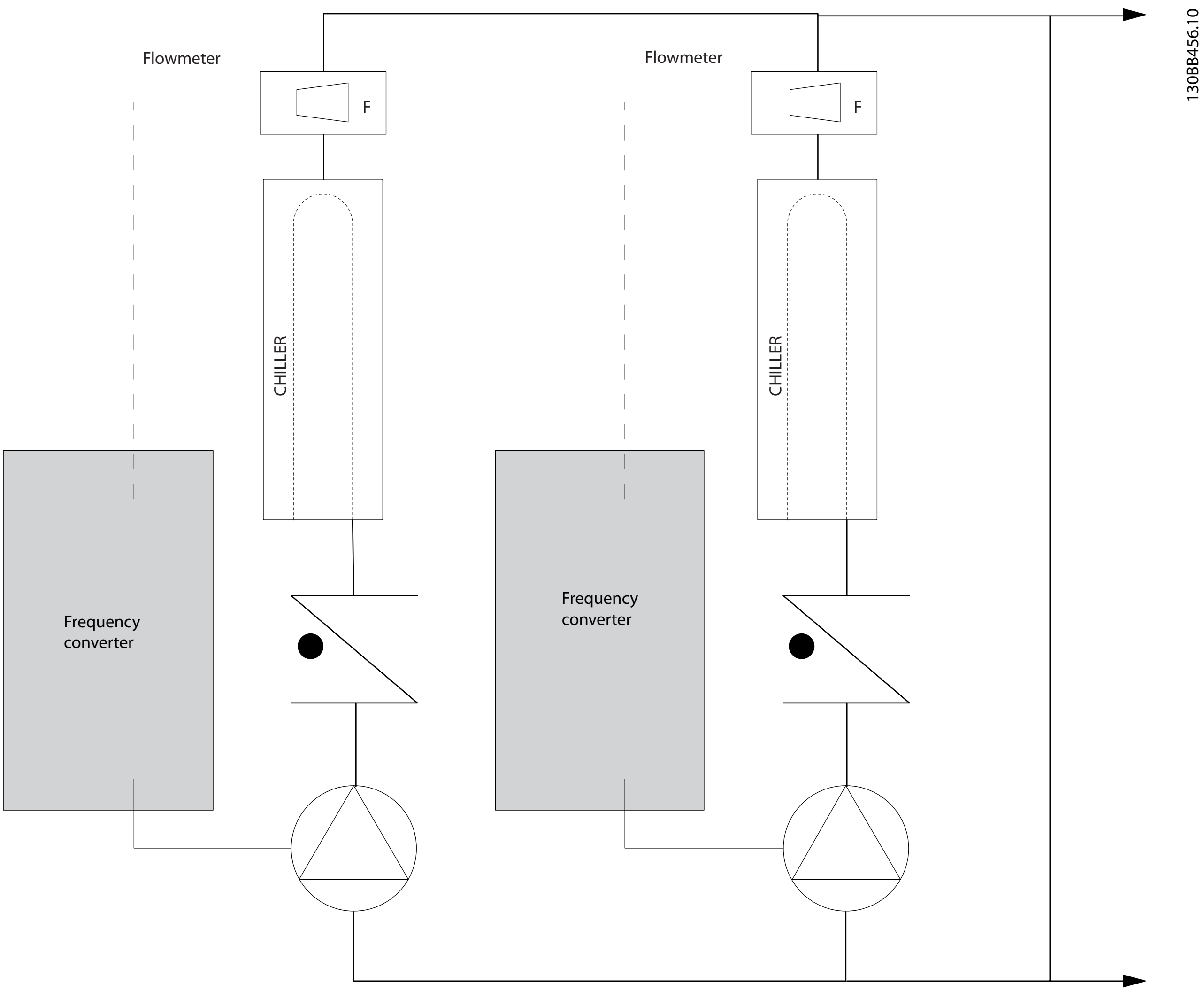


Illustration 2.15 Primary Pumps

2

2.6.22 Secondary Pumps

Secondary pumps in a primary/secondary chilled water pumping system distribute the chilled water to the loads from the primary production loop. The primary/secondary pumping system is used to hydronically de-couple one piping loop from another. In this case, the primary pump is used to maintain a constant flow through the chillers while allowing the secondary pumps to vary in flow, increase control and save energy.
If the primary/secondary design concept is not used and a variable volume system is designed, when the flow rate drops far enough or too quickly, the chiller cannot shed its load properly. The chiller's low evaporator temperature safety then trips the chiller requiring a manual reset. This situation is common in large installations especially when 2 or more chillers in parallel are installed.

2.6.23 The VLT Solution

While the primary-secondary system with 2-way valves improves energy savings and eases system control problems, the true energy savings and control potential is realised by adding frequency converters.

With the proper sensor location, the addition of frequency converters allows the pumps to vary their speed to follow the system curve instead of the pump curve.
This results in the elimination of wasted energy and eliminates most of the over-pressurization, 2-way valves can be subjected too.
As the monitored loads are reached, the 2-way valves close down. This increases the differential pressure measured across the load and 2-way valve. As this differential pressure starts to rise, the pump is slowed to maintain the control head also called setpoint value. This set-point value is calculated by summing the pressure drop of the load and two way valve together under design conditions.

NOTICE

When running multiple pumps in parallel, they must run at the same speed to maximize energy savings, either with individual dedicated drives or one frequency converter running multiple pumps in parallel.

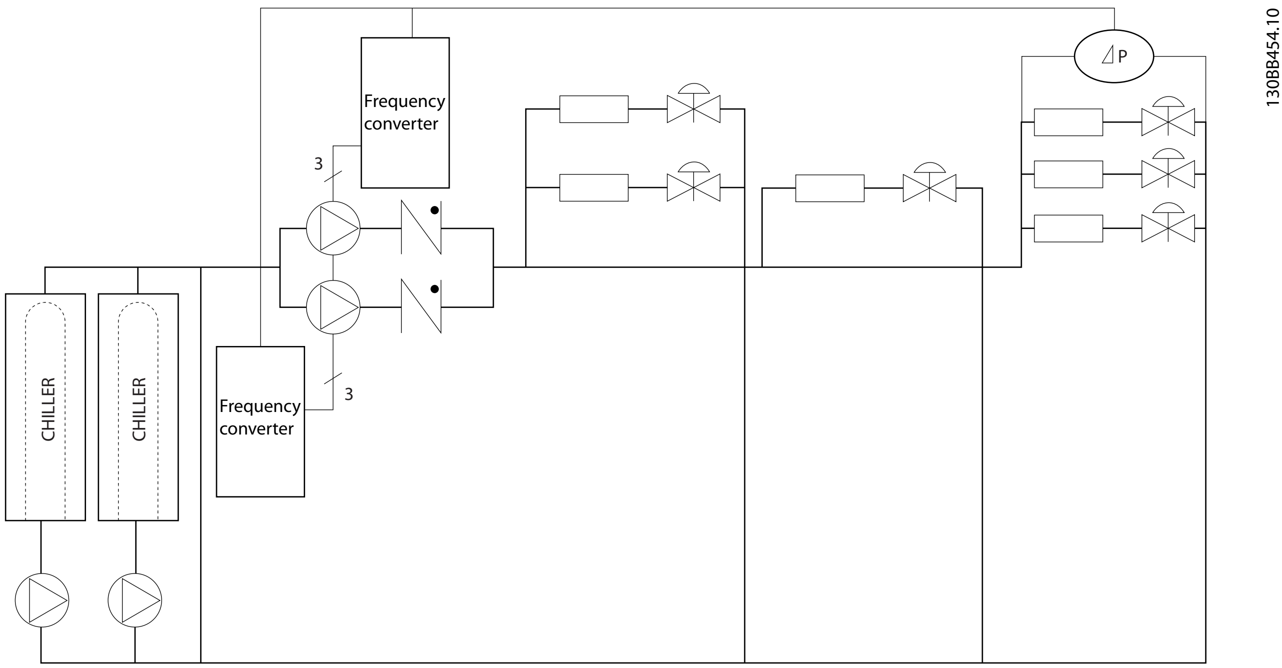


Illustration 2.16 Secondary Pumps

2.7 Control Structures

2.7.1 Control Principle

1-00 Configuration Mode can be selected if open or closed loop is to be used.

2.7.2 Control Structure Open Loop

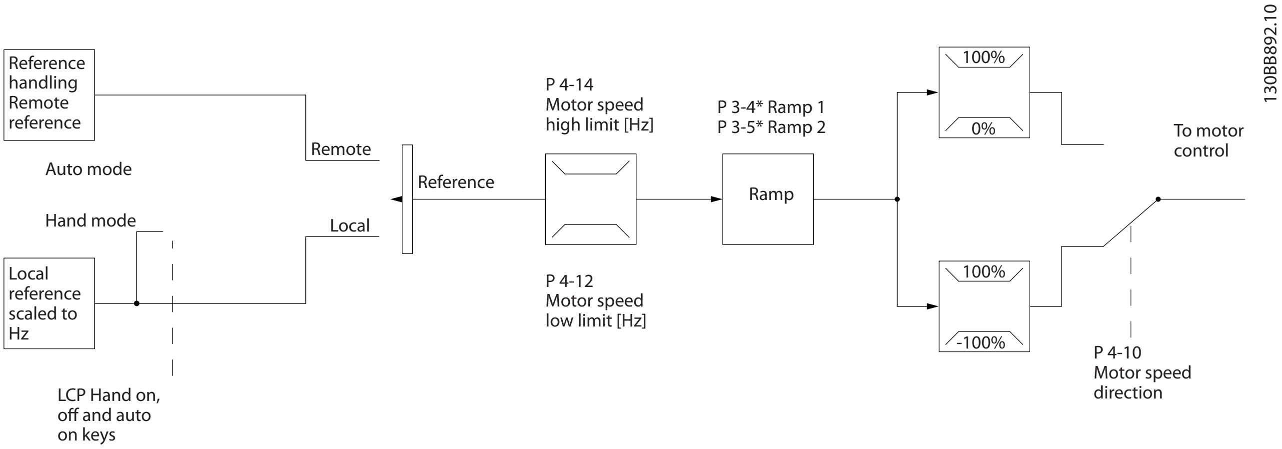


Illustration 2.17 Open Loop Structure

In the configuration shown in *Illustration 2.17*, *1-00 Configuration Mode* is set to *[0] Open loop*. The resulting reference from the reference handling system or the local reference is received and fed through the ramp limitation and speed limitation before being sent to the motor control. The output from the motor control is then limited by the maximum frequency limit.

2.7.3 PM/EC+ Motor Control

The Danfoss EC+ concept provides the possibitily for using high efficient PM motors (permanent magnet motors) in IEC standard frame size operated by Danfoss frequency converters.
The commissioning procedure is comparable to the existing one for asynchronous (induction) motors by utilising the Danfoss VVC^{plus} PM control strategy.

Customer advantages:

- Free choice of motor technology (permanent magnet or induction motor)
- Installation and operation as know on induction motors
- Manufacturer independent when selecting system components (e.g. motors)
- Best system efficiency by selecting best components
- Possible retrofit of existing installations
- Power range: 45 kW (200 V), 0.37-90 kW (400 V), 90 kW (600 V) for induction motors and 0.37-22 kW (400 V) for PM motors.

Current limitations for PM motors:

- Currently only supported up to 22 kW
- Currently limited to non salient type PM motors
- LC filters not supported together with PM motors
- Over Voltage Control algorithm is not supported with PM motors
- Kinetic backup algorithm is not supported with PM motors
- Support reduced AMA of the stator resistance Rs in the system only
- No stall detection
- No ETR function

2

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

The frequency converter can be operated manually via the local control panel (LCP) or remotely via analog/digital inputs or serial bus. If allowed in *0-40 [Hand on] Key on LCP*, *0-44 [Off/Reset] Key on LCP*, and *0-42 [Auto on] Key on LCP*, it is possible to start and stop the frequency converter by LCP using the [Hand On] and [Off/Reset] keys. Alarms can be reset via the [Off/Reset] key.

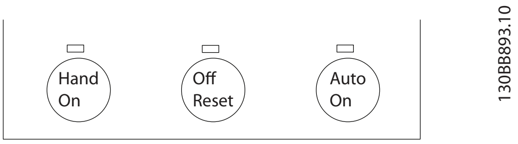


Illustration 2.18 LCP Keys

Local reference forces the configuration mode to open loop, independent on the setting of *1-00 Configuration Mode*.

Local Reference is restored at power-down.

2.7.5 Control Structure Closed Loop

The internal controller allows the frequency converter to become an integral part of the controlled system. The frequency converter receives a feedback signal from a sensor in the system. It then compares this feedback to a set-point reference value and determines the error, if any, between these 2 signals. It then adjusts the speed of the motor to correct this error.

For example, consider a pump application where the speed of a pump is to be controlled so that the static pressure in a pipe is constant. The desired static pressure value is supplied to the frequency converter as the set-point reference. A static pressure sensor measures the actual static pressure in the pipe and supplies this to the frequency converter as a feedback signal. If the feedback signal is greater than the set-point reference, the frequency converter slows down to reduce the pressure. In a similar way, if the pipe pressure is lower than the set-point reference, the frequency converter automatically speed up to increase the pressure provided by the pump.

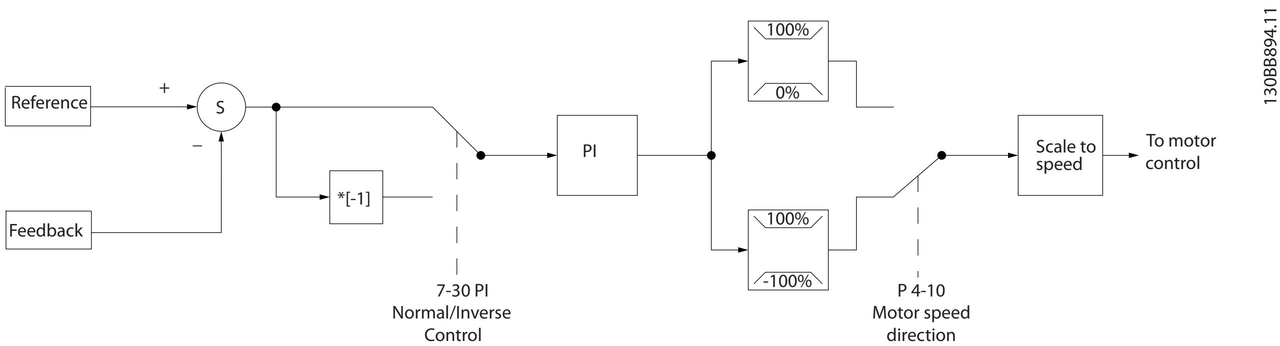


Illustration 2.19 Control Structure Closed Loop

While the default values for the frequency converter's Closed Loop controller often provides satisfactory performance, the control of the system can often be optimized by adjusting some of the Closed Loop controller's parameters.

2.7.6 Feedback Conversion

In some applications it may be useful to convert the feedback signal. One example of this is using a pressure signal to provide flow feedback. Since the square root of pressure is proportional to flow, the square root of the pressure signal yields a value proportional to the flow. See *Illustration 2.20*.

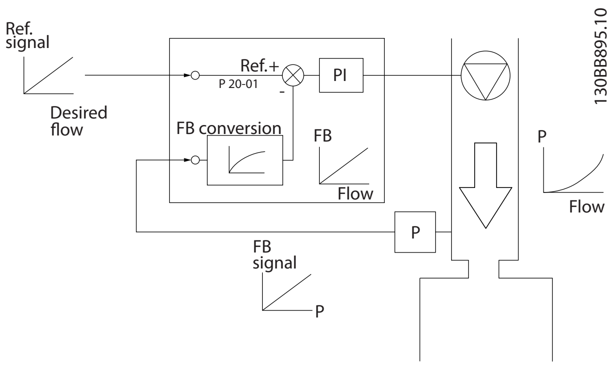


Illustration 2.20 Feedback Signal Conversion

2.7.7 Reference Handling

Details for Open Loop and Closed Loop operation.

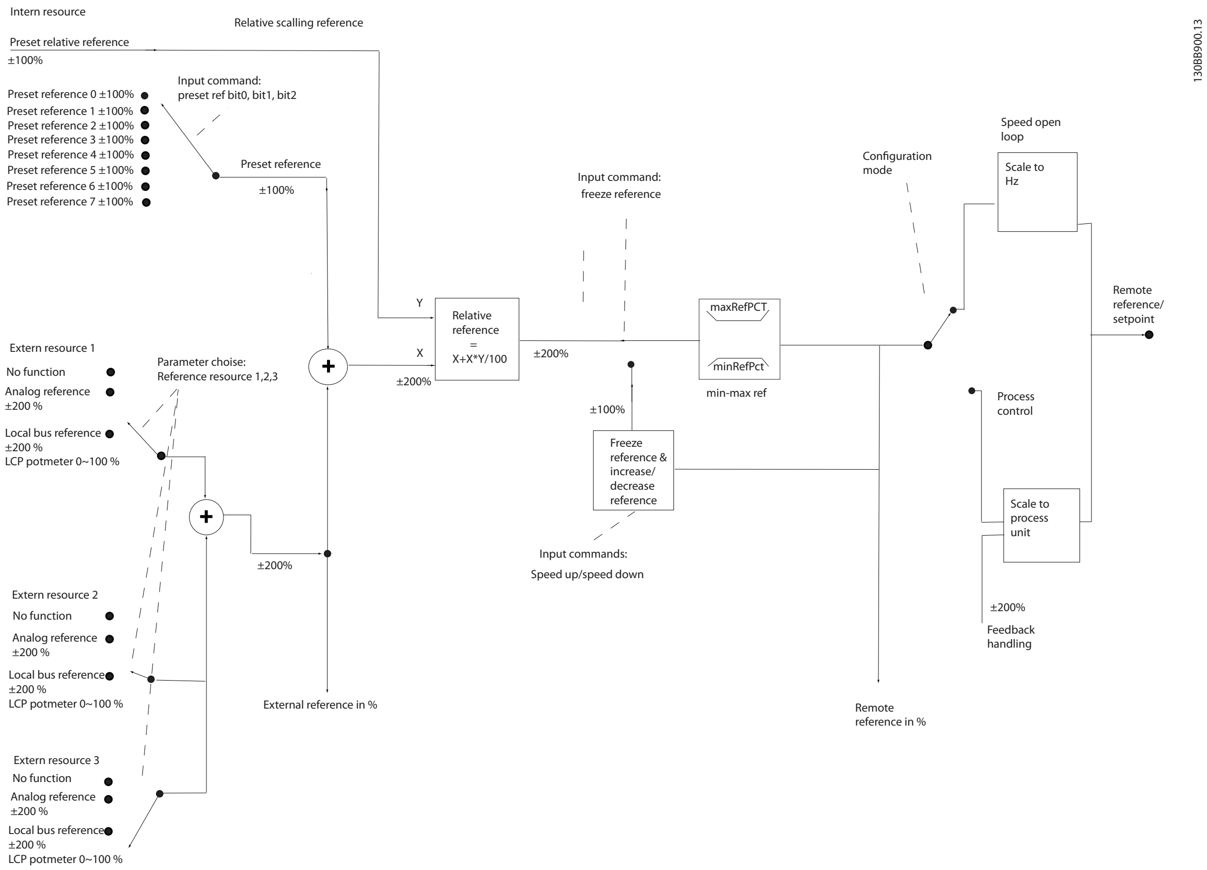


Illustration 2.21 Block Diagram Showing Remote Reference

The remote reference is comprised of:

- Preset references
- External references (analog inputs and serial communication bus references)
- The preset relative reference
- Feedback controlled setpoint

Up to 8 preset references can be programmed in the frequency converter. The active preset reference can be selected using digital inputs or the serial communications bus. The reference can also be supplied externally, most commonly from an analog input. This external source is selected by one of the 3 Reference Source parameters (*3-15 Reference 1 Source*, *3-16 Reference 2 Source* and *3-17 Reference 3 Source*). All reference resources and the bus reference are added to produce the total external reference. The external reference, the preset reference or the sum of the 2 can be selected to be the active reference. Finally, this reference can by be scaled using *3-14 Preset Relative Reference*.

The scaled reference is calculated as follows:

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

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

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

2.7.8 Closed Loop Set-up Wizard

Illustration 2.22 Closed Loop Set-up Wizard

Closed Loop Set-up Wizard

Parameter	Range	Default	Function
0-03 Regional Settings	[0] International [1] US	0	
0-06 GridType	[0] -[[132] see start -up wizard for open loop application	Size selected	Select operating mode for restart upon reconnection of the frequency converter to mains voltage after power down
1-00 Configuration Mode	[0] Open loop [3] Closed loop	0	Change this parameter to Closed loop
1-10 Motor Construction	*[0] Motor construction [1] PM, non salient SPM	[0] Asynchron	Setting the parameter value might change these parameters: 1-01 Motor Control Principle 1-03 Torque Characteristics 1-14 Damping Gain 1-15 Low Speed Filter Time Const 1-16 High Speed Filter Time Const 1-17 Voltage filter time const 1-20 Motor Power 1-22 Motor Voltage 1-23 Motor Frequency 1-25 Motor Nominal Speed 1-26 Motor Cont. Rated Torque 1-30 Stator Resistance (Rs) 1-33 Stator Leakage Reactance (X1) 1-35 Main Reactance (Xh) 1-37 d-axis Inductance (Ld) 1-39 Motor Poles 1-40 Back EMF at 1000 RPM 1-66 Min. Current at Low Speed 1-72 Start Function 1-73 Flying Start 4-19 Max Output Frequency 4-58 Missing Motor Phase Function
1-20 Motor Power	0.09-110 kW	Size related	Enter motor power from nameplate data
1-22 Motor Voltage	50.0-1000.0 V	Size related	Enter motor voltage from nameplate data
1-23 Motor Frequency	20.0-400.0 Hz	Size related	Enter motor frequency from nameplate data
1-24 Motor Current	0.0 -10000.00 A	Size related	Enter motor current from nameplate data
1-25 Motor Nominal Speed	100.0-9999.0 RPM	Size related	Enter motor nominal speed from nameplate data
1-26 Motor Cont. Rated Torque	0.1-1000.0	Size related	This parameter is available only when 1-10 Motor Construction Design is set to *[1] PM, non-salient SPM.* **NOTICE** **Changing this parameter affects settings of other parameters**
1-29 Automatic Motor Adaption (AMA)		Off	Performing an AMA optimizes motor performance
1-30 Stator Resistance (Rs)	0.000-99.990	Size related	Set the stator resistance value
1-37 d-axis Inductance (Ld)	0-1000	Size related	Enter the value of the d-axis inductance. Obtain the value from the permanent magnet motor data sheet. The de-axis inductance cannot be found by performing an AMA.
1-39 Motor Poles	2-100	4	Enter the number of motor poles
1-40 Back EMF at 1000 RPM	10-9000	Size related	Line-Line RMS back EMF voltage at 1000 RPM

Parameter	Range	Default	Function
1-73 Flying Start	[0] Disabled [1] Enabled	0	Select *[1] Enable* to enable the frequency converter to catch a spinning motor. I.e. fan applications. When PM is selected, Flying Start is enabled.
3-02 Minimum Reference	-4999-4999	0	The minimum reference is the lowest value obtainable by summing all references
3-03 Maximum Reference	-4999-4999	50	The maximum reference is the highest value obtainable by summing all references
3-10 Preset Reference	-100-100%	0	Enter the set point
3-41 Ramp 1 Ramp Up Time	0.05-3600.0 s	Size related	Ramp up time from 0 to rated *1-23 Motor Frequency* if Asynchron motor is selected; ramp up time from 0 to 1-25 Motor Nominal Speed if PM motor is selected"
3-42 Ramp 1 Ramp Down Time	0.05-3600.0 s	Size related	Ramp down time from rated *1-23 Motor Frequency* to 0 if Asynchron motor is selected; ramp down time from *1-25 Motor Nominal Speed* to 0 if PM motor is selected
4-12 Motor Speed Low Limit [Hz]	0.0-400 Hz	0.0 Hz	Enter the minimum limit for low speed
4-14 Motor Speed High Limit [Hz]	0-400 Hz	65 Hz	Enter the minimum limit for high speed
4-19 Max Output Frequency	0-400	Size related	Enter the maximum output frequency value
6-20 Terminal 54 Low Voltage	0-10 V	0.07 V	Enter the voltage that corresponds to the low reference value
6-21 Terminal 54 High Voltage	0-10 V	10 V	Enter the voltage that corresponds to the low high reference value
6-22 Terminal 54 Low Current	0-20 mA	4	Enter the current that corresponds to the high reference value
6-23 Terminal 54 High Current	0-20 mA	20	Enter the current that corresponds to the high reference value
6-24 Terminal 54 Low Ref./Feedb. Value	-4999-4999	0	Enter the feedback value that corresponds to the voltage or current set in *6-20 Terminal 54 Low Voltage/6-22 Terminal 54 Low Current*
6-25 Terminal 54 High Ref./Feedb. Value	-4999-4999	50	Enter the feedback value that corresponds to the voltage or current set in *6-21 Terminal 54 High Voltage/6-23 Terminal 54 High Current*
6-26 Terminal 54 Filter Time Constant	0-10 s	0.01	Enter the filter time comstant
6-29 Terminal 54 mode	[0] Current [1] Voltage	1	Select if terminal 54 is used for current- or voltage input
20-81 PI Normal/ Inverse Control	[0] Normal [1] Inverse	0	Select *[0] Normal* to set the process control to increase the output speed when the process error is positive. Select *[1] Inverse* to reduce the output speed.
20-83 PI Start Speed [Hz]	0-200 Hz	0	Enter the motor speed to be attained as a start signal for commencement of PI control
20-93 PI Proportional Gain	0-10	0.01	Enter the process controller proportional gain. Quick control is obtained at high amplification. However if amplification is too great, the process may become unstable
20-94 PI Integral Time	0.1-999.0 s	999.0 s	Enter the process controller integral time. Obtain quick control through a short integral time, though if the integral time is too short, the process becomes unstable. An excessively long integral time disables the integral action.

Table 2.8 Closed Loop Set-up Wizard

2.7.9 Tuning the Drive Closed Loop Controller

Once the frequency converter's closed loop controller has been set up, the performance of the controller should be tested. In many cases, its performance may be acceptable using the default values of *20-93 PI Proportional Gain* and *20-94 PI Integral Time*. However, in some cases it may be helpful to optimize these parameter values to provide faster system response while still controlling speed overshoot.

2.7.10 Manual PI Adjustment

1. Start the motor.
2. Set *20-93 PI Proportional Gain* to 0.3 and increase it until the feedback signal begins to oscillate. If necessary, start and stop the frequency converter or make step changes in the set-point reference to attempt to cause oscillation. Next reduce the PI proportional gain until the feedback signal stabilises. Then reduce the proportional gain by 40-60%.
3. Set *20-94 PI Integral Time* to 20 s and reduce it until the feedback signal begins to oscillate. If necessary, start and stop the frequency converter or make step changes in the set-point reference to attempt to cause oscillation. Next, increase the PI integral time until the feedback signal stabilises. Then increase of the integral time by 15-50%.

2.8 General Aspects of EMC

Electrical interference is usually 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 2.23*, capacitance 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 2.23*) 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 approximately 5 MHz. Since the leakage current (I_1) is carried back to the unit through the screen (I_3), there is in principle only a small electro-magnetic field (I_4) from the screened motor cable according to *Illustration 2.23*.

The screen reduces the radiated interference, but increases the low-frequency interference on the mains. Connect the motor cable screen to the frequency converter enclosure as well as on the motor enclosure. This is best done by using integrated screen clamps so as to avoid twisted screen ends (pigtails). Pigtails 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 relay, control cable, signal interface and brake, mount the screen on the enclosure at both ends. In some situations, however, it is necessary to break the screen to avoid current loops.

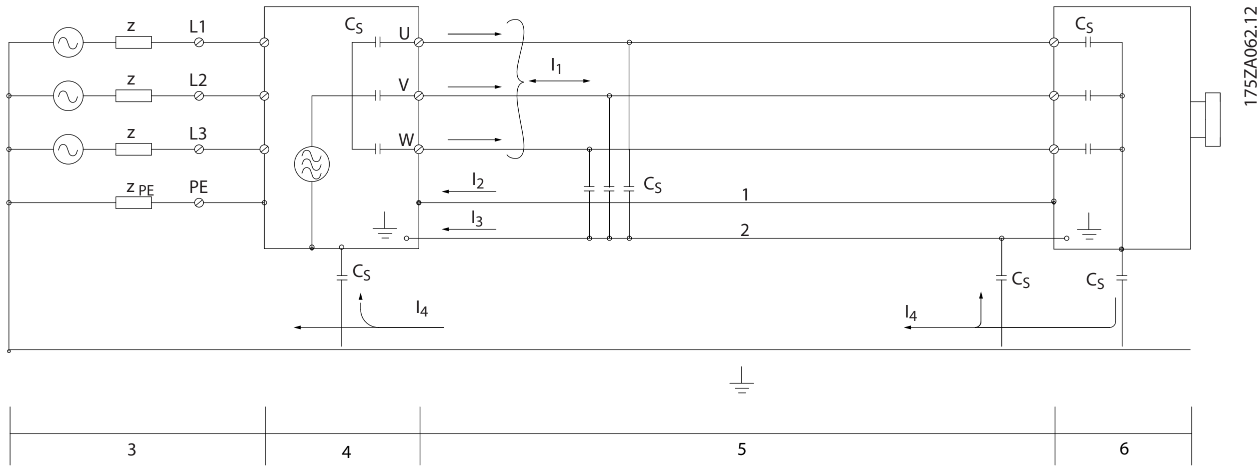


Illustration 2.23 Situation that Generates Leakage Currents

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

Table 2.9 Legend to *Illustration 2.23*

If the screen is to be placed on a mounting plate for the frequency converter, the mounting plate must be made of metal, because the screen currents have to be conveyed back to the unit. Moreover, 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 most immunity requirements are observed.

To reduce the interference level from the entire system (unit+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 especially generated by the control electronics. See *5.2.4 EMC Compliant Electrical Installation* for more information on EMC.

2.8.1 Emission Requirements

According to the EMC product standard for frequency converters, EN/IEC 61800-3:2004 the EMC requirements depend on the intended use of the frequency converter. The EMC product standard defines 4 categories. The 4 categories and the requirements for mains supply voltage conducted emissions are defined in *Table 2.11*.

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, which are neither plug-in nor movable and are intended to be installed and commissioned by a professional.	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. An EMC plan should be made.

Table 2.10 Emission Requirements

When the generic (conducted) emission standards are used, the frequency converters are required to comply with the following limits

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 2.11 Limits at Generic Emission Standards

2.8.2 EMC Test Results

The following test results have been obtained using a system with a frequency converter, a screened control cable, a control box with potentiometer, as well as a motor screened cable.

RFI Filter Type	Conduct emission. Maximum shielded cable length [m]						Radiated emission			
	Industrial environment				Housing, trades and light industries		Industrial environment		Housing, trades and light industries	
	EN 55011 Class A2		EN 55011 Class A1		EN 55011 Class B		EN 55011 Class A1		EN 55011 Class B	
	Without external filter	With external filter	Without external filter	With external filter	Without external filter	With external filter	Without external filter	With external filter	Without external filter	With external filter
H4 RFI filter (Class A1)										
0.25-11 kW 3x200-240 V IP20			25	50		20	Yes	Yes		No
0.37-22 kW 3x380-480 V IP20			25	50		20	Yes	Yes		No
H2 RFI filter (Class A2)										
15-45 kW 3x200-240 V IP20	25						No		No	
30-90 kW 3x380-480 V IP20	25						No		No	
0.75-18.5 kW 3x380-480 V IP54	25						Yes			
22-90 kW 3x380-480 V IP54	25						No		No	
H3 RFI filter (Class A1/B)										
15-45 kW 3x200-240 V IP20			50		20		Yes		No	
30-90 kW 3x380-480 V IP20			50		20		Yes		No	
0.75-18.5 kW 3x380-480 V IP54			25		10		Yes			
22-90 kW 3x380-480 V IP54			25		10		Yes		No	

Table 2.12 Test Results

2.8.3 General Aspects of Harmonics Emission

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:

	I_1	I_5	I_7
Hz	50	250	350

Table 2.13 Harmonic Currents

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.

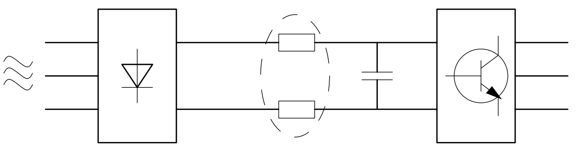


Illustration 2.24 Harmonic Currents

NOTICE

Some of the harmonic currents might disturb communication equipment connected to the same transformer or cause resonance in connection with power-factor correction batteries.

To ensure low harmonic currents, the frequency converter is equipped with intermediate circuit coils as standard. This normally reduces the input current I_{RMS} by 40%.

The voltage distortion on the mains supply voltage depends on the size of the harmonic currents multiplied by the mains impedance for the frequency in question. The total voltage distortion THD is calculated on the basis of the individual voltage harmonics using this formula:

$$THD\% = \sqrt{U_5^2 + U_7^2 + ... + U_N^2}$$

(U_N% of U)

2.8.4 Harmonics Emission Requirements

Equipment connected to the public supply network

Options	Definition
1	IEC/EN 61000-3-2 Class A for 3-phase balanced equipment (for professional equipment only up to 1 kW total power).
2	IEC/EN 61000-3-12 Equipment 16 A-75 A and professional equipment as from 1 kW up to 16 A phase current.

Table 2.14 Connected Equipment

2.8.5 Harmonics Test Results (Emission)

Power sizes up to PK75 in T4 and P3K7 in T2 complies with IEC/EN 61000-3-2 Class A. Power sizes from P1K1 and up to P18K in T2 and up to P90K in T4 complies with IEC/EN 61000-3-12, Table 4.

	Individual Harmonic Current I_n/I_1 (%)			
	I_5	I_7	I_{11}	I_{13}
Actual 0.25-11 kW, IP20, 200 V (typical)	32.6	16.6	8.0	6.0
Limit for R_{sce}≥120	40	25	15	10
	Harmonic current distortion factor (%)			
	THD		**PWHD**	
Actual 0.25-11 kW, 200 V (typical)	39		41.4	
Limit for R_{sce}≥120	48		46	

Table 2.15 Harmonic Current 0.25-11 kW, 200 V

	Individual Harmonic Current I_n/I_1 (%)			
	I_5	I_7	I_{11}	I_{13}
Actual 0.37-22 kW, IP20, 380-480 V (typical)	36.7	20.8	7.6	6.4
Limit for R_{sce}≥120	40	25	15	10
	Harmonic current distortion factor (%)			
	THD		**PWHD**	
Actual 0.37-22 kW, 380-480 V (typical)	44.4		40.8	
Limit for R_{sce}≥120	48		46	

Table 2.16 Harmonic Current 0.37-22 kW, 380-480 V

	Individual Harmonic Current I_n/I_1 (%)			
	I_5	I_7	I_{11}	I_{13}
Actual 30-90 kW, IP20, 380-480 V (typical)	36.7	13.8	6.9	4.2
Limit for R_{sce}≥120	40	25	15	10
	Harmonic current distortion factor (%)			
	THD		PWHD	
Actual 30-90 kW, 380-480 V (typical)	40.6		28.8	
Limit for R_{sce}≥120	48		46	

Table 2.17 Harmonic Current 30-90 kW, 380-480 V

	Individual Harmonic Current I_n/I_1 (%)			
	I_5	I_7	I_{11}	I_{13}
Actual 2.2-15 kW, IP20, 525-600 V (typical)	48	25	7	5
	Harmonic current distortion factor (%)			
	THD		PWHD	
Actual 2.2-15 kW, 525-600 V (typical)	55		27	

Table 2.18 Harmonic Current 2.2-15 kW, 525-600 V

	Individual Harmonic Current I_n/I_1 (%)			
	I_5	I_7	I_{11}	I_{13}
Actual 18.5-90 kW, IP20, 525-600 V (typical)	48.8	24.7	6.3	5
	Harmonic current distortion factor (%)			
	THD		PWHD	
Actual 18.5-90 kW, 525-600 V (typical)	55.7		25.3	

Table 2.19 Harmonic Current 18.5-90 kW, 525-600 V

	Individual Harmonic Current I_n/I_1 (%)			
	I_5	I_7	I_{11}	I_{13}
Actual 22-90 kW, IP54, 400 V (typical)	36.3	14	7	4.3
Limit for R_{sce}≥120	40	25	15	10
	Harmonic current distortion factor (%)			
	THD		PWHD	
Actual 22-90 kW, IP54 400 V (typical)	40.1		27.1	
Limit for R_{sce}≥120	48		46	

Table 2.20 Harmonic Current 22-90 kW, 400 V

	Individual Harmonic Current I_n/I_1 (%)			
	I_5	I_7	I_{11}	I_{13}
Actual 0.75-18.5 kW, IP54, 380-480 V (typical)	36.7	20.8	7.6	6.4
Limit for R_{sce}≥120	40	25	15	10
	Harmonic current distortion factor (%)			
	THD		PWHD	
Actual 0.75-18.5 kW, IP54, 380-480 V (typical)	44.4		40.8	
Limit for R_{sce}≥120	48		46	

Table 2.21 Harmonic Current 0.75-18.5 kW, 380-480 V

	Individual Harmonic Current I_n/I_1 (%)			
	I_5	I_7	I_{11}	I_{13}
Actual 15-45 kW, IP20, 200 V (typical)	26.7	9.7	7.7	5
Limit for R_{sce}≥120	40	25	15	10
	Harmonic current distortion factor (%)			
	THD		PWHD	
Actual 15-45 kW, 200 V (typical)	30.3		27.6	
Limit for R_{sce}≥120	48		46	

Table 2.22 Harmonic Current 15-45 kW, 200 V

Provided that the short-circuit power of the supply S_{sc} is greater than or equal to:

$$S_{SC} = \sqrt{3} \times R_{SCE} \times U_{mains} \times I_{equ} = \sqrt{3} \times 120 \times 400 \times I_{equ}$$

at the interface point between the user's supply and the public system (R_{sce}).

It is the responsibility of the installer or user of the equipment to ensure, by consultation with the distribution network operator if necessary, that the equipment is connected only to a supply with a short-circuit power S_{sc} greater than or equal to specified above.
Other power sizes can be connected to the public supply network by consultation with the distribution network operator.

Compliance with various system level guidelines:
The harmonic current data in *Table 2.16* to *Table 2.23* are given in accordance with IEC/EN 61000-3-12 with reference to the Power Drive Systems product standard. They may be used as the basis for calculation of the harmonic currents' influence on the power supply system and for the documentation of compliance with relevant regional guidelines: IEEE 519 -1992; G5/4.

2.8.6 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.

2.9 Galvanic Isolation (PELV)

2.9.1 PELV - Protective Extra Low Voltage

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 440 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, as described, 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 *Illustration 2.26*.

To maintain PELV all connections made to the control terminals must be PELV, e.g. thermistor must be reinforced/double insulated.

0.25-22 kW

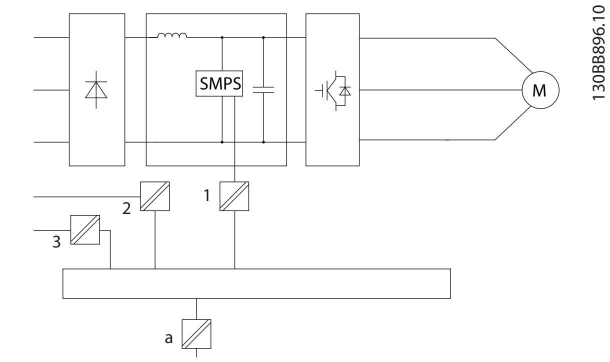


Illustration 2.25 Galvanic Isolation

1	Power supply (SMPS)
2	Optocouplers, communication between AOC and BOC
3	Custom relays
a	Control card terminals

Table 2.23 Legend to *Illustration 2.25*

30-90 kW

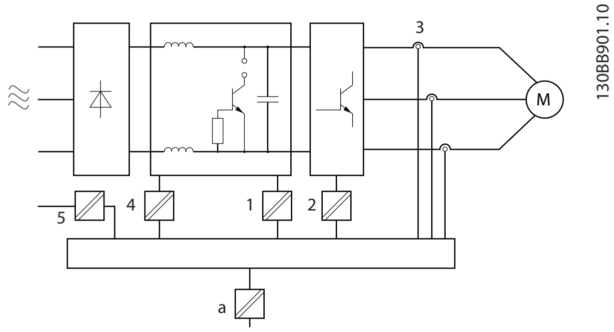


Illustration 2.26 Galvanic Isolation

1	Power supply (SMPS) incl. signal isolation of UDC, indicating the intermediate current voltage
2	Gate drive that runs the IGBTs (trigger transformers/opto-couplers)
3	Current transducers
4	Internal soft-charge, RFI and temperature measurement circuits
5	Custom relays
a	Control card terminals

Table 2.24 Legend to *Illustration 2.26*

The functional galvanic isolation (see *Illustration 2.25*) is for the RS-485 standard bus interface.

CAUTION

Installation at high altitude:
At altitudes above 2 km, contact Danfoss regarding PELV.

2

2.10 Earth Leakage Current

WARNING

DISCHARGE TIME

Touching the electrical parts could be fatal - even after the equipment has been disconnected from mains.
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.
Before touching any electrical parts, wait at least the amount of time indicated in the *Table 2.1*.
Shorter time is allowed only if indicated on the nameplate for the specific unit.

NOTICE

Leakage Current
The earth leakage current from the frequency converter exceeds 3.5 mA. To ensure that the earth cable has a good mechanical connection to the earth connection, the cable cross section must be at least 10 mm² Cu or 16 mm² Al or 2 rated earth wires terminated separately.
Residual Current Device protection RCD
This product can cause a DC current in the protective conductor. Where a residual current device (RCD) is used for protection in case of direct or indirect contact, only an RCD of Type B is allowed on the supply side of this product. Otherwise, another protective measure shall be applied, such as separation from the environment by double or reinforced insulation, or isolation from the supply system by a transformer. See also Application Note *Protection against Electrical Hazards, MN90G*.
Protective earthing of the frequency converter and the use of RCDs must always follow national and local regulations.

2.11 Extreme Running Conditions

Short circuit (motor phase – phase)
Current measurement in each of the 3 motor phases or in the DC-link, protects the frequency converter against short circuits. A short circuit between 2 output phases causes an overcurrent in the inverter. The inverter is 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.

Switching on the output
Switching on the output between the motor and the frequency converter is fully permitted. The frequency converter is not damaged in any way by switching on the output. However, 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 following cases:

1. The load drives the motor (at constant output frequency from the frequency converter), that is 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 (*1-62 Slip Compensation*) may cause higher DC link voltage.

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.

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.

2.11.1 Motor Thermal Protection

This is the way Danfoss protects the motor from being overheated. It is an electronic feature that simulates a bimetal relay based on internal measurements. The characteristic is shown in *Illustration 2.27*.

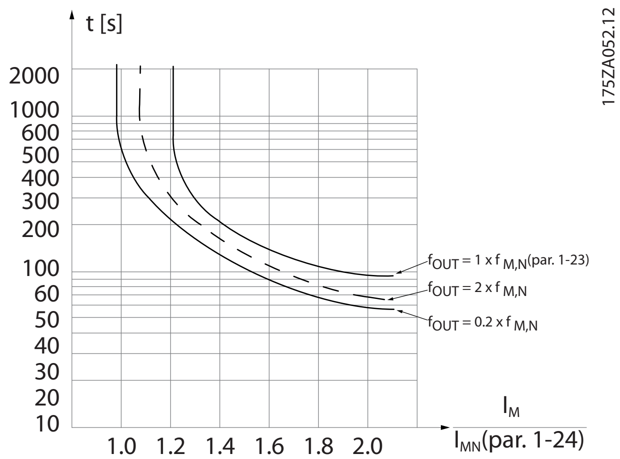


Illustration 2.27 Motor Thermal Protection Characteristic

The X-axis is showing the ratio between I_{motor} and I_{motor} nominal. The Y-axis is showing the time in seconds before the ETR cuts off and trips the frequency converter. The curves are showing the characteristic nominal speed at twice the nominal speed and at 0.2x the nominal speed.

It is clear that at lower speed the ETR cuts off at lower heat due to less cooling of the motor. In that way the motor are protected from being over heated even at low speed. The ETR feature is calculating the motor temperature based on actual current and speed.

The thermistor cut-out value is >3 kΩ.

Integrate a thermistor (PTC sensor) in the motor for winding protection.

Motor protection can be implemented using a range of techniques: PTC sensor in motor windings; mechanical thermal switch (Klixon type); or Electronic Thermal Relay (ETR).

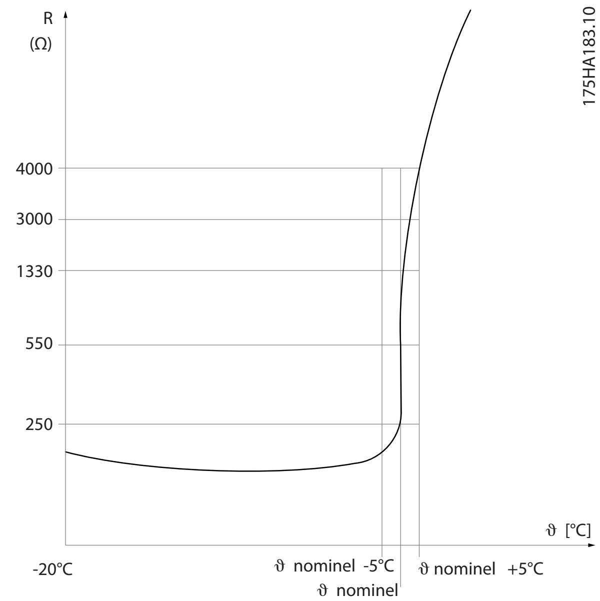


Illustration 2.28 Trip due to High Motor Temperature

Using a digital input and 10 V as power supply:
Example: The frequency converter trips when the motor temperature is too high.
Parameter set-up:
Set *1-90 Motor Thermal Protection* to *[2] Thermistor Trip*
Set *1-93 Thermistor Source* to *[6] Digital Input 29*

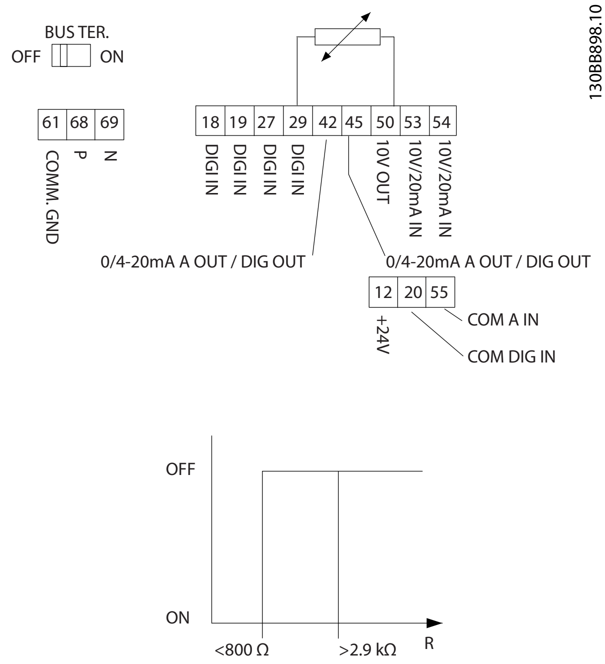


Illustration 2.29 Digital Input/10 V Power Supply

Using an analog input and 10 V as power supply:
Example: The frequency converter trips when the motor temperature is too high.
Parameter set-up:
Set *1-90 Motor Thermal Protection* to *[2] Thermistor Trip*
Set *1-93 Thermistor Source* to *[2] Analog Input 54*

NOTICE

Do not set *Analog Input 54* as reference source.

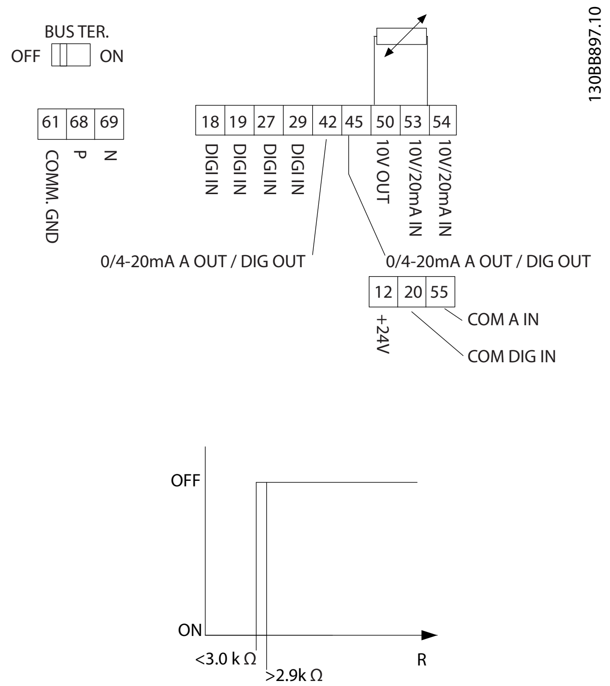


Illustration 2.30 Analog Input/10 V Power Supply

Input	Supply Voltage [V]	Threshold Cut-out Values [Ω]
Digital	10	<800 ⇒ 2.9 k
Analog	10	<800 ⇒ 2.9 k

Table 2.25 Supply Voltage

NOTICE

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

Summary
With the ETR, the motor is protected for being over-heated and there is no need for any further motor protection. That means when the motor is heated up, the ETR timer controls for how long time the motor can run at the high temperature before it is stopped to prevent over heating. If the motor is overloaded without reaching the temperature, the ETR shuts of the motor.

ETR is activated in *1-90 Motor Thermal Protection*.

3 Selection

3.1 Options and Accessories

3.1.1 Local Control Panel (LCP)

Ordering no.	Description
132B0200	LCP for all IP20 units

Table 3.1 Ordering Number

Enclosure	IP55 front
Max. cable length to unit	10 ft (3 m)
Communication std.	RS-485

Table 3.2 Technical Data

3.1.2 Mounting of LCP in Panel Front

Step 1
Fit gasket on LCP.

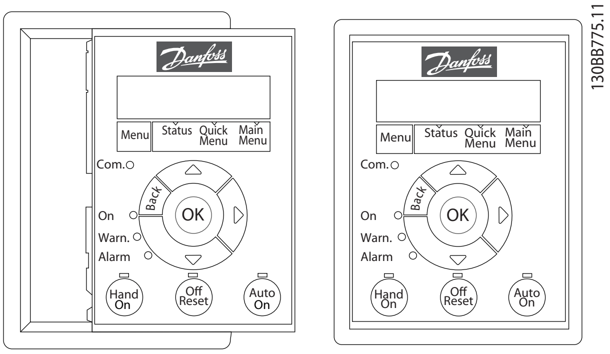


Illustration 3.1 Fit Gasket

Step 2
Place LCP on panel, see dimensions of hole on *Illustration 3.2.*

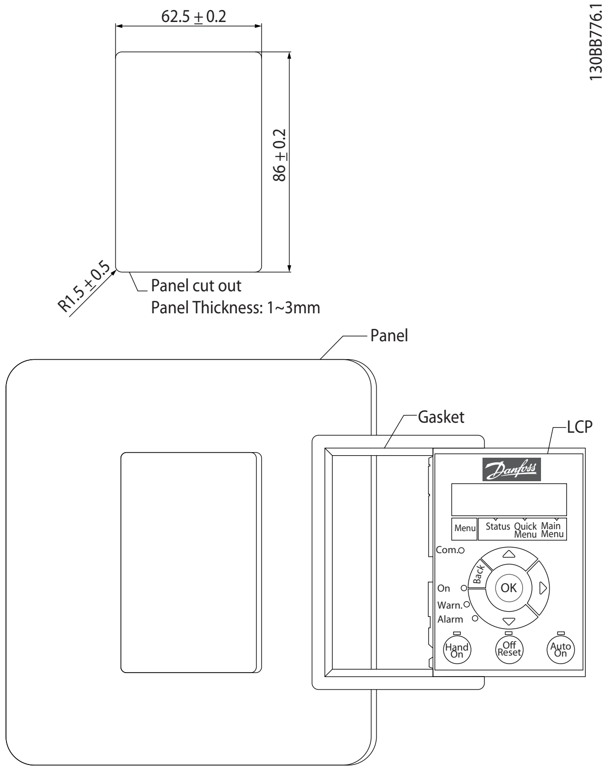


Illustration 3.2 Place LCP on Panel

Step 3
Place bracket on back of the LCP, then slide down. Tighten screws and connect cable female side to LCP.

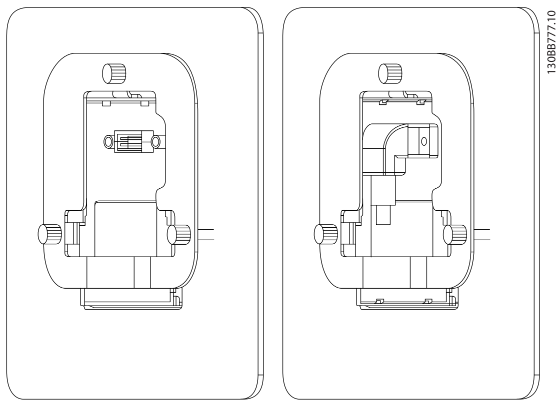


Illustration 3.3 Place Bracket on LCP

Step 4
Connect cable to frequency converter.

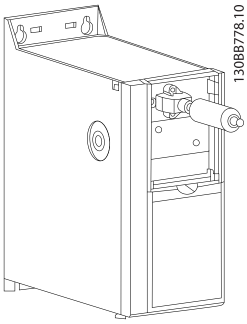


Illustration 3.4 Connect Cable

NOTICE

Use the provided thread cutting screws to fasten connector to the frequency converter, tightening torque 1.3 Nm.

3.1.3 IP21/TYPE 1 Enclosure Kit

IP21/TYPE 1 is an optional enclosure element available for IP20 units.
If the enclosure kit is used, an IP20 unit is upgraded to comply with enclosure IP21/TYPE 1.

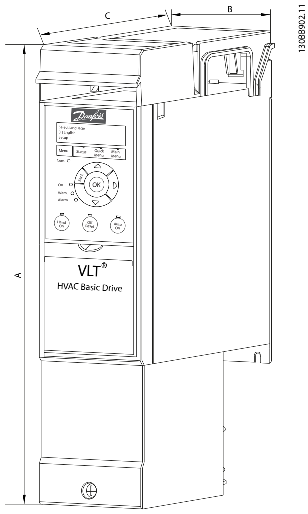


Illustration 3.5 H1-H5

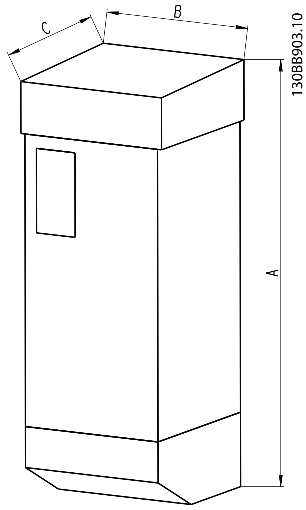


Illustration 3.6 Dimensions

Frame	IP class	Power			Height [mm] A	Width [mm] B	Depth [mm] C	IP21 kit ordering no.	Type 1 kit ordering no.
		3 x 200-240 V	3 x 380-480 V	3 x 525-600 V					
H1	IP20	0.25-1.5 kW	0.37-1.5 kW		293	81	173	132B0212	132B0222
H2	IP20	2.2 kW	2.2-4 kW		322	96	195	132B0213	132B0223
H3	IP20	3.7 kW	5.5-7.5 kW		346	106	210	132B0214	132B0224
H4	IP20	5.5-7,5 kW	11-15 kW		374	141	245	132B0215	132B0225
H5	IP20	11 kW	18.5-22 kW		418	161	260	132B0216	132B0226
H6	IP20	15-18.5 kW	30-45 kW	18.5-30 kW	663	260	242	132B0217	132B0217
H7	IP20	22-30 kW	55-75 kW	37-55 kW	807	329	335	132B0218	132B0218
H8	IP20	37-45 kW	90 kW	75-90 kW	943	390	335	132B0219	132B0219
H9	IP20			2.2-7.5 kW	372	130	205	132B0220	132B0220
H10	IP20			11-15 kW	475	165	249	132B0221	132B0221

Table 3.3 Enclosure Kit Specifications

3.1.4 Decoupling Plate

Use the decoupling plate for EMC correct installation.

Shown here on a H3 enclosure.

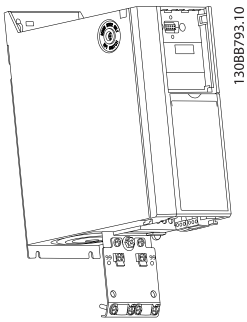


Illustration 3.7 Decoupling Plate

		Power [kW]			Decoupling plate
Frame	IP class	3 x 200-240 V	3 x 380-480 V	3 x 525-600 V	
H1	IP20	0.25-1.5	0.37-1.5		132B0202
H2	IP20	2.2	2.2-4		132B0202
H3	IP20	3.7	5.5-7.5		132B0204
H4	IP20	5.5-7.5	11-15		132B0205
H5	IP20	11	18.5-22		130B0205
H6	IP20	15-18.5	30	18.5-30	132B0207
H6	IP20		37-45		132B0242
H7	IP20	22-30	55	37-55	132B0208
H7	IP20		75		132B0243
H8	IP20	37-45	90	75-90	132B0209

Table 3.4 Decoupling Plate Specifications

NOTICE

For H9 and H10 frequency converters, the decoupling plates are included in the accessory bag.

4 How to Order

4.1 Configuration

4.1.1 Drive Configurator

4

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

Frequency converters can be ordered as standard or with internal options by using a type code string, i.e.

FC-101PK25T2E20H4XXCXXXSXXXXAXBXCXXXXDX

Use the Internet based Drive Configurator to configure the right frequency converter for the right application and generate the type code string. The Drive Configurator automatically generates an 8-digit sales number to be delivered to your local sales office.
Furthermore, a project list with several products can be established and sent it Danfoss sales representative.

4.1.2 Type Code String

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	-	1	0	1	P				T					H		X			X	X	X	S	X	X	X	X	A	X	B	X	C	X	X	X	X	D	X

130BB899.10

Illustration 4.1 Type Code

Description	Pos.	Possible choice
Product group & FC series	1-6	FC 101
Power rating	7-10	0.25-90 kW (PK25-P90K)
Number of phases	11	Three phases (T)
Mains voltage	11-12	T2: 200-240 V AC T4: 380-480 V AC T6: 525-600 V AC
Enclosure	13-15	E20: IP20/Chassis P20: IP20/Chassis with back plate E5A: IP54 P5A: IP54 with back plate
RFI filter	16-17	H1: RFI filter class A1/B H2: RFI filter class A2 H3: RFI filter class A1/B (reduced cable length) H4: RFI filter class A1
Brake	18	X: No brake chopper included
Display	19	A: Alpha Numeric Local Control Panel X: No Local Control Panel
Coating PCB	20	X: No coated PCB C: Coated PCB
Mains option	21	X: No mains option
Adaption	22	X: No adaption
Adaption	23	X: No adaption
Software release	24-27	SXXXX: Latest release - std. software
Software language	28	X: Standard
A options	29-30	AX: No A options
B options	31-32	BX: No B options
C0 options MCO	33-34	CX: No C options
C1 options	35	X: No C1 options
C option software	36-37	XX: No options
D options	38-39	DX: No D0 options

Table 4.1 Type Code Descriptions

4.2 Ordering Numbers

4

4.2.1 Ordering Numbers: Options and Accessories

	Enclosure frame size Mains voltage	H1 [kW/Hp]	H2 [kW/Hp]	H3 [kW/Hp]	H4 [kW/Hp]	H5 [kW/Hp]	H6 [kW/Hp]		H7 [kW/Hp]		H8 [kW/Hp]
	T2 (200-240 V AC)	0.25-1.5/0.33-2	2.2/3	3.7/5	5.5-7.5/7.5-10	11/15	15-18.5/20		22-30/30		37-45/50-60
	T4 (380-480 V AC)	0.37-1.5/0.5-2	2.2-4/3-5.4	5.5-7.5/7.5-10	11-15/15-20	18.5-22/25-30	30/40	37-45/50-60	55/75	75/100	90/125
	T6 (525-600 V AC)						18.5-30/30		37-55/60		75-90/120-125
Description											
LCP		132B0200									
LCP panel mounting kit IP55 incl. 3 m cable		132B0201									
Decoupling plate		132B0202	132B0202	132B0204	132B0205	132B0205	132B0207	132B0242	132B0208	132B0243	132B0209
IP21 option		132B0212	132B0213	132B0214	132B0215	132B0216	132B0217		132B0218		132B0219
Nema Type 1 Kit		132B0222	132B0223	132B0224	132B0225	132B0226	132B0217		132B0218		132B0219

Table 4.2 Options and Accessories

4.2.2 Harmonic Filters

3x380-480 V 50 Hz					
Power [kW]	Drive input current Continuous [A]	Default switching frequency [kHz]	THID level [%]	Order number filter IP00	Code number filter IP20
22	41.5	4	4	130B1397	130B1239
30	57	4	3	130B1398	130B1240
37	70	4	3	130B1442	130B1247
45	84	3	3	130B1442	130B1247
55	103	3	5	130B1444	130B1249
75	140	3	4	130B1445	130B1250
90	176	3	4	130B1445	130B1250

Table 4.3 AHF Filters (5% current distortion)

3x440-480 V 60 Hz					
Power [kW]	Drive input current Continuous [A]	Default switching frequency [kHz]	THID level [%]	Order number filter IP00	Code number filter IP20
22	34.6	4	3	130B1792	130B1757
30	49	4	3	130B1793	130B1758
37	61	4	3	130B1794	130B1759
45	73	3	4	130B1795	130B1760
55	89	3	4	130B1796	130B1761
75	121	3	5	130B1797	130B1762
90	143	3	5	130B1798	130B1763

Table 4.5 AHF Filters (5% current distortion)

3x380-480 V 50 Hz					
Power [kW]	Drive input current Continuous [A]	Default switching frequency [kHz]	THID level [%]	Order number filter IP00	Code number filter IP20
22	41.5	4	6	130B1274	130B1111
30	57	4	6	130B1275	130B1176
37	70	4	9	130B1291	130B1201
45	84	3	9	130B1291	130B1201
55	103	3	9	130B1292	130B1204
75	140	3	8	130B1294	130B1213
90	176	3	8	130B1294	130B1213

Table 4.4 AHF Filters (10% current distortion)

3x440-480 V 60 Hz					
Power [kW]	Drive input current Continuous [A]	Default switching frequency [kHz]	THID level [%]	Order number filter IP00	Code number filter IP20
22	34.6	4	6	130B1775	130B1487
30	49	4	8	130B1776	130B1488
37	61	4	7	130B1777	130B1491
45	73	3	9	130B1778	130B1492
55	89	3	8	130B1779	130B1493
75	121	3	9	130B1780	130B1494
90	143	3	10	130B1781	130B1495

Table 4.6 AHF Filters (10% current distortion)

4.2.3 External RFI Filter

External filters to fulfil A1 50 m/B1 20 m.

Power [kW] Size 380-480 V	Type	A	B	C	D	E	F	G	H	I	J	K	L1	Torque [Nm]	Weight [kg]	Ordering Number
0.37-2.2	FN3258-7-45	190	40	70	160	180	20	4.5	1	10.6	M5	20	31	0.7-0.8	0.5	132B0244
3-7.5	FN3258-16-45	250	45	70	220	235	25	4.5	1	10.6	M5	22.5	31	0.7-0.8	0.8	132B0245
11-15	FN3258-30-47	270	50	85	240	255	30	5.4	1	10.6	M5	25	40	1.9-2.2	1.2	132B0246
18.5-22	FN3258-42-47	310	50	85	280	295	30	5.4	1	10.6	M5	25	40	1.9-2.2	1.4	132B0247

Table 4.7 RFI Filters - Details

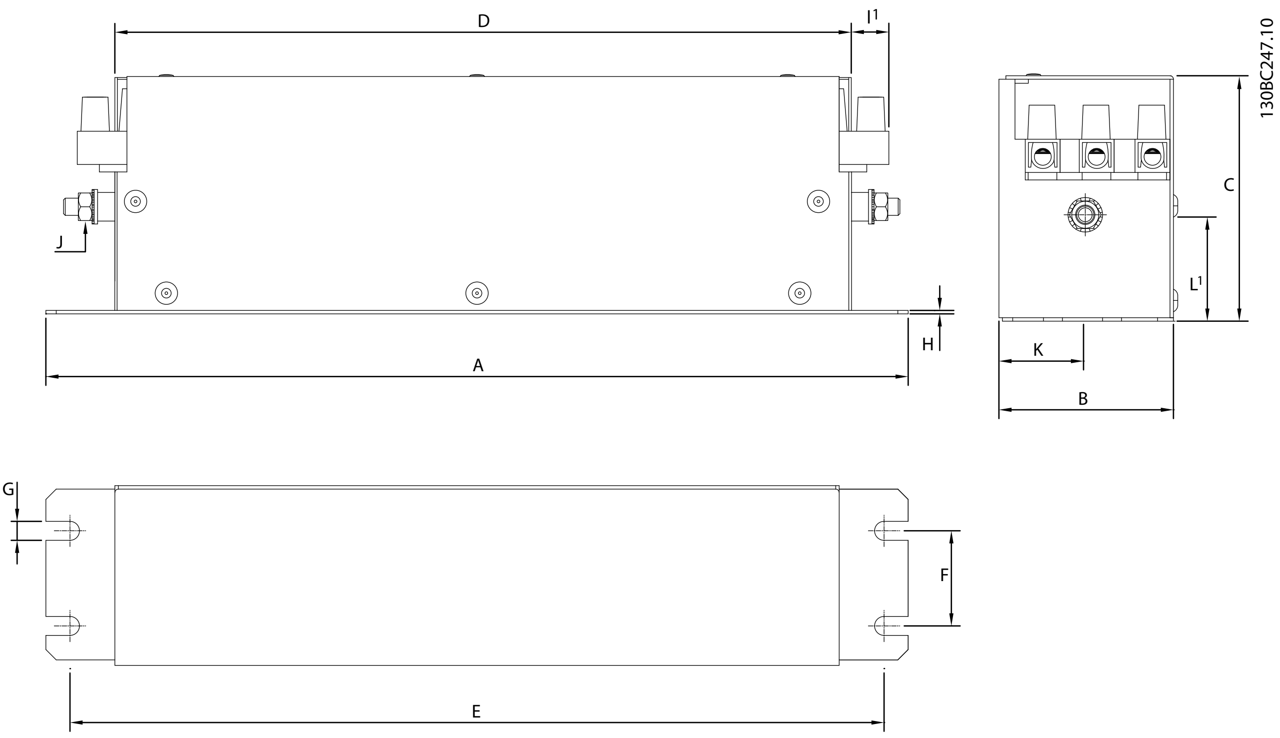
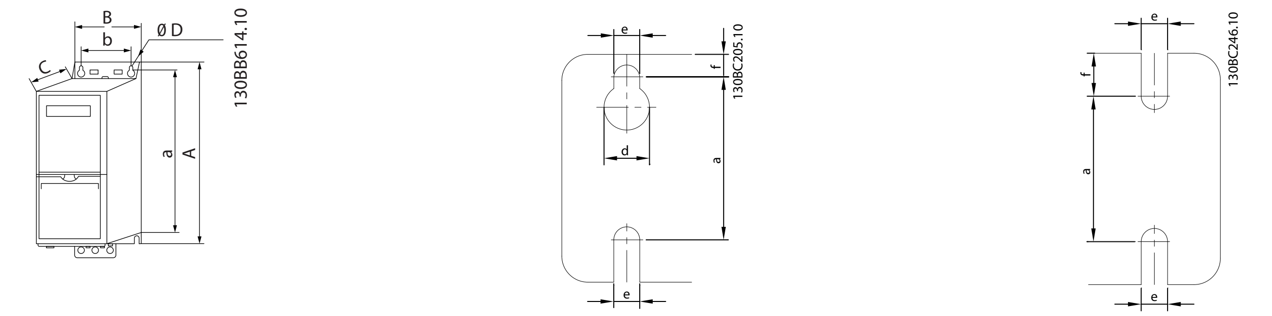


Illustration 4.2 RFI Filter

5 How to Install

5.1 Mechanical Dimensions

5.1.1 Frequency Converter Dimensions



Enclosure		Power [kW]			Height [mm]			Width [mm]		Depth [mm]	Mounting hole [mm]			Max. Weight
Frame	IP Class	3x200-240 V	3x380-480 V	3x525-600 V	A	A[1]	a	B	b	C	d	e	f	kg
H1	IP20	0.25-1.5	0.37-1.5		195	273	183	75	56	168	9	4.5	5.3	2.1
H2	IP20	2.2	2.2-4.0		227	303	212	90	65	190	11	5.5	7.4	3.4
H3	IP20	3.7	5.5-7.5		255	329	240	100	74	206	11	5.5	8.1	4.5
H4	IP20	5.5-7.5	11-15		296	359	275	135	105	241	12.6	7	8.4	7.9
H5	IP20	11	18.5-22		334	402	314	150	120	255	12.6	7	8.5	9.5
H6	IP20	15-18.5	30-45	18.5-30	518	595/635 (45 kW)	495	239	200	242	-	8.5	15	24.5
H7	IP20	22-30	55-75	37-55	550	630/690 (75 kW)	521	313	270	335	-	8.5	17	36
H8	IP20	37-45	90	75-90	660	800	631	375	330	335	-	8.5	17	51
H9	IP20			2.2-7.5	269	374	257	130	110	205	11	5.5	9	6.6
H10	IP20			11-15	399	419	380	165	140	248	12	6.8	7.5	12
I2	IP54		0.75-4.0		332	-	318.5	115	74	225	11	5.5	9	5.3
I3	IP54		5.5-7.5		368	-	354	135	89	237	12	6.5	9.5	7.2
I4	IP54		11-18.5		476	-	460	180	133	290	12	6.5	9.5	13.8
I6	IP54		22-37		650	-	624	242	210	260	19	9	9	27
I7	IP54		45-55		680	-	648	308	272	310	19	9	9.8	45
I8	IP54		75-90		770	-	739	370	334	335	19	9	9.8	65

Table 5.1 Dimensions

[1] *Including decoupling plate*

The dimensions are only for the physical units, but when installing in an application it is necessary to add space for free air passage both above and below the units. The amount of space for free air passage is listed in *Table 5.2*:

Enclosure		Clearance [mm]	
Frame	**IP class**	**Above unit**	**Below unit**
H1	20	100	100
H2	20	100	100
H3	20	100	100
H4	20	100	100
H5	20	100	100
H6	20	200	200
H7	20	200	200
H8	20	225	225
H9	20	100	100
H10	20	200	200
I2	54	100	100
I3	54	100	100
I4	54	100	100
I6	54	200	200
I7	54	200	200
I8	54	225	225

Table 5.2 Clearance Needed for Free Air Passage

5.1.2 Shipping Dimensions

Enclosure frame size Mains voltage	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	I2	I3	I4	I5	I6	I7	I8
T2 (200-240 V AC) [kW/Hp]	0.25-1.5/ 0.33-2	2.2/3	3.7/5	5.5-7.5/ 7.5-10	11/15	15-18.5/ 20	22-30/ 30-40	37-45/ 50-60									
T4 (380-480 V AC) [kW/Hp]	0.37-1.5/ 0.5-2	2.2-4/ 3-5.4	5.5-7.5/ 7.5-10	11-15/ 15-20	18.5-22/ 25-30	30-45/ 40-60	55-75/ 73-100	90/ 125			0.75/ 1.0-5.0	5.5-7.5/ 7.5-10	11-18.5/ 15-25	11-18.5/ 15-25	22-37/ 30-50	45-55/ 60-70	75-90/ 125
T6 (525-600 V AC) [kW/Hp]						18.5-30/ 30-40	37-55/ 60-70	75-90/ 100-125	2.2-7.5/ 3.0-10	11-15/ 15-20							
IP frame	**IP20**										**IP54**						
Maximum weight [kg]	2.1	3.4	4.5	7.9	9.5	24.5	36	51	6.6	11.5	6.1	7.8	13.8	23.3	28.3	41.5	60.5
Shipping dimensions																	
Height [mm/inch]	255/10.0	300/ 11.8	330/ 13.0	380/ 15.0	420 / 16.5	850	850	850	380	500	440	470	588	850	850	850	950
Width [mm/inch]	154/6.1	170/ 6.7	188/ 7.4	250/ 9.8	290/ 11.4	370	410	490	290	330	200	240	285	370	370	410	490
Depth [mm/inch]	235/9.3	260/ 10.2	282/ 11.1	375/ 14.8	375/ 14.8	460	540	490	200	350	300	330	385	460	460	540	490

Table 5.3 Dimensions

5.1.3 Side-by-Side Installation

The frequency converter can be mounted side-by-side and requires the clearance above and below for cooling.

		Power [kW]			Clearance above/below [mm/inch]
Frame	IP class	3x200-240 V	3x380-480 V	3x525-600 V	
H1	IP20	0.25-1.5	0.37-1.5		100/4
H2	IP20	2.2	2.2-4		100/4
H3	IP20	3.7	5.5-7.5		100/4
H4	IP20	5.5-7.5	11-15		100/4
H5	IP20	11	18.5-22		100/4
H6	IP20	15-18.5	30-45	18.5-30	200/7.9
H7	IP20	22-30	55-75	37-55	200/7.9
H8	IP20	37-45	90	75-90	225/8.9
H9	IP20			2.2-7.5	100/4
H10	IP20			11-15	200/7.9

Table 5.4 Clearance

NOTICE

With IP21/Nema Type1 option kit mounted, a distance of 50 mm between the units is required.

5.1.4 Field Mounting

IP21/TYPE 1 kits are recommended.

5.2 Electrical Data

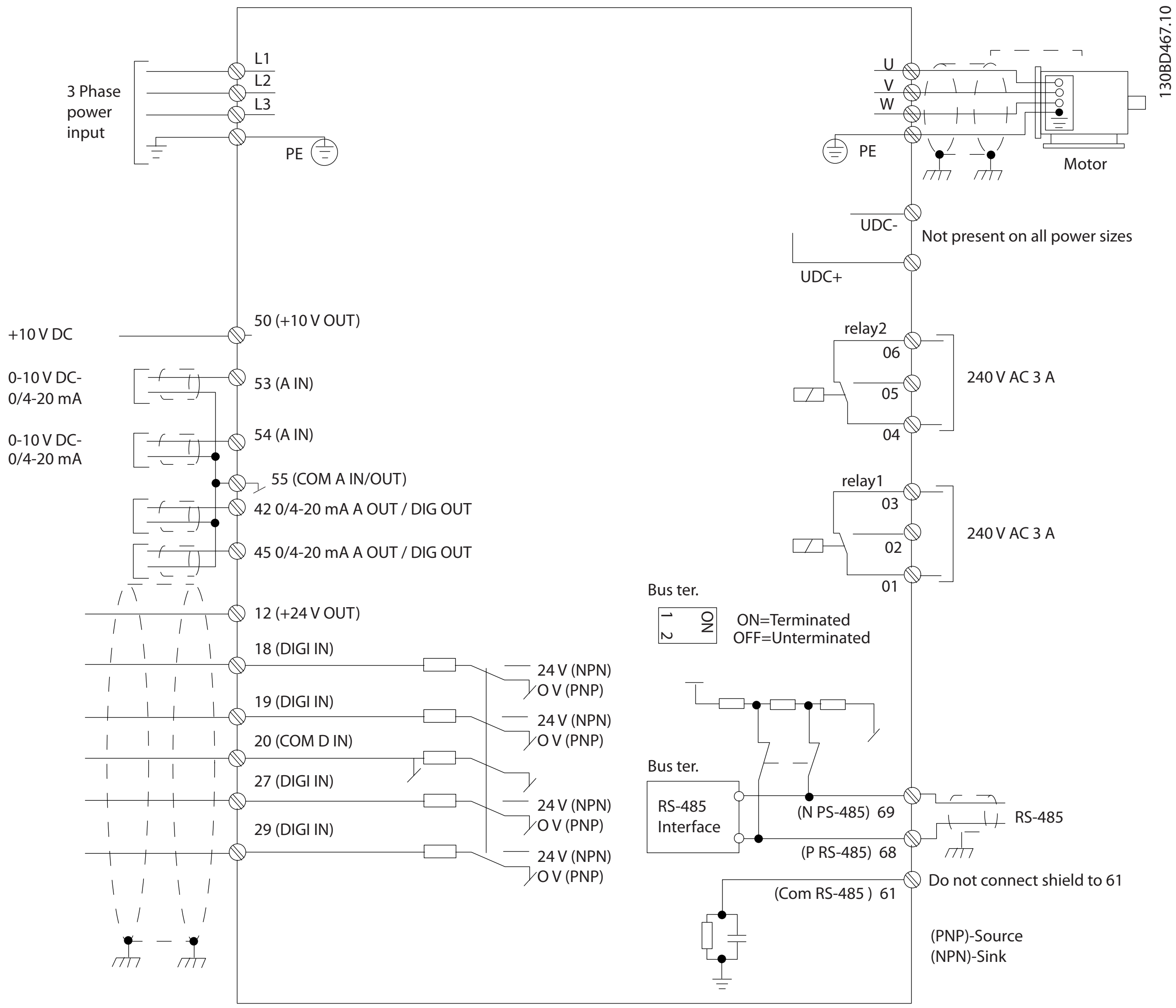


Illustration 5.1 Basic Wiring Schematic Drawing

NOTICE

There is no access to UDC- and UDC+ on the following units:
IP20 380-480 V 30-90 kW
IP20 200-240 V 15-45 kW
IP20 525-600 V 2.2-90 kW
IP54 380-480 V 22-90 kW

5.2.1 Electrical Installation in General

All cabling must comply with national and local regulations on cable cross-sections and ambient temperature. Copper conductors required, (75 °C) recommended.

Power [kW]				Torque [Nm]					
Frame	IP class	3x200-240 V	3x380-480 V	Line	Motor	DC connection	Control terminals	Earth	Relay
H1	IP20	0.25-1.5	0.37-1.5	1.4	0.8	0.8	0.5	0.8	0.5
H2	IP20	2.2	2.2-4	1.4	0.8	0.8	0.5	0.8	0.5
H3	IP20	3.7	5.5-7.5	1.4	0.8	0.8	0.5	0.8	0.5
H4	IP20	5.5-7.5	11-15	1.2	1.2	1.2	0.5	0.8	0.5
H5	IP20	11	18.5-22	1.2	1.2	1.2	0.5	0.8	0.5
H6	IP20	15-18	30-45	4.5	4.5	-	0.5	3	0.5
H7	IP20	22-30	55	10	10	-	0.5	3	0.5
H7	IP20	-	75	14	14	-	0.5	3	0.5
H8	IP20	37-45	90	24[2]	24[2]	-	0.5	3	0.5

Table 5.5 Enclosure H1-H8

Power [kW]			Torque [Nm]					
Frame	IP class	3x380-480 V	Line	Motor	DC connection	Control terminals	Earth	Relay
I2	IP54	0.75-4.0	1.4	0.8	0.8	0.5	0.8	0.5
I3	IP54	5.5-7.5	1.4	0.8	0.8	0.5	0.8	0.5
I4	IP54	11-18.5	1.4	0.8	0.8	0.5	0.8	0.5
I6	IP54	22-37	4.5	4.5	-	0.5	3	0.6
I7	IP54	45-55	10	10	-	0.5	3	0.6
I8	IP54	75-90	14/24[1]	14/24[1]	-	0.5	3	0.6

Table 5.6 Enclosure I1-I8

Power [kW]			Torque [Nm]					
Frame	IP class	3x525-600 V	Line	Motor	DC connection	Control terminals	Earth	Relay
H9	IP20	2.2-7.5	1.8	1.8	not recommended	0.5	3	0.6
H10	IP20	11-15	1.8	1.8	not recommended	0.5	3	0.6
H6	IP20	18.5-30	4.5	4.5	-	0.5	3	0.5
H7	IP20	37-55	10	10	-	0.5	3	0.5
H8	IP20	75-90	14/24[1]	14/24[1]	-	0.5	3	0.5

Table 5.7 Details of Tightening Torques

[1] Cable dimensions ≤95 mm²

[2] Cable dimensions >95 mm²

5.2.2 Connecting to Mains and Motor

The frequency converter is designed to operate all standard 3-phased asynchronous motors. For maximum cross-section on wires see *8.2 General Specifications*.

- Use a shielded/armored motor cable to comply with EMC emission specifications, and connect this cable to both the decoupling plate and the motor metal.
- Keep motor cable as short as possible to reduce the noise level and leakage currents.
- For further details on mounting of the decoupling plate, see *FC 101 De-coupling Plate Mounting Instruction*.
- Also see *EMC-Correct Installation in the VLT® HVAC Basic Design Guide*.

1. Mount the earth wires to earth terminal.
2. Connect motor to terminals U, V and W.
3. Mount mains supply to terminals L1, L2 and L3 and tighten.

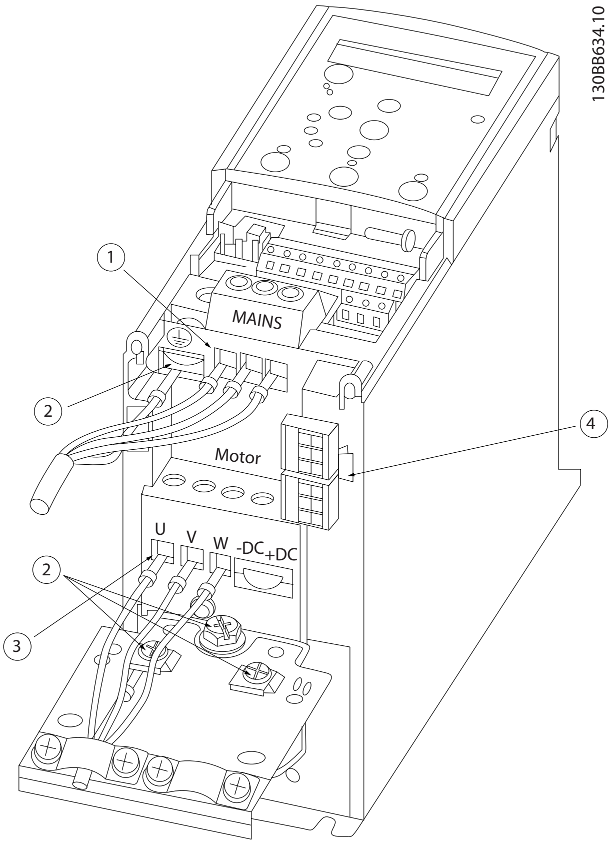


Illustration 5.2 H1-H5 Frame
IP20 200-240 V 0.25-11 kW and IP20 380-480 V 0.37-22 kW

1	Line
2	Earth
3	Motor
4	Relays

Table 5.8 Legend to *Illustration 5.2*

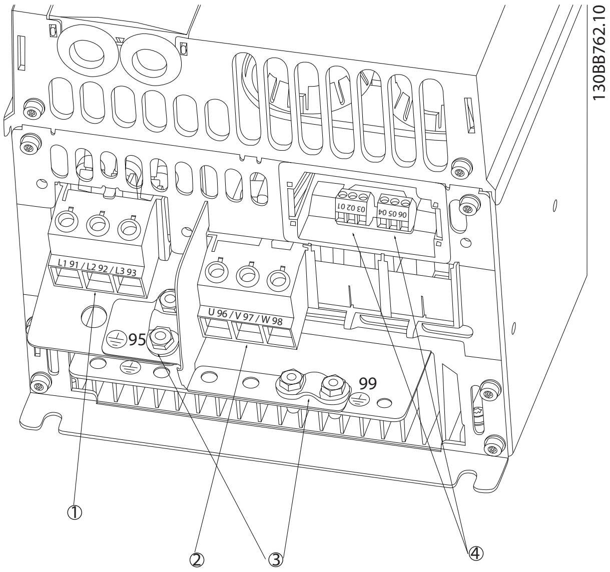


Illustration 5.3 H6 Frame
IP20 380-480 V 30-45 kW
IP20 200-240 V 15-18.5 kW
IP20 525-600 V 22-30 kW

1	Line
2	Motor
3	Earth
4	Relays

Table 5.9 Legend to *Illustration 5.3*

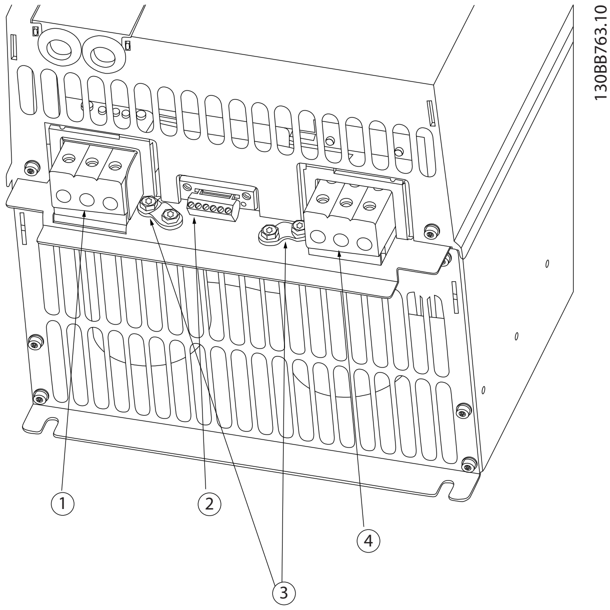


Illustration 5.4 H7 Frame
IP20 380-480 V 55-75 kW
IP20 200-240 V 22- 30 kW
IP20 525-600 V 45-55 kW

1	Line
2	Relays
3	Earth
4	Motor

Table 5.10 Legend to *Illustration 5.4*

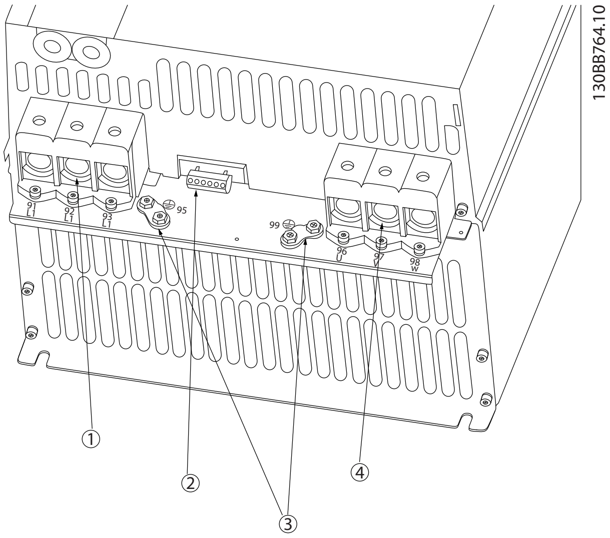


Illustration 5.5 H8 Frame
IP20 380-480 V 90 kW
IP20 200-240 V 37-45 kW
IP20 525-600 V 75-90 kW

1	Line
2	Relays
3	Earth
4	Motor

Table 5.11 Legend to

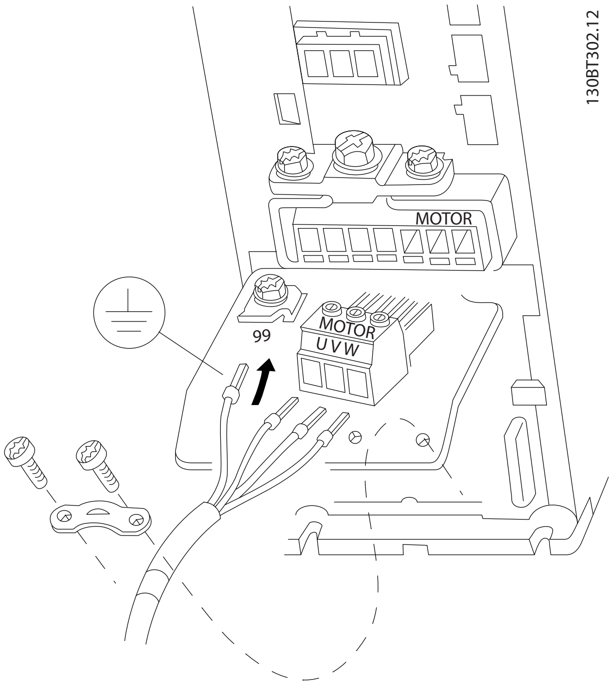


Illustration 5.6 H9 Frame
IP20 600 V 2.2-7.5 kW

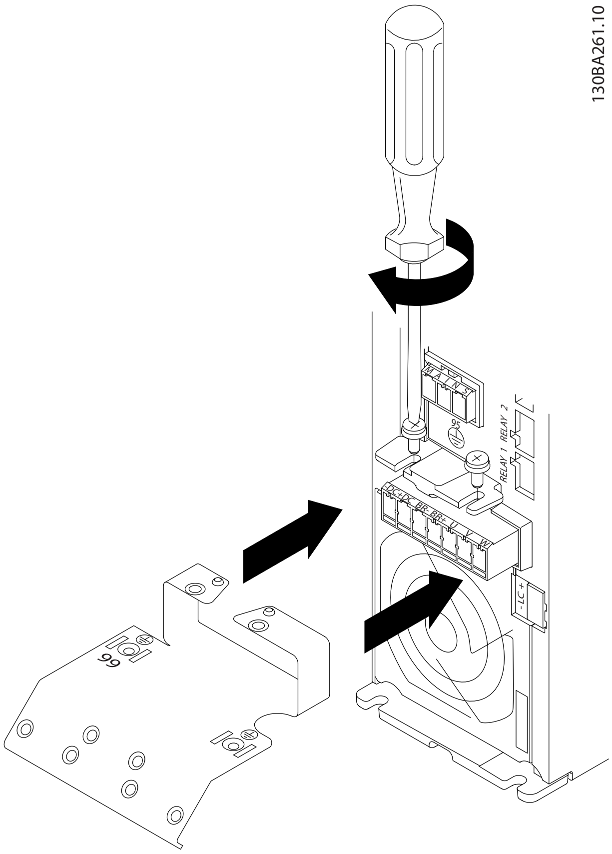


Illustration 5.7 Mount the 2 screws in the mounting plate, slide it into place and tighten fully

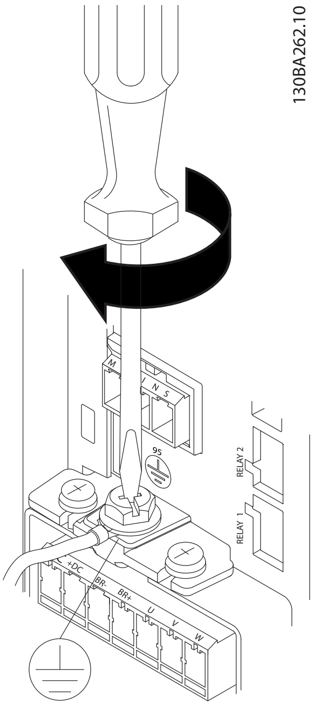


Illustration 5.8 When mounting cables, first mount and tighten earth cable

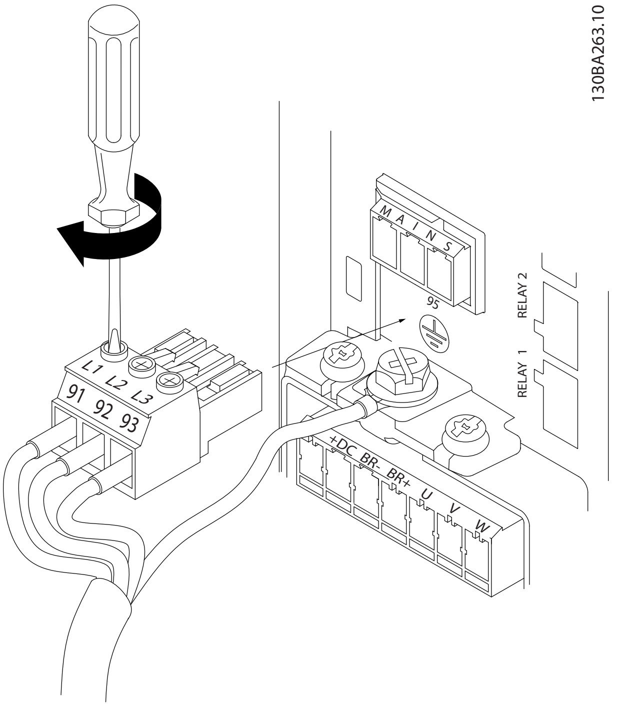


Illustration 5.9 Mount mains plug and tighten wires

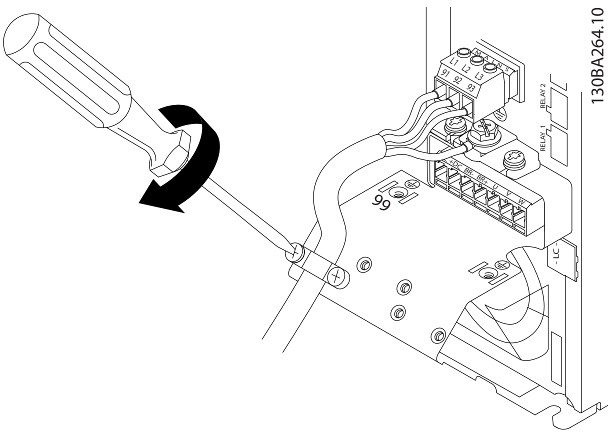


Illustration 5.10 Tighten support bracket on mains wires

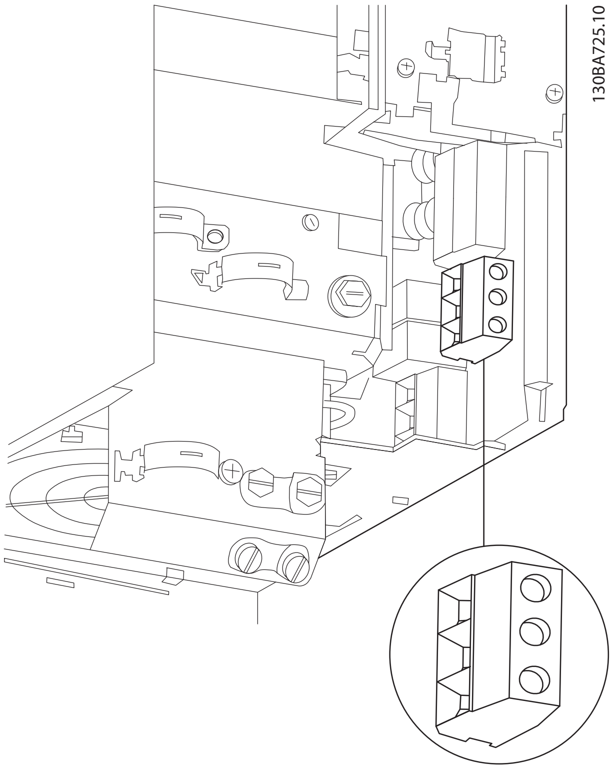


Illustration 5.11 H10 Frame IP20 600 V 11-15 kW

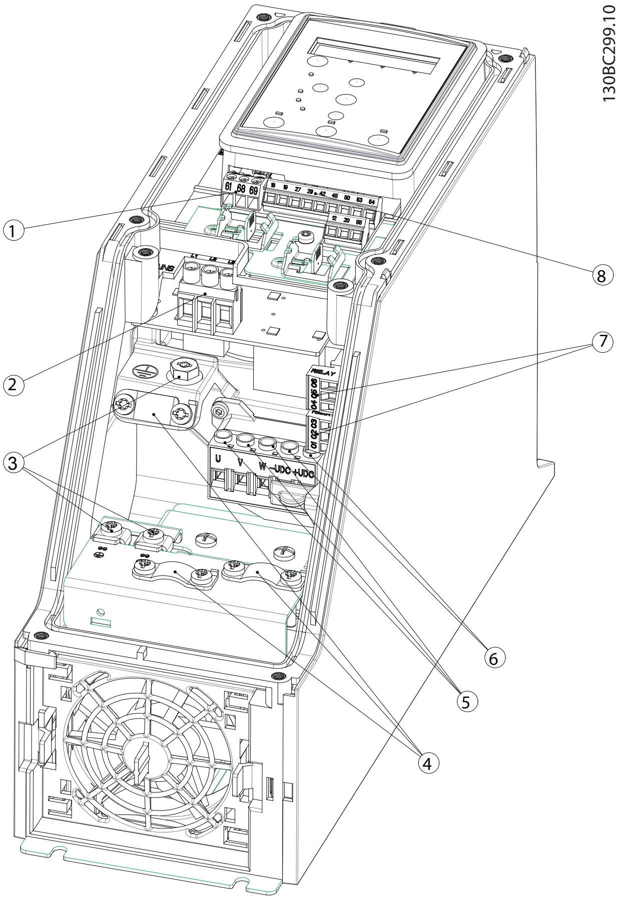


Illustration 5.12 I2 Frame
IP54 380-480 V 0.75-4.0 kW

1	RS-485
2	Line in
3	Earth
4	Wire clamps
5	Motor
6	UDC
7	Relays
8	I/O

Table 5.12 Legend to *Illustration 5.12*

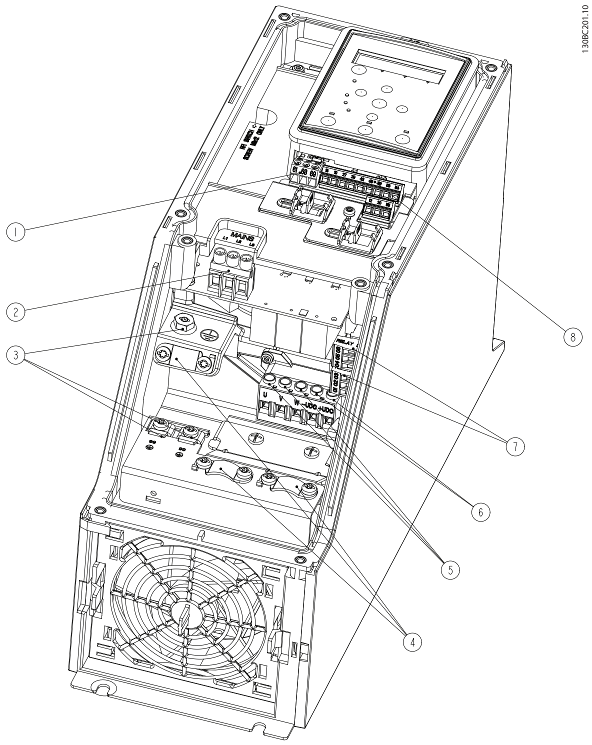


Illustration 5.13 I3 Frame
IP54 380-480 V 5.5-7.5 kW

1	RS-485
2	Line in
3	Earth
4	Wire clamps
5	Motor
6	UDC
7	Relays
8	I/O

Table 5.13 Legend to *Illustration 5.13*

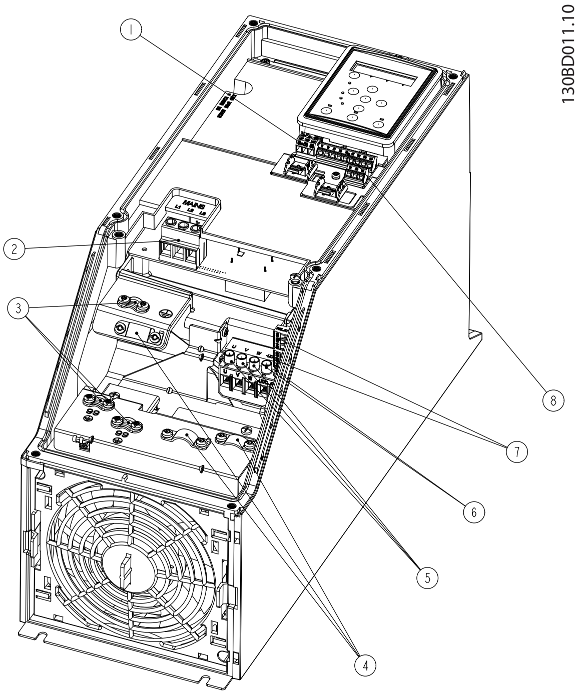


Illustration 5.14 I4 Frame
IP54 380-480 V 0.75-4.0 kW

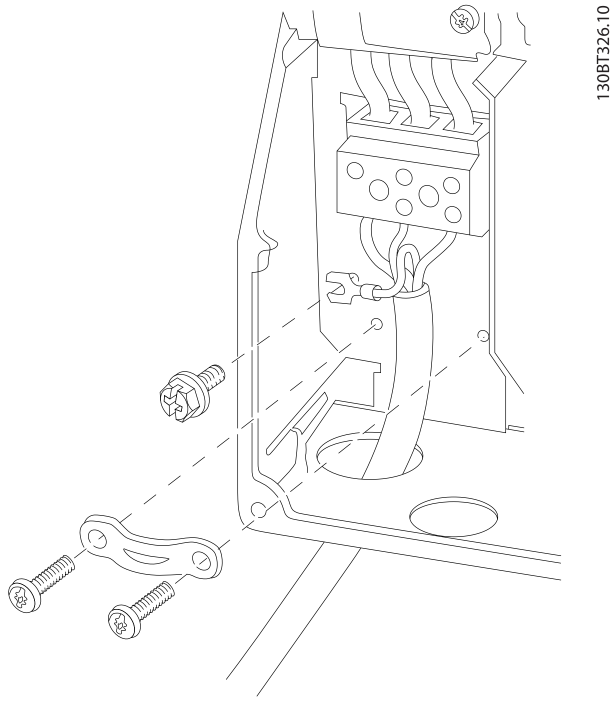


Illustration 5.16 I6 Frame
IP54 380-480 V 22-37 kW

1	RS-485
2	Line in
3	Earth
4	Wire clamps
5	Motor
6	UDC
7	Relays
8	I/O

Table 5.14 Legend to *Illustration 5.14*

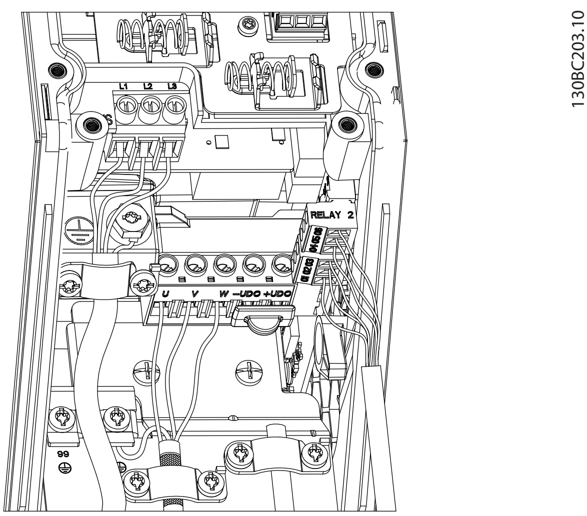


Illustration 5.15 IP54 I2-I3-I4 frame

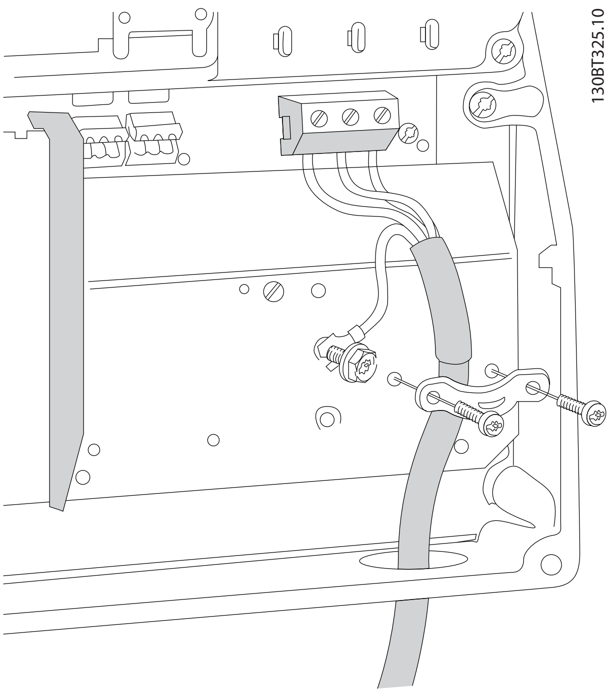


Illustration 5.17 I6 Frame
IP54 380-480 V 22-37 kW

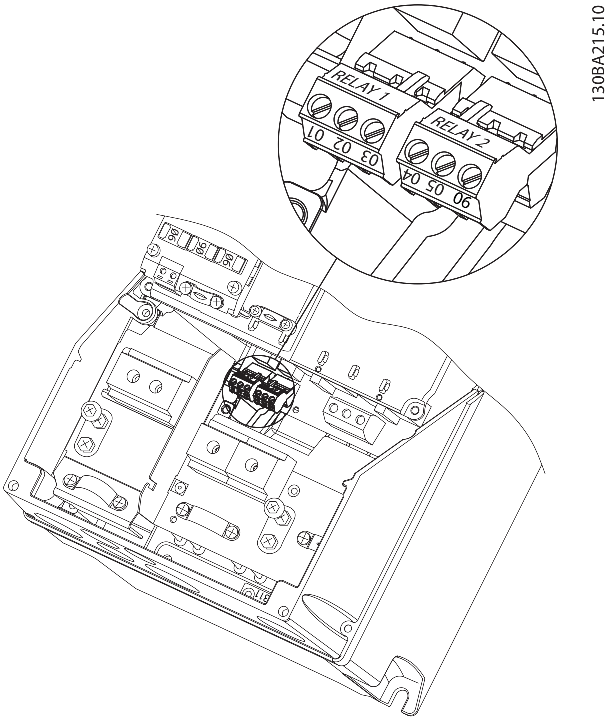


Illustration 5.18 I6 Frame
IP54 380-480 V 22-37 kW

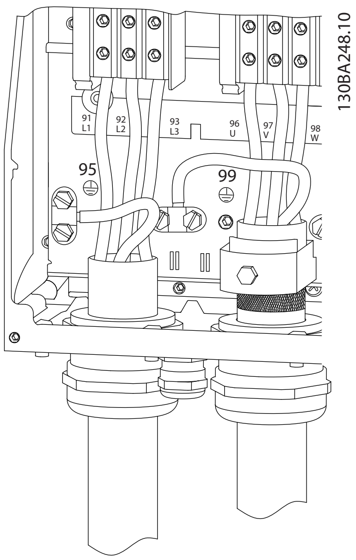


Illustration 5.19 I7, I8 Frame
IP54 380-480 V 45-55 kW
IP54 380-480 V 75-90 kW

5.2.3 Fuses and Circuit Breakers

Branch circuit protection
To protect the installation against electrical and fire hazard, all branch circuits in an installation, switch gear, machines etc., must be short-circuit and overcurrent protected according to national and local regulations.

Short circuit protection
Danfoss recommends using the fuses and circuit breakers listed in *Table 5.15* to protect service personnel or other equipment in case of an internal failure in the unit or short-circuit on DC-link. The frequency converter provides full short circuit protection in case of a short-circuit on the motor.

Overcurrent protection
Provide overload protection to avoid overheating of the cables in the installation. Overcurrent protection must always be carried out according to local and national regulations. Circuit breakers and fuses must be designed for protection in a circuit capable of supplying a maximum of 100,000 A_{rms} (symmetrical), 480 V maximum.

UL/Non UL compliance
Use the circuit breakers or fuses listed in *Table 5.15*, to ensure compliance with UL or IEC 61800-5-1.
Circuit breakers must be designed for protection in a circuit capable of supplying a maximum of 10,000 Arms (symmetrical), 480 V maximum.

NOTICE

In the event of malfunction, failure to follow the protection recommendation may result in damage to the frequency converter.

	Circuit Breaker		Fuse				
	UL	Non UL	UL				Non UL
			Bussmann	Bussmann	Bussmann	Bussmann	Max fuse
Power [kW]			Type RK5	Type RK1	Type J	Type T	Type G
3x200-240 V IP20							
0.25			FRS-R-10	KTN-R10	JKS-10	JJN-10	10
0.37			FRS-R-10	KTN-R10	JKS-10	JJN-10	10
0.75			FRS-R-10	KTN-R10	JKS-10	JJN-10	10
1.5			FRS-R-10	KTN-R10	JKS-10	JJN-10	10
2.2			FRS-R-15	KTN-R15	JKS-15	JJN-15	16
3.7			FRS-R-25	KTN-R25	JKS-25	JJN-25	25
5.5			FRS-R-50	KTN-R50	JKS-50	JJN-50	50
7.5			FRS-R-50	KTN-R50	JKS-50	JJN-50	50
11			FRS-R-80	KTN-R80	JKS-80	JJN-80	65
15	Cutler-Hammer EGE3100FFG	Moeller NZMB1-A125	FRS-R-100	KTN-R100	JKS-100	JJN-100	125
18.5			FRS-R-100	KTN-R100	JKS-100	JJN-100	125
22	Cutler-Hammer JGE3150FFG	Moeller NZMB1-A160	FRS-R-150	KTN-R150	JKS-150	JJN-150	160
30			FRS-R-150	KTN-R150	JKS-150	JJN-150	160
37	Cutler-Hammer JGE3200FFG	Moeller NZMB1-A200	FRS-R-200	KTN-R200	JKS-200	JJN-200	200
45			FRS-R-200	KTN-R200	JKS-200	JJN-200	200

Table 5.15 Circuit Breakers and Fuses

	Circuit Breaker		Fuse				
	UL	Non UL	UL				Non UL
			Bussmann	Bussmann	Bussmann	Bussmann	Max fuse
Power [kW]			Type RK5	Type RK1	Type J	Type T	Type G
3x380-480 V IP20							
0.37			FRS-R-10	KTS-R10	JKS-10	JJS-10	10
0.75			FRS-R-10	KTS-R10	JKS-10	JJS-10	10
1.5			FRS-R-10	KTS-R10	JKS-10	JJS-10	10
2.2			FRS-R-15	KTS-R15	JKS-15	JJS-15	16
3			FRS-R-15	KTS-R15	JKS-15	JJS-15	16
4			FRS-R-15	KTS-R15	JKS-15	JJS-15	16
5.5			FRS-R-25	KTS-R25	JKS-25	JJS-25	25
7.5			FRS-R-25	KTS-R25	JKS-25	JJS-25	25
11			FRS-R-50	KTS-R50	JKS-50	JJS-50	50
15			FRS-R-50	KTS-R50	JKS-50	JJS-50	50
18.5			FRS-R-80	KTS-R80	JKS-80	JJS-80	65
22			FRS-R-80	KTS-R80	JKS-80	JJS-80	65
30	Cutler-Hammer EGE3125FFG	Moeller NZMB1-A125	FRS-R-125	KTS-R125	JKS-R125	JJS-R125	80
37			FRS-R-125	KTS-R125	JKS-R125	JJS-R125	100
45			FRS-R-125	KTS-R125	JKS-R125	JJS-R125	125
55	Cutler-Hammer JGE3200FFG	Moeller NZMB1-A200	FRS-R-200	KTS-R200	JKS-R200	JJS-R200	150
75			FRS-R-200	KTS-R200	JKS-R200	JJS-R200	200
90	Cutler-Hammer JGE3250FFG	Moeller NZMB2-A250	FRS-R-250	KTS-R250	JKS-R250	JJS-R250	250
3x525-600 V IP20							
2.2			FRS-R-20	KTS-R20	JKS-20	JJS-20	20
3			FRS-R-20	KTS-R20	JKS-20	JJS-20	20
3.7			FRS-R-20	KTS-R20	JKS-20	JJS-20	20
5.5			FRS-R-20	KTS-R20	JKS-20	JJS-20	20
7.5			FRS-R-20	KTS-R20	JKS-20	JJS-20	30
11			FRS-R-30	KTS-R30	JKS-30	JJS-30	35
15			FRS-R-30	KTS-R30	JKS-30	JJS-30	35
18.5	Cutler-Hammer EGE3080FFG	Cutler-Hammer EGE3080FFG	FRS-R-80	KTN-R80	JKS-80	JJS-80	80
22			FRS-R-80	KTN-R80	JKS-80	JJS-80	80
30			FRS-R-80	KTN-R80	JKS-80	JJS-80	80
37	Cutler-Hammer JGE3125FFG	Cutler-Hammer JGE3125FFG	FRS-R-125	KTN-R125	JKS-125	JJS-125	125
45			FRS-R-125	KTN-R125	JKS-125	JJS-125	125
55			FRS-R-125	KTN-R125	JKS-125	JJS-125	125
75	Cutler-Hammer JGE3200FAG	Cutler-Hammer JGE3200FAG	FRS-R-200	KTN-R200	JKS-200	JJS-200	200
90			FRS-R-200	KTN-R200	JKS-200	JJS-200	200

Table 5.16 Circuit Breakers and Fuses

	Circuit Breaker		Fuse				
	UL	Non UL	UL				Non UL
			Bussmann	Bussmann	Bussmann	Bussmann	Max fuse
Power [kW]			Type RK5	Type RK1	Type J	Type T	Type G
3x380-480 V IP54							
0.75		PKZM0-16	FRS-R-10	KTS-R-10	JKS-10	JJS-10	16
1.5		PKZM0-16	FRS-R-10	KTS-R-10	JKS-10	JJS-10	16
2.2		PKZM0-16	FRS-R-15	KTS-R-15	JKS-15	JJS-15	16
3		PKZM0-16	FRS-R-15	KTS-R-15	JKS-15	JJS-15	16
4		PKZM0-16	FRS-R-15	KTS-R-15	JKS-15	JJS-15	16
5.5		PKZM0-25	FRS-R-25	KTS-R-25	JKS-25	JJS-25	25
7.5		PKZM0-25	FRS-R-25	KTS-R-25	JKS-25	JJS-25	25
11		PKZM4-63	FRS-R-50	KTS-R-50	JKS-50	JJS-50	63
15		PKZM4-63	FRS-R-50	KTS-R-50	JKS-50	JJS-50	63
18.5		PKZM4-63	FRS-R-80	KTS-R-80	JKS-80	JJS-80	63
22	Moeller NZMB1-A125		FRS-R-80	KTS-R-80	JKS-80	JJS-80	125
30			FRS-R-125	KTS-R-125	JKS-125	JJS-125	125
37			FRS-R-125	KTS-R-125	JKS-125	JJS-125	125
45	Moeller NZMB2-A160		FRS-R-125	KTS-R-125	JKS-125	JJS-125	160
55			FRS-R-200	KTS-R-200	JKS-200	JJS-200	160
75	Moeller NZMB2-A250		FRS-R-200	KTS-R-200	JKS-200	JJS-200	200
90			FRS-R-250	KTS-R-250	JKS-200	JJS-200	200

Table 5.17 Circuit Breakers and Fuses

5.2.4 EMC Compliant Electrical Installation

General points to be observed to ensure EMC-correct electrical installation.

- Use only screened/armoured motor cables and screened/armoured control cables.
- Connect the screen to earth at both ends.
- Avoid installation with twisted screen ends (pigtails), since this ruins the screening effect at high frequencies. Use the cable clamps provided instead.
- It is important to ensure good electrical contact from the installation plate through the installation screws to the metal cabinet of the frequency converter.
- Use starwashers and galvanically conductive installation plates.
- Do not use unscreened/unarmoured motor cables in the installation cabinets.

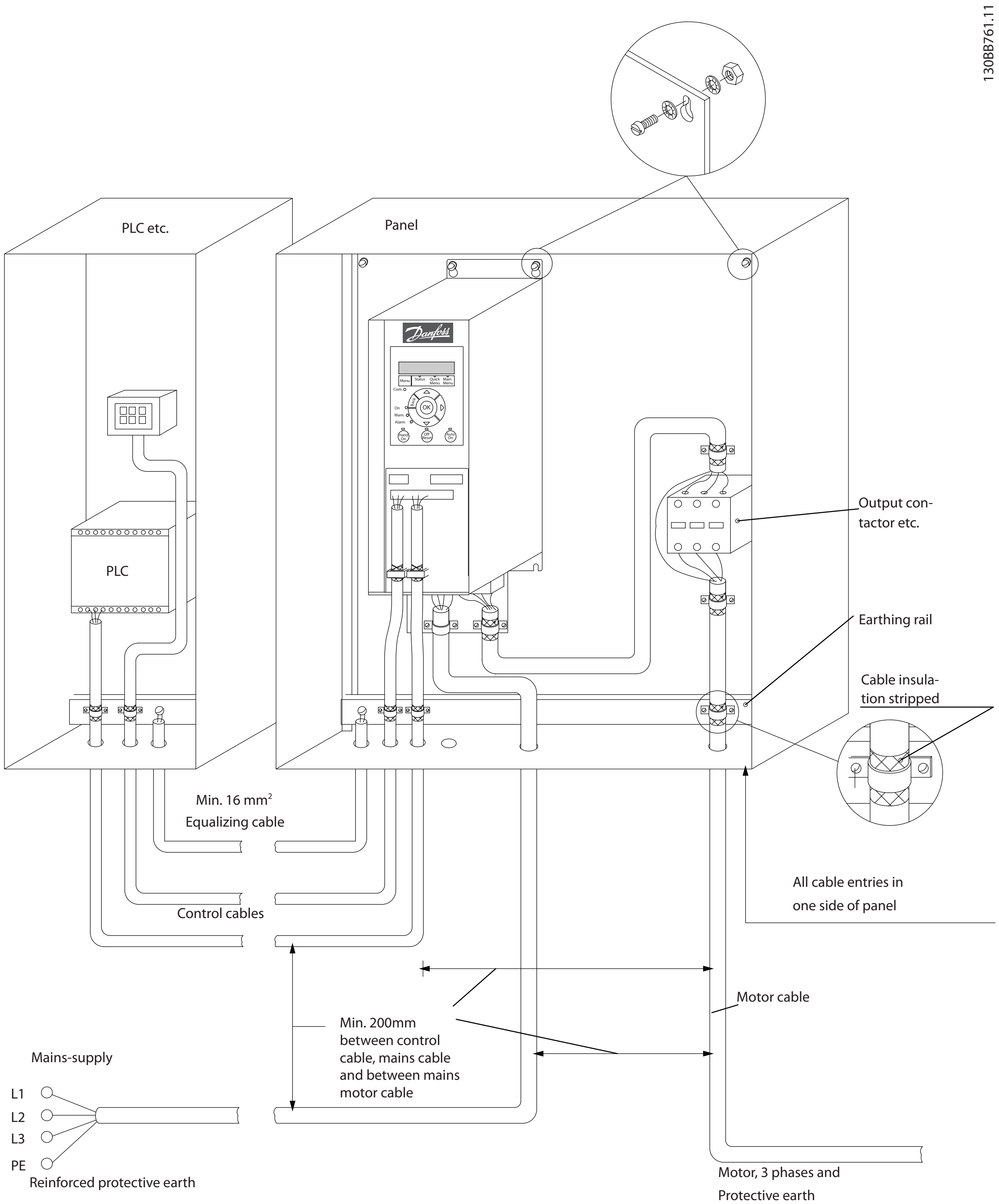


Illustration 5.20 EMC-correct Electrical Installation

NOTICE

For North America use metal conduits instead of shielded cables.

5.2.5 Control Terminals

IP20 200-240 V 0.25-11 kW and IP20 380-480 V 0.37-22 kW:

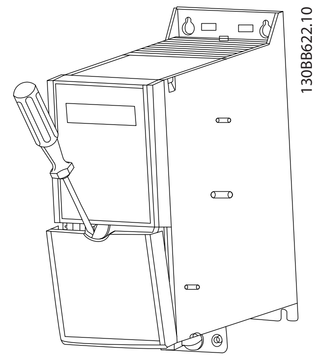


Illustration 5.21 Location of Control Terminals

1. Place a screwdriver behind the terminal cover to activate snap.
2. Tilt the screwdriver outwards to open the cover.

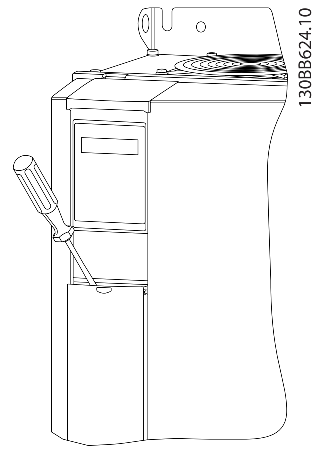


Illustration 5.22 IP20 380-480 V 30-90 kW

1. Place a screwdriver behind the terminal cover to activate snap.
2. Tilt the screwdriver outwards to open the cover.

Digital input 18, 19 and 27 mode is set in *5-00 Digital Input Mode* (PNP is default value) and digital input 29 mode is set in *5-03 Digital Input 29 Mode* (PNP is default value).

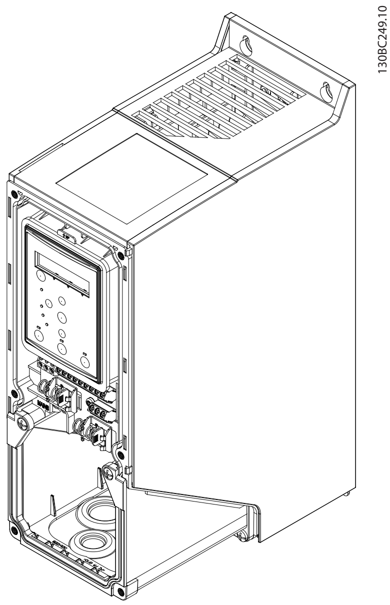


Illustration 5.23 IP54 400 V 0.75-7.5 kW

1. Remove the front cover.

Control terminals

Illustration 5.24 shows all control terminals of the frequency converter. Applying Start (term. 18), connection between terminal 12-27 and an analog reference (term. 53 or 54 and 55) make the frequency converter run.

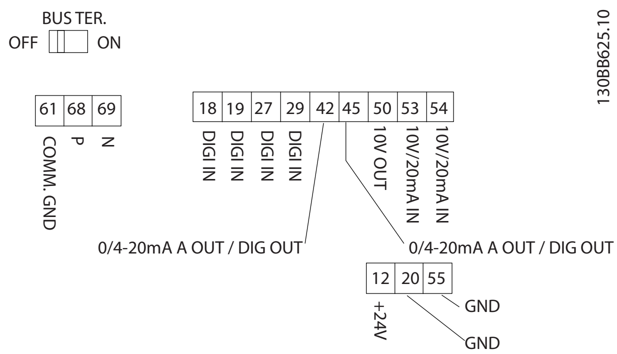


Illustration 5.24 Control Terminals

6 How to Programme

6.1 Programming with MCT 10 Set-up Software

The frequency converter can be programmed from a PC via RS-485 COM port by using the MCT 10 Set-up Software.

6.2 Local Control Panel (LCP)

The LCP is divided into 4 functional sections.

A. Display

B. Menu key

C. Navigation keys and indicator lights (LEDs)

D. Operation keys and indicator lights (LEDs)

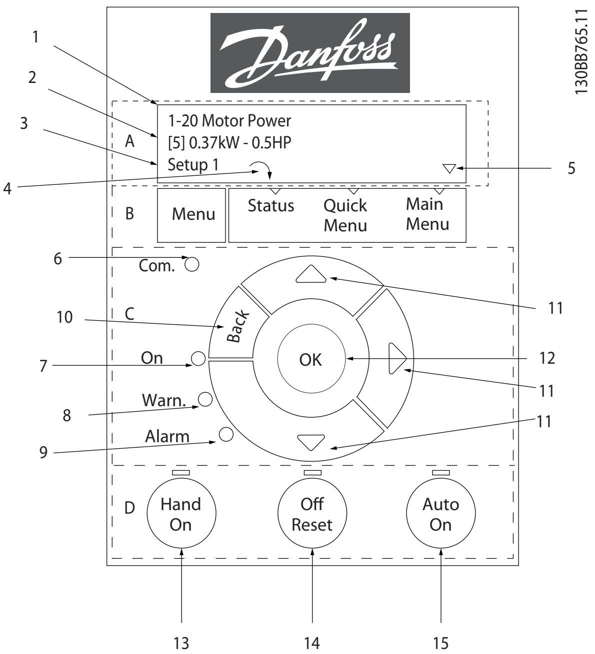


Illustration 6.1 Local Control Panel (LCP)

A. Display
The LCD-display is back-lit with 2 alphanumeric lines. All data is displayed on the LCP.

Information can be read from the display.

1	Parameter number and name.
2	Parameter value.
3	Set-up number shows the active set-up and the edit set-up. If the same set-up acts as both active and edit set-up, only that set-up number is shown (factory setting). When active and edit set-up differ, both numbers are shown in the display (set-up 12). The number flashing, indicates the edit set-up.
4	Motor direction is shown to the bottom left of the display – indicated by a small arrow pointing either clockwise or counterclockwise.
5	The triangle indicates if the LCP is in status, quick menu or main menu.

Table 6.1 Legend to *Illustration 6.1*

B. Menu key
Press [Menu] to select between status, quick menu or main menu.

C. Navigation keys and indicator lights (LEDs)

6	Com LED: Flashes when bus communication is communicating.
7	Green LED/On: Control section is working.
8	Yellow LED/Warn.: Indicates a warning.
9	Flashing Red LED/Alarm: Indicates an alarm.
10	[Back]: For moving to the previous step or layer in the navigation structure
11	[▲] [▼] [►]: For maneuvering between parameter groups, parameters and within parameters. Can also be used for setting local reference.
12	[OK]: For selecting a parameter and for accepting changes to parameter settings

Table 6.2 Legend to *Illustration 6.1*

D. Operation keys and indicator lights (LEDs)

13	[Hand On]: Starts the motor and enables control of the frequency converter via the LCP. ***NOTICE*** **Terminal 27 Digital Input (*5-12 Terminal 27 Digital Input*) has coast inverse as default setting. This means that [Hand On] does not start the motor if there is no 24 V to terminal 27. Connect terminal 12 to terminal 27.**
14	[Off/Reset]: Stops the motor (Off). If in alarm mode, the alarm is reset.
15	[Auto On]: Frequency converter is controlled either via control terminals or serial communication.

Table 6.3 Legend to *Illustration 6.1*

6.3 Menus

6.3.1 Status Menu

In the Status menu the selection options are:

- Motor Frequency [Hz], *16-13 Frequency*
- Motor Current [A], *16-14 Motor current*
- Motor Speed Reference in Percentage [%], *16-02 Reference [%]*
- Feedback, *16-52 Feedback[Unit]*
- Motor Power [kW] (if *0-03 Regional Settings* is set to *[1] North America*, Motor Power is shown in the unit of hp instead of kW), *16-10 Power [kW]* for kW, *16-11 Power [hp]* for hp
- Custom Readout *16-09 Custom Readout*

6.3.2 Quick Menu

Use the Quick Menu to programme the most common VLT® HVAC Basic Drive functions. The Quick Menu consists of:

- Wizard for open loop applications
- Closed loop set-up wizard
- Motor set-up
- Changes made

6.3.3 Start-up Wizard for Open Loop Applications

The built-in wizard menu guides the installer through the set-up of the frequency converter to an open loop application. An open loop application is here an application with a start signal, analog reference (voltage or current) and optionally also relay signals (but no feed back signal from the process applied).

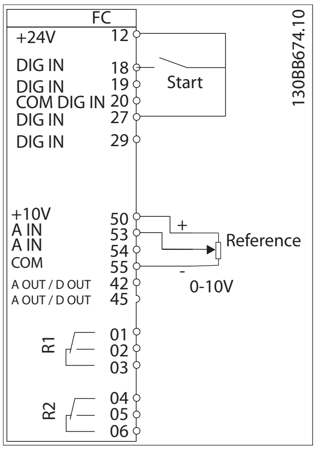


Illustration 6.2 Set-up of the Frequency Converter

The wizard is initially shown after power up until any parameter has been changed. The wizard can always be accessed again through the Quick Menu. Press [OK] to start the wizard. Press [Back] to return to the status screen.

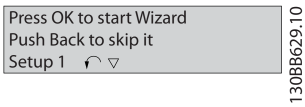


Illustration 6.3 Wizard

6

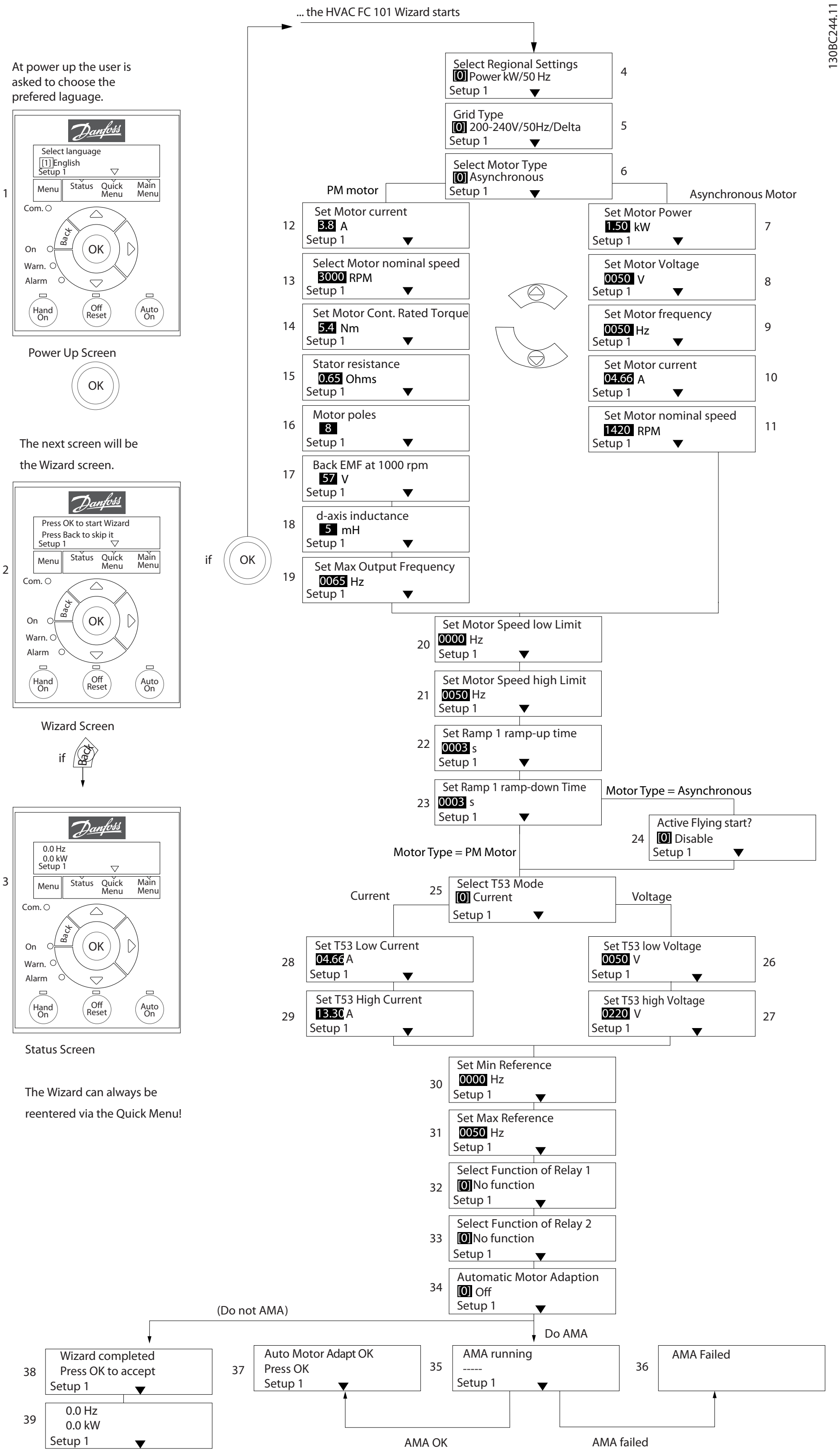


Illustration 6.4 Open Loop Set-up Wizard

Start-up Wizard for Open Loop Applications

Parameter	Range	Default	Function
0-03 Regional Settings	[0] International [1] US	0	
0-06 GridType	[0] 200-240 V/50 Hz/IT-grid [1] 200-240 V/50 Hz/Delta [2] 200-240 V/50 Hz [10] 380-440 V/50 Hz/IT-grid [11] 380-440 V/50 Hz/Delta [12] 380-440 V/50 Hz [20] 440-480 V/50 Hz/IT-grid [21] 440-480 V/50 Hz/Delta [22] 440-480 V/50 Hz [30] 525-600 V/50 Hz/IT-grid [31] 525-600 V/50 Hz/Delta [32] 525-600 V/50 Hz [100] 200-240 V/60 Hz/IT-grid [101] 200-240 V/60 Hz/Delta [102] 200-240 V/60 Hz [110] 380-440 V/60 Hz/IT-grid [111] 380-440 V/60 Hz/Delta [112] 380-440 V/60 Hz [120] 440-480 V/60 Hz/IT-grid [121] 440-480 V/60 Hz/Delta [122] 440-480 V/60 Hz [130] 525-600 V/60 Hz/IT-grid [131] 525-600 V/60 Hz/Delta [132] 525-600 V/60 Hz	Size related	Select operating mode for restart upon reconnection of the frequency converter to mains voltage after power down
1-10 Motor Construction	*[0] Asynchron [1] PM, non salient SPM	[0] Asynchron	Setting the parameter value might change these parameters: 1-01 Motor Control Principle 1-03 Torque Characteristics 1-14 Damping Gain 1-15 Low Speed Filter Time Const 1-16 High Speed Filter Time Const 1-17 Voltage filter time const 1-20 Motor Power 1-22 Motor Voltage 1-23 Motor Frequency 1-24 Motor Current 1-25 Motor Nominal Speed 1-26 Motor Cont. Rated Torque 1-30 Stator Resistance (Rs) 1-33 Stator Leakage Reactance (X1) 1-35 Main Reactance (Xh) 1-37 d-axis Inductance (Ld) 1-39 Motor Poles 1-40 Back EMF at 1000 RPM 1-66 Min. Current at Low Speed 1-72 Start Function 1-73 Flying Start 4-19 Max Output Frequency 4-58 Missing Motor Phase Function
1-20 Motor Power	0.12-110 kW/0.16-150 hp	Size related	Enter motor power from nameplate data
1-22 Motor Voltage	50.0-1000.0 V	Size related	Enter motor voltage from nameplate data
1-23 Motor Frequency	20.0-400.0 Hz	Size related	Enter motor frequency from nameplate data

Parameter	Range	Default	Function
1-24 Motor Current	0.01-10000.00 A	Size related	Enter motor current from nameplate data
1-25 Motor Nominal Speed	100.0-9999.0 RPM	Size related	Enter motor nominal speed from nameplate data
1-26 Motor Cont. Rated Torque	0.1-1000.0	Size related	This parameter is available only when *1-10 Motor Construction* Design is set to *[1] PM, non-salient SPM*. **NOTICE** **Changing this parameter affects settings of other parameters**
1-29 Automatic Motor Adaption (AMA)	See 1-29 Automatic Motor Adaption (AMA)	Off	Performing an AMA optimises motor performance
1-30 Stator Resistance (Rs)	0.000-99.990	Size related	Set the stator resistance value
1-37 d-axis Inductance (Ld)	0-1000	Size related	Enter the value of the d-axis inductance. Obtain the value from the permanent magnet motor data sheet. The de-axis inductance cannot be found by performing an AMA.
1-39 Motor Poles	2-100	4	Enter the number of motor poles
1-40 Back EMF at 1000 RPM	10-9000	Size related	Line-Line RMS back EMF voltage at 1000 RPM
1-73 Flying Start			When PM is selected, Flying Start is enabled and can not disable
1-73 Flying Start	[0] Disabled [1] Enabled	0	Select *[1] Enable* to enable the frequency converter to catch a motor spinning due to mains drop-out. Select *[0] Disable* if this function is not required. When is enabled *1-71 Start Delay* and *1-72 Start Function* have no function. is active in VVC^{plus} mode only
3-02 Minimum Reference	-4999-4999	0	The minimum reference is the lowest value obtainable by summing all references
3-03 Maximum Reference	-4999-4999	50	The maximum reference is the lowest obtainable by summing all references
3-41 Ramp 1 Ramp Up Time	0.05-3600.0 s	Size related	Ramp up time from 0 to rated *1-23 Motor Frequency* if Asynchron motor is selected; ramp up time from 0 to *1-25 Motor Nominal Speed* if PM motor is selected
3-42 Ramp 1 Ramp Down Time	0.05-3600.0 s	Size related	Ramp down time from rated *1-23 Motor Frequency* to 0 if Asynchron motor is selected; ramp down time from *1-25 Motor Nominal Speed* to 0 if PM motor is selected
4-12 Motor Speed Low Limit [Hz]	0.0-400 Hz	0 Hz	Enter the minimum limit for low speed
4-14 Motor Speed High Limit [Hz]	0.0-400 Hz	65 Hz	Enter the maximum limit for high speed
4-19 Max Output Frequency	0-400	Size related	Enter the maximum output frequency value
5-40 Function Relay [0] Function relay	See 5-40 Function Relay	Alarm	Select the function to control output relay 1
5-40 Function Relay [1] Function relay	See 5-40 Function Relay	Drive running	Select the function to control output relay 2
6-10 Terminal 53 Low Voltage	0-10 V	0.07 V	Enter the voltage that corresponds to the low reference value

Parameter	Range	Default	Function
6-11 Terminal 53 High Voltage	0-10 V	10 V	Enter the voltage that corresponds to the high reference value
6-12 Terminal 53 Low Current	0-20 mA	4	Enter the current that corresponds to the low reference value
6-13 Terminal 53 High Current	0-20 mA	20	Enter the current that corresponds to the high reference value
6-19 Terminal 53 mode	[0] Current [1] Voltage	1	Select if terminal 53 is used for current- or voltage input

Table 6.4 Open Loop Application

Illustration 6.5 Closed Loop Set-up Wizard

Closed Loop Set-up Wizard

Parameter	Range	Default	Function
0-03 Regional Settings	[0] International [1] US	0	
0-06 GridType	[0] -[[132] see start -up wizard for open loop application	Size selected	Select operating mode for restart upon reconnection of the frequency converter to mains voltage after power down
1-00 Configuration Mode	[0] Open loop [3] Closed loop	0	Change this parameter to Closed loop
1-10 Motor Construction	*[0] Motor construction [1] PM, non salient SPM	[0] Asynchron	Setting the parameter value might change these parameters: 1-01 Motor Control Principle 1-03 Torque Characteristics 1-14 Damping Gain 1-15 Low Speed Filter Time Const 1-16 High Speed Filter Time Const 1-17 Voltage filter time const 1-20 Motor Power 1-22 Motor Voltage 1-23 Motor Frequency 1-25 Motor Nominal Speed 1-26 Motor Cont. Rated Torque 1-30 Stator Resistance (Rs) 1-33 Stator Leakage Reactance (X1) 1-35 Main Reactance (Xh) 1-37 d-axis Inductance (Ld) 1-39 Motor Poles 1-40 Back EMF at 1000 RPM 1-66 Min. Current at Low Speed 1-72 Start Function 1-73 Flying Start 4-19 Max Output Frequency 4-58 Missing Motor Phase Function
1-20 Motor Power	0.09-110 kW	Size related	Enter motor power from nameplate data
1-22 Motor Voltage	50.0-1000.0 V	Size related	Enter motor voltage from nameplate data
1-23 Motor Frequency	20.0-400.0 Hz	Size related	Enter motor frequency from nameplate data
1-24 Motor Current	0.0 -10000.00 A	Size related	Enter motor current from nameplate data
1-25 Motor Nominal Speed	100.0-9999.0 RPM	Size related	Enter motor nominal speed from nameplate data
1-26 Motor Cont. Rated Torque	0.1-1000.0	Size relate	This parameter is available only when *1-10 Motor Construction* Design is set to *[1] PM, non-salient SPM*. **NOTICE** **Changing this parameter affects settings of other parameters**
1-29 Automatic Motor Adaption (AMA)		Off	Performing an AMA optimizes motor performance
1-30 Stator Resistance (Rs)	0.000-99.990	Size related	Set the stator resistance value
1-37 d-axis Inductance (Ld)	0-1000	Size related	Enter the value of the d-axis inductance. Obtain the value from the permanent magnet motor data sheet. The de-axis inductance cannot be found by performing an AMA.
1-39 Motor Poles	2-100	4	Enter the number of motor poles
1-40 Back EMF at 1000 RPM	10-9000	Size related	Line-Line RMS back EMF voltage at 1000 RPM

Parameter	Range	Default	Function
1-73 Flying Start	[0] Disabled [1] Enabled	0	Select *[1] Enable* to enable the frequency converter to catch a spinning motor. I.e. fan applications. When PM is selected, Flying Start is enabled.
3-02 Minimum Reference	-4999-4999	0	The minimum reference is the lowest value obtainable by summing all references
3-03 Maximum Reference	-4999-4999	50	The maximum reference is the highest value obtainable by summing all references
3-10 Preset Reference	-100-100%	0	Enter the set point
3-41 Ramp 1 Ramp Up Time	0.05-3600.0 s	Size related	Ramp up time from 0 to rated *1-23 Motor Frequency* if Asynchron motor is selected; ramp up time from 0 to *1-25 Motor Nominal Speed* if PM motor is selected"
3-42 Ramp 1 Ramp Down Time	0.05-3600.0 s	Size related	Ramp down time from rated *1-23 Motor Frequency* to 0 if Asynchron motor is selected; ramp down time from *1-25 Motor Nominal Speed* to 0 if PM motor is selected
4-12 Motor Speed Low Limit [Hz]	0.0-400 Hz	0.0 Hz	Enter the minimum limit for low speed
4-14 Motor Speed High Limit [Hz]	0-400 Hz	65 Hz	Enter the minimum limit for high speed
4-19 Max Output Frequency	0-400	Size related	Enter the maximum output frequency value
6-29 Terminal 54 mode	[0] Current [1] Voltage	1	Select if terminal 54 is used for current- or voltage input
6-20 Terminal 54 Low Voltage	0-10 V	0.07 V	Enter the voltage that corresponds to the low reference value
6-21 Terminal 54 High Voltage	0-10 V	10 V	Enter the voltage that corresponds to the low high reference value
6-22 Terminal 54 Low Current	0-20 mA	4	Enter the current that corresponds to the high reference value
6-23 Terminal 54 High Current	0-20 mA	20	Enter the current that corresponds to the high reference value
6-24 Terminal 54 Low Ref./Feedb. Value	-4999-4999	0	Enter the feedback value that corresponds to the voltage or current set in *6-20 Terminal 54 Low Voltage*/*6-22 Terminal 54 Low Current*
6-25 Terminal 54 High Ref./Feedb. Value	-4999-4999	50	Enter the feedback value that corresponds to the voltage or current set in *6-21 Terminal 54 High Voltage*/*6-23 Terminal 54 High Current*
6-26 Terminal 54 Filter Time Constant	0-10 s	0.01	Enter the filter time comstant
20-81 PI Normal/ Inverse Control	[0] Normal [1] Inverse	0	Select *[0] Normal* to set the process control to increase the output speed when the process error is positive. Select *[1] Inverse* to reduce the output speed.
20-83 PI Start Speed [Hz]	0-200 Hz	0	Enter the motor speed to be attained as a start signal for commencement of PI control
20-93 PI Proportional Gain	0-10	0.01	Enter the process controller proportional gain. Quick control is obtained at high amplification. However if amplification is too great, the process may become unstable
20-94 PI Integral Time	0.1-999.0 s	999.0 s	Enter the process controller integral time. Obtain quick control through a short integral time, though if the integral time is too short, the process becomes unstable. An excessively long integral time disables the integral action.

Table 6.5 Closed Loop Application

Motor Set-up

The Quick Menu Motor Set-up guides through the needed motor parameters.

Parameter	Range	Default	Function
0-03 Regional Settings	[0] International [1] US	0	
0-06 GridType	[0] -[132] see start -up wizard for open loop application	Size selected	Select operating mode for restart upon reconnection of the frequency converter to mains voltage after power down
1-10 Motor Construction	*[0] Motor construction [1] PM, non salient SPM	[0] Asynchron	
1-20 Motor Power	0.12-110 kW/0.16-150 hp	Size related	Enter motor power from nameplate data
1-22 Motor Voltage	50.0-1000.0 V	Size related	Enter motor voltage from nameplate data
1-23 Motor Frequency	20.0-400.0 Hz	Size related	Enter motor frequency from nameplate data
1-24 Motor Current	0.01-10000.00 A	Size related	Enter motor current from nameplate data
1-25 Motor Nominal Speed	100.0-9999.0 RPM	Size related	Enter motor nominal speed from nameplate data
1-26 Motor Cont. Rated Torque	0.1-1000.0	Size related	This parameter is available only when *1-10 Motor Construction* Design is set to *[1] PM, non-salient SPM.* **NOTICE** **Changing this parameter affects settings of other parameters**
1-30 Stator Resistance (Rs)	0.000-99.990	Size related	Set the stator resistance value
1-37 d-axis Inductance (Ld)	0-1000	Size related	Enter the value of the d-axis inductance. Obtain the value from the permanent magnet motor data sheet. The de-axis inductance cannot be found by performing an AMA.
1-39 Motor Poles	2-100	4	Enter the number of motor poles
1-40 Back EMF at 1000 RPM	10-9000	Size related	Line-Line RMS back EMF voltage at 1000 RPM
1-73 Flying Start	[0] Disabled [1] Enabled	0	Select *[1] Enable* to enable the frequency converter to catch a spinning motor
3-41 Ramp 1 Ramp Up Time	0.05-3600.0 s	Size related	Ramp up time from 0 to rated *1-23 Motor Frequency*
3-42 Ramp 1 Ramp Down Time	0.05-3600.0 s	Size related	Ramp down time from rated *1-23 Motor Frequency* to 0
4-12 Motor Speed Low Limit [Hz]	0.0-400 Hz	0.0 Hz	Enter the minimum limit for low speed
4-14 Motor Speed High Limit [Hz]	0.0-400 Hz	65	Enter the maximum limit for high speed
4-19 Max Output Frequency	0-400	Size related	Enter the maximum output frequency value

Table 6.6 Motor Parameters

Changes Made
Changes Made lists all parameters changed since factory setting. Only the changed parameters in current edit-setup are listed in changes made.

If the parameter's value is changed back to factory setting's value from another different value, the parameter will NOT be listed in *Changes Made*.

1. Press [Menu] to enter the Quick Menu until indicator in display is placed above Quick Menu.
2. Press [▲] [▼] to select either wizard, closed loop setup, motor setup or changes made, then press [OK].
3. Press [▲] [▼] to browse through the parameters in the Quick Menu.
4. Press [OK] to select a parameter.
5. Press [▲] [▼] to change the value of a parameter setting.
6. Press [OK] to accept the change.
7. Press either [Back] twice to enter "Status", or press [Menu] once to enter "Main Menu".

6.3.4 Main Menu

[Main Menu] is used for access to and programming of all parameters. The Main Menu parameters can be accessed readily unless a password has been created via *0-60 Main Menu Password*.
For the majority of VLT® HVAC Basic Drive applications it is not necessary to access the Main Menu parameters but instead the Quick Menu provides the simplest and quickest access to the typical required parameters.

The Main Menu accesses all parameters.

1. Press [Menu] until indicator in display is placed above "Main Menu".
2. Press [▲] [▼] to browse through the parameter groups.
3. Press [OK] to select a parameter group.
4. Press [▲] [▼] to browse through the parameters in the specific group.
5. Press [OK] to select the parameter.
6. Press [▲] [▼] to set/change the parameter value.

Press [Back] to go back one level.

6.4 Quick Transfer of Parameter Settings between Multiple Frequency Converters

Once the set-up of a frequency converter is complete, Danfoss recommends to store the data in the LCP or on a PC via MCT 10 Set-up Software tool.

Data transfer from frequency converter to LCP:

⚠WARNING

Stop the motor before performing this operation.

1. Go to *0-50 LCP Copy*
2. Press [OK]
3. Select *[1] All to LCP*
4. Press [OK]

Connect the LCP to another frequency converter and copy the parameter settings to this frequency converter as well.

Data transfer from LCP to frequency converter:

⚠WARNING

Stop the motor before performing this operation.

1. Go to *0-50 LCP Copy*
2. Press [OK]
3. Select *[2] All from LCP*
4. Press [OK]

6.5 Read-out and Programming of Indexed Parameters

Select the parameter, press [OK], and press [▲]/[▼] to scroll through the indexed values. To change the parameter value, select the indexed value and press [OK]. Change the value by pressing [▲]/[▼]. Press [OK] to accept the new setting. Press [Cancel] to abort. Press [Back] to leave the parameter.

6.6 Initialise the Frequency Converter to Default Settings in two Ways

Recommended initialisation (via *14-22 Operation Mode*)

1. Select *14-22 Operation Mode*.
2. Press [OK].
3. Select *[2] Initialisation* and Press [OK].
4. Cut off the mains supply and wait until the display turns off.

5. Reconnect the mains supply - the frequency converter is now reset.

Except the following parameters:

8-30 Protocol

8-31 Address

8-32 Baud Rate

8-33 Parity / Stop Bits

8-35 Minimum Response Delay

8-36 Maximum Response Delay

8-37 Maximum Inter-char delay

8-70 BACnet Device Instance

8-72 MS/TP Max Masters

8-73 MS/TP Max Info Frames

8-74 "I am" Service

8-75 Intialisation Password

15-00 Operating hours to 15-05 Over Volt's

15-03 Power Up's

15-04 Over Temp's

15-05 Over Volt's

15-30 Alarm Log: Error Code

15-4* Drive identification parameters

1-06 Clockwise Direction

2 finger initialisation

1. Power off the frequency converter.
2. Press [OK] and [Menu].
3. Power up the frequency converter while still pressing the keys above for 10 s.
4. The frequency converter is now reset, except the following parameters:

    15-00 Operating hours

    15-03 Power Up's

    15-04 Over Temp's

    15-05 Over Volt's

    15-4* Drive identification parameters

Initialisation of parameters is confirmed by AL80 in the display after the power cycle.

7 RS-485 Installation and Set-up

7.1 RS-485

7.1.1 Overview

RS-485 is a 2-wire bus interface compatible with multi-drop network topology, that is, 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.

NOTICE

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

Terminate each segment at both ends, using either the termination switch (S801) of the 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, for example with 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 [Ω]	120
Cable length [m]	Max. 1200 (including drop lines) Max. 500 station-to-station

Table 7.1 Cable

7.1.2 Network Connection

Connect the frequency converter to the RS-485 network as follows (see also *Illustration 7.1*):

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

NOTICE

Screened, twisted-pair cables are recommended to reduce noise between conductors.

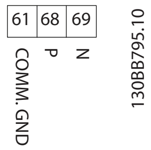


Illustration 7.1 Network Connection

7.1.3 Frequency Converter Hardware Set-up

Use the terminator dip switch on the main control board of the frequency converter to terminate the RS-485 bus.

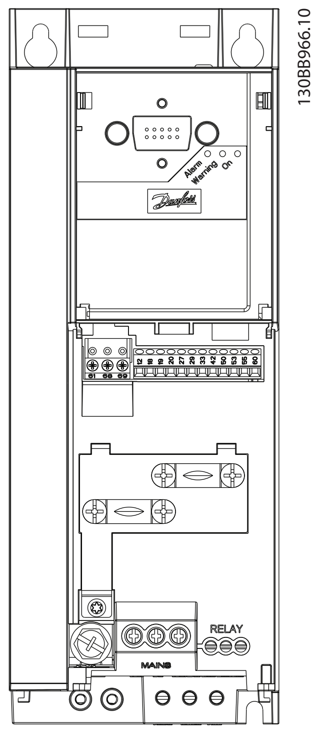


Illustration 7.2 Terminator Switch Factory Setting

The factory setting for the dip switch is OFF.

7.1.4 Frequency Converter Parameter Settings for Modbus Communication

Define the RS-485 Communicaiton Set-up

Parameter	Function
8-30 Protocol	Select the application protocol to run on the RS-485 interface
8-31 Address	Set the node address. **NOTICE** **The address range depends on the protocol selected in *8-30 Protocol***
8-32 Baud Rate	Set the baud rate. **NOTICE** **The default baud rate depends on the protocol selected in *8-30 Protocol***
8-33 Parity / Stop Bits	Set the parity and number of stop bits. **NOTICE** **The default selection depends on the protocol selected in *8-30 Protocol***
8-35 Minimum Response Delay	Specify a minimum delay time between receiving a request and transmitting a response. This function is for overcoming modem turnaround delays.
8-36 Maximum Response Delay	Specify a maximum delay time between transmitting a request and receiving a response.
8-37 Maximum Inter-char delay	If transmission is interrupted, specify a maximum delay time between two received bytes to ensure time-out.

Table 7.2 Modbus Communication Parameter Settings

7.1.5 EMC Precautions

To achieve interference-free operation of the RS-485 network, Danfoss recommends the following EMC precautions.

NOTICE

Observe relevant national and local regulations, for example regarding protective earth connection. To avoid coupling of high-frequency noise between the cables, the RS-485 communication cable must be kept away from motor and brake resistor cables. Normally, a distance of 200 mm (8 inches) is sufficient, but Danfoss recommends keeping the greatest possible distance between the cables. 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°.

7.2 FC Protocol Overview

The FC protocol, also referred to as FC bus or Standard bus, is the Danfoss standard fieldbus. It defines an access technique according to the master-follower principle for communications via a serial bus.
One master and a maximum of 126 followers can be connected to the bus. The master selects the individual followers via an address character in the telegram. A follower itself can never transmit without first being requested to do so, and direct message transfer between the individual followers is not possible. communications occur in the half-duplex mode.
The master function cannot be transferred to another node (single-master system).

The physical layer is RS-485, thus utilising the RS-485 port built into the frequency converter. The FC protocol supports different telegram formats:

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

7.2.1 FC with Modbus RTU

The FC protocol 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 of the active set-up
- Control of the 2 relays built into 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.

7.3 Network Configuration

7.3.1 Frequency Converter Set-up

Set the following parameters to enable the FC protocol for the frequency converter.

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

Table 7.3 Network Configuration Parameters

7.4 FC Protocol Message Framing Structure

7.4.1 Content of a Character (byte)

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

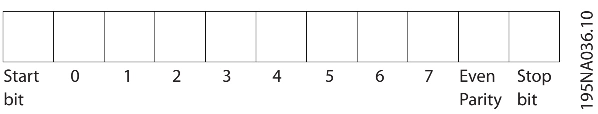


Illustration 7.3 Content of a Character

7.4.2 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.

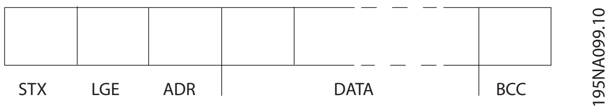


Illustration 7.4 Telegram Structure

7.4.3 Telegram Length (LGE)

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

4 data bytes	LGE=4+1+1=6 bytes
12 data bytes	LGE=12+1+1=14 bytes
Telegramscontaining texts	10[1)]+n bytes

Table 7.4 Length of Telegrams

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

7.4.4 Frequency Converter Address (ADR)

Address format 1-126

Bit 7=1 (address format 1-126 active)

Bit 0-6=frequency converter address 1-126

Bit 0-6=0 Broadcast

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

7.4.5 Data Control Byte (BCC)

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

7.4.6 The Data Field

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

The 3 types of telegram are:

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

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

Illustration 7.5 Process Block

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

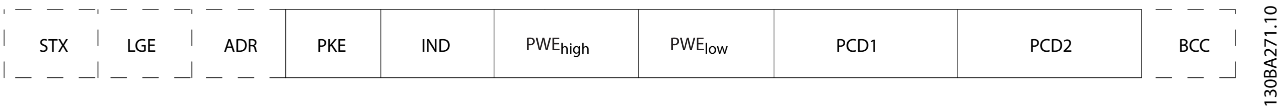


Illustration 7.6 Parameter Block

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

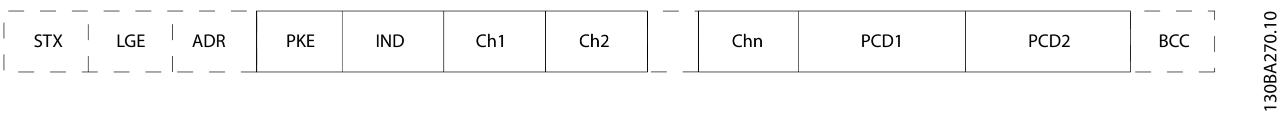


Illustration 7.7 Text Block

7.4.7 The PKE Field

The PKE field contains 2 subfields: Parameter command and response (AK) and Parameter number (PNU):

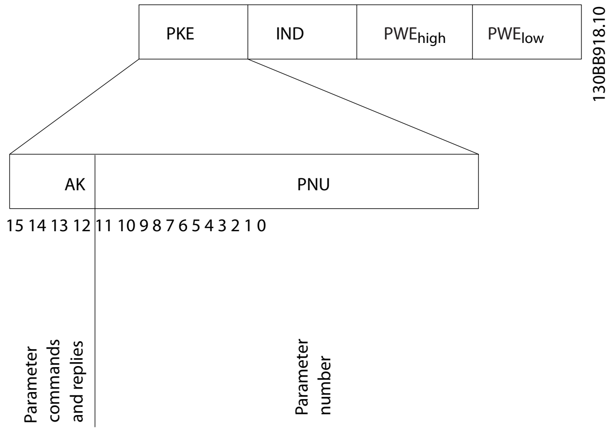


Illustration 7.8 PKE Field

Bits no. 12-15 transfer parameter commands from master to follower and return processed follower responses to the master.

Parameter commands master ⇒ follower				
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 text

Table 7.5 Parameter Commands

Response follower ⇒ master				
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 7.6 Response

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

Error code	FC+ Specification
0	Illegal Parameter Number
1	Parameter cannot be changed.
2	Upper or lower limit exceeded
3	Subindex corrupted
4	No Array
5	Wrong Data Type
6	Not used
7	Not used
9	Description element not available
11	No parameter write access
15	No text available
17	Not while Running
18	Other error
100	
>100	
130	No bus access for this parameter
131	Write to factory set-up not possible
132	No LCP access
252	Unknown viewer
253	Request not supported
254	Unknown attribute
255	No error

Table 7.7 Follower Report

7.4.8 Parameter Number (PNU)

Bits no. 0-11 transfer parameter numbers. The function of the relevant parameter is defined in the parameter description in *6 How to Programme*.

7.4.9 Index (IND)

The index is used with the parameter number to read/write-access parameters with an index, for example, *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.

7.4.10 Parameter Value (PWE)

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

write the new value in the PWE block and send from the master to the follower.

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

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".

7.4.11 Data Types Supported by the Frequency Converter

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

Table 7.8 Data Types

7.4.12 Conversion

The various attributes of each parameter are displayed in the chapter *Parameter Lists* in the *Programming Guide*. 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.

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

Table 7.9 Conversion

7.4.13 Process Words (PCD)

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

PCD 1	PCD 2
Control telegram (master⇒ follower Control word)	Reference-value
Control telegram (follower⇒ master) Status word	Present output frequency

Table 7.10 Process Words (PCD)

7.5 Examples

7.5.1 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

PWEHIGH=0000 Hex

PWELOW=03E8 Hex

Data value 1000, corresponding to 100 Hz, see *7.4.12 Conversion*.

The telegram looks like this:

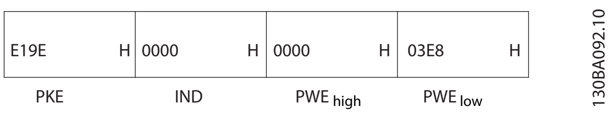


Illustration 7.9 Telegram

NOTICE

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

The response from the follower to the master is:

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

130BA093.10

Illustration 7.10 Response from Master

7.5.2 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

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

130BA094.10

Illustration 7.11 Telegram

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

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

130BA267.10

Illustration 7.12 Response

3E8 Hex corresponds to 1000 decimal. The conversion index for *3-41 Ramp 1 Ramp Up Time* is -2, that is, 0.01. *3-41 Ramp 1 Ramp Up Time* is of the type *Unsigned 32*.

7.6 Modbus RTU Overview

7.6.1 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.

7.6.2 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.

7.6.3 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-follower technique in which only the master can initiate transactions (called queries). Followers respond by supplying the requested data to the master, or by taking the action requested in the query.
The master can address individual followers, or can initiate a broadcast message to all followers. Followers return a response to queries that are addressed to them individually. No responses are returned to broadcast queries from the master. The Modbus RTU protocol establishes the format for the master’s query by providing the device (or broadcast) address, a function code defining the requested action, any data to be sent, and an error-checking field. The follower’s response message is also constructed using Modbus protocol. It contains fields confirming the action taken, any data to be returned, and an error-checking field. If an error occurs in receipt of the message, or if the follower is unable to perform the requested action, the follower constructs an error message, and send it in response, or a time-out occurs.

7.6.4 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 a variety of preset speeds
- Run in reverse
- Change the active set-up
- Control the frequency converter's built-in relay

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.

7.7 Network Configuration

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 7.11 Network Configuration

7.8 Modbus RTU Message Framing Structure

7.8.1 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 7.12*.

Start bit	Data byte								Stop/ parity	Stop

Table 7.12 Format for Each Byte

Coding System	8-bit binary, hexadecimal 0-9, A-F. 2 hexadecimal characters contained in each 8-bit field of the message
Bits Per Byte	1 start bit 8 data bits, least significant bit sent first 1 bit for even/odd parity; no bit for no parity 1 stop bit if parity is used; 2 bits if no parity
Error Check Field	Cyclical Redundancy Check (CRC)

7.8.2 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 7.14*.

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 7.13 Typical Modbus RTU Message Structure

7.8.3 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 field to be transmitted is the device address. Following the last transmitted character, a similar period of at least 3.5 character intervals marks the end of the message. A new message can begin after this period. The entire message frame must be transmitted as a continuous stream. If a silent period of more than 1.5 character intervals occurs before completion of the frame, the receiving device flushes the incomplete message and assumes that the next byte is the address field of a new message. Similarly, if a new message begins before 3.5 character intervals after a previous message, the receiving device considers it a continuation of the previous message. This causes a time-out (no response from the follower), since the value in the final CRC field is not valid for the combined messages.

7.8.4 Address Field

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

7.8.5 Function Field

The function field of a message frame contains 8 bits. Valid codes are in the range of 1-FF. Function fields are used to send messages between master and follower. When a message is sent from a master to a follower device, the function code field tells the follower what kind of action to perform. When the follower responds to the master, it uses the function code field to indicate either a normal (error-free) response, or that some kind of error occurred (called an exception response). For a normal response, the follower simply echoes the original function code. For an exception response, the follower returns a code that is equivalent to the original function code with its most significant bit set to logic 1. In addition, the follower places a unique code into the data field of the response message. This tells the master what kind of error occurred, or the reason for the exception. Also refer to *7.8.10 Function Codes Supported by Modbus RTU* and *7.8.11 Modbus Exception Codes*

7.8.6 Data Field

The data field is constructed using sets of 2 hexadecimal digits, in the range of 00 to FF hexadecimal. These are made up of one RTU character. The data field of messages sent from a master to follower device contains additional information which the follower must use to take the action defined by the function code. This can include items such as coil or register addresses, the quantity of items to be handled, and the count of actual data bytes in the field.

7.8.7 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 2 values are unequal, a bus time-out results. The error-checking field contains a 16-bit binary value implemented as 2 8-bit bytes. When this is done, 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.

7.8.8 Coil Register Addressing

In Modbus, all data are organised in coils and holding registers. Coils hold a single bit, whereas holding registers hold a 2-byte word (that is 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 7.16*)	Master to follower
17-32	Frequency converter speed or set-point reference Range 0x0-0xFFFF (-200% ... -200%)	Master to follower
33-48	Frequency converter status word (see *Table 7.16* and *Table 7.17*)	Follower to master
49-64	Open loop mode: Frequency converter output frequency Closed loop mode: Frequency converter feedback signal	Follower to master
65	Parameter write control (master to follower) 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.	Master to follower
66-65536	Reserved	

Table 7.14 Coil Register

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		
16	No reversing	Reversing

Table 7.15 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 7.16 Frequency Converter Status Word (FC Profile)

Bus adress	Bus register[1]	PLC Register	Content	Access	Description
0	1	40001	Reserved		Reserved for Legacy Drives VLT 5000 and VLT 2800
1	2	40002	Reserved		Reserved for Legacy Drives VLT 5000 and VLT 2800
2	3	40003	Reserved		Reserved for Legacy Drives VLT 5000 and VLT 2800
3	4	40004	Free		
4	5	40005	Free		
5	6	40006	Modbus conf	Read/Write	TCP only. Reserved for Modbus TCP (p12-28 and 12-29 - store in Eeprom etc.)
6	7	40007	Last error code	Read only	Error code recieved from parameter database, refer to WHAT 38295 for details
7	8	40008	Last error register	Read only	Address of register with which last error occurred, refer to WHAT 38296 for details
8	9	40009	Index pointer	Read/Write	Sub index of parameter to be accessed. Refer to WHAT 38297 for details
9	10	40010	FC par. 0-01	Dependent on parameter access	Parameter 0-01 (Modbus Register=10 parameter number 20 bytes space reserved pr parameter in Modbus Map
19	20	40020	FC par. 0-02	Dependent on parameter access	Parameter 0-02 20 bytes space reserved pr parameter in Modbus Map
29	30	40030	FC par. xx-xx	Dependent on parameter access	Parameter 0-03 20 bytes space reserved pr parameter in Modbus Map

Table 7.17 Adress/Registers

1) Value written in Modbus RTU telegram must be one or less than register number. E.g. Read Modbus Register 1 by writing value 0 in telegram.

7

7.8.9 How to Control the Frequency Converter

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

7.8.10 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 follower ID	11 hex

Table 7.18 Function Codes

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

Table 7.19 Function Codes

7.8.11 Modbus Exception Codes

For a full explanation of the structure of an exception code response, refer to *7.8.5 Function Field*.

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

Table 7.20 Modbus Exception Codes

7.9 How to Access Parameters

7.9.1 Parameter Handling

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

Reading *3-14 Preset Relative Reference* (32bit): The holding registers 3410 & 3411 holds the parameters value. A value of 11300 (Decimal), means that the parameter is set to 1113.00 S.

For information on the parameters, size and converting index, consult the product relevant programming guide.

7.9.2 Storage of Data

The Coil 65 decimal determines whether data written to the frequency converter are stored in EEPROM and RAM (coil 65=1) or only in RAM (coil 65= 0).

7.9.3 IND

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

7.9.4 Text Blocks

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

7.9.5 Conversion Factor

The different attributes for each parameter can be seen in the section on factory settings. Since a parameter value can only be transferred as a whole number, a conversion factor must be used to transfer decimals.

7.9.6 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 10 HEX "Preset Multiple Registers" for 2 registers (32 bits). Readable sizes range from 1 register (16 bits) up to 10 registers (20 characters).

Non standard data types
Non standard data types are text strings and are stored as 4x registers (40001–4FFFF). The parameters are read using function 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).

7.10 Examples

The following examples illustrate various Modbus RTU commands.

7.10.1 Read Coil Status (01 HEX)

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

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

Example of a request to read coils 33-48 (Status Word) from follower device 01.

Field Name	Example (HEX)
Follower Address	01 (frequency converter address)
Function	01 (read coils)
Starting Address HI	00
Starting Address LO	20 (32 decimals) Coil 33
No. of Points HI	00
No. of Points LO	10 (16 decimals)
Error Check (CRC)	-

Table 7.21 Query

Response
The coil status in the response message is packed as one coil per bit of the data field. Status is indicated as: 1=ON; 0=OFF. The LSB of the first data byte contains the coil addressed in the query. The other coils follow toward the high order end of this byte, and from 'low-order to high-order' in subsequent bytes.
If the returned coil quantity is not a multiple of 8, the remaining bits in the final data byte is padded with zeros (toward the high order end of the byte). The Byte Count field specifies the number of complete bytes of data.

Field Name	Example (HEX)
Follower Address	01 (frequency converter address)
Function	01 (read coils)
Byte Count	02 (2 bytes of data)
Data (Coils 40-33)	07
Data (Coils 48-41)	06 (STW=0607hex)
Error Check (CRC)	-

Table 7.22 Response

NOTICE

Coils and registers are addressed explicit with an off-set of -1 in Modbus.
I.e. Coil 33 is addressed as Coil 32.

7.10.2 Force/Write Single Coil (05 HEX)

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

Query
The query message specifies the coil 65 (parameter write control) to be forced. Coil addresses start at zero, that is, coil 65 is addressed as 64. Force Data=00 00HEX (OFF) or FF 00HEX (ON).

Field Name	Example (HEX)
Follower Address	01 (Frequency converter address)
Function	05 (write single coil)
Coil Address HI	00
Coil Address LO	40 (64 decimal) Coil 65
Force Data HI	FF
Force Data LO	00 (FF 00=ON)
Error Check (CRC)	-

Table 7.23 Query

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

Field Name	Example (HEX)
Follower Address	01
Function	05
Force Data HI	FF
Force Data LO	00
Quantity of Coils HI	00
Quantity of Coils LO	01
Error Check (CRC)	-

Table 7.24 Response

7.10.3 Force/Write Multiple Coils (0F HEX)

Description
This function forces each coil in a sequence of coils to either ON or OFF. When broadcasting the function forces the same coil references in all attached followers.

Query
The query message specifies the coils 17 to 32 (speed set-point) to be forced.

Field Name	Example (HEX)
Follower Address	01 (frequency converter address)
Function	0F (write multiple coils)
Coil Address HI	00
Coil Address LO	10 (coil address 17)
Quantity of Coils HI	00
Quantity of Coils LO	10 (16 coils)
Byte Count	02
Force Data HI (Coils 8-1)	20
Force Data LO (Coils 16-9)	00 (ref.=2000 hex)
Error Check (CRC)	-

Table 7.25 Query

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

Field Name	Example (HEX)
Follower Address	01 (frequency converter address)
Function	0F (write multiple coils)
Coil Address HI	00
Coil Address LO	10 (coil address 17)
Quantity of Coils HI	00
Quantity of Coils LO	10 (16 coils)
Error Check (CRC)	-

Table 7.26 Response

7.10.4 Read Holding Registers (03 HEX)

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

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

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

Field Name	Example (HEX)
Follower Address	01
Function	03 (read holding registers)
Starting Address HI	0B (Register address 3029)
Starting Address LO	05 (Register address 3029)
No. of Points HI	00
No. of Points LO	02 - (*3-03 Maximum Reference* is 32 bits long, i.e. 2 registers)
Error Check (CRC)	-

Table 7.27 Query

Response
The register data in the response message are packed as 2 bytes per register, with the binary contents right justified within each byte. For each register, the first byte contains the high-order bits and the second contains the low-order bits.

Example: Hex 000088B8=35.000=15 Hz.

Field Name	Example (HEX)
Follower Address	01
Function	03
Byte Count	04
Data HI (Register 3030)	00
Data LO (Register 3030)	16
Data HI (Register 3031)	E3
Data LO (Register 3031)	60
Error Check (CRC)	-

Table 7.28 Response

7.10.5 Preset Single Register (06 HEX)

Description
This function presets a value into a single holding register.

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

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

Field Name	Example (HEX)
Follower Address	01
Function	06
Register Address HI	03 (Register address 999)
Register Address LO	E7 (Register address 999)
Preset Data HI	00
Preset Data LO	01
Error Check (CRC)	-

Table 7.29 Query

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

Field Name	Example (HEX)
Follower Address	01
Function	06
Register Address HI	03
Register Address LO	E7
Preset Data HI	00
Preset Data LO	01
Error Check (CRC)	-

Table 7.30 Response

7.10.6 Preset Multiple Registers (10 HEX)

Description
This function presets values into a sequence of holding registers.

Query
The query message specifies the register references to be preset. Register addresses start at zero, that is, register 1 is addressed as 0. Example of a request to preset 2 registers (set *1-24 Motor Current* to 738 (7.38 A)):

Field Name	Example (HEX)
Follower Address	01
Function	10
Starting Address HI	04
Starting Address LO	19
No. of Registers HI	00
No. of registers LO	02
Byte Count	04
Write Data HI (Register 4: 1049)	00
Write Data LO (Register 4: 1049)	00
Write Data HI (Register 4: 1050)	02
Write Data LO (Register 4: 1050)	E2
Error Check (CRC)	-

Table 7.31 Query

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

Field Name	Example (HEX)
Follower Address	01
Function	10
Starting Address HI	04
Starting Address LO	19
No. of Registers HI	00
No. of registers LO	02
Error Check (CRC)	-

Table 7.32 Response

7.11 Danfoss FC Control Profile

7.11.1 Control Word According to FC Profile (8-10 Protocol = FC profile)

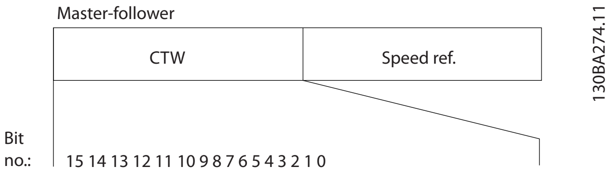


Illustration 7.13 Control Word According to FC Profile

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

Table 7.33 Control Word According to FC Profile

Explanation of the control bits

Bits 00/01
Bits 00 and 01 are used to select between the 4 reference values, which are pre-programmed in *3-10 Preset Reference* according to the *Table 7.35*.

Programmed ref. value	Parameter	Bit 01	Bit 00
1	*3-10 Preset Reference* [0]	0	0
2	*3-10 Preset Reference* [1]	0	1
3	*3-10 Preset Reference* [2]	1	0
4	*3-10 Preset Reference* [3]	1	1

Table 7.34 Control Bits

NOTICE

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

Bit 02, DC brake
Bit 02='0' leads to DC braking and stop. Set braking current and duration in *2-01 DC Brake Current* and *2-02 DC Braking Time*.
Bit 02='1' leads to ramping.

Bit 03, Coasting
Bit 03='0': The frequency converter immediately "lets go" of the motor, (the output transistors are "shut off") and it coasts to a standstill.
Bit 03='1': The frequency converter starts the motor if the other starting conditions are met.

Make a selection in *8-50 Coasting Select* to define how Bit 03 gates with the corresponding function on a digital input.

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

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

NOTICE

If Freeze output is active, the frequency converter can only be stopped by the following:

- **Bit 03 Coasting stop**
- **Bit 02 DC braking**
- **Digital input (*5-10 Terminal 18 Digital Input* to *5-13 Terminal 29 Digital Input*) programmed to *DC braking=5*, *Coasting stop=2*, or *Reset and coasting stop=3*.**

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 signal's leading edge, that is, when changing from logic '0' to logic '1'.

Bit 08, Jog
Bit 08='1': The output frequency is determined by *3-11 Jog Speed [Hz]*.

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. Turn off the control word if not wanting to use it when updating or reading parameters.

Bit 11, Relay 01
Bit 11="0": Relay not activated.
Bit 11="1": Relay 01 activated provided that *Control word bit 11=36* is chosen in *5-40 Function Relay*.

Bit 12, Relay 02
Bit 12="0": Relay 02 is not activated.
Bit 12="1": Relay 02 is activated provided that *Control word bit 12=37* is chosen in *5-40 Function Relay*.

Bit 13, Selection of set-up
Use bit 13 to select from the 2 menu set-ups according to *Table 7.36*.

Set-up	Bit 13
1	0
2	1

The function is only possible when *Multi Set-Ups=9* is selected in *0-10 Active Set-up*.

Make a selection in *8-55 Set-up Select* to define how Bit 13 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 Serial communication, Logic or Logic and is selected.

7.11.2 Status Word According to FC Profile (STW) (*8-30 Protocol* = FC profile)

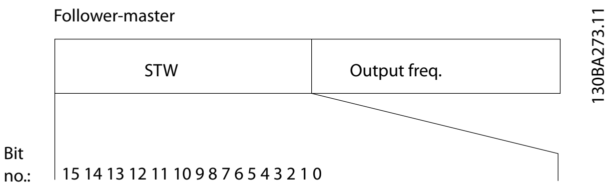


Illustration 7.14 Status Word

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 7.35 Status Word According to FC Profile

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='0': The frequency converter is not 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, press [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 might for example, 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': [Off/Reset] is activate on the control unit or *Local control* in *3-13 Reference Site* is selected. It is not possible to control the frequency converter 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 *4-12 Motor Speed Low Limit [Hz]* or *4-14 Motor Speed High Limit [Hz]*.
Bit 10="1": The output frequency is within the defined limits.

Bit 11, No operation/in operation
Bit 11='0': The motor is not running.
Bit 11='1': The coasting 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 frequency converter's 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%.

7.11.3 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 by means of 2's complement. The Actual Output frequency (MAV) is scaled in the same way as the bus reference.

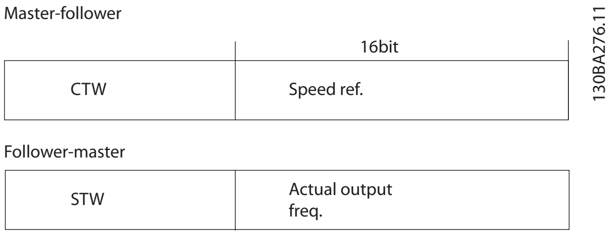


Illustration 7.15 Actual Output Frequency (MAV)

The reference and MAV are scaled as follows:

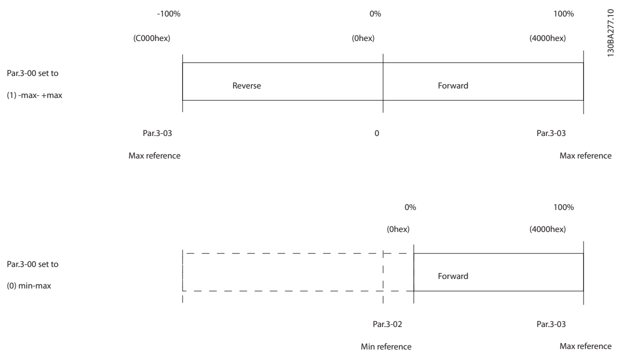


Illustration 7.16 Reference and MAV

8 General Specifications and Troubleshooting

8.1 Mains Supply Specifications

8.1.1 Mains Supply 3x200-240 V AC

Frequency converter	**PK25**	**PK37**	**PK75**	**P1K5**	**P2K2**	**P3K7**	**P5K5**	**P7K5**	**P11K**	**P15K**	**P18K**	**P22K**	**P30K**	**P37K**	**P45K**
Typical shaft output [kW]	0.25	0.37	0.75	1.5	2.2	3.7	5.5	7.5	11.0	15.0	18.5	22.0	30.0	37.0	45.0
Typical shaft output [hp]	0.33	0.5	1.0	2.0	3.0	5.0	7.5	10.0	15.0	20.0	25.0	30.0	40.0	50.0	60.0
IP20 frame	H1	H1	H1	H1	H2	H3	H4	H4	H5	H6	H6	H7	H7	H8	H8
Max. cable size in terminals (mains, motor) [mm²/AWG]	4/10	4/10	4/10	4/10	4/10	4/10	16/6	16/6	16/6	35/2	35/2	50/1	50/1	95/0	120/(4/0)
Output current															
40 °C ambient temperature															
Continuous (3x200-240 V) [A]	1.5	2.2	4.2	6.8	9.6	15.2	22.0	28.0	42.0	59.4	74.8	88.0	115.0	143.0	170.0
Intermittent (3x200-240 V) [A]	1.7	2.4	4.6	7.5	10.6	16.7	24.2	30.8	46.2	65.3	82.3	96.8	126.5	157.3	187.0
Max. input current															
Continuous 3x200-240 V) [A]	1.1	1.6	2.8	5.6	8.6/7.2	14.1/12.0	21.0/18.0	28.3/24.0	41.0/38.2	52.7	65.0	76.0	103.7	127.9	153.0
Intermittent (3x200-240 V) [A]	1.2	1.8	3.1	6.2	9.5/7.9	15.5/13.2	23.1/19.8	31.1/26.4	45.1/42.0	58.0	71.5	83.7	114.1	140.7	168.3
Max. mains fuses	See *5.2.3 Fuses and Circuit Breakers*														
Estimated power loss [W], Best case/typical[1)]	12/14	15/18	21/26	48/60	80/102	97/120	182/204	229/268	369/386	512	697	879	1149	1390	1500
Weight enclosure IP20 [kg]	2.	2.0	2.0	2.1	3.4	4.5	7.9	7.9	9.5	24.5	24.5	36.0	36.0	51.0	51.0
Efficiency [%], best case/typical[1)]	97.0/96.5	97.3/96.8	98.0/97.6	97.6/97.0	97.1/96.3	97.9/97.4	97.3/97.0	98.5/97.1	97.2/97.1	97.0	97.1	96.8	97.1	97.1	97.3
Output current															
50 °C ambient temperature															
Continuous (3x200-240 V) [A]	1.5	1.9	3.5	6.8	9.6	13.0	19.8	23.0	33.0	41.6	52.4	61.6	80.5	100.1	119
Intermittent (3x200-240 V) [A]	1.7	2.1	3.9	7.5	10.6	14.3	21.8	25.3	36.3	45.8	57.6	67.8	88.6	110.1	130.9

Table 8.1 3x200-240 V AC, PK25-P45K

1) At rated load conditions

8.1.2 Mains Supply 3x380-480 V AC

Frequency converter	**PK37**	**PK75**	**P1K5**	**P2K2**	**P3K0**	**P4K0**	**P5K5**	**P7K5**	**P11K**	**P15K**
Typical shaft output [kW]	0.37	0.75	1.5	2.2	3.0	4.0	5.5	7.5	11.0	15.0
Typical shaft output [hp]	0.5	1.0	2.0	3.0	4.0	5.0	7.5	10.0	15.0	20.0
IP20 frame	H1	H1	H1	H2	H2	H2	H3	H3	H4	H4
Max. cable size in terminals (mains, motor) [mm^2/AWG]	4/10	4/10	4/10	4/10	4/10	4/10	4/10	4/10	16/6	16/6
Output current - 40 °C ambient temperature										
Continuous (3x380-440 V)[A]	1.2	2.2	3.7	5.3	7.2	9.0	12.0	15.5	23.0	31.0
Intermittent (3x380-440 V) [A]	1.3	2.4	4.1	5.8	7.9	9.9	13.2	17.1	25.3	34.0
Continuous (3x440-480 V) [A]	1.1	2.1	3.4	4.8	6.3	8.2	11.0	14.0	21.0	27.0
Intermittent (3x440-480 V) [A]	1.2	2.3	3.7	5.3	6.9	9.0	12.1	15.4	23.1	29.7
Max. input current										
Continuous (3x380-440 V) [A]	1.2	2.1	3.5	4.7	6.3	8.3	11.2	15.1	22.1	29.9
Intermittent (3x380-440 V) [A]	1.3	2.3	3.9	5.2	6.9	9.1	12.3	16.6	24.3	32.9
Continuous (3x440-480 V) [A]	1.0	1.8	2.9	3.9	5.3	6.8	9.4	12.6	18.4	24.7
Intermittent (3x440-480 V) [A]	1.1	2.0	3.2	4.3	5.8	7.5	10.3	13.9	20.2	27.2
Max. mains fuses	See *5.2.3 Fuses and Circuit Breakers*									
Estimated power loss [W], best case/typical[1)]	13/15	16/21	46/57	46/58	66/83	95/118	104/131	159/198	248/274	353/379
Weight enclosure IP20 [kg]	2.0	2.0	2.1	3.3	3.3	3.4	4.3	4.5	7.9	7.9
Efficiency [%], best case/typical[1)]	97.8/97.3	98.0/97.6	97.7/97.2	98.3/97.9	98.2/97.8	98.0/97.6	98.4/98.0	98.2/97.8	98.1/97.9	98.0/97.8
Output current - 50 °C ambient temperature										
Continuous (3x380-440 V) [A]	1.04	1.93	3.7	4.85	6.3	8.4	10.9	14.0	20.9	28.0
Intermittent (3x380-440 V) [A]	1.1	2.1	4.07	5.4	6.9	9.2	12.0	15.4	23.0	30.8
Continuous (3x440-480 V) [A]	1.0	1.8	3.4	4.4	5.5	7.5	10.0	12.6	19.1	24.0
Intermittent (3x440-480 V) [A]	1.1	2.0	3.7	4.8	6.1	8.3	11.0	13.9	21.0	26.4

Table 8.2 3x380-480 V AC, PK37-P11K, H1-H4

1) At rated load conditions

8

Frequency converter	P18K	P22K	P30K	P37K	P45K	P55K	P75K	P90K
Typical shaft output [kW]	18.5	22.0	30.0	37.0	45.0	55.0	75.0	90.0
Typical shaft output [hp]	25.0	30.0	40.0	50.0	60.0	70.0	100.0	125.0
IP20 frame	H5	H5	H6	H6	H6	H7	H7	H8
Max. cable size in terminals (mains, motor) [mm^2/AWG]	16/6	16/6	35/2	35/2	35/2	50/1	95/0	120/250MCM
Output current - 40 °C ambient temperature								
Continuous (3x380-440 V)[A]	37.0	42.5	61.0	73.0	90.0	106.0	147.0	177.0
Intermittent (3x380-440 V) [A]	40.7	46.8	67.1	80.3	99.0	116.0	161.0	194.0
Continuous (3x440-480 V) [A]	34.0	40.0	52.0	65.0	80.0	105.0	130.0	160.0
Intermittent (3x440-480 V) [A]	37.4	44.0	57.2	71.5	88.0	115.0	143.0	176.0
Max. input current								
Continuous (3x380-440 V) [A]	35.2	41.5	57.0	70.0	84.0	103.0	140.0	166.0
Intermittent (3x380-440 V) [A]	38.7	45.7	62.7	77.0	92.4	113.0	154.0	182.0
Continuous (3x440-480 V) [A]	29.3	34.6	49.2	60.6	72.5	88.6	120.9	142.7
Intermittent (3x440-480 V) [A]	32.2	38.1	54.1	66.7	79.8	97.5	132.9	157.0
Max. mains fuses								
Estimated power loss [W], best case/typical[1)]	412/456	475/523	733	922	1067	1133	1733	2141
Weight enclosure IP20 [kg]	9.5	9.5	24.5	24.5	24.5	36.0	36.0	51.0
Efficiency [%], best case/typical[1)]	98.1/97.9	98.1/97.9	97.8	97.7	98	98.2	97.8	97.9
Output current - 50 °C ambient temperature								
Continuous (3x380-440 V) [A]	34.1	38.0	48.8	58.4	72.0	74.2	102.9	123.9
Intermittent (3x380-440 V) [A]	37.5	41.8	53.7	64.2	79.2	81.6	113.2	136.3
Continuous (3x440-480 V) [A]	31.3	35.0	41.6	52.0	64.0	73.5	91.0	112.0
Intermittent (3x440-480 V) [A]	34.4	38.5	45.8	57.2	70.4	80.9	100.1	123.2

Table 8.3 3x380-480 V AC, P18K-P90K, H5-H8

1) At rated load conditions

8

Frequency converter	PK75	P1K5	P2K2	P3K0	P4KO	P5K5	P7K5	P11K	P15K	P18K
Typical shaft output [kW]	0.75	1.5	2.2	3.0	4.0	5.5	7.5	11	15	18.5
Typical shaft output [hp]	1.0	2.0	3.0	4.0	5.0	7.5	10.0	15	20	25
IP54 frame	I2	I2	I2	I2	I2	I3	I3	I4	I4	I4
Max. cable size in terminals (mains, motor) [mm²/AWG]	4/10	4/10	4/10	4/10	4/10	4/10	4/10	16/6	16/6	16/6
Output current										
40 °C ambient temperature										
Continuous (3x380-440 V) [A]	2.2	3.7	5.3	7.2	9.0	12.0	15.5	23.0	31.0	37.0
Intermittent (3x380-440 V) [A]	2.4	4.1	5.8	7.9	9.9	13.2	17.1	25.3	34.0	40.7
Continuous (3x440-480 V) [A]	2.1	3.4	4.8	6.3	8.2	11.0	14.0	21.0	27.0	34.0
Intermittent (3x440-480 V) [A]	2.3	3.7	5.3	6.9	9.0	12.1	15.4	23.1	29.7	37.4
Max. input current										
Continuous (3x380-440 V)[A]	2.1	3.5	4.7	6.3	8.3	11.2	15.1	22.1	29.9	35.2
Intermittent (3x380-440 V) [A]	2.3	3.9	5.2	6.9	9.1	12.3	16.6	24.3	32.9	38.7
Continuous (3x440-480 V) [A]	1.8	2.9	3.9	5.3	6.8	9.4	12.6	18.4	24.7	29.3
Intermittent (3 x 440-480 V) [A]	2.0	3.2	4.3	5.8	7.5	10.3	13.9	20.2	27.2	32.2
Max. mains fuses	See *5.2.3 Fuses and Circuit Breakers*									
Estimated power loss [W], best case/typical[1)]	21/ 16	46/ 57	46/ 58	66/ 83	95/ 118	104/ 131	159/ 198	248/ 274	353/ 379	412/ 456
Weight enclosure IP54 [kg]	5.3	5.3	5.3	5.3	5.3	7.2	7.2	13.8	13.8	13.8
Efficiency [%], best case/typical[1)]	98.0/ 97.6	97.7/ 97.2	98.3/ 97.9	98.2/ 97.8	98.0/ 97.6	98.4/ 98.0	98.2/ 97.8	98.1/ 97.9	98.0/ 97.8	98.1/ 97.9
Output current - 50 °C ambient temperature										
Continuous (3x380-440 V) [A]	1.93	3.7	4.85	6.3	7.5	10.9	14.0	20.9	28.0	33.0
Intermittent (3x380-440 V) [A]	2.1	4.07	5.4	6.9	9.2	12.0	15.4	23.0	30.8	36.3
Continuous (3x440-480 V) [A]	1.8	3.4	4.4	5.5	6.8	10.0	12.6	19.1	24.0	30.0
Intermittent (3x440-480 V) [A]	2.0	3.7	4.8	6.1	8.3	11.0	13.9	21.0	26.4	33.0

Table 8.4 3x380-480 V AC, PK75-P18K, I2-I4

1) At rated load conditions

Frequency converter	P22K	P30K	P37K	P45K	P55K	P75K	P90K
Typical shaft output [kW]	22.0	30.0	37.0	45.0	55.0	75.0	90.0
Typical shaft output [hp]	30.0	40.0	50.0	60.0	70.0	100.0	125.0
IP54 frame	I6	I6	I6	I7	I7	I8	I8
Max. cable size in terminals (mains, motor) [mm^2/AWG]	35/2	35/2	35/2	50/1	50/1	95/(3/0)	120/(4/0)
Output current							
40 °C ambient temperature							
Continuous (3x380-440 V) [A]	44.0	61.0	73.0	90.0	106.0	147.0	177.0
Intermittent (3x380-440 V) [A]	48.4	67.1	80.3	99.0	116.6	161.7	194.7
Continuous (3x440-480 V) [A]	40.0	52.0	65.0	80.0	105.0	130.0	160.0
Intermittent (3x440-480 V) [A]	44.0	57.2	71.5	88.0	115.5	143.0	176.0
Max. input current							
Continuous (3x380-440 V)[A]	41.8	57.0	70.3	84.2	102.9	140.3	165.6
Intermittent (3x380-440 V) [A]	46.0	62.7	77.4	92.6	113.1	154.3	182.2
Continuous (3x440-480 V) [A]	36.0	49.2	60.6	72.5	88.6	120.9	142.7
Intermittent (3 x 440-480 V) [A]	39.6	54.1	66.7	79.8	97.5	132.9	157.0
Max. mains fuses							
Estimated power loss [W], best case/typical[1)]	496	734	995	840	1099	1520	1781
Weight enclosure IP54 [kg]	27	27	27	45	45	65	65
Efficiency [%], best case/Typical[1)]	98.0	97.8	97.6	98.3	98.2	98.1	98.3
Output current - 50 °C ambient temperature							
Continuous (3x380-440 V) [A]	35.2	48.8	58.4	63.0	74.2	102.9	123.9
Intermittent (3x380-440 V) [A]	38.7	53.9	64.2	69.3	81.6	113.2	136.3
Continuous (3x440-480 V) [A]	32.0	41.6	52.0	56.0	73.5	91.0	112.0
Intermittent (3x440-480 V) [A]	35.2	45.8	57.2	61.6	80.9	100.1	123.2

Table 8.5 3x380-480 V AC, P11K-P90K, I6-I8

1) At rated load conditions

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روبروی پالایشگاه نفت پارس، پلاک ۱۲

8.1.3 Mains Supply 3x380-480 V AC

Frequency converter	**PK75**	**P1K5**	**P2K2**	**P3K0**	**P4KO**	**P5K5**	**P7K5**	**P11K**	**P15K**
Typical shaft output [kW]	0.75	1.5	2.2	3.0	4.0	5.5	7.5	11	15
Typical shaft output [hp]	1.0	2.0	3.0	4.0	5.0	7.5	10.0	15	20
IP54 frame	I2	I2	I2	I2	I2	I3	I3	I4	I4
Max. cable size in terminals (mains, motor) [mm^2/AWG]	4/10	4/10	4/10	4/10	4/10	4/10	4/10	16/6	16/6
Output current									
40 °C ambient temperature									
Continuous (3x380-440 V) [A]	2.2	3.7	5.3	7.2	9.0	12.0	15.5	23.0	31.0
Intermittent (3x380-440 V) [A]	2.4	4.1	5.8	7.9	9.9	13.2	17.1	25.3	34.0
Continuous (3x440-480 V) [A]	2.1	3.4	4.8	6.3	8.2	11.0	14.0	21.0	27.0
Intermittent (3x440-480 V) [A]	2.3	3.7	5.3	6.9	9.0	12.1	15.4	23.1	29.7
Max. input current									
Continuous (3x380-440 V)[A]	2.1	3.5	4.7	6.3	8.3	11.2	15.1	22.1	29.9
Intermittent (3x380-440 V) [A]	2.3	3.9	5.2	6.9	9.1	12.3	16.6	24.3	32.9
Continuous (3x440-480 V) [A]	1.8	2.9	3.9	5.3	6.8	9.4	12.6	18.4	24.7
Intermittent (3 x 440-480 V) [A]	2.0	3.2	4.3	5.8	7.5	10.3	13.9	20.2	27.2
Max. mains fuses	See *5.2.3 Fuses and Circuit Breakers*								
Estimated power loss [W], Best case/typical[1)]	21/ 16	46/ 57	46/ 58	66/ 83	95/ 118	104/ 131	159/ 198	248/ 274	353/ 379
Weight enclosure IP54 [kg]	5.3	5.3	5.3	5.3	5.3	7.2	7.2	13.8	13.8
Efficiency [%], Best case/Typical[1)]	98.0/ 97.6	97.7/ 97.2	98.3/ 97.9	98.2/ 97.8	98.0/ 97.6	98.4/ 98.0	98.2/ 97.8	98.1/ 97.9	98.0/ 97.8
Output current									
50 °C ambient temperature									
Continuous (3x380-440 V) [A]	1.93	3.7	4.85	6.3	7.5	10.9	14.0	20.9	28.0
Intermittent (3x380-440 V) [A]	2.1	4.07	5.4	6.9	9.2	12.0	15.4	23.0	30.8
Continuous (3x440-480 V) [A]	1.8	3.4	4.4	5.5	6.8	10.0	12.6	19.1	24.0
Intermittent (3x440-480 V) [A]	2.0	3.7	4.8	6.1	8.3	11.0	13.9	21.0	26.4

Table 8.6 PK75-P15K

1) At rated load conditions

8

Frequency converter	P18K	P22K	P30K	P37K	P45K	P55K	P75K	P90K
Typical shaft output [kW]	18.5	22.0	30.0	37.0	45.0	55.0	75.0	90.0
Typical shaft output [hp]	25	30.0	40.0	50.0	60.0	70.0	100.0	125.0
IP54 frame	I4	I6	I6	I6	I7	I7	I8	I8
Max. cable size in terminals (mains, motor) [mm²/AWG]	16/6	35/2	35/2	35/2	50/1	50/1	95/(3/0)	120/(4/0)
Output current								
40 °C ambient temperature								
Continuous (3x380-440 V) [A]	37.0	44.0	61.0	73.0	90.0	106.0	147.0	177.0
Intermittent (3x380-440 V) [A]	40.7	48.4	67.1	80.3	99.0	116.6	161.7	194.7
Continuous (3x440-480 V) [A]	34.0	40.0	52.0	65.0	80.0	105.0	130.0	160.0
Intermittent (3x440-480 V) [A]	37.4	44.0	57.2	71.5	88.0	115.5	143.0	176.0
Max. input current								
Continuous (3x380-440 V)[A]	35.2	41.8	57.0	70.3	84.2	102.9	140.3	165.6
Intermittent (3x380-440 V) [A]	38.7	46.0	62.7	77.4	92.6	113.1	154.3	182.2
Continuous (3x440-480 V) [A]	29.3	36.0	49.2	60.6	72.5	88.6	120.9	142.7
Intermittent (3 x 440-480 V) [A]	32.2	39.6	54.1	66.7	79.8	97.5	132.9	157.0
Max. mains fuses								
Estimated power loss [W], Best case/typical[1)]	412/ 456	496	734	995	840	1099	1520	1781
Weight enclosure IP54 [kg]	13.8	27	27	27	45	45	65	65
Efficiency [%], Best case/Typical[1)]	98.1/ 97.9	98.0	97.8	97.6	98.3	98.2	98.1	98.3
Output current								
50 °C ambient temperature								
Continuous (3x380-440 V) [A]	33.0	35.2	48.8	58.4	63.0	74.2	102.9	123.9
Intermittent (3x380-440 V) [A]	36.3	38.7	53.9	64.2	69.3	81.6	113.2	136.3
Continuous (3x440-480 V) [A]	30.0	32.0	41.6	52.0	56.0	73.5	91.0	112.0
Intermittent (3x440-480 V) [A]	33.0	35.2	45.8	57.2	61.6	80.9	100.1	123.2

Table 8.7 P18K-P90K

1) At rated load conditions

8.1.4 Mains Supply 3x525-600 V AC

Frequency converter	P2K2	P3K0	P3K7	P5K5	P7K5	P11K	P15K	P18K	P22K	P30K	P37K	P45K	P55K	P75K	P90K
Typical shaft output [kW]	2.2	3.0	3.7	5.5	7.5	11.0	15.0	18.5	22.0	30.0	37	45.0	55.0	75.0	90.0
Typical shaft output [hp]	3.0	4.0	5.0	7.5	10.0	15.0	20.0	25.0	30.0	40.0	50.0	60.0	70.0	100.0	125.0
IP20 frame	H9	H9	H9	H9	H9	H10	H10	H6	H6	H6	H7	H7	H7	H8	H8
Max. cable size in terminals (mains, motor) [mm²/AWG]	4/10	4/10	4/10	4/10	4/10	10/8	10/8	35/2	35/2	35/2	50/1	50/1	50/1	95/0	120/ (4/0)
Output current - 40 °C ambient temperature															
Continuous (3x525-550 V) [A]	4.1	5.2	6.4	9.5	11.5	19.0	23.0	28.0	36.0	43.0	54.0	65.0	87.0	105.0	137.0
Intermittent (3x525-550 V) [A]	4.5	5.7	7.0	10.5	12.7	20.9	25.3	30.8	39.6	47.3	59.4	71.5	95.7	115.5	150.7
Continuous (3x551-600 V) [A]	3.9	4.9	6.1	9.0	11.0	18.0	22.0	27.0	34.0	41.0	52.0	62.0	83.0	100.0	131.0
Intermittent (3x551-600 V) [A]	4.3	5.4	6.7	9.9	12.1	19.8	24.2	29.7	37.4	45.1	57.2	68.2	91.3	110.0	144.1
Max. input current															
Continuous (3x525-550 V) [A]	3.7	5.1	5.0	8.7	11.9	16.5	22.5	27.0	33.1	45.1	54.7	66.5	81.3	109.0	130.9
Intermittent (3x525-550 V) [A]	4.1	5.6	6.5	9.6	13.1	18.2	24.8	29.7	36.4	49.6	60.1	73.1	89.4	119.9	143.9
Continuous (3x551-600 V) [A]	3.5	4.8	5.6	8.3	11.4	15.7	21.4	25.7	31.5	42.9	52.0	63.3	77.4	103.8	124.5
Intermittent (3x551-600 V) [A]	3.9	5.3	6.2	9.2	12.5	17.3	23.6	28.3	34.6	47.2	57.2	69.6	85.1	114.2	137.0
Max. mains fuses	See *5.2.3 Fuses and Circuit Breakers*														
Estimated power loss [W], best case/typical[1)]	65	90	110	132	180	216	294	385	458	542	597	727	1092	1380	1658
Weight enclosure IP54 [kg]	6.6	6.6	6.6	6.6	6.6	11.5	11.5	24.5	24.5	24.5	36.0	36.0	36.0	51.0	51.0
Efficiency [%], best case/typical[1)]	97.9	97	97.9	98.1	98.1	98.4	98.4	98.4	98.4	98.5	98.5	98.7	98.5	98.5	98.5
Output current - 50 °C ambient temperature															
Continuous (3x525-550 V) [A]	2.9	3.6	4.5	6.7	8.1	13.3	16.1	19.6	25.2	30.1	37.8	45.5	60.9	73.5	95.9
Intermittent (3x525-550 V) [A]	3.2	4.0	4.9	7.4	8.9	14.6	17.7	21.6	27.7	33.1	41.6	50.0	67.0	80.9	105.5
Continuous (3x551-600 V) [A]	2.7	3.4	4.3	6.3	7.7	12.6	15.4	18.9	23.8	28.7	36.4	43.3	58.1	70.0	91.7
Intermittent (3x551-600 V) [A]	3.0	3.7	4.7	6.9	8.5	13.9	16.9	20.8	26.2	31.6	40.0	47.7	63.9	77.0	100.9

Table 8.8 3x525-600 V AC, P2K2-P90K, H6-H10

1) At rated load conditions

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8.2 General Specifications

Protection and features

- Electronic thermal motor protection against overload.
- Temperature monitoring of the heat sink ensures that the frequency converter trips in case of overtemperature
- The frequency converter is protected against short-circuits between motor terminals U, V, W.
- When a motor phase is missing, the frequency converter trips and issues an alarm.
- When 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, when the intermediate circuit voltage is too low or too high.
- The frequency converter is protected against earth faults on motor terminals U, V, W.

Mains supply (L1, L2, L3)

Supply voltage	200-240 V ±10%
Supply voltage	380-480 V ±10%
Supply voltage	525-600 V ±10%
Supply frequency	50/60 Hz
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 (cosφ) near unity	(>0.98)
Switching on the input supply L1, L2, L3 (power-ups) enclosure frame H1-H5, I2, I3, I4	Max. 2 times/min.
Switching on the input supply L1, L2, L3 (power-ups) enclosure frame H6-H8, I6-I8	Max. 1 time/min.
Environment according to EN 60664-1	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, 240/480 V maximum.

Motor output (U, V, W)

Output voltage	0-100% of supply voltage
Output frequency	0-200 Hz (VVC^{plus}), 0-400 Hz (u/f)
Switching on output	Unlimited
Ramp times	0.05-3600 s

Cable lengths and cross sections

Max. motor cable length, screened/armoured (EMC correct installation)	See *2.8.2 EMC Test Results*
Max. motor cable length, unscreened/unarmoured	50 m
Max. cross section to motor, mains*	
Cross section DC terminals for filter feedback on enclosure frame H1-H3, I2, I3, I4	4 mm^2/11 AWG
Cross section DC terminals for filter feedback on enclosure frame H4-H5	16 mm^2/6 AWG
Maximum cross section to control terminals, rigid wire	2.5 mm^2/14 AWG)
Maximum cross section to control terminals, flexible cable	2.5 mm^2/14 AWG)
Minimum cross section to control terminals	0.05 mm^2/30 AWG

*See *8.1.2 Mains Supply 3x380-480 V AC* for more information

Digital inputs

Programmable digital inputs	4
Terminal number	18, 19, 27, 29
Logic	PNP or NPN
Voltage level	0-24 V DC
Voltage level, logic '0' PNP	<5 V DC
Voltage level, logic '1' PNP	>10 V DC
Voltage level, logic '0' NPN	>19 V DC
Voltage level, logic '1' NPN	<14 V DC
Maximum voltage on input	28 V DC
Input resistance, R_i	Approx. 4 kΩ

Digital input 29 as thermistor input	Fault: >2.9 kΩ and no fault: <800 Ω
Digital input 29 as Pulse input	Max frequency 32 kHz Push-Pull-Driven & 5 kHz (O.C.)

Analog inputs

Number of analog inputs	2
Terminal number	53, 54
Terminal 53 mode	Parameter 6-19: 1=voltage, 0=current
Terminal 54 mode	Parameter 6-29: 1=voltage, 0=current
Voltage level	0-10 V
Input resistance, R_i	approx. 10 kΩ
Max. voltage	20 V
Current level	0/4 to 20 mA (scalable)
Input resistance, R_i	<500 Ω
Max. current	29 mA

Analog output

Number of programmable analog outputs	2
Terminal number	42, 45[1)]
Current range at analog output	0/4-20 mA
Max. load to common at analog output	500 Ω
Max. voltage at analog output	17 V
Accuracy on analog output	Max. error: 0.4% of full scale
Resolution on analog output	10 bit

[1)] Terminal 42 and 45 can also be programmed as digital outputs.

Digital output

Number of digital outputs	2
Terminal number	42, 45[1)]
Voltage level at digital output	17 V
Max. output current at digital output	20 mA
Max. load at digital output	1 kΩ

1) Terminals 42 and 45 can also be programmed as analog output.

Control card, RS-485 serial communication[A)]

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

Control card, 24 V DC output

Terminal number	12
Max. load	80 mA

Relay output

Programmable relay output	2
Relay 01 and 02	01-03 (NC), 01-02 (NO), 04-06 (NC), 04-05 (NO)
Max. terminal load (AC-1)[1)] on 01-02/04-05 (NO) (Resistive load)	250 V AC, 3 A
Max. terminal load (AC-15)[1)] on 01-02/04-05 (NO) (Inductive load @ cosφ 0.4)	250 V AC, 0.2 A
Max. terminal load (DC-1)[1)] on 01-02/04-05 (NO) (Resistive load)	30 V DC, 2 A
Max. terminal load (DC-13)[1)] on 01-02/04-05 (NO) (Inductive load)	24 V DC, 0.1 A
Max. terminal load (AC-1)[1)] on 01-03/04-06 (NC) (Resistive load)	250 V AC, 3 A
Max. terminal load (AC-15)[1)] on 01-03/04-06 (NC) (Inductive load @ cosφ 0.4)	250 V AC, 0.2 A
Max. terminal load (DC-1)[1)] on 01-03/04-06	30 V DC, 2 A
(NC) (Resistive load)	Min. terminal load on 01-03 (NC), 01-02 (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 parts 4 and 5.

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Control card, 10 V DC output[A)]

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

[A)] All inputs, outputs, circuits, DC supplies and relay contacts are galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

Surroundings

Enclosure	IP20
Enclosure kit available	IP21, TYPE 1
Vibration test	1.0 g
Max. relative humidity	5%-95% (IEC 60721-3-3; Class 3K3 (non-condensing) during operation
Aggressive environment (IEC 60721-3-3), coated (standard) frame H1-H5	Class 3C3
Aggressive environment (IEC 60721-3-3), non-coated frame H6-H10	Class 3C2
Aggressive environment (IEC 60721-3-3), coated (optional) frame H6-H10	Class 3C3
Aggressive environment (IEC 60721-3-3), non-coated frame I2-I8	Class 3C2
Test method according to IEC 60068-2-43 H2S (10 days)	
Ambient temperature	See max. output current at 40/50 °C in *8.1.2 Mains Supply 3x380-480 V AC*

Derating for high ambient temperature, see *8.5 Derating according to Ambient Temperature and Switching Frequency8.5 Derating according to Ambient Temperature and Switching Frequency*.

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Minimum ambient temperature during full-scale operation	0 °C
Minimum ambient temperature at reduced performance	-20 °C
Minimum ambient temperature at reduced performance	-10 °C
Temperature during storage/transport	-30 to +65/70 °C
Maximum altitude above sea level without derating	1000 m
Maximum altitude above sea level with derating	3000 m
Derating for high altitude, see	
Safety standards	EN/IEC 61800-5-1, UL 508C
EMC standards, Emission	EN 61800-3, EN 61000-6-3/4, EN 55011, IEC 61800-3
EMC standards, Immunity	EN 61800-3, EN 61000-3-12, 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

8.3 Acoustic Noise or Vibration

If the motor or the equipment driven by the motor - e.g. a fan blade - is making noise or vibrations at certain frequencies, try the following:

- Speed Bypass, parameter group *4-6* Speed Bypass*
- Over-modulation, *14-03 Overmodulation* set to *[0] Off*
- Switching pattern and switching frequency parameter group *14-0* Inverter Switching*
- Resonance Dampening, *1-64 Resonance Dampening*

The acoustic noise from the frequency converter comes from 3 sources:

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

Frame	Level [dBA]
H1	57.3
H2	59.5
H3	53.8
H4	64
H5	63.7
H6	71.5
H7	67.5 (75 kW 71.5 dB)
H8	73.5
H9	60
H10	62.9
I2	50.2
I3	54
I4	60.8
I6	70
I7	62
I8	65.6

Table 8.9 Typical Values Measured at a Distance of 1 m from the Unit

8.4 dU/Dt

	Cable length [m]	AC line voltage [V]	Rise time [usec]	V_{peak} [kV]	dU/dt [kV/usec]
200 V 0.25 kW	5	240	0,121	0,498	3.256
	25	240	0,182	0,615	2,706
	50	240	0,258	0,540	1.666
200 V 0.37 kW	5	240	0,121	0,498	3.256
	25	240	0,182	0,615	2,706
	50	240	0,258	0,540	1.666
200 V 0.75 kW	5	240	0,121	0,498	3.256
	25	240	0,182	0,615	2,706
	50	240	0,258	0,540	1.666
200 V 1.5 kW	5	240	0,121	0,498	3.256
	25	240	0,182	0,615	2,706
	50	240	0,258	0,540	1.666
200 V 2.2 kW	5	240	0,18	0,476	2.115
	25	240	0,230	0,615	2.141
	50	240	0,292	0,566	1.550
200 V 3.7 kW	5	240	0,168	0,570	2.714
	25	240	0,205	0,615	2.402
	50	240	0,252	0,620	1.968
200 V 5.5 kW	5	240	0,128	0,445	2781
	25	240	0,224	0,594	2121
	50	240	0,328	0,596	1454
200 V 7.5 kW	5	240	0,18	0,502	2244
	25	240	0,22	0,598	2175
	50	240	0,292	0,615	1678
200 V 11 kW	36	240	0,176	0,56	2545
	50	240	0,216	0,599	2204
400 V 0.37 kW	5	400	0,160	0,808	4.050
	25	400	0,240	1.026	3.420
	50	400	0,340	1.056	2.517
400 V 0.75 kW	5	400	0,160	0,808	4.050
	25	400	0,240	1.026	3.420
	50	400	0,340	1.056	2.517
400 V 1.5 kW	5	400	0,160	0,808	4.050
	25	400	0,240	1.026	3.420
	50	400	0,340	1.056	2.517
400 V 2.2 kW	5	400	0,190	0,760	3.200
	25	400	0,293	1.026	2.801
	50	400	0,422	1.040	1.971
400 V 3.0 kW	5	400	0,190	0,760	3.200
	25	400	0,293	1.026	2.801
	50	400	0,422	1.040	1.971
400 V 4.0 kW	5	400	0,190	0,760	3.200
	25	400	0,293	1.026	2.801
	50	400	0,422	1.040	1.971
400 V 5.5 kW	5	400	0,168	0,81	3.857
	25	400	0,239	1.026	3.434
	50	400	0,328	1,05	2.560
400 V 7.5 kW	5	400	0,168	0,81	3.857
	25	400	0,239	1.026	3.434
	50	400	0,328	1,05	2.560

	Cable length [m]	AC line voltage [V]	Rise time [usec]	V_{peak} [kV]	dU/dt [kV/usec]
400 V 11 kW	5	400	0,116	0,69	4871
	25	400	0,204	0,985	3799
	50	400	0,316	1,01	2563
400 V 15 kW	5	400	0,139	0,864	4,955
	50	400	0,338	1,008	2,365
400 V 18.5 kW	5	400	0,132	0,88	5.220
	25	400	0,172	1.026	4.772
	50	400	0,222	1,00	3.603
400 V 22 kW	5	400	0,132	0,88	5.220
	25	400	0,172	1.026	4.772
	50	400	0,222	1,00	3.603
400 V 30 kW	10	400	0,376	0,92	1,957
	50	400	0,536	0,97	1,448
	100	400	0,696	0,95	1,092
	150	400	0,8	0,965	0,965
	10	480	0,384	1,2	2,5
	50	480	0,632	1,18	1,494
	100	480	0,712	1,2	1,348
	150	480	0,832	1,17	1,125
	10	500	0,408	1,24	2,431
	50	500	0,592	1,29	1,743
	100	500	0,656	1,28	1,561
	150	500	0,84	1,26	1,2
400 V 37 kW	10	400	0,276	0,928	2,69
	50	400	0,432	1,02	1,889
	10	480	0,272	1,17	3,441
	50	480	0,384	1,21	2,521
	10	500	0,288	1,2	3,333
	50	500	0,384	1,27	2,646
400 V 45 kW	10	400	0,3	0,936	2,496
	50	400	0,44	0,924	1,68
	100	400	0,56	0,92	1,314
	150	400	0,8	0,92	0,92
	10	480	0,3	1,19	3,173
	50	480	0,4	1,15	2,3
	100	480	0,48	1,14	1,9
	150	480	0,72	1,14	1,267
	10	500	0,3	1,22	3,253
	50	500	0,38	1,2	2,526
	100	500	0,56	1,16	1,657
	150	500	0,74	1,16	1,254
400 V 55 kW	10	400	0,46	1,12	1,948
		480	0,468	1,3	2,222
400 V 75 kW	10	400	0,502	1,048	1,673
		480	0,52	1,212	1,869
		500	0,51	1,272	1,992
400 V 90 kW	10	400	0,402	1,108	2,155
		400	0,408	1,288	2,529
		400	0,424	1,368	2,585

	Cable length [m]	AC line voltage [V]	Rise time [usec]	V_{peak} [kV]	dU/dt [kV/usec]
600 V 7.5 kW	5	525	0,192	0,972	4,083
	50	525	0,356	1,32	2,949
	5	600	0,184	1,06	4,609
	50	600	0,42	1,49	2,976

Table 8.10

8.5 Derating according to Ambient Temperature and Switching Frequency

The ambient temperature measured over 24 hours should be at least 5 °C lower than the max. ambient temperature. If the frequency converter is operated at high ambient temperature, the continuous output current should be decreased.

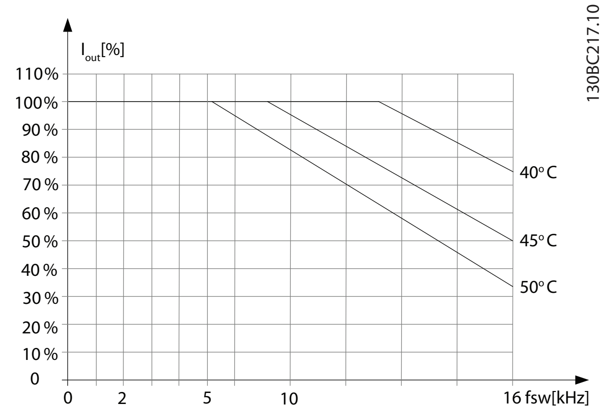

Illustration 8.1 200 V IP20 H1 0.25-0.75 kW

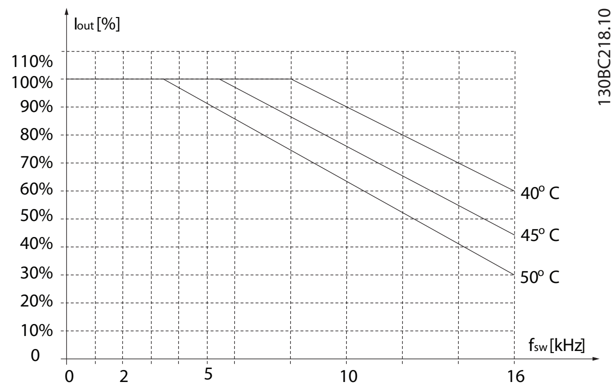

Illustration 8.2 400 V IP20 H1 0.37-1.5 kW

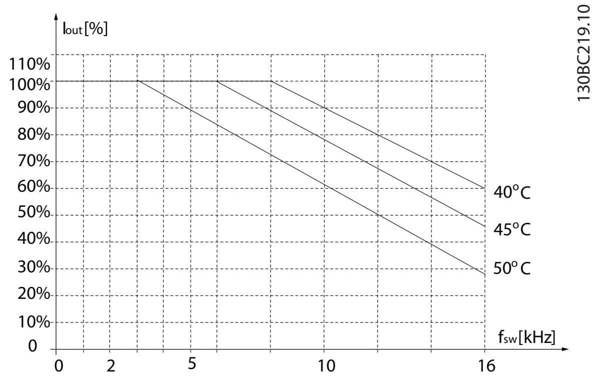

Illustration 8.3 200 V IP20 H2 2.2 kW

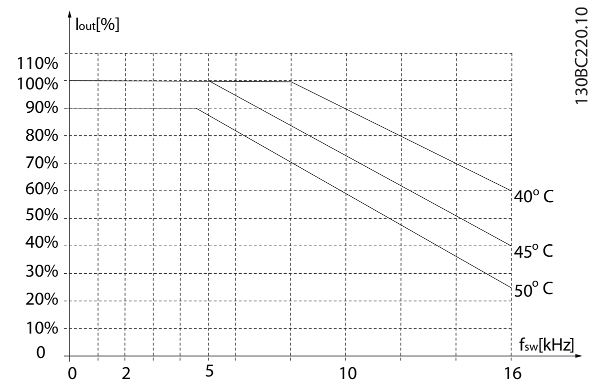

Illustration 8.4 400 V IP20 H2 2.2-4.0 kW

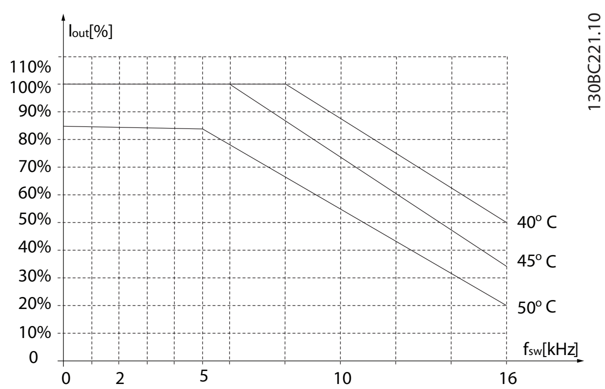

Illustration 8.5 200 V IP20 H3 3.7 kW

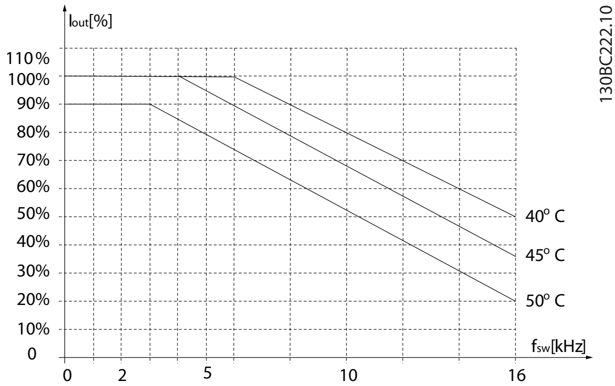

Illustration 8.6 400 V IP20 H3 5.5-7.5 kW

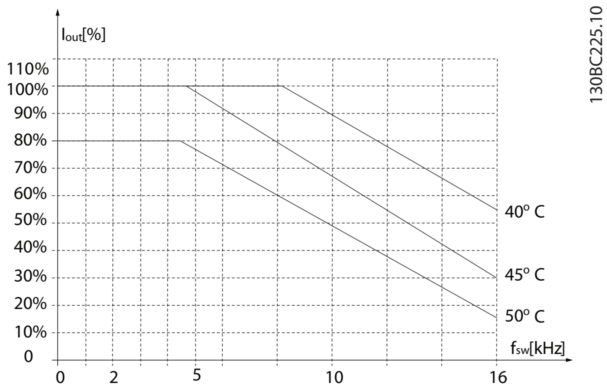

Illustration 8.9 200 V IP20 H5 11 kW

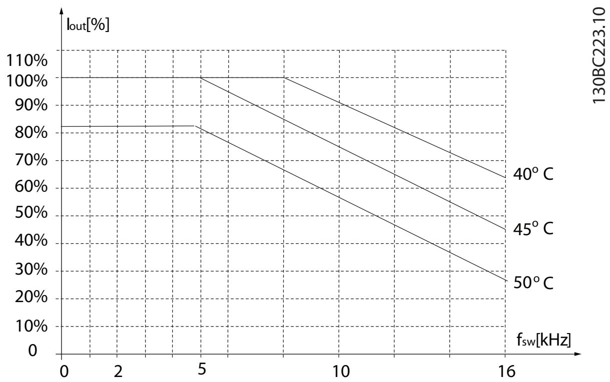

Illustration 8.7 200 V IP20 H4 5.5-7.5 kW

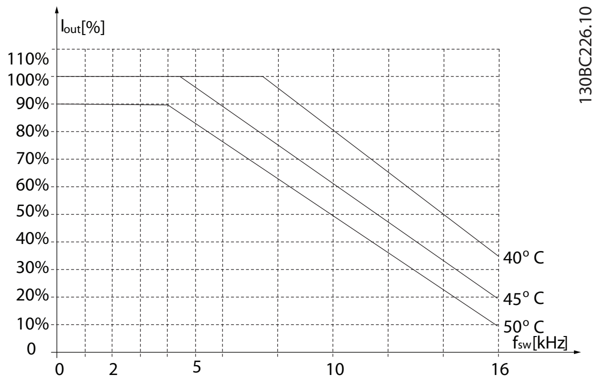

Illustration 8.10 400 V IP20 H5 18.5-22 kW

8

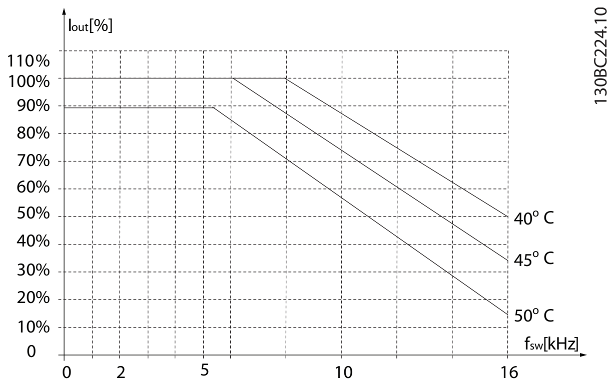

Illustration 8.8 400 V IP20 H4 11-15 kW

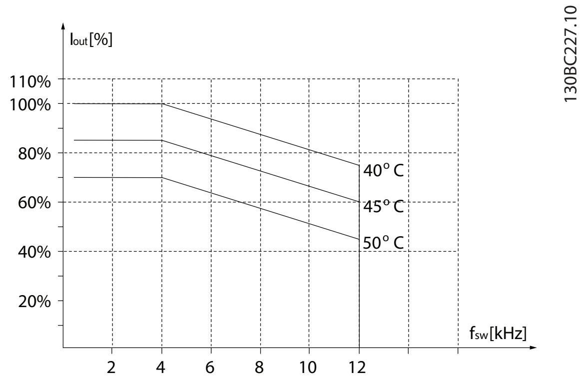

Illustration 8.11 200 V IP20 H6 15-18.5 kW

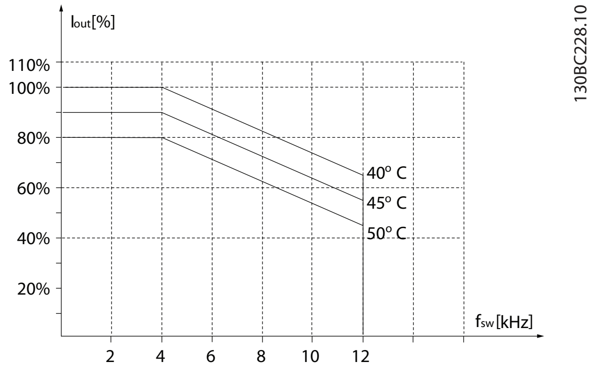

Illustration 8.12 400 V IP20 H6 30-37 kW

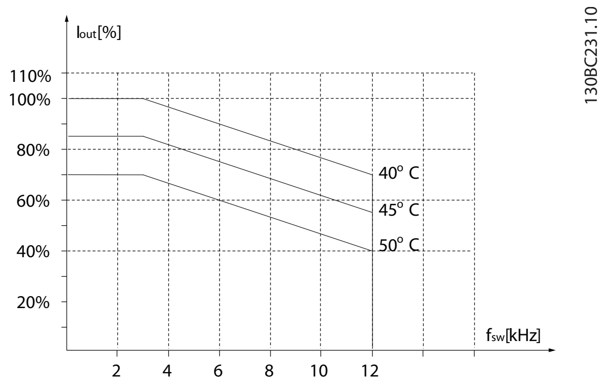

Illustration 8.15 200 V IP20 H7 22-30 kW

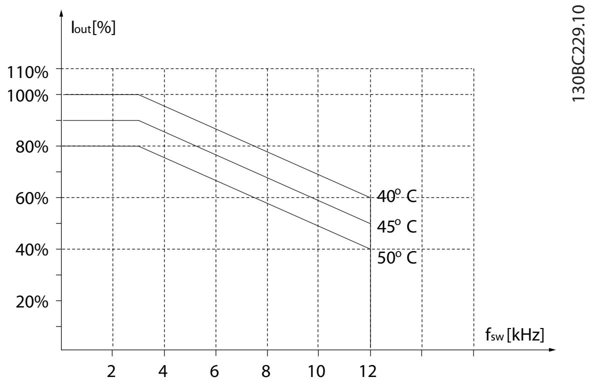

Illustration 8.13 400 V IP20 H6 45 kW

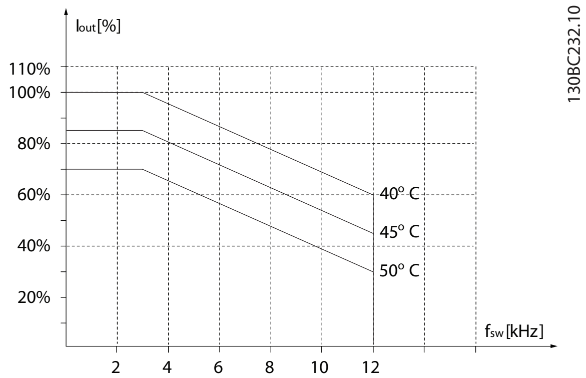

Illustration 8.16 400 V IP20 H7 55-75 kW

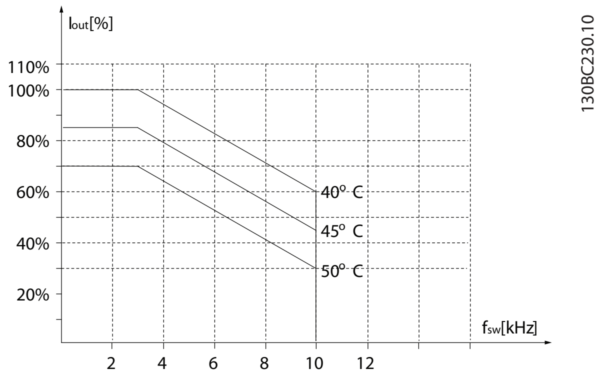

Illustration 8.14 600 V IP20 H6 22-30 kW

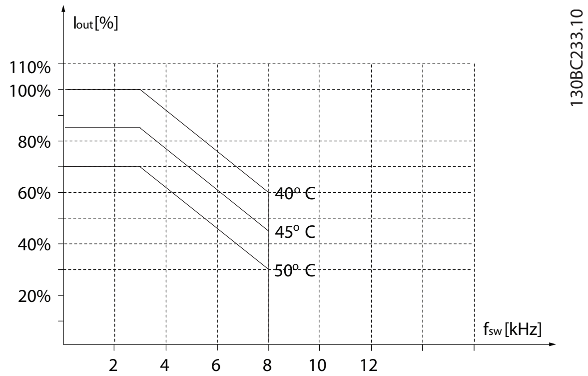

Illustration 8.17 600 V IP20 H7 45-55 kW

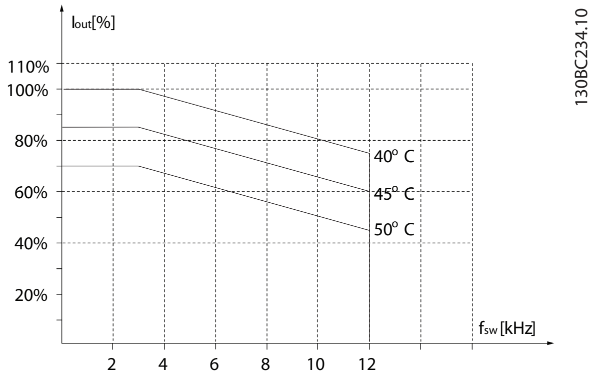

Illustration 8.18 200 V IP20 H8 37-45 kW

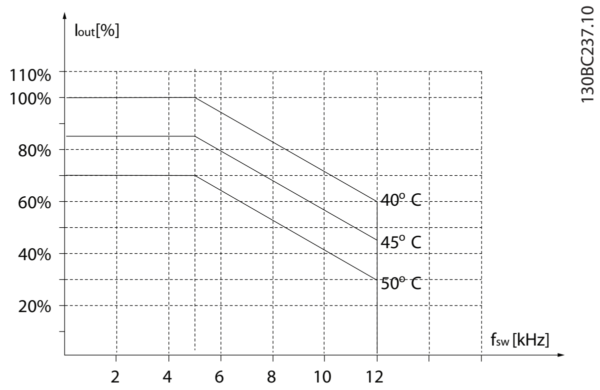

Illustration 8.21 600 V IP20 H9 2.2-3 kW

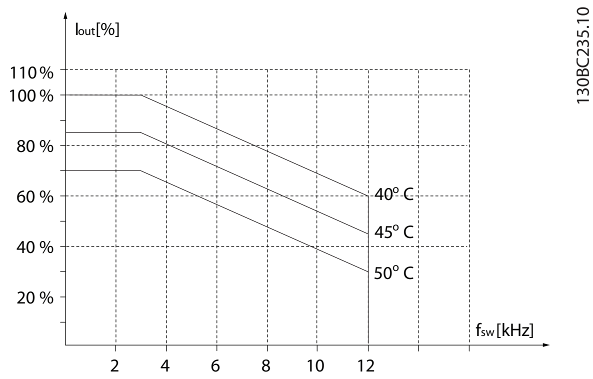

Illustration 8.19 400 V IP20 H8 90 kW

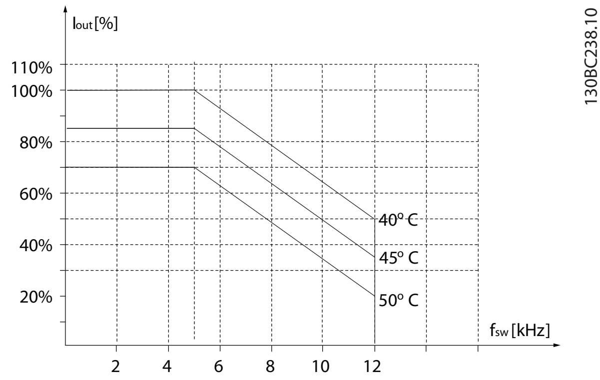

Illustration 8.22 600 V IP20 H9 5.5-7.5 kW

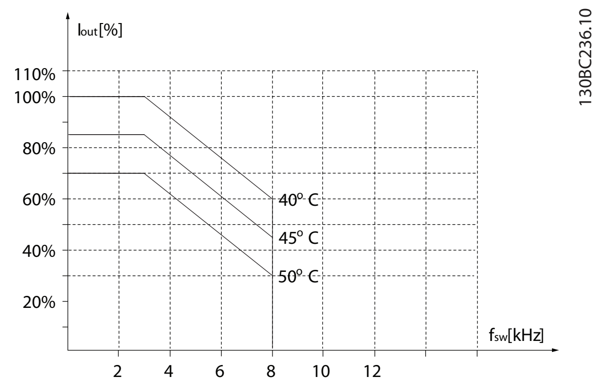

Illustration 8.20 600 V IP20 H8 75-90 kW

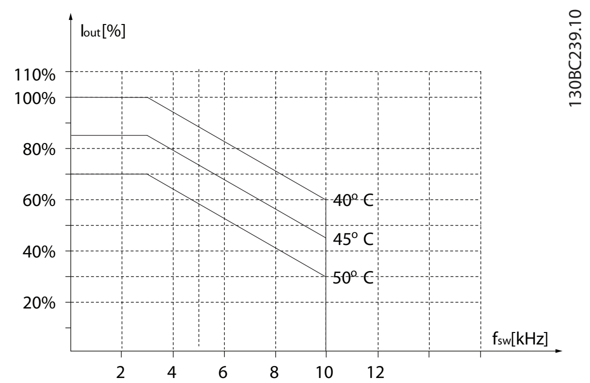

Illustration 8.23 600 V IP20 H10 11-15 kW

8

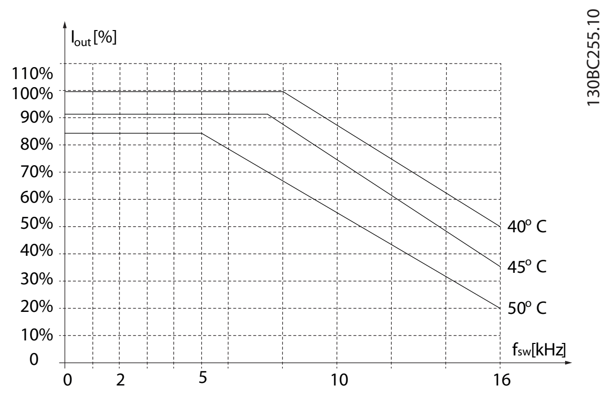

Illustration 8.24 400 V IP54 I2 0.75-4.0 kW

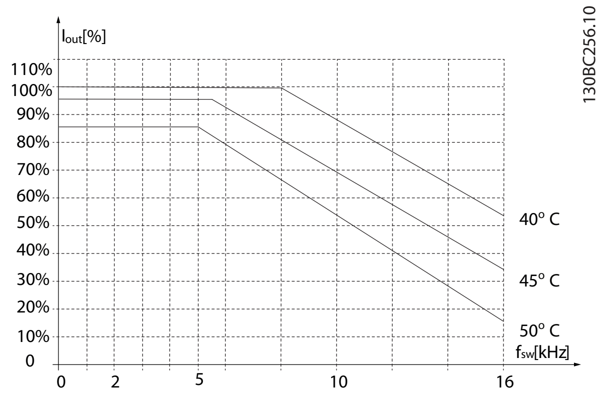

Illustration 8.25 400 V IP54 I3 5.5-7.5 kW

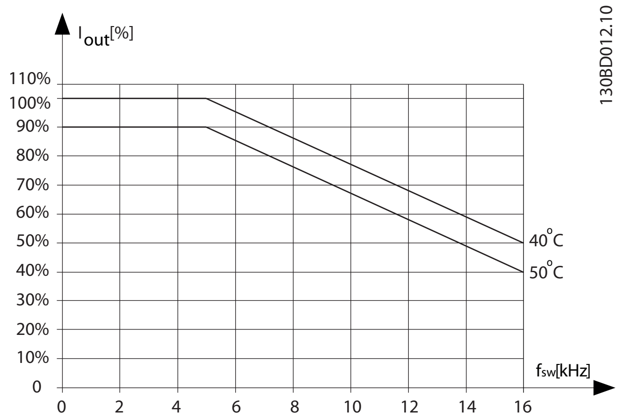

Illustration 8.26 400 V IP54 I4 11-18.5 kW

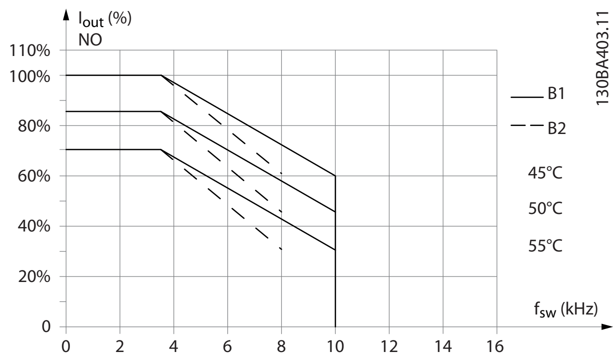

Illustration 8.27 400 V IP54 I5 11-18.5 kW

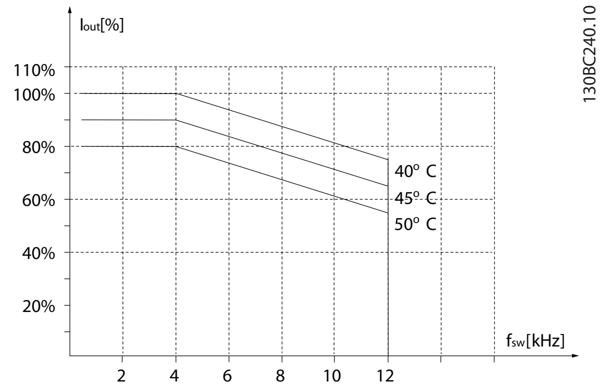

Illustration 8.28 400 V IP54 I6 22-30 kW

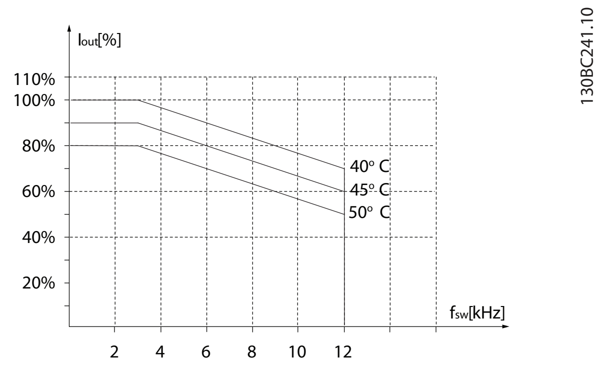

Illustration 8.29 400 V IP54 I6 37 kW

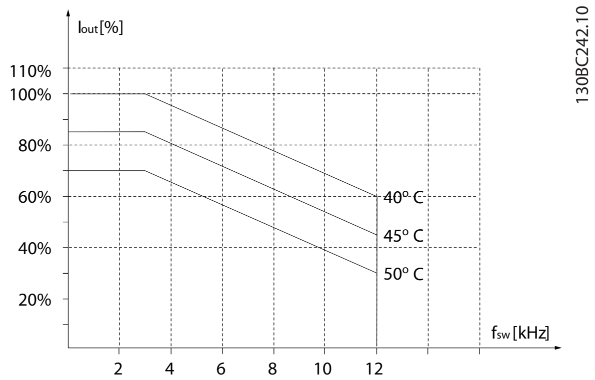

Illustration 8.30 400 V IP54 I7 45-55 kW

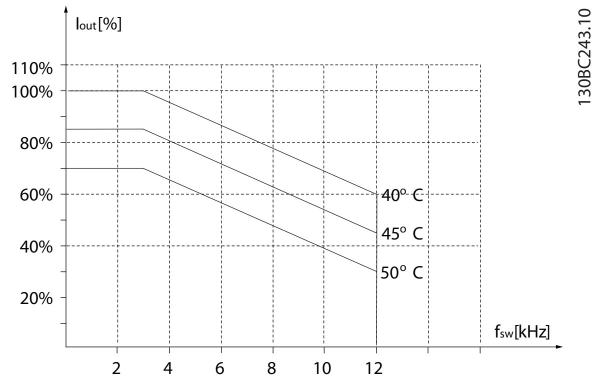

Illustration 8.31 400 V IP54 I8 75-90 kW

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روبـروی پالایشگاه نفت پارس، پلاک ۱۲

130R0222 MG18C502 *MG18C502* Rev. 2013-09-05

MA .IVING POSSIBLE

Design Guide
VLT® HVAC Drive FC 102
1.1-90 kW

THE REAL DRIVE

FAMCO
هایپرصنعت

Contents

1 How to Read this Design Guide

VLT® HVAC Drive **FC 102 Series** This guide can be used with all VLT® HVAC Drive frequency converters with software version 3.9x. The actual software version number can be read from *15-43 Software Version*.

Table 1.1 Software Version

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Danfoss does not warrant that a software program produced according to the guidelines provided in this manual functions properly in every physical, hardware or software environment.

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Danfoss reserves the right to revise this publication at any time and to make changes to its contents without prior notice or any obligation to notify former or present users of such revisions or changes.

- *Design Guide* entails all technical information about the frequency converter and customer design and applications.
- *Programming Guide* provides information on how to programme and includes complete parameter descriptions.
- *Application Note, Temperature Derating Guide*
- *MCT 10 Set-up Software Operating Instructions* enables the user to configure the frequency converter from a Windows™ based PC environment.
- Danfoss VLT®

- *VLT® HVAC Drive BACnet, Operating Instructions*
- *VLT® HVAC Drive Metasys, Operating Instructions*
- *VLT® HVAC Drive FLN, Operating Instructions*

Table 1.2

The frequency converter complies with UL508C thermal memory retention requirements. For more information, refer to *chapter 6.4.2 Motor Thermal Protection*.

The following symbols are used in this document.

WARNING

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

CAUTION

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

NOTICE

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

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

Table 1.3 Abbreviations

1

1.1.1 Definitions

Frequency Converter:

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

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

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

Input:

Control command		
Control command Start and stop the connected motor with the LCP or the digital inputs. Functions are divided into two groups. Functions in group 1 have higher priority than functions in group 2.	Group 1	Reset, Coasting stop, Reset and Coasting stop, Quick-stop, DC braking, Stop and the "Off" key.
	Group 2	Start, Pulse start, Reversing, Start reversing, Jog and Freeze output

Table 1.4 Function Groups

Motor:

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

f_M
The motor frequency.

f_{MAX}
The maximum motor frequency.

f_{MIN}
The minimum motor frequency.

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

I_M
The motor current.

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

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

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

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

U_M
The instantaneous motor voltage.

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

Break-away torque

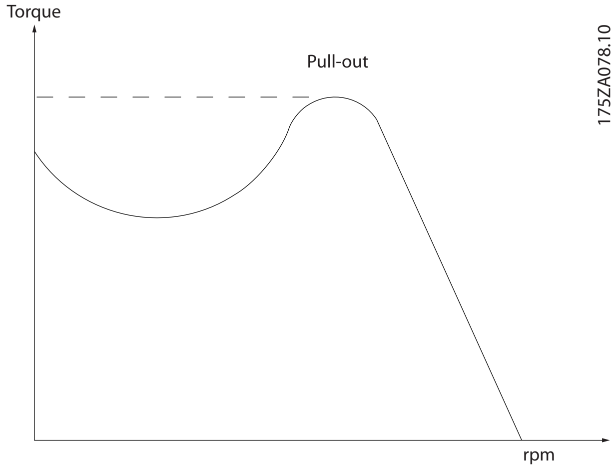


Illustration 1.1 Break-away Torque

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

Start-disable command
A stop command belonging to the group 1 control commands - see *Table 1.4*.

Stop command
See Control commands.

References:

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

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

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

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

Ref_{MAX}
Determines the relationship between the reference input at 100% full scale value (typically 10 V, 20mA) 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 0V, 0mA, 4mA) and the resulting reference. The minimum reference value set in *3-02 Minimum Reference*

Miscellaneous:

Advanced Vecter Control

Analog Inputs
The analog inputs are used for controlling various functions of the frequency converter.
There are 2 types of analog inputs:
Current input, 0-20 mA and 4-20 mA
Voltage input, 0-10 V DC.

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

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

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

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

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

Digital Outputs
The frequency converter features 2 Solid State outputs that can supply a 24 V DC (max. 40 mA) signal.

DSP
Digital Signal Processor.

Relay Outputs
The frequency converter features 2 programmable Relay Outputs.

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

GLCP
Graphical Local Control Panel (LCP102)

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

Intermittent Duty Cycle
An intermittent duty rating refers to a sequence of duty cycles. Each cycle consists of an on-load and an off-load period. The operation can be either periodic duty or none-periodic duty.

LCP
The Local Control Panel makes up a complete interface for control and programming of the frequency converter. The LCP is detachable and can be installed up to 3 metres from the frequency converter, i.e. in a front panel by means of the installation kit option.
The LCP is available in 2 versions:

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

lsb
Least significant bit.

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

msb
Most significant bit.

NLCP
Numerical Local Control Panel LCP 101

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

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

RCD
Residual Current Device.

Set-up
Save parameter settings in 4 Set-ups. Change between the 4 parameter Set-ups and edit one Set-up, while another Set-up is active.

SFAVM
Switching pattern called Stator Flux oriented Asynchronous V ector M odulation (*14-00 Switching Pattern*).

Slip Compensation
The frequency converter compensates for the motor slip by giving the frequency a supplement that follows the measured motor load keeping the motor speed almost constant.

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

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

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 locked 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 (See *14-00 Switching Pattern*).

1.1.2 Power Factor

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

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

The power factor for 3-phase control:

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

The power factor indicates to 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.

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

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

2 Introduction to VLT® HVAC Drive

2.1 Safety

2.1.1 Safety Note

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. Disconnect the frequency converter from mains, if 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 plugs.
2. The [Stop/Reset] key on the LCP of the frequency converter does not disconnect the equipment from mains and is thus not to be used as a safety switch.
3. Established correct protective earthing of the equipment, protect the user against supply voltage, and protect the motor against overload in accordance with applicable national and local regulations.
4. The earth leakage currents are higher than 3.5 mA.
5. Protection against motor overload is set by *1-90 Motor Thermal Protection*. If this function is desired, set *1-90 Motor Thermal Protection* to data value [ETR trip] (default value) or data value [ETR warning]. Note: The function is initialised at 1.16 x rated motor current and rated motor frequency. For the North American market: The ETR functions provide class 20 motor overload protection in accordance with NEC.
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 inputs than L1, L2 and L3, when load sharing (linking of DC intermediate circuit) and external 24 V DC have been installed. Check that all voltage inputs have been disconnected and that the necessary time has passed before commencing repair work.

Installation at high altitudes

CAUTION

380-500 V, enclosure types A, B and C: At altitudes above 2 km, contact Danfoss regarding PELV.
525-690 V: At altitudes above 2 km, contact Danfoss regarding PELV.

WARNING

Warning against unintended start

1. **The motor can be stopped with digital commands, bus commands, references or a local stop, while the frequency converter is connected to mains. If personal safety considerations make it necessary to ensure that no unintended start occurs, these stop functions are not sufficient.**
2. **While parameters are being changed, the motor may start. Consequently, the [Reset] key must always be activated; following which data can be modified.**
3. **A motor that has been stopped may start if faults occur in the electronics of the frequency converter, or if a temporary overload or a fault in the supply mains or the motor connection ceases.**

WARNING

Touching the electrical parts may be fatal - even after the equipment has been disconnected from mains.

Also make 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. Refer to the *Operating Instructions* for further safety guidelines.

2.1.2 Caution

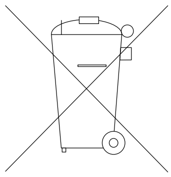
WARNING

The DC link capacitors remain charged after power has been disconnected. To avoid an electrical shock hazard, disconnect the from the mains before carrying out maintenance. Wait at least as follows before doing service on the frequency converter:

Voltage [V]	Min. waiting time (minutes)	
	4	15
200-240	1.1-3.7 kW	5.5-45 kW
380-480	1.1-7.5 kW	11-90 kW
525-600	1.1-7.5 kW	11-90 kW
525-690		11 - 90 kW
Be aware that there may be high voltage on the DC link even when the LEDs are turned off.		

Table 2.1 Discharge Time

2.1.3 Disposal Instruction



Equipment containing electrical components may not be disposed of together with domestic waste.
It must be separately collected with electrical and electronic waste according to local and currently valid legislation.

2.2 CE Labelling

2.2.1 CE Conformity and Labelling

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 3 EU directives:
The machinery directive (2006/42/EC)
Frequency converters with integrated safety function are now falling under the Machinery Directive. Danfoss CE-labels in accordance with the directive and issues a declaration of conformity upon request. Frequency converters without safety function do not fall under the machinery directive. However, if a frequency converter is supplied for use in a machine, we provide information on safety aspects relating to the frequency converter.
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 the instructions in this *Design Guide*. In addition, Danfoss specifies which standards our products comply with. Danfoss offers 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.

2.2.2 What Is Covered

The EU "*Guidelines on the Application of Council Directive 2004/108/EC*" outline 3 typical situations of using a frequency converter.

1. The frequency converter is sold directly to the end user. For such applications, the frequency converter must be CE labelled in accordance with the EMC directive.
2. The frequency converter is sold as part of a system. It is being marketed as 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 by testing the EMC of the system. The components of the system need not to be CE marked.
3. The frequency converter is sold for installation in a plant. It could be a production or a heating/ ventilation plant designed and installed by professionals of the trade. The frequency converter must be CE labelled under the EMC directive. The finished plant should not bear the CE mark. However, the installation must comply with the essential requirements of the directive. This is assumed by using appliances and systems that are CE labelled under the EMC directive

2.2.3 Danfoss Frequency Converter and CE Labelling

The purpose of CE labelling is to facilitate trade within the EU and EFTA.

However, CE labelling may cover many different specifications. Thus, check what a given CE label specifically covers.

The covered specifications can be very different and a CE label may therefore give the installer a false feeling of security when using a frequency converter as a component in a system or an appliance.

Danfoss CE labels the frequency converters in accordance with the low-voltage directive. This means 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 provided that 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.

This *Design Guide* offers detailed instructions for installation to ensure EMC-correct installation. Furthermore, Danfoss specifies which the different products comply with.

Danfoss provides other types of assistance that can help obtaining the best EMC result.

2.2.4 Compliance with EMC Directive 2004/108/EC

As mentioned, the frequency converter is mostly used by professionals of the trade as a complex component forming part of a larger appliance, system, or installation. Note 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 .

2.3 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.

2.4 Aggressive Environments

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

CAUTION

Do no install the frequency converter 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 Torque Off 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 IP 54/55 or a cabinet for IP 00/IP 20/TYPE 1 equipment.

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

Such chemical reactions rapidly affect and damage the electronic components. In such environments, mount the equipment in a cabinet with fresh air ventilation, keeping aggressive gases away from the frequency converter.
An extra protection in such areas is a coating of the printed circuit boards, which can be ordered as an option.

NOTICE

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

Before installing the frequency converter, check the ambient air for liquids, particles, and gases. 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 enclosure types 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 frequnecy converter. Contact Danfoss for additional information.

2

2.5 Vibration and Shock

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

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

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

2.6 Safe Torque Off

The FC 102 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]).
Before integrating and using Safe Torque Off in an installation, a thorough risk analysis on the installation must be carried out in order to determine whether the Safe Torque Off functionality and safety levels are appropriate and sufficient. It is designed and approved suitable for the requirements of :

- Category 3 in 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 Torque Off
The Safe Torque Off (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 Torque Off Category 1 can be obtained. The Safe Torque Off function of FC 102 can be used for asynchronous, synchronous motors and permanent magnet motors. See examples in *chapter 2.6.1 Terminal 37 Safe Torque Off Function*.

⚠WARNING

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

Safe Torque Off Technical Data
The following values are associated to the different types of safety levels:

Reaction time for T37

- Maximum reaction time: 20 ms

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

Data for EN ISO 13849-1

- Performance Level "d"
- $MTTF_d$ (Mean Time To Dangerous Failure): 14000 years
- DC (Diagnstic Coverage): 90%
- 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) = 1E-10/h
- SFF (Safe Failure Fraction) > 99%
- HFT (Hardware Fault Tolerance) = 0 (1001 architecture)
- Lifetime 20 years

Data for EN IEC 61508 low demand

- PFDavg for 1 year proof test: 1E-10
- PFDavg for 3 year proof test: 1E-10
- PFDavg for 5 year proof test: 1E-10

No maintenance of the STO functionality is needed.

Take security measures, e.g. only skilled personnel must be able to access and install in closed cabinets.

SISTEMA Data
From Danfoss, functional safety data is available 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 ISO 13849-1	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
PFD	IEC 61508	Average probability of failure on demand, value used for low demand operation.
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 2.2 Abbreviations Related to Functional Safety

2.6.1 Terminal 37 Safe Torque Off Function

The FC 102 is available with Safe Torque Off functionality via control terminal 37. Safe Torque Off 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 Torque Off (T37) is activated, the frequency converter issues an alarm, trips the unit, and coasts the motor to a stop. Manual restart is required. The Safe Torque Off function can be used for stopping the frequency converter in emergency stop situations. In the normal operating mode when Safe Torque Off is not required, use the frequency converter's regular stop function instead. When automatic restart is used – the requirements according to ISO 12100-2 paragraph 5.3.2.5 must be fulfilled.

Liability Conditions
It is the user's responsibility to ensure personnel installing and operating the Safe Torque Off 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 *Design Guide*
- Have a good knowledge of the generic and safety standards applicable to the specific application

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

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

The information and instructions of the *Operating Instructions* are not sufficient for a proper and safe use of the Safe Torque Off functionality. The related information and instructions of the relevant *Design Guide* must be followed.

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 to eliminate hazards

Safe Torque Off Installation and Set-Up

⚠WARNING

SAFE TORQUE OFF FUNCTION!

The Safe Torque Off 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 under Safety in this manual. 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 trips and stops by coasting. If this is not acceptable, e.g. causes danger, 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.

Meet the following requirements 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 2.1*.)
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 Torque Off) and either terminal 12 or 13 (24 V DC). The Safety monitoring relay must comply with Category 3/PL “d” (ISO 13849-1) or SIL 2 (EN 62061).

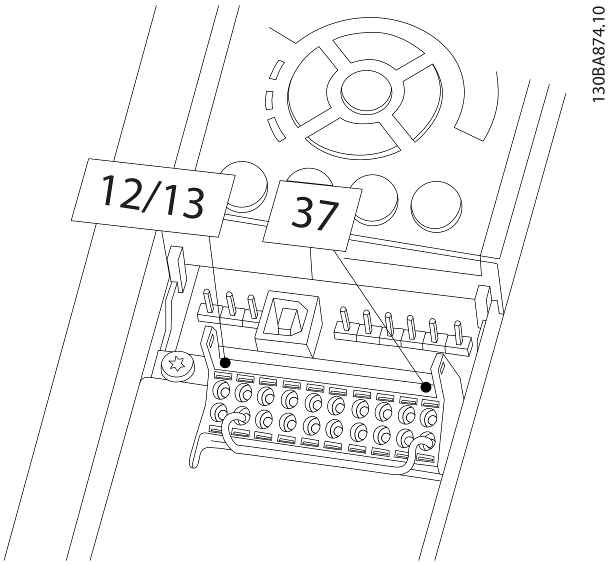


Illustration 2.1 Jumper between Terminal 12/13 (24 V) and 37

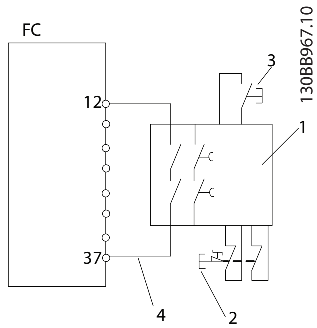


Illustration 2.2 Installation to Achieve a Stopping Category 0 (EN 60204-1) with Safety Cat. 3/PL “d” (ISO 13849-1) or SIL 2 (EN 62061).

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 2.3 Legend to *Illustration 2.2*

Safe Torque Off Commissioning Test

After installation and before first operation, perform a commissioning test of the installation making use of Safe Torque Off. 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 2.3*). 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 runs 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 plant at a standstill. If an external force effect is to be anticipated, provide additional measures to safely prevent any potential movement (e.g. mechanical brakes).

NOTICE

For all applications with Safe Torque Off, 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 2.4*). When activating the safety function, a normal controlled stop is performed. This can be activated through terminal 27. After the safe delay time has expired on the external safety module, the STO istriggered and terminal 37 is set low. Ramp down is performed as configured in the frequency converter. If the frequency converter is not stopped after the safe delay time, the activation of STO coasts the frequency converter.

NOTICE

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

Example with Category 4/PL e application

Where the safety control system design requires 2 channels for the STO function to achieve Category 4/PL e, one channel can be implemented by Safe Torque Off T37 (STO) and the other by a contactor, which may be connected in either the frequency converter input or output power circuits and controlled by the safety relay (see *Illustration 2.5*). The contactor must be monitored through an auxiliary guided contact, and connected to the reset input of the safety relay.

Paralleling of Safe Torque Off input the one safety relay

Safe Torque Off inputs T37 (STO) may be connected directly, if it is required to control multiple frequency converters from the same control line via one safety relay (see *Illustration 2.6*). Connecting inputs increases the probability of a fault in the unsafe direction, since a fault in one frequency converter might result in all frequency converters becoming enabled. The probability of a fault for T37 is so low, that the resulting probability still meets the requirements for SIL2.

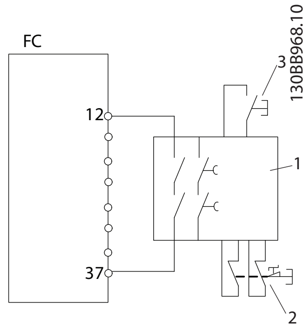


Illustration 2.3 STO Example

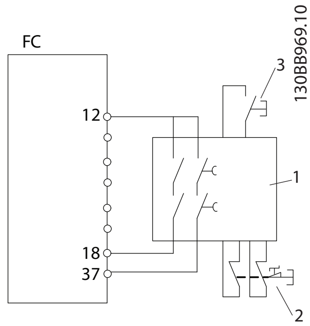


Illustration 2.4 SS1 Example

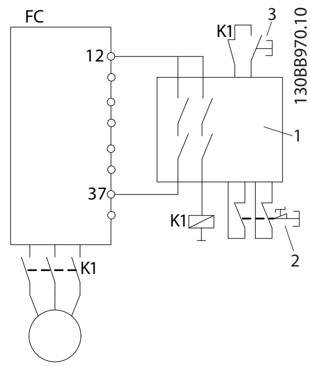


Illustration 2.5 STO Category 4 Example

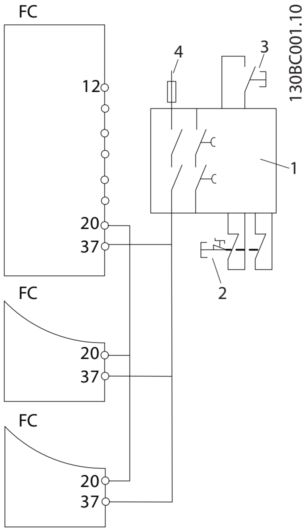


Illustration 2.6 Paralleling of Multiple Frequency Converters Example

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

Table 2.4 Legend to *Illustration 2.3* to *Illustration 2.6*

⚠WARNING

Safe Torque Off activation (i.e. removal of 24 V DC voltage supply to terminal 37) does not provide electrical safety. The Safe Torque Off 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 Torque Off function by removing the 24 V DC voltage supply to the terminal 37.
2. After activation of Safe Torque Off (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 10 ms for the complete performance range of the frequency converter.

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

NOTICE

The requirements of Cat. 3/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/PL "d" (ISO 13849-1). If external forces act on the motor e.g. in case of vertical axis (suspended loads) - and an unwanted movement, for example caused by gravity, could cause a hazard, the motor must not be operated without additional measures for fall protection. E.g. mechanical brakes must be installed additionally.

To resume operation after activation of Safe Torque Off, first reapply 24 V DC voltage to terminal 37 (text Safe Torque Off activated is still displayed), second create a reset signal (via bus, Digital I/O, or [Reset] key on inverter).

By default the Safe Torque Off functions is set to an Unintended Restart Prevention behaviour. This means, in order to terminate Safe Torque Off and resume normal operation, first the 24 V DC must be reapplied to Terminal 37. Subsequently, give a reset signal (via Bus, Digital I/O, or [Reset] key).

The Safe Torque Off 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 a MCB 112 Option is connected to the frequency converter, then Automatic Restart Behaviour is set by values [7] and [8]. Automatic Restart means that Safe Torque Off 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 the 2 situations:

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

2.6.2 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 Torque Off. This means that the output to Safe Torque Off terminal 37 is HIGH (24 V) only, if both the signal from

MCB 112 output X44/12 and the signal from the safety-related sensor are HIGH. If at least one of the 2 signals is LOW, the output to Terminal 37 must be LOW, too. The safety device with this AND logic itself must conform to IEC 61508, SIL 2. The connection from the output of the safety device with safe AND logic to Safe Torque Off terminal 37 must be short-circuit protected. See *Illustration 2.7*.

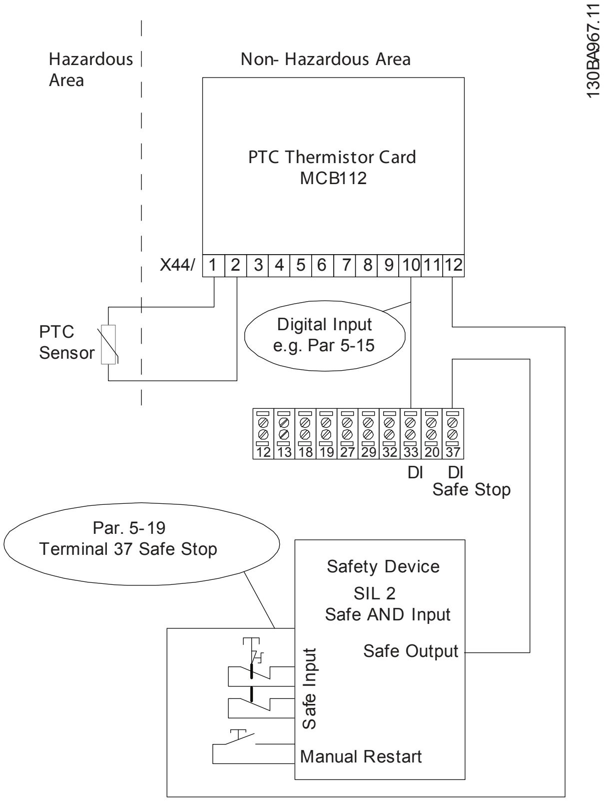


Illustration 2.7 Illustration of the essential aspects for installing a combination of a Safe Torque Off application and a MCB 112 application. The diagram shows a Restart input for the external Safety Device. This means that in this installation *5-19 Terminal 37 Safe Stop* might be set to value *[7] PTC 1 & Relay W* or [8] *[8] PTC 1 & Relay A/W*. Refer to *MCB 112 operating instructions* for further details.

Parameter settings for external safety device in combination with MCB112

If MCB 112 is connected, then additional selections (*[4] PTC 1 Alarm* to *[9] PTC 1 & Relay W/A*) become possible for *5-19 Terminal 37 Safe Stop*. Selections *[1] Safe Torque Off Alarm* and *[3] Safe Torque Off Warning* are still available but are not to be used as these are for installations without MCB 112 or any external safety devices. If *[1] Safe Torque Off Alarm* or *[3] Safe Torque Off Warning* should be selected by mistake and MCB 112 is triggered, then the frequency converter reacts with an alarm ”Dangerous Failure [A72]” and coasts the frequency converter safely, without Automatic Restart. Selections *[4] PTC 1 Alarm* and *[5] PTC 1 Warning* are not to be selected when an external safety device is used. These selections are for when only MCB 112 uses the Safe Torque Off. If selection *[4] PTC 1 Alarm* or *[5] PTC 1 Warning* is selected by mistake and the external safety device triggers Safe Torque Off, the frequency converter issues an alarm ”Dangerous Failure [A72]” and coasts the frequency converter safely, without Automatic Restart.

Selections *[6] PTC 1 & Relay A* to *[9] PTC 1 & Relay W/A* must be selected for the combination of external safety device and MCB 112.

NOTICE

Note that selections *[7] PTC 1 & Relay W* and *[8] PTC 1 & Relay A/W* open up for Automatic restart when the external safety device is de-activated again.

This is only allowed in the following cases:

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

See *MCB 112 operating instructions* for further information.

2.6.3 Safe Torque Off Commissioning Test

After installation and before first operation, perform a commissioning test of an installation or application making use of Safe Torque Off.

Moreover, perform the test after each modification of the installation or application, which the Safe Torque Off is part of.

NOTICE

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 Torque Off is required (i.e. Safe Torque Off only where *5-19 Terminal 37 Safe Stop* is set to default value [1], or combined Safe Torque Off and MCB112 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 102 (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 Torque Off [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 Torque Off 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 4 test steps 1.1, 1.2, 1.3 and 1.4 are passed.

Case 2: Automatic Restart of Safe Torque Off is wanted and allowed (i.e. Safe Torque Off only where *5-19 Terminal 37 Safe Stop* is set to [3], or combined Safe Torque Off and MCB112 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 102 (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 Torque Off [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.

NOTICE

See warning on the restart behaviour in *chapter 2.6.1 Terminal 37 Safe Torque Off Function*

2.7 Advantages

2.7.1 Why use a Frequency Converter for Controlling Fans and Pumps?

A frequency converter takes advantage of the fact that centrifugal fans and pumps follow the laws of proportionality for such fans and pumps. For further information see the text and figure *The Laws of Proportionality*.

2.7.2 The Clear Advantage - Energy Savings

The advantage of using a frequency converter for controlling the speed of fans or pumps lies in the electricity savings.

When comparing with alternative control systems and technologies, a frequency converter is the optimum energy control system for controlling fan and pump systems.

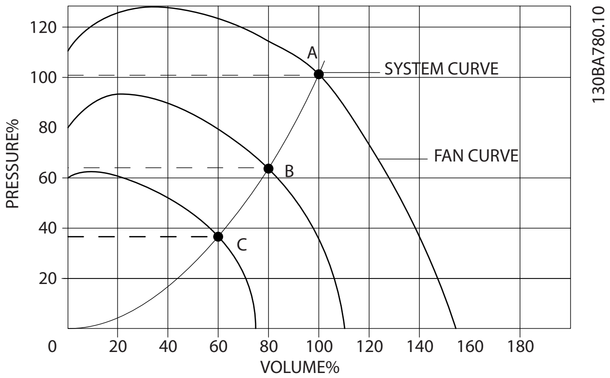


Illustration 2.8 Fan Curves (A, B and C) for Reduced Fan Volumes

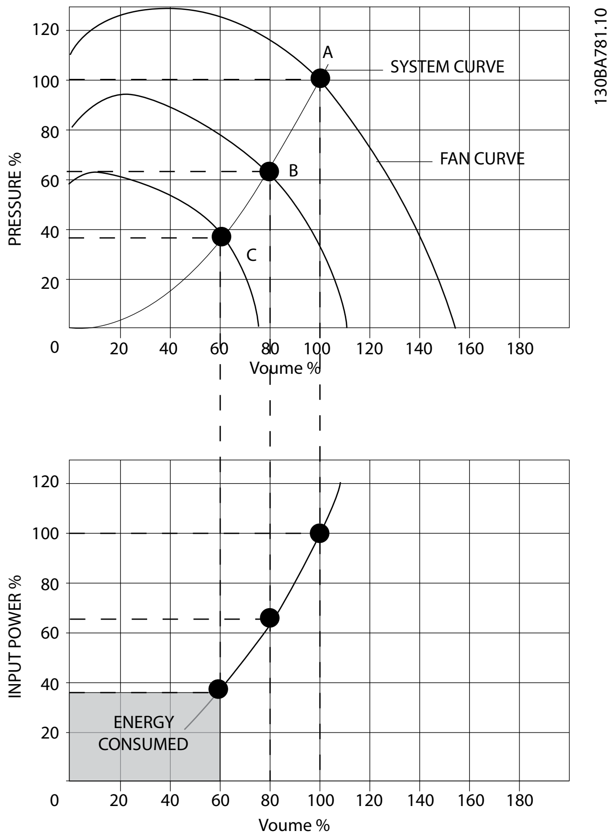


Illustration 2.9 When Using a Frequency Converter to Reduce Fan Capacity to 60% - More Than 50% Energy Savings May Be Obtained in Typical Applications.

2.7.3 Example of Energy Savings

As shown in the figure (the laws of proportionality), the flow is controlled by changing the RPM. By reducing the speed only 20% from the rated speed, the flow is also

reduced by 20%. This is because the flow is directly proportional to the RPM. The consumption of electricity, however, is reduced by 50%.
If the system in question only needs to be able to supply a flow that corresponds to 100% a few days in a year, while the average is below 80% of the rated flow for the remainder of the year, the amount of energy saved is even more than 50%.

The laws of proportionality	
Illustration 2.10 describes the dependence of flow, pressure and power consumption on RPM.	
Q = Flow	P = Power
Q_1 = Rated flow	P_1 = Rated power
Q_2 = Reduced flow	P_2 = Reduced power
H = Pressure	n = Speed regulation
H_1 = Rated pressure	n_1 = Rated speed
H_2 = Reduced pressure	n_2 = Reduced speed

Table 2.5 Abbreviations Used in Equation

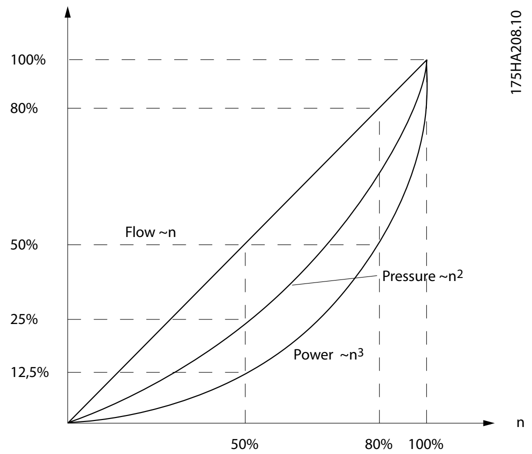


Illustration 2.10 The Dependence of Flow, Pressure and Power Consumption on RPM

$$Flow: \frac{Q1}{Q2} = \frac{n1}{n2}$$

$$Pressure: \frac{H1}{H2} = \left(\frac{n1}{n2}\right)^2$$

$$Power: \frac{P1}{P2} = \left(\frac{n1}{n2}\right)^3$$

2.7.4 Comparison of Energy Savings

The Danfoss frequency converter solution offers major savings compared with traditional energy saving solutions. This is because the frequency converter is able to control fan speed according to thermal load on the system and the fact that the frequency converter has a built-in facility that enables the frequency converter to function as a Building Management System, BMS.

Illustration 2.12 shows typical energy savings obtainable with 3 well-known solutions when fan volume is reduced to i.e. 60%.
Illustration 2.12 shows more than 50% energy savings can be achieved in typical applications.

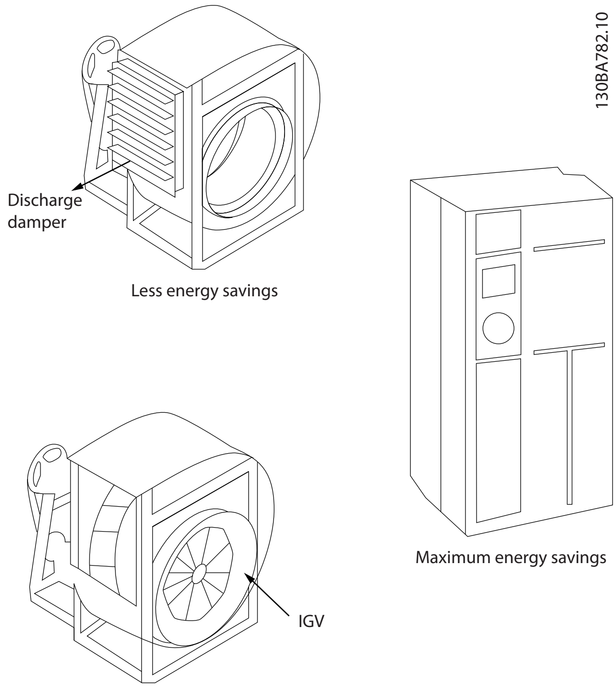


Illustration 2.11 The 3 Common Energy Saving Systems

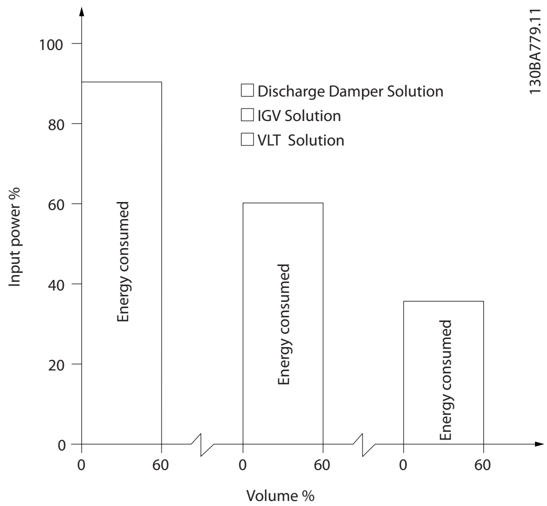


Illustration 2.12 Discharge dampers reduce power consumption somewhat. Inlet Guide Vans offer a 40% reduction but are expensive to install. The Danfoss frequency converter solution reduces energy consumption with more than 50% and is easy to install.

2.7.5 Example with Varying Flow over 1 Year

The example below is calculated on the basis of pump characteristics obtained from a pump datasheet.
The result obtained shows energy savings in excess of 50% at the given flow distribution over a year. The pay back period depends on the price per kWh and price of frequency converter. In this example it is less than a year when compared with valves and constant speed.

Flow distribution over 1 year
$P_{shaft}=P_{shaft\ output}$

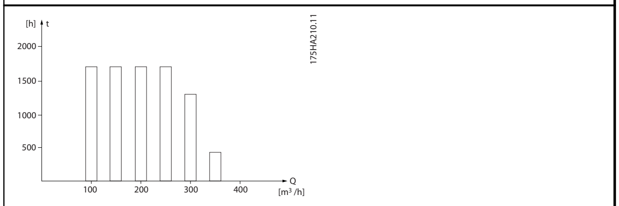


Table 2.6 Energy Savings

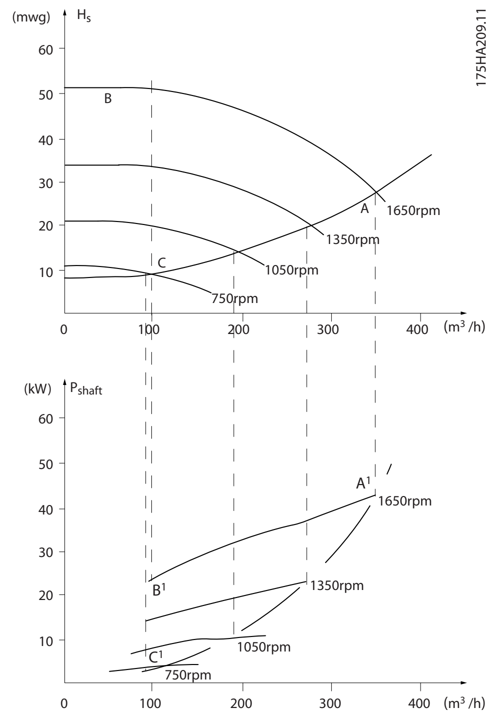


Illustration 2.13 Example with Varying Flow

m³/ h	Distri-bution		Valve regulation		Frequency converter control	
	%	Hours	Power	Consumption	Power	Consumption
			A_1-B_1	kWh	A_1-C_1	kWh
350	5	438	42,5	18.615	42,5	18.615
300	15	1314	38,5	50.589	29,0	38.106
250	20	1752	35,0	61.320	18,5	32.412
200	20	1752	31,5	55.188	11,5	20.148
150	20	1752	28,0	49.056	6,5	11.388
100	20	1752	23,0	40.296	3,5	6.132
Σ	100	8760		275.064		26.801

Table 2.7 Consumption

2.7.6 Better Control

If a frequency converter is used for controlling the flow or pressure of a system, improved control is obtained.
A frequency converter can vary the speed of the fan or pump, thereby obtaining variable control of flow and pressure.
Furthermore, a frequency converter can quickly adapt the speed of the fan or pump to new flow or pressure conditions in the system.
Simple control of process (Flow, Level or Pressure) utilising the built-in PID control.

2.7.7 Cos φ Compensation

Generally speaking, the VLT® HVAC Drive has a cos φ of 1 and provides power factor correction for the cos φ of the motor, which means that there is no need to make allowance for the cos φ of the motor when sizing the power factor correction unit.

2.7.8 Star/Delta Starter or Soft-starter not Required

When larger motors are started, it is necessary in many countries to use equipment that limits the start-up current. In more traditional systems, a star/delta starter or soft-starter is widely used. Such motor starters are not required if a frequency converter is used.

As illustrated in *Illustration 2.14*, a frequency converter does not consume more than rated current.

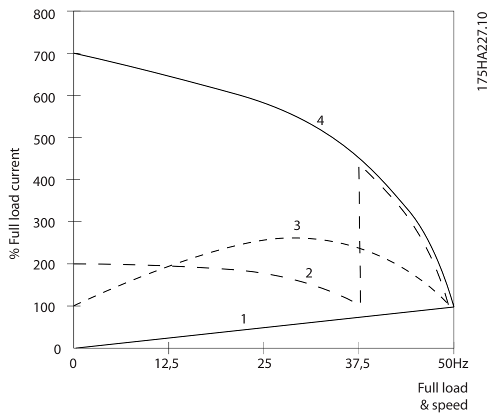


Illustration 2.14 A Frequency Converter Does Not Consume More Than Rated Current

1 VLT® HVAC Drive	
2 Star/delta starter	
3 Soft-starter	
4 Start directly on mains	

Table 2.8 Legend to *Illustration 2.14*

2.7.9 Using a Frequency Converter Saves Money

The example on the following page shows that a lot of equipment is not required when a frequency converter is used. It is possible to calculate the cost of installing the 2 different systems. In the example on the following page, the 2 systems can be established at roughly the same price.

2.7.10 Without a Frequency Converter

D.D.C.	=	Direct Digital Control	E.M.S.	=	Energy Management system
V.A.V.	=	Variable Air Volume			
Sensor P	=	Pressure	Sensor T	=	Temperature

Table 2.9 Abbreviations used in *Illustration 2.15* and *Illustration 2.16*

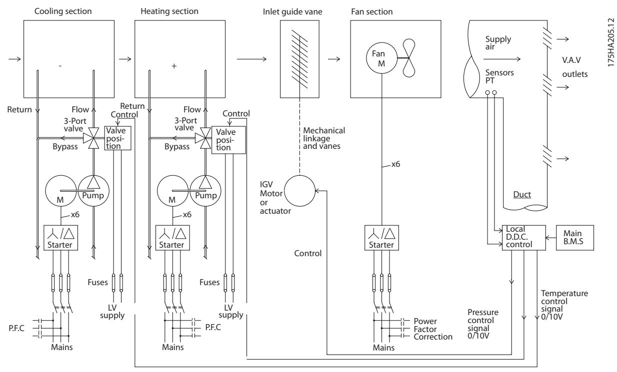


Illustration 2.15 Traditional Fan System

2.7.11 With a Frequency Converter

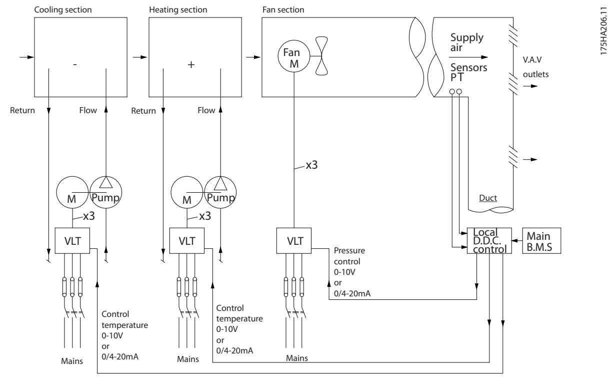


Illustration 2.16 Fan System Controlled by Frequency Converters.

2.7.12 Application Examples

The next pages give typical examples of applications within HVAC.
For further information about a given application, ask a Danfoss supplier for an information sheet that gives a full description of the application.

Variable Air Volume

Ask for The Drive to...Improving Variable Air Volume Ventilation Systems MN.60.A1.02

Constant Air Volume

Ask for The Drive to...Improving Constant Air Volume Ventilation Systems MN.60.B1.02

Cooling Tower Fan

Ask for The Drive to...Improving fan control on cooling towers MN.60.C1.02

Condenser pumps

Ask for The Drive to...Improving condenser water pumping systems MN.60.F1.02

Primary pumps

Ask for The Drive to...Improve your primary pumping in primay/secondary pumping systems MN.60.D1.02

Secondary pumps

Ask for The Drive to...Improve your secondary pumping in primay/secondary pumping systems MN.60.E1.02

2.7.13 Variable Air Volume

VAV or Variable Air Volume systems, are used to control both the ventilation and temperature to satisfy the requirements of a building. Central VAV systems are considered to be the most energy efficient method to air condition buildings. By designing central systems instead of distributed systems, a greater efficiency can be obtained.
The efficiency comes from utilising larger fans and larger chillers, which have much higher efficiencies than small motors and distributed air-cooled chillers. Savings are also seen from the decreased maintenance requirements.

2.7.14 The VLT Solution

While dampers and IGVs work to maintain a constant pressure in the ductwork, a solution saves much more energy and reduces the complexity of the installation. Instead of creating an artificial pressure drop or causing a decrease in fan efficiency, the decreases the speed of the fan to provide the flow and pressure required by the system.
Centrifugal devices such as fans behave according to the centrifugal laws. This means the fans decrease the pressure and flow they produce as their speed is reduced. Their power consumption is thereby significantly reduced.
The return fan is frequently controlled to maintain a fixed difference in airflow between the supply and return. The advanced PID controller of the HVAC can be used to eliminate the need for additional controllers.

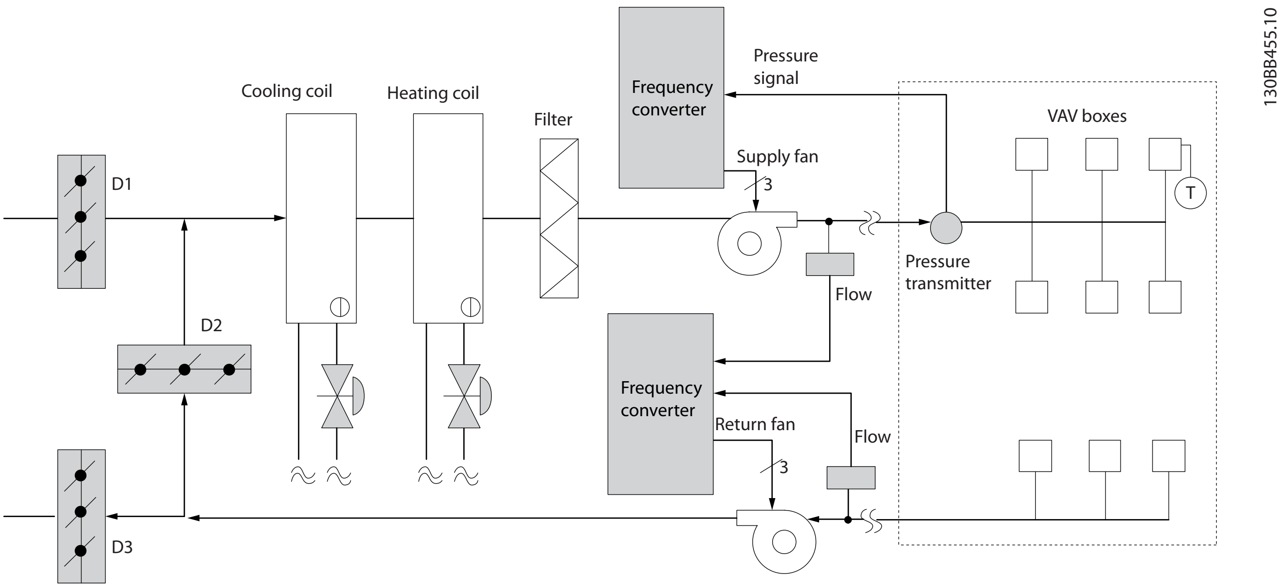


Illustration 2.17 The VLT Solution

2.7.15 Constant Air Volume

CAV, or Constant Air Volume systems are central ventilation systems usually used to supply large common zones with the minimum amounts of fresh tempered air. They preceded VAV systems and therefore are found in older multi-zoned commercial buildings as well. These systems preheat amounts of fresh air utilising Air Handling Units (AHUs) with a heating coil, and many are also used to air condition buildings and have a cooling coil. Fan coil units are frequently used to assist in the heating and cooling requirements in the individual zones.

2.7.16 The VLT Solution

With a frequency converter, significant energy savings can be obtained while maintaining decent control of the building. Temperature sensors or CO_2 sensors can be used as feedback signals to frequency converters. Whether controlling temperature, air quality, or both, a CAV system can be controlled to operate based on actual building conditions. As the number of people in the controlled area decreases, the need for fresh air decreases. The CO_2 sensor detects lower levels and decreases the supply fans speed. The return fan modulates to maintain a static pressure setpoint or fixed difference between the supply and return air flows.

With temperature control, especially used in air conditioning systems, as the outside temperature varies as well as the number of people in the controlled zone changes, different cooling requirements exist. As the temperature decreases below the set-point, the supply fan can decrease its speed. The return fan modulates to maintain a static pressure set-point. By decreasing the air flow, energy used to heat or cool the fresh air is also reduced, adding further savings.
Several features of the Danfoss HVAC dedicated frequency converter can be utilised to improve the performance of a CAV system. One concern of controlling a ventilation system is poor air quality. The programmable minimum frequency can be set to maintain a minimum amount of supply air regardless of the feedback or reference signal. The frequency converter also includes a 3-zone, 3-setpoint PID controller which allows monitoring both temperature and air quality. Even if the temperature requirement is satisfied, the frequency converter will maintain enough supply air to satisfy the air quality sensor. The frequency converter is capable of monitoring and comparing 2 feedback signals to control the return fan by maintaining a fixed differential air flow between the supply and return ducts as well.

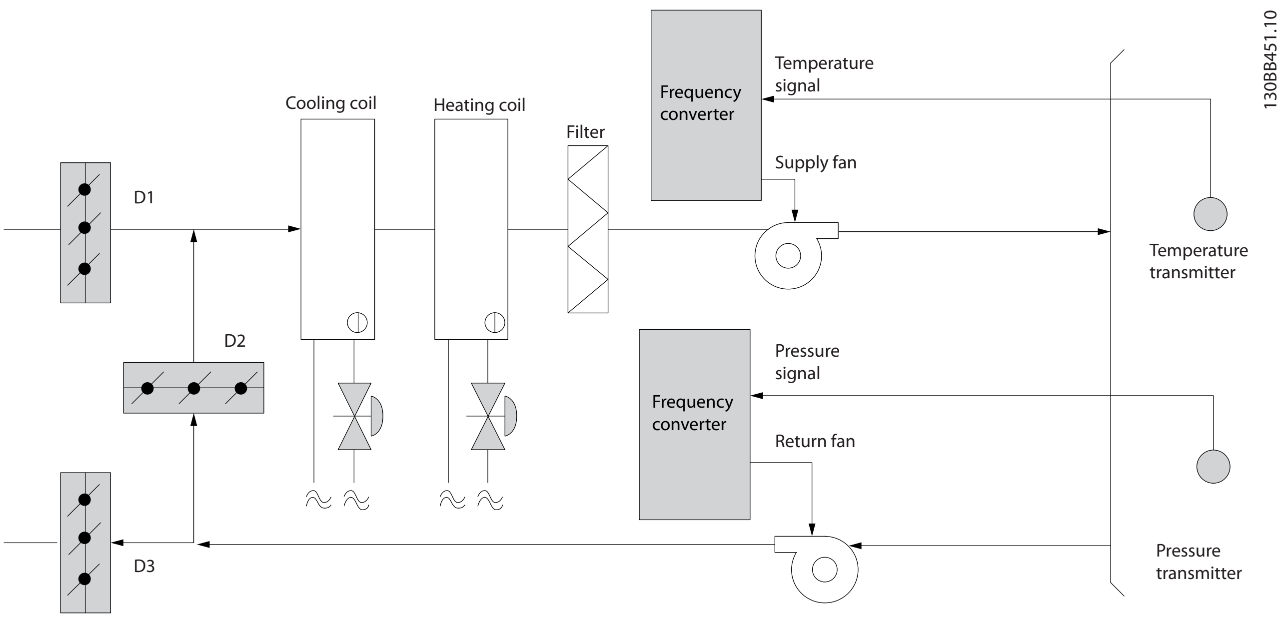


Illustration 2.18 The VLT Solution

2.7.17 Cooling Tower Fan

Cooling Tower Fans are used to cool condenser water in water cooled chiller systems. Water cooled chillers provide the most efficient means of creating chilled water. They are as much as 20% more efficient than air cooled chillers. Depending on climate, cooling towers are often the most energy efficient method of cooling the condenser water from chillers.
They cool the condenser water by evaporation.
The condenser water is sprayed into the cooling tower onto the cooling towers “fill” to increase its surface area. The tower fan blows air through the fill and sprayed water to aid in the evaporation. Evaporation removes energy from the water dropping its temperature. The cooled water collects in the cooling towers basin where it is pumped back into the chillers condenser and the cycle is repeated.

2.7.18 The VLT Solution

With a frequency converter, the cooling towers fans can be controlled to the required speed to maintain the condenser water temperature. The frequency converters can also be used to turn the fan on and off as needed.

Several features of the Danfoss HVAC dedicated frequency converter, the HVAC frequency converter can be utilised to improve the performance of a cooling tower fans application. As the cooling tower fans drop below a certain speed, the effect the fan has on cooling the water becomes small. Also, when utilising a gear-box to frequency control the tower fan, a minimum speed of 40-50% may be required.
The customer programmable minimum frequency setting is available to maintain this minimum frequency even as the feedback or speed reference calls for lower speeds.

Also as a standard feature, program the frequency converter to enter a “sleep” mode and stop the fan until a higher speed is required. Additionally, some cooling tower fans have undesireable frequencies that may cause vibrations. These frequencies can easily be avoided by programming the bypass frequency ranges in the frequency converter.

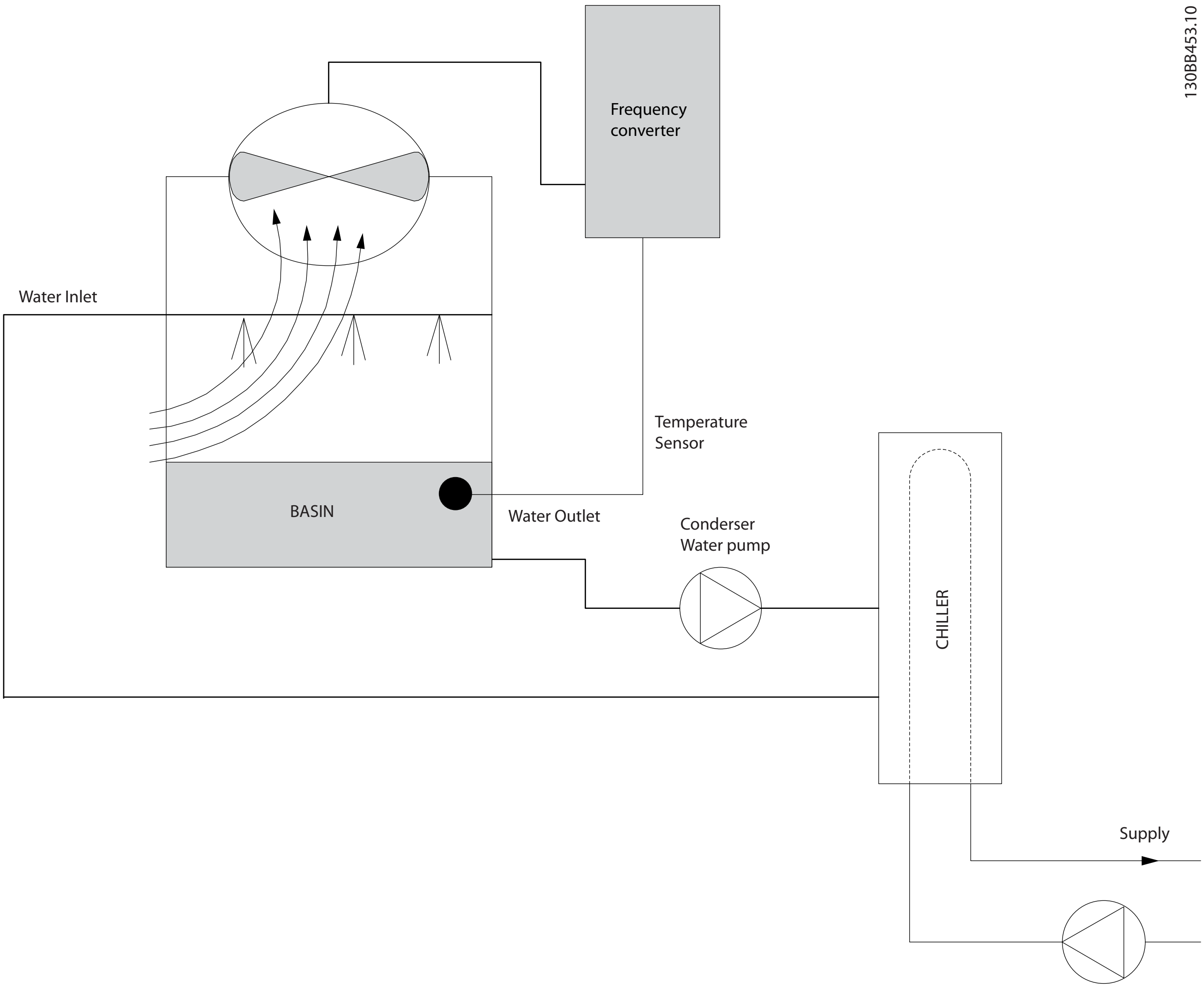


Illustration 2.19 The VLT Solution

2.7.19 Condenser Pumps

Condenser Water pumps are primarily used to circulate water through the condenser section of water cooled chillers and their associated cooling tower. The condenser water absorbs the heat from the chiller's condenser section and releases it into the atmosphere in the cooling tower. These systems are used to provide the most efficient means of creating chilled water, they are as much as 20% more efficient than air cooled chillers.

2.7.20 The VLT Solution

Frequency converters can be added to condenser water pumps instead of balancing the pumps with a throttling valve or trimming the pump impeller.

Using a frequency converter instead of a throttling valve simply saves the energy that would have been absorbed by the valve. This can amount to savings of 15-20% or more. Trimming the pump impeller is irreversible, thus if the conditions change and higher flow is required the impeller must be replaced.

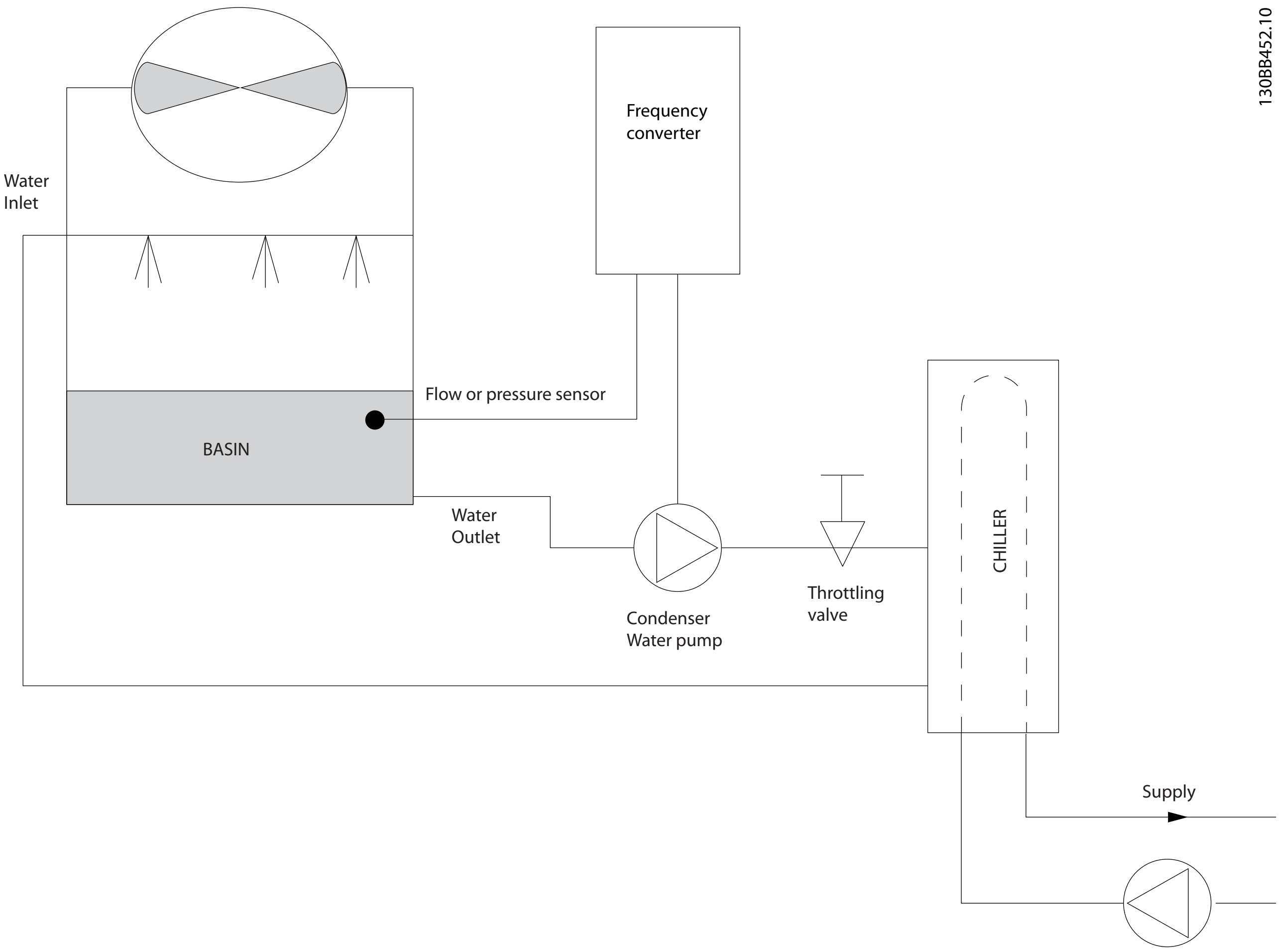


Illustration 2.20 The VLT Solution

2.7.21 Primary Pumps

Primary pumps in a primary/secondary pumping system can be used to maintain a constant flow through devices that encounter operation or control difficulties when exposed to variable flow. The primary/secondary pumping technique decouples the “primary” production loop from the “secondary” distribution loop. This allows devices such as chillers to obtain constant design flow and operate properly, while allowing the rest of the system to vary in flow.

As the evaporator flow rate decreases in a chiller, the chilled water begins to become over-chilled. As this happens, the chiller attempts to decrease its cooling capacity. If the flow rate drops far enough, or too quickly, the chiller cannot shed its load sufficiently and the chiller’s low evaporator temperature safety trips the chiller requiring a manual reset. This situation is common in large installations especially when 2 or more chillers in parallel are installed if primary/secondary pumping is not utilised.

2.7.22 The VLT Solution

Depending on the size of the system and the size of the primary loop, the energy consumption of the primary loop can become substantial.
A frequency converter can be added to the primary system, to replace the throttling valve and/or trimming of the impellers, leading to reduced operating expenses. 2 control methods are common:

The first method uses a flow meter. Because the desired flow rate is known and is constant, a flow meter installed at the discharge of each chiller, can be used to control the pump directly. Using the built-in PID controller, the frequency converter always maintains the appropriate flow rate, even compensating for the changing resistance in the primary piping loop as chillers and their pumps are staged on and off.

The other method is local speed determination. The operator simply decreases the output frequency until the design flow rate is achieved.
Using a frequency converter to decrease the pump speed is very similar to trimming the pump impeller, except it does not require any labour and the pump efficiency remains higher. The balancing contractor simply decreases the speed of the pump until the proper flow rate is achieved and leaves the speed fixed. The pump operates at this speed any time the chiller is staged on. Because the primary loop does not have control valves or other devices that can cause the system curve to change, and the variance due to staging pumps and chillers on and off is usually small, this fixed speed remains appropriate. In the event the flow rate needs to be increased later in the systems life, the frequency converter can simply increase the pump speed instead of requiring a new pump impeller.

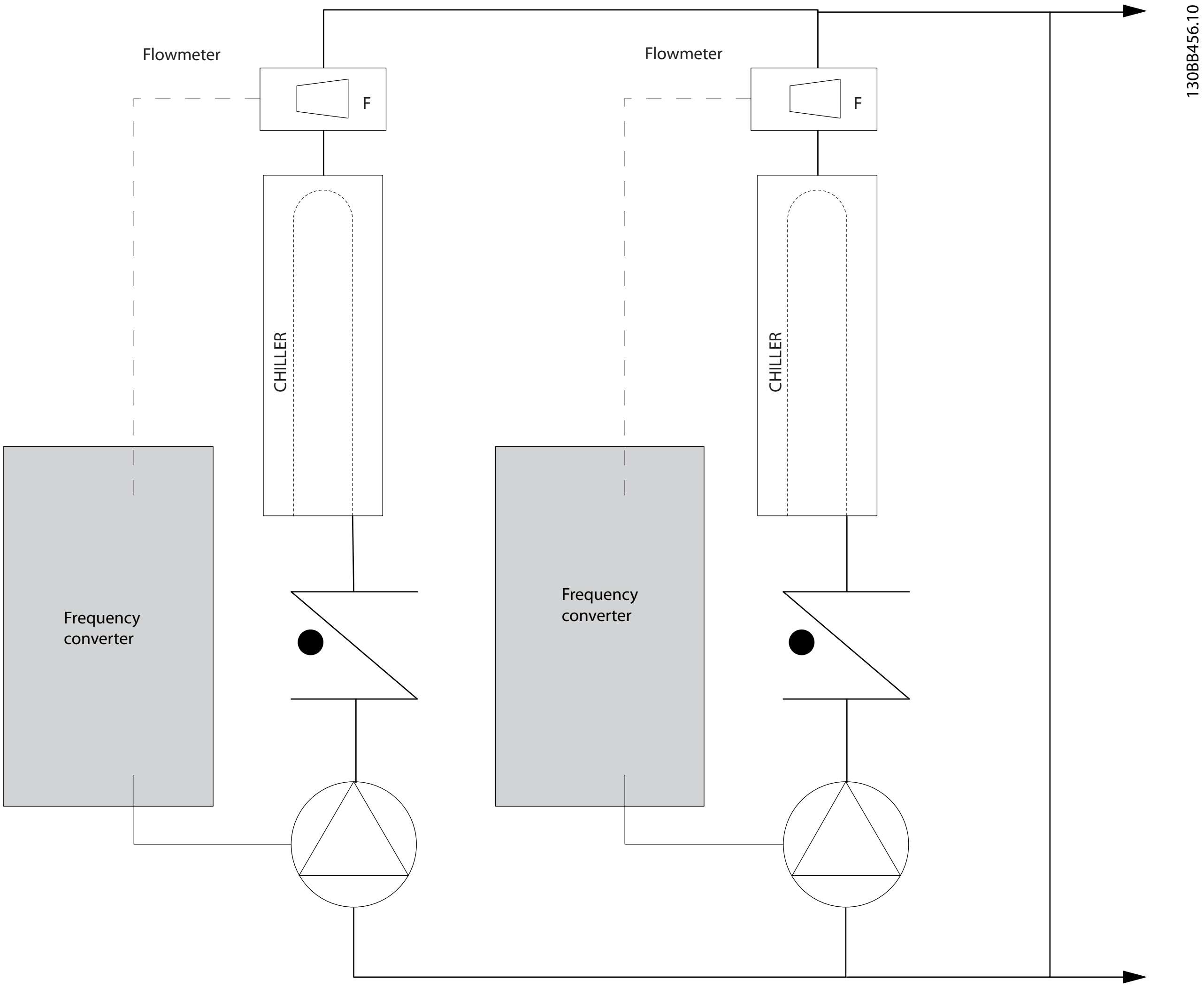


Illustration 2.21 The VLT Solution

2.7.23 Secondary Pumps

Secondary pumps in a primary/secondary chilled water pumping system are used to distribute the chilled water to the loads from the primary production loop. The primary/secondary pumping system is used to hydronically de-couple one piping loop from another. In this case, the primary pump is used to maintain a constant flow through the chillers while allowing the secondary pumps to vary in flow, increase control and save energy.
If the primary/secondary design concept is not used, and a variable volume system is designed, when the flow rate drops far enough or too quickly, the chiller cannot shed its load properly. The chiller's low evaporator temperature safety then trips the chiller requiring a manual reset. This situation is common in large installations especially when 2 or more chillers in parallel are installed.

2.7.24 The VLT Solution

While the primary-secondary system with 2-way valves improves energy savings and eases system control problems, the true energy savings and control potential is realised by adding frequency converters.
With the proper sensor location, the addition of frequency converters allows the pumps to vary their speed to follow the system curve instead of the pump curve.
This results in the elimination of wasted energy and eliminates most of the over-pressurisation, 2-way valves can be subjected too.
As the monitored loads are reached, the 2-way valves close down. This increases the differential pressure measured across the load and 2-way valve. As this differential pressure starts to rise, the pump is slowed to maintain the control head also called setpoint value. This setpoint value is calculated by summing up the pressure drop of the load and 2-way valve under design conditions.

Note that when running multiple pumps in parallel, they must run at the same speed to maximize energy savings, either with individual dedicated drives or one running multiple pumps in parallel.

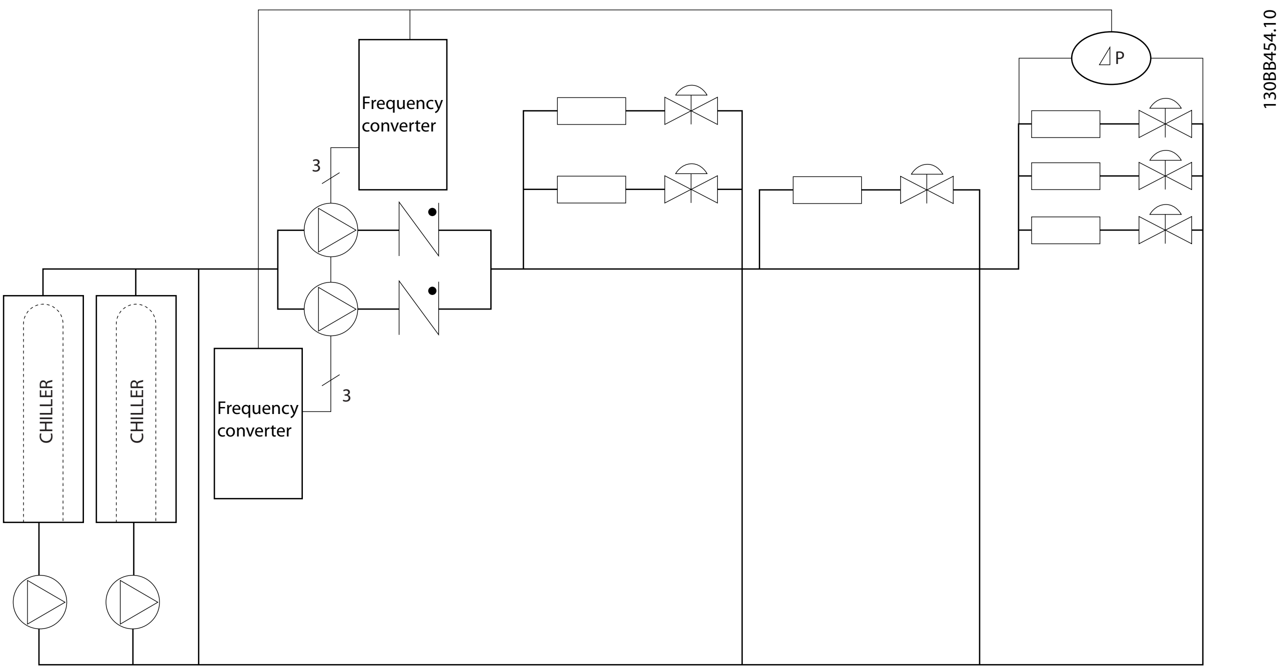


Illustration 2.22 The VLT Solution

2

2.8 Control Structures

2.8.1 Control Principle

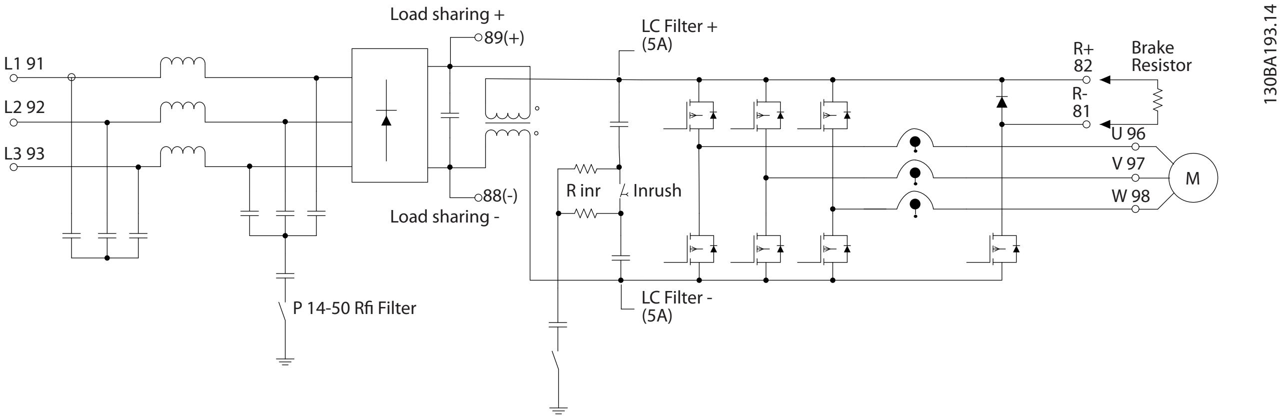


Illustration 2.23 Control Structures

The frequency converter is a high-performance unit for demanding applications. It can handle various kinds of motor control principles such as U/f special motor mode and VVC^{plus} and can handle normal squirrel cage asynchronous motors. Short circuit behavior on this frequency converter depends on the 3 current transducers in the motor phases.

Select between open loop and closed loop in *1-00 Configuration Mode*.

2.8.2 Control Structure Open Loop

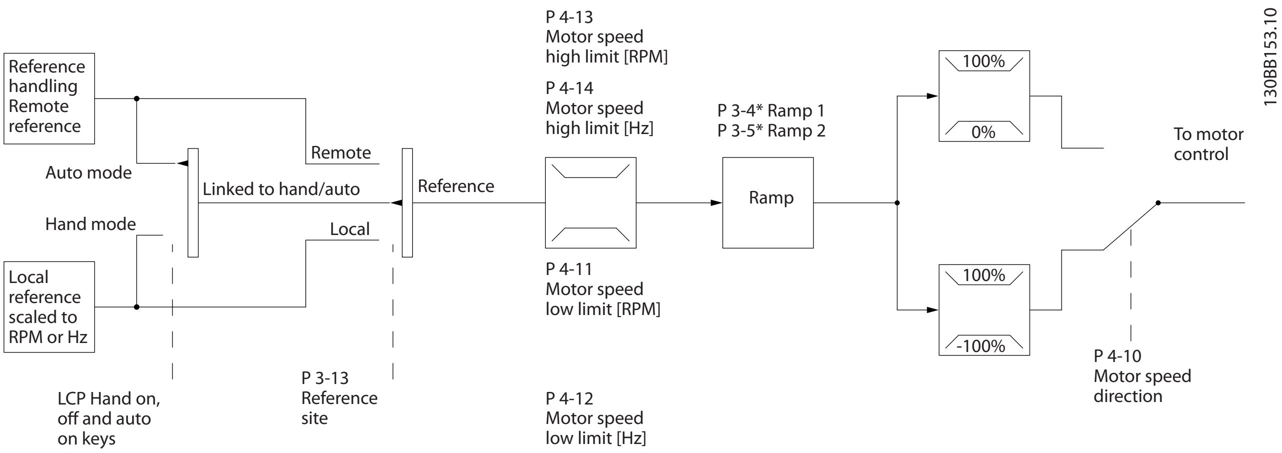


Illustration 2.24 Open Loop Structure

In the configuration shown in *Illustration 2.24*, *1-00 Configuration Mode* is set to *[0] Open loop*. The resulting reference from the reference handling system or the local reference is received and fed through the ramp limitation and speed limitation before being sent to the motor control.
The output from the motor control is then limited by the maximum frequency limit.

2

2.8.3 PM/EC+ Motor Control

The Danfoss EC+ concept provides the possibitily for using high efficient PM motors in IEC standard enclosure types operated by Danfoss frequency converters.
The commissioning procedure is comparable to the existing one for asynchronous (induction) motors by utilising the Danfoss VVC^{plus} PM control strategy.

Customer advantages:

- Free choice of motor technology (permanent magnet or induction motor)
- Installation and operation as known for induction motors
- Manufacturer independent when choosing system components (e.g. motors)
- Best system efficiency by choosing best components
- Possible retrofit of existing installations
- Power range: 1.1–22 kW

Current limitations:

- Currently only supported up to 22 kW
- Currently limited to non salient type PM motors
- LC filters not supported together with PM motors
- Over Voltage Control algorithm is not supported with PM motors
- Kinetic back-up algorithm is not supported with PM motors
- AMA algorithm is not supported with PM motors
- No missing motorphase detection
- No stall detection
- No ETR function

2.8.4 Sizing of Frequency Converter and PM motor

The low motor inductances of PM motors can cause current ripples in the frequency converter.

To select the right frequency converter for a given PM motor, ensure that:

- The frequency converter can deliver the required power and current in all operating conditions.
- The power rating of the frequency converter is equal to or higher than the power rating of the motor.
- Size the frequency converter for a constant 100% operating load with sufficient safety margin.

The current (A) and the typical power rating (kW) for a PM motor can be found in *chapter 9.1 Mains Supply Tables* for different voltages.

Sizing examples for nominal power rating
Example 1

- PM motor size: 1.5 kW / 2.9 A
- Mains: 3 x 400 V

Frequency Converter	Typical [kW]	Typical [hp] at 460V	Continuous [A] (3x380-440 V)	Intermitted [A] (3x380-440V)	Continuous [A] (3x441-480 V)	Intermitted [A] (3x441-480V)
P1K1	1.1	1.5	3.0	3.3	2.7	3.0
P1K5	1.5	2.0	4.1	4.5	3.4	3.7

Table 2.10 Sizing Data for 1.1 and 1.5 kW Frequency Converters

The current rating of the PM motor (2.9 A) matches the current rating of both the 1.1 kW frequency converter (3 A @ 400 V) and the 1.5 kW frequency converter (4.1 A @ 400 V). However, since the power rating of the motor is 1.5 kW, the 1.5 kW frequency converter is the correct choice.

	Motor	Frequency Converter 1.5 kW
Power	1.5 kW	1.5 kW
Current	2.9 A	4.1 A @ 400V

Table 2.11 Correctly Sized Frequency Converter

Example 2

- PM motor size: 5.5 kW / 12.5 A
- Mains: 3 x 400 V

Frequency Converter	Typical [kW]	Typical [hp] at 460V	Continuous [A] (3x380-440 V)	Intermitted [A] (3x380-440V)	Continuous [A] (3x441-480 V)	Intermitted [A] (3x441-480V)
P4K0	4.0	5.0	10.0	11.0	8.2	9.0
P5K5	5.5	7.5	13.0	14.3	11.0	12.1

Table 2.12 Sizing Data for 4.0 and 5.5 kW Frequency Converters

The current rating of the PM motor (12.5 A) matches the current rating of the 5.5 kW frequency converter (13 A @ 400 V), not the current rating of the 4.0 kW frequency converter (10 A @ 400 V). Since the power rating of the motor is 5.5 kW, the 5.5 kW frequency converter is the correct choice.

	Motor	Frequency Converter 5.5 kW
Power	5.5 kW	5.5 kW
Current	12.5 A	13 A @ 400V

Table 2.13 Correctly Sized Frequency Converter

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

The frequency converter can be operated manually via the local control panel (LCP) or remotely via analog/digital inputs or 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 by LCP using the [Hand On] and [Off] keys. Alarms can be reset via the [Reset] key. After pressing [Hand On], the frequency converter goes into Hand Mode and follows (as default) the local reference set by using [▲] and [▼].

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*.

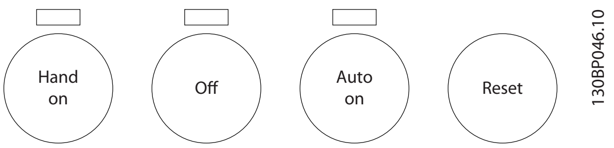


Illustration 2.25 Operation Keys

Hand Off Auto LCP Keys	***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 2.14 Conditions for Either Local or Remote Reference

Table 2.14 shows under which conditions either the local reference or the remote reference is active. One of them is always active, but both cannot be active at the same time.

Local reference forces the configuration mode to open loop, independent on the setting of *1-00 Configuration Mode*.

Local reference is restored at power-down.

2.8.6 Control Structure Closed Loop

The internal controller allows the frequency converter to become an integral part of the controlled system. The frequency converter receives a feedback signal from a sensor in the system. It then compares this feedback to a setpoint reference value and determines the error, if any, between these 2 signals. It then adjusts the speed of the motor to correct this error.

For example, consider a pump application where the speed of a pump is to be controlled so that the static pressure in a pipe is constant. The desired static pressure value is supplied to the frequency converter as the set-point reference. A static pressure sensor measures the actual static pressure in the pipe and supplies this to the frequency converter as a feedback signal. If the feedback signal is greater than the set-point reference, the frequency converter slows down to reduce the pressure. In a similar way, if the pipe pressure is lower than the setpoint reference, the frequency converter automatically speeds up to increase the pressure provided by the pump.

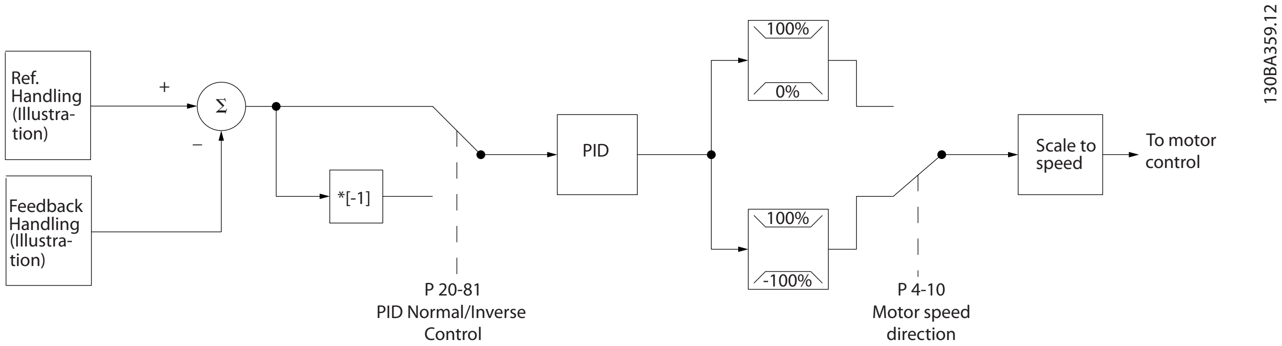


Illustration 2.26 Block Diagram of Closed Loop Controller

While the default values for the frequency converter's closed loop controller often provides satisfactory performance, the control of the system can often be optimised by adjusting some of the closed loop controller's parameters. It is also possible to autotune the PI constants.

2.8.7 Feedback Handling

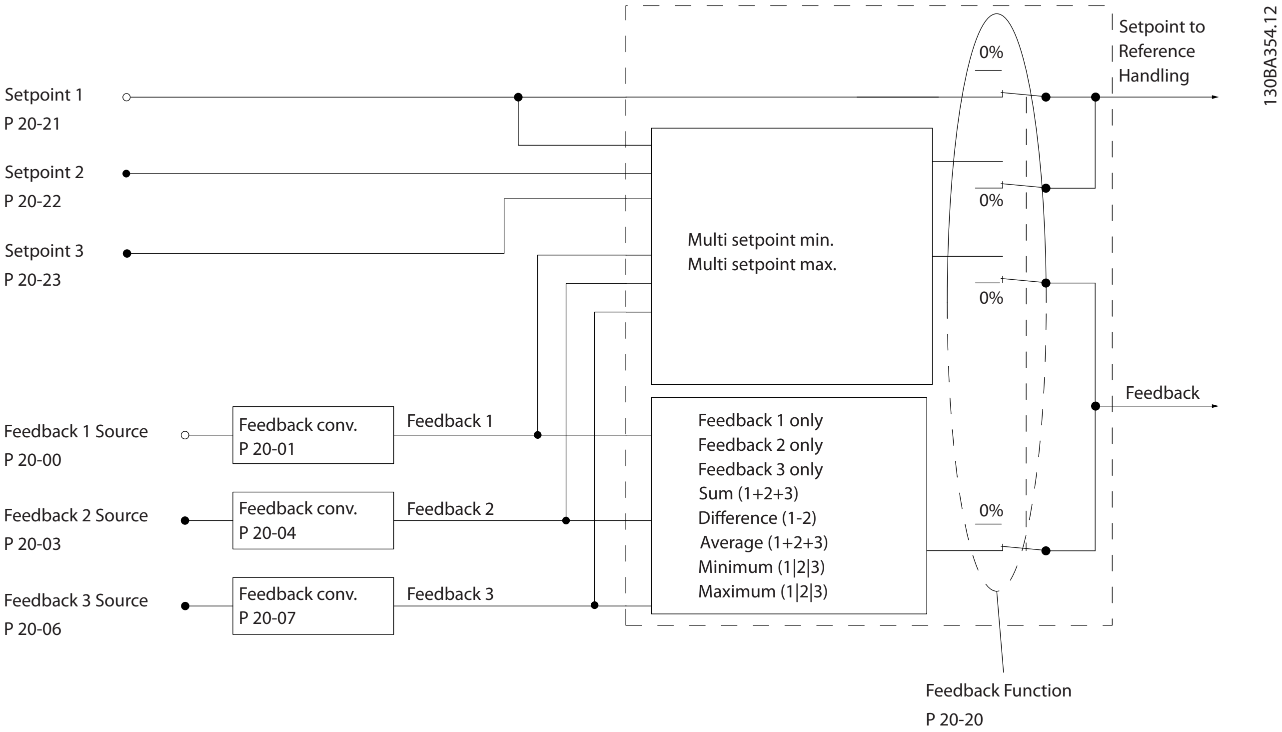


Illustration 2.27 Block Diagram of Feedback Signal Processing

Feedback handling can be configured to work with applications requiring advanced control, such as multiple setpoints and multiple feedbacks. 3 types of control are common.

Single Zone, Single Setpoint
Single Zone, Single Setpoint is a basic configuration. Setpoint 1 is added to any other reference (if any, see Reference Handling) and the feedback signal is selected using *20-20 Feedback Function*.

Multi Zone, Single Setpoint
Multi Zone Single Setpoint uses 2 or 3 feedback sensors, but only one setpoint. The feedbacks can be added, subtracted (only feedback 1 and 2) or averaged. In addition, the maximum or minimum value may be used. Setpoint 1 is used exclusively in this configuration.

If *[13] Multi Setpoint Min* is selected, the setpoint/feedback pair with the largest difference controls the speed of the frequency converter. *[14] Multi Setpoint Maximum* attempts to keep all zones at or below their respective setpoints, while *[13] Multi Setpoint Min* attempts to keep all zones at or above their respective setpoints.

Example

A 2-zone 2 setpoint application Zone 1 setpoint is 15 bar and the feedback is 5.5 bar. Zone 2 setpoint is 4.4 bar and the feedback is 4.6 bar. If *[14] Multi Setpoint Max* is selected, Zone 1's setpoint and feedback are sent to the PID controller, since this has the smaller difference (feedback is higher than setpoint, resulting in a negative difference). If *[13] Multi Setpoint Min* is selected, Zone 2's setpoint and feedback is sent to the PID controller, since this has the larger difference (feedback is lower than setpoint, resulting in a positive difference).

2.8.8 Feedback Conversion

In some applications, it may be useful to convert the feedback signal. One example of this is using a pressure signal to provide flow feedback. Since the square root of pressure is proportional to flow, the square root of the pressure signal yields a value proportional to the flow. This is shown in *Illustration 2.28*.

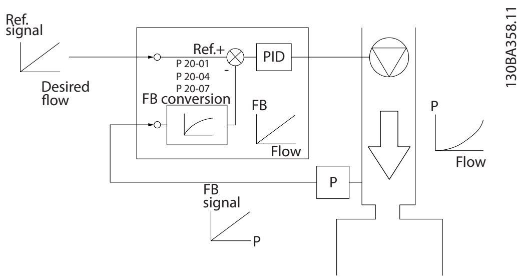


Illustration 2.28 Feedback Conversion

2.8.9 Reference Handling

Details for Open Loop and Closed Loop operation

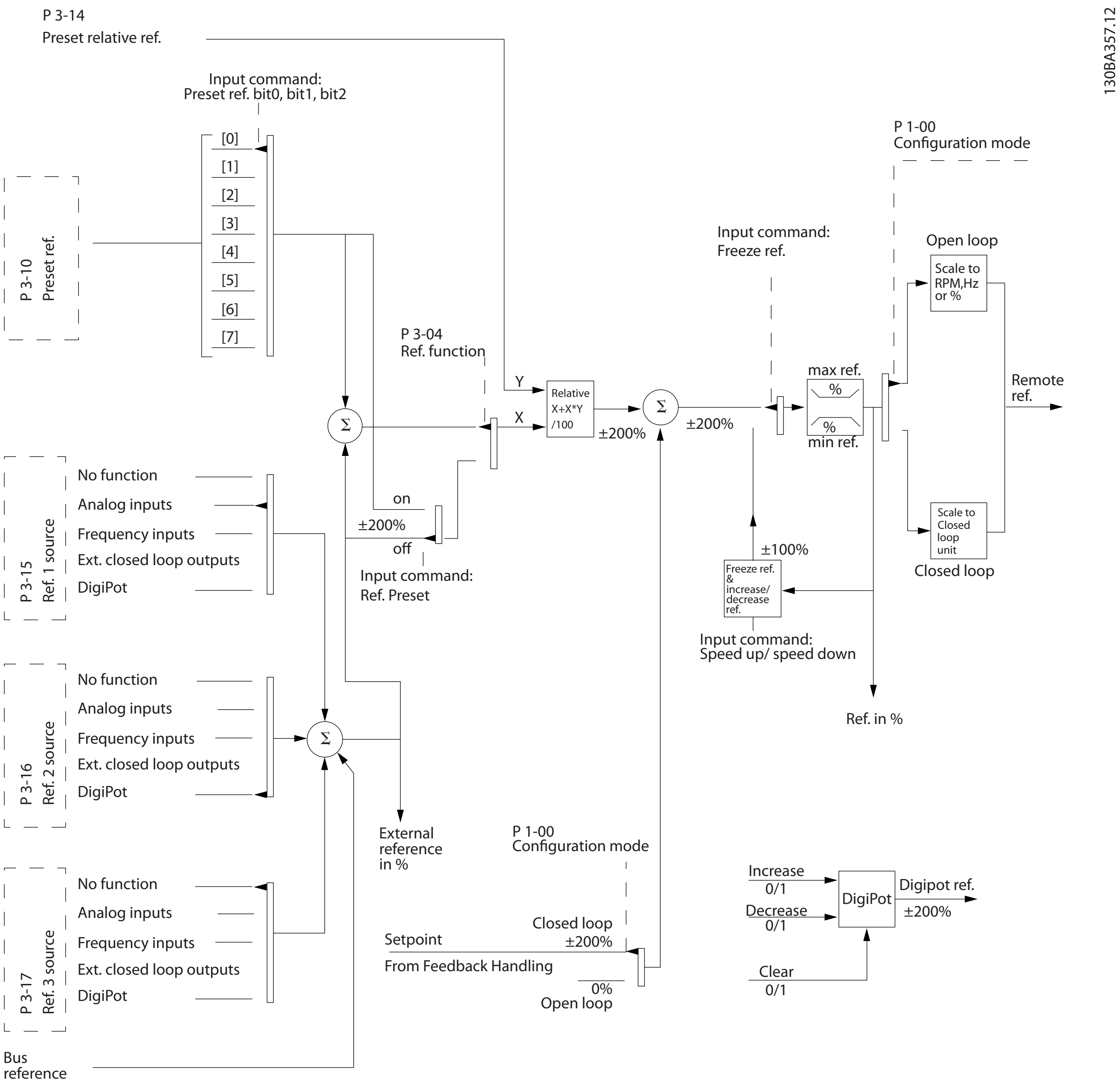


Illustration 2.29 Block Diagram Showing Remote Reference

The remote reference is comprised of:

- Preset references.
- External references (analog inputs, pulse frequency inputs, digital potentiometer inputs and serial communication bus references).
- The Preset relative reference.
- Feedback controlled setpoint.

Up to 8 preset references can be programmed in the frequency converter. The active preset reference can be selected using digital inputs or the serial communications bus. The reference can also be supplied externally, most commonly from an analog input. This external source is selected by one of the 3 Reference Source parameters (*3-15 Reference 1 Source*, *3-16 Reference 2 Source* and *3-17 Reference 3 Source*). Digipot is a digital potentiometer. This is also commonly called a Speed Up/Speed Down Control or a Floating Point Control. To set it up, one digital input is programmed to increase the reference, while another digital input is programmed to decrease the reference. A third digital input can be used to reset the Digipot reference. All reference resources and the bus reference are added to produce the total external reference. The external reference, the preset reference or the sum of the 2 can be selected to be the active reference. Finally, this reference can by be scaled using *3-14 Preset Relative Reference*.

The scaled reference is calculated as follows:

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

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

If Y, *3-14 Preset Relative Reference* is set to 0%, the reference is affected by the scaling.

2.8.10 Example of Closed Loop PID Control

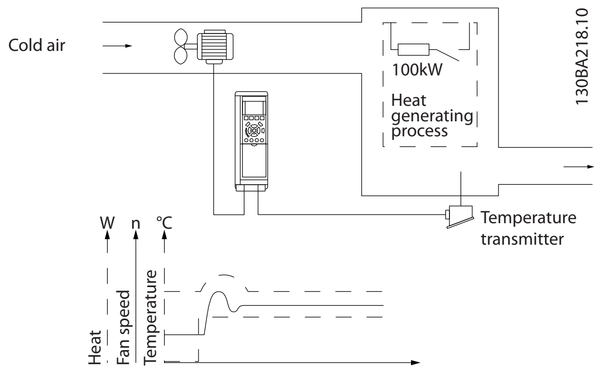


Illustration 2.30 Closed Loop Control for a Ventilation System

In a ventilation system, the temperature is to be maintained at a constant value. The desired temperature is set between -5 and +35 °C using a 0-10 V potentiometer. Because this is a cooling application, if the temperature is above the set-point value, the speed of the fan must be increased to provide more cooling air flow. The temperature sensor has a range of -10 to +40 °C and uses a 2-wire transmitter to provide a 4-20 mA signal. The output frequency range of the frequency converter is 10 to 50 Hz.

1. Start/Stop via switch connected between terminals 12 (+24 V) and 18.
2. Temperature reference via a potentiometer (-5 to +35 °C, 0 to 10 V) connected to terminals 50 (+10 V), 53 (input) and 55 (common).
3. Temperature feedback via transmitter (-10 to 40 °C, 4-20 mA) connected to terminal 54. Switch S202 behind the LCP set to ON (current input).

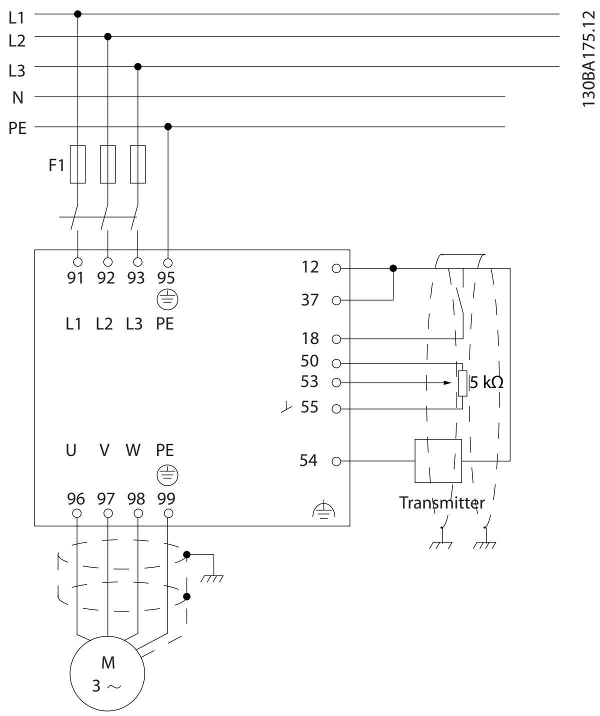


Illustration 2.31 Example of Closed Loop PID Control

2.8.11 Programming Order

NOTICE

In this example, it is assumed that an induction motor is used, i.e. that *1-10 Motor Construction* = [0] Asynchron.

Function	Paramete r	Setting
1) Make sure the motor runs properly. Do the following:		
Set the motor parameters using nameplate data.	1-2*	As specified by motor name plate
Run Automatic Motor Adaptation.	1-29	*[1] Enable complete AMA* and then run the AMA function.
2) Check that the motor is running in the right direction.		
Run Motor Rotation Check.	1-28	If the motor runs in the wrong direction, remove power temporarily and reverse 2 of the motor phases.
3) Make sure the frequency converter limits are set to safe values		
Check that the ramp settings are within capabilities of the frequency converter and allowed application operating specifications.	3-41 3-42	60 s 60 s Depends on motor/load size! Also active in Hand mode.
Prohibit the motor from reversing (if necessary)	4-10	*[0] Clockwise*

2

Function	Parameter	Setting
Set acceptable limits for the motor speed.	4-12 4-14 4-19	10 Hz, *Motor min speed* 50 Hz, *Motor max speed* 50 Hz, *Drive max output frequency*
Switch from open loop to closed loop.	1-00	*[3] Closed Loop*
4) Configure the feedback to the PID controller.		
Select the appropriate reference/feedback unit.	20-12	*[71] Bar*
5) Configure the set-point reference for the PID controller.		
Set acceptable limits for the set-point reference.	20-13 20-14	0 Bar 10 Bar
Select current or voltage by switches S201 / S202		
6) Scale the analog inputs used for set-point reference and feedback.		
Scale Analog Input 53 for the pressure range of the potentiometer (0 - 10 Bar, 0 - 10 V).	6-10 6-11 6-14 6-15	0 V 10 V (default) 0 Bar 10 Bar
Scale Analog Input 54 for pressure sensor (0 - 10 Bar, 4 - 20 mA)	6-22 6-23 6-24 6-25	4 mA 20 mA (default) 0 Bar 10 Bar
7) Tune the PID controller parameters.		
Adjust the frequency converter's Closed Loop Controller, if needed.	20-93 20-94	See Optimisation of the PID Controller, below.
8) Save to finish.		
Save the parameter setting to the LCP for safe keeping	0-50	*[1] All to LCP*

Table 2.15 Programming Order

2.8.12 Tuning the Frequency Converter Closed Loop Controller

Once the frequency converter's closed loop controller has been set up, the performance of the controller should be tested. In many cases, its performance may be acceptable using the default values of *20-93 PID Proportional Gain* and *20-94 PID Integral Time*. However, in some cases it may be helpful to optimise these parameter values to provide faster system response while still controlling speed overshoot.

2.8.13 Manual PID Adjustment

1. Start the motor.
2. Set *20-93 PID Proportional Gain* to 0.3 and increase it until the feedback signal begins to oscillate. If necessary, start and stop the frequency converter or make step changes in the set-point reference to attempt to cause oscillation. Next reduce the PID proportional gain until the feedback signal stabilizes. Then reduce the proportional gain by 40-60%.
3. Set *20-94 PID Integral Time* to 20 s and reduce it until the feedback signal begins to oscillate. If necessary, start and stop the frequency converter or make step changes in the set-point reference to attempt to cause oscillation. Next, increase the PID integral time until the feedback signal stabilizes. Then increase of the integral time by 15-50%.
4. *20-95 PID Differentiation Time* should only be used for very fast-acting systems. The typical value is 25% of *20-94 PID Integral Time*. The differential function should only be used when the setting of the proportional gain and the integral time has been fully optimised. Make sure that oscillations of the feedback signal are sufficiently dampened by the low-pass filter for the feedback signal (parameters 6-16, 6-26, 5-54 or 5-59 as required).

2.9 General Aspects of EMC

Electrical interference is usually 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 2.32*, capacitance 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 2.32*) 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 approximately 5 MHz. Since the leakage current (I_1) is carried back to the unit through the screen (I_3), there is in principle only a small electro-magnetic field (I_4) from the screened motor cable according to *Illustration 2.32*.

The screen reduces the radiated interference, but increases the low-frequency interference on the mains. Connect the motor cable screen to the frequency converter enclosure as well as on the motor enclosure. This is best done by using integrated screen clamps so as to avoid twisted screen ends (pigtails). Pigtails 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 relay, control cable, signal interface and brake, mount the screen on the enclosure at both ends. In some situations, however, it is necessary to break the screen to avoid current loops.

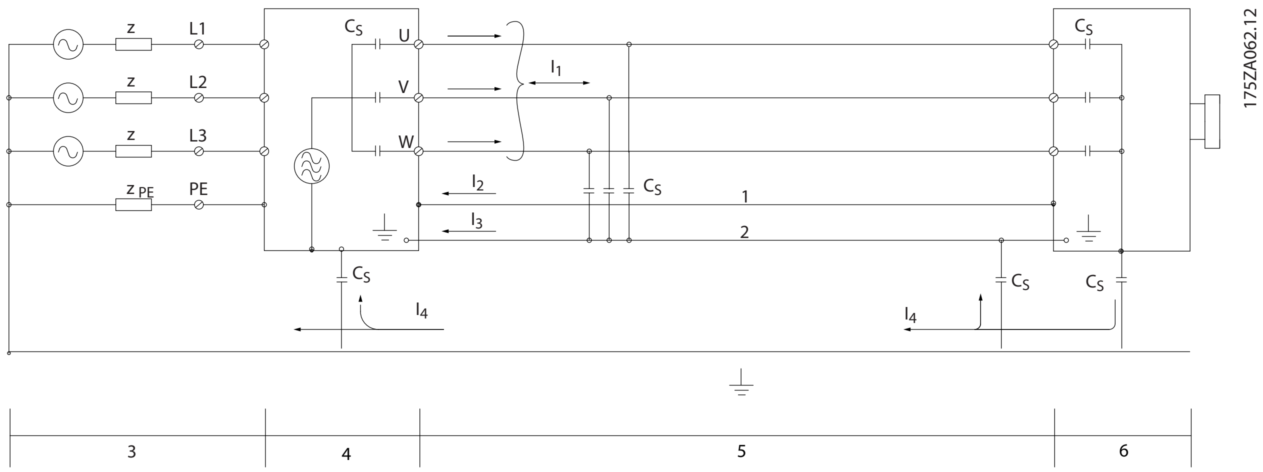


Illustration 2.32 Situation that Generates Leakage Currents

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

Table 2.16 Legend to *Illustration 2.32*

If the screen is to be placed on a mounting plate for the frequency converter, the mounting plate must be made of metal, to convey the screen currents back to the unit. Moreover, 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 most immunity requirements are observed.

To reduce the interference level from the entire system (unit+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 especially generated by the control electronics. See for more information on EMC.

2.9.1 Emission Requirements

According to the EMC product standard for adjustable speed frequency converters EN/IEC 61800-3:2004 the EMC requirements depend on the intended use of the frequency converter. Four categories are defined in the EMC product standard. The definitions of the 4 categories together with the requirements for mains supply voltage conducted emissions are given in *Table 2.17*.

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, which are neither plug-in nor movable and are intended to be installed and commissioned by a professional.	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. An EMC plan should be made.

Table 2.17 Emission Requirements

When the generic (conducted) emission standards are used the frequency converters are required to comply with the following limits

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 2.18 Limits at Generic Emission Standards

2.9.2 EMC Test Results

The following test results have been obtained using a system with a frequency converter, a screened control cable, a control box with potentiometer, as well as a motor and screened motor cable at nominal switching frequency. In *Table 2.19* the maximum motor cable lengths for compliance are stated.

RFI filter type		Conducted emission			Radiated emission		
		Cable length [m]			Cable length [m]		
Standards and requirements	**EN 55011**	**Class B** Housing, trades and light industries	**Class A Group 1** Industrial environment	**Class A Group 2** Industrial environment	**Class B** Housing, trades and light industries	**Class A Group 1** Industrial environment	**Class A Group 2** Industrial environment
	EN/IEC 61800-3	**Category C1** First environment Home and office	**Category C2** First environment Home and office	**Category C3** Second environment Industrial	**Category C1** First environment Home and office	**Category C2** First environment Home and office	**Category C3** Second environment Industrial
H1							
FC 102	1.1-45 kW 200-240 V	50	150	150	No	Yes	Yes
	1.1-90 kW 380-480 V	50	150	150	No	Yes	Yes
H2							
FC 102	1.1-3.7 kW 200-240 V	No	No	5	No	No	No
	5.5-45 kW 200-240 V	No	No	25	No	No	No
	1.1-7.5 kW 380-500 V	No	No	5	No	No	No
	11-90 kW 380-500 V 4)	No	No	25	No	No	No
	11-22 kW 525-690 V 1, 4)	No	No	25	No	No	No
	30-90 kW 525-690 V 2, 4)	No	No	25	No	No	No
H3							
FC 102	1.1-45 kW 200-240V	10	50	75	No	Yes	Yes
	1.1-90 kW 380-480V	10	50	75	No	Yes	Yes
H4							
FC 102	11-30 kW 525-690 V 1)	No	100	100	No	Yes	Yes
	37-90 kW 525-690 V 2)	No	150	150	No	Yes	Yes
Hx 3)							
FC 102	1.1-90 kW 525-600 V	No	No	No	No	No	No

Table 2.19 EMC Test Results (Emission)

1) Enclosure Type B

2) Enclosure Type C

3) Hx versions can be used according to EN/IEC 61800-3 category C4

4) T7, 37-90 kW complies with class A group 1 with 25 m motor cable. Some restrictions for the installation apply (contact Danfoss for details).

HX, H1, H2, H3, H4 or H5 is defined in the type code pos. 16-17 for EMC filters

HX - No EMC filters built in the frequency converter (600 V units only)

H1 - Integrated EMC filter. Fulfil EN 55011 Class A1/B and EN/IEC 61800-3 Category 1/2

H2 - No additional EMC filter. Fulfil EN 55011 Class A2 and EN/IEC 61800-3 Category 3

H3 - Integrated EMC filter. Fulfil EN 55011 class A1/B and EN/IEC 61800-3 Category 1/2

H4 - Integrated EMC filter. Fulfil EN 55011 class A1 and EN/IEC 61800-3 Category 2

H5 – Marine versions. Fulfill same emissions levels as H2 versions

2.9.3 General Aspects of Harmonics Emission

A frequency converter takes up a non-sinusoidal current from mains, which increases the input current I_{RMS}. A non-sinusoidal current is transformed with a Fourier analysis and split into sine-wave currents with different frequencies, that is, different harmonic currents I_n with 50 Hz basic frequency:

	I_1	I_5	I_7
Hz	50	250	350

Table 2.20 Harmonic Currents

The harmonics do not affect the power consumption directly, but increase the heat losses in the installation (transformer, cables). So, 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.

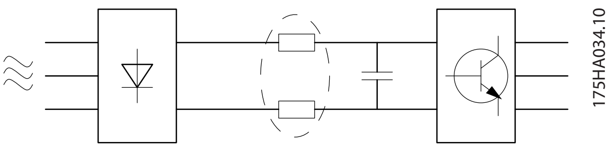


Illustration 2.33 Harmonic Currents

NOTICE

Some of the harmonic currents might disturb communication equipment connected to the same transformer or cause resonance with power-factor correction batteries.

To ensure low harmonic currents, the frequency converter is equipped with intermediate circuit coils as standard. This normally reduces the input current I_{RMS} by 40%.

The voltage distortion on the mains supply voltage depends on the size of the harmonic currents multiplied by the mains impedance for the frequency in question.
The total voltage distortion THD is calculated based on the individual voltage harmonics using this formula:

$$THD\% = \sqrt{U_5^2 + U_7^2 + ... + U_N^2}$$

(U_N% of U)

2.9.4 Harmonics Emission Requirements

Equipment connected to the public supply network

Options	Definition
1	IEC/EN 61000-3-2 Class A for 3-phase balanced equipment (for professional equipment only up to 1 kW total power).
2	IEC/EN 61000-3-12 Equipment 16 A-75 A and professional equipment as from 1 kW up to 16 A phase current.

Table 2.21 Connected Equipment

2.9.5 Harmonics Test Results (Emission)

Power sizes up to PK75 in T2 and T4 comply with IEC/EN 61000-3-2 Class A. Power sizes from P1K1 and up to P18K in T2 and up to P90K in T4 comply with IEC/EN 61000-3-12, Table 4. Power sizes P110 - P450 in T4 also comply with IEC/EN 61000-3-12 even though not required because currents are above 75 A.

	Individual harmonic current I_n/I_1 (%)			
	I_5	I_7	I_{11}	I_{13}
Actual (typical)	40	20	10	8
Limit for $R_{sce} \geq 120$	40	25	15	10
	Harmonic current distortion factor (%)			
	THD		**PWHD**	
Actual (typical)	46		45	
Limit for $R_{sce} \geq 120$	48		46	

Table 2.22 Harmonics Test Results (Emission)

If the short-circuit power of the supply S_{sc} is greater than or equal to:

$$SSC = \sqrt{3} \times RSCE \times Umains \times Iequ = \sqrt{3} \times 120 \times 400 \times Iequ$$

at the interface point between the user's supply and the public system (R_{sce}).

It is the responsibility of the installer or user of the equipment to ensure that the equipment is connected only to a supply with a short-circuit power S_{sc} greater than or equal to what is specified above. If necessary, consult the distribution network operator.
Other power sizes can be connected to the public supply network by consultation with the distribution network operator.

Compliance with various system level guidelines:
The harmonic current data in *Table 2.22* are given in accordance with IEC/EN61000-3-12 with reference to the

Power Drive Systems product standard. The data may be used to calculate the harmonic currents' influence on the power supply system and to document compliance with relevant regional guidelines: IEEE 519 -1992; G5/4.

2.9.6 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 from electrical phenomena, the following immunity tests have been made in accordance with 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 e.g. by lightning that strikes near installations.
- **EN 61000-4-6 (IEC 61000-4-6):** RF Common mode: Simulation of the effect from radio-transmission equipment joined by connection cables.

See *Table 2.23*.

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
Voltage range: 200-240 V, 380-500 V, 525-600 V, 525-690 V					
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 Ω1)	—	—	10 V_{RMS}
Load sharing	4 kV CM	4 kV/2 Ω 1)	—	—	10 V_{RMS}
Control wires	2 kV CM	2 kV/2 Ω1)	—	—	10 V_{RMS}
Standard bus	2 kV CM	2 kV/2 Ω1)	—	—	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	10V/m	—

Table 2.23 EMC Immunity Form

1) Injection on cable shield
AD: Air Discharge
CD: Contact Discharge
CM: Common mode
DM: Differential mode

2.10 Galvanic Isolation (PELV)

2.10.1 PELV - Protective Extra Low Voltage

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), with the exception of grounded Delta leg above 400 V.

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

The components that make up the electrical isolation, as described below, also comply with the requirements for higher isolation and the relevant test as described in EN 61800-5-1.
The PELV galvanic isolation can be shown in 6 locations (see *Illustration 2.34*):

To maintain PELV, all connections made to the control terminals must be PELV, e.g. thermistor must be reinforced/double insulated.

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

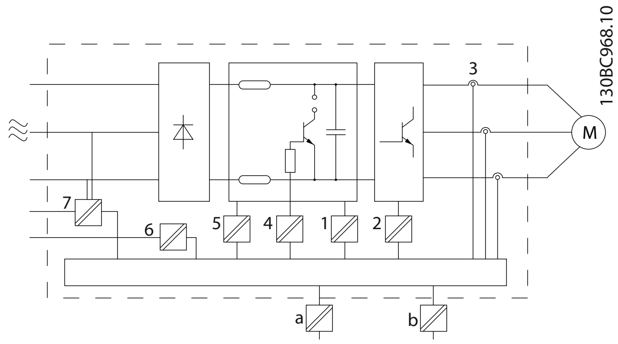


Illustration 2.34 Galvanic Isolation

The functional galvanic isolation (a and b on drawing) is for the 24 V back-up option and for the RS-485 standard bus interface.

⚠WARNING

Installation at high altitude:
380-500 V, enclosure types A, B and C: At altitudes above 2 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.
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.
Before touching any electrical parts, wait at least the amount of time indicated in *Table 2.19*.
Shorter time is allowed only if indicated on the nameplate for the specific unit.

2.11 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 might 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 contri-butions and depends on various system configurations including RFI filtering, screened motor cables, and frequency converter power.

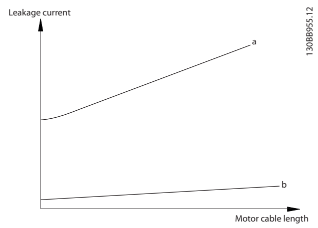


Illustration 2.35 Cable Length and Power Size Influence on Leakage Current. Pa > Pb

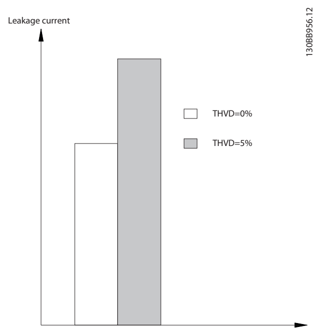


Illustration 2.36 Line Distortion Influences Leakage Current

NOTICE

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

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

- Ground wire (terminal 95) of at least 10 mm^2
- 2 separate 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 which are 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

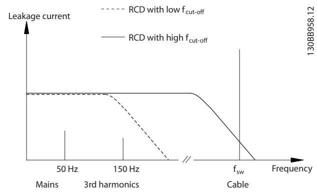


Illustration 2.37 Main Contributions to Leakage Current

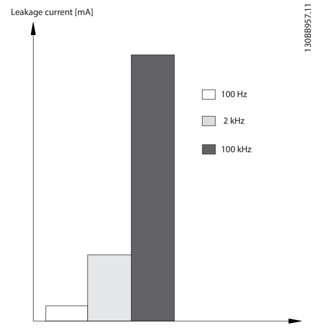


Illustration 2.38 The Influence of the Cut-off Frequency of the RCD on what Is Responded to/measured

See also *RCD Application Note, MN90G*.

2.12 Brake Function

2.12.1 Selection of Brake Resistor

In certain applications, for instance in tunnel or underground railway station ventilation systems, it is desirable to bring the motor to a stop more rapidly than can be achieved through controlling via ramp down or by free-wheeling. In such applications, dynamic braking with a brake resistor may be utilised. Using a brake resistor ensures that the energy is absorbed in the resistor and not in the frequency converter.

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 intermitted duty cycle. The resistor intermittent duty cycle is an indication of the duty cycle at which the resistor is active. *Illustration 2.39* shows a typical braking cycle.

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

$$Duty\ Cycle = t_b / T$$

T = cycle time in seconds
t_b is the braking time in seconds (as part of the total cycle time)

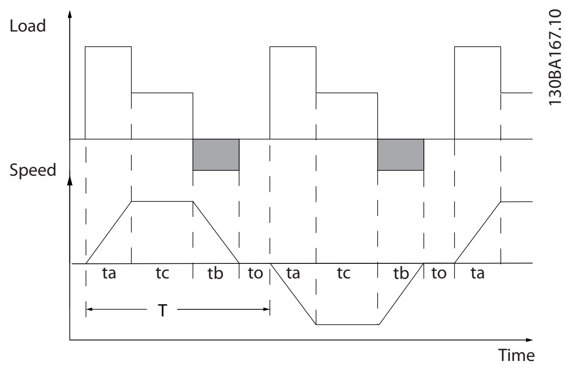


Illustration 2.39 Intermittent Duty Cycle for the Resistor

Danfoss offers brake resistors with duty cycle of 5%, 10% and 40% suitable for use with the VLT® HVAC Drive frequency converter series. If a 10% duty cycle resistor is applied, this is able of absorbing braking power upto 10% of the cycle time with the remaining 90% being used to dissipate heat from the resistor.

For further selection advice, contact Danfoss.

2.12.2 Brake Resistor Calculation

The brake resistance is calculated as shown:

$Rbr\ [\Omega] = \frac{U_{dc}^2}{Ppeak}$
where
$P_{peak} = P_{motor} \times M_{br} \times \eta_{motor} \times \eta [W]$

Table 2.24 Brake Resistor Calculation

As can be seen, the brake resistance depends on the intermediate circuit voltage (U_{DC}).
The brake function of the frequency converter is settled in 3 areas of mains power supply:

Size [V]	Brake active [V]	Warning before cut out [V]	Cut out (trip) [V]
3x200-240	390 (U_{DC})	405	410
3x380-480	778	810	820
3x525-600	943	965	975
3x525-690	1084	1109	1130

Table 2.25 Brake Function Settled in 3 Areas of Mains Supply

NOTICE

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

Danfoss recommends the brake resistance R_{rec}, i.e. one that guarantees that the is able to brake at the highest braking torque ($M_{br(\%)}$) of 110%. The formula can be written as:

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

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

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

$$200V:\ Rrec = \frac{107780}{Pmotor}[\Omega]$$

$$480V:\ Rrec = \frac{375300}{Pmotor}[\Omega]^{1)}$$

$$480V:\ Rrec = \frac{428914}{Pmotor}[\Omega]^{2)}$$

$$600V:\ Rrec = \frac{630137}{Pmotor}[\Omega]$$

$$690V:\ Rrec = \frac{832664}{Pmotor}[\Omega]$$

1) For frequency converters ≤ 7.5 kW shaft output
2) For frequency converters > 7.5 kW shaft output

NOTICE

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

NOTICE

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).

⚠WARNING

Do not touch the brake resistor as it can get very hot while/after braking.

2.12.3 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 enables reading out the momentary power and the mean power for the latest 120 s. The brake can also monitor the power energising and ensure that it does not exceed the 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)*.

NOTICE

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.

Overvoltage 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.

NOTICE

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

2.12.4 Brake Resistor Cabling

EMC (twisted cables/shielding)
Twist the wires to reduce the electrical noise from the wires between the brake resistor and the frequency converter.

For enhanced EMC performance, use a metal screen.

2.13 Extreme Running Conditions

Short Circuit (Motor Phase – Phase)
The frequency converter is protected against short circuits by current measurement in each of the 3 motor phases or in the DC-link. A short circuit between 2 output phases causes an overcurrent in the inverter. The inverter is 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.

Switching on the output
Switching on the output between the motor and the frequency converter is permitted. Fault messages may appear. Enable flying start to catch a spinning motor.

Motor-generated overvoltage
The voltage in the intermediate circuit is increased when the motor acts as a generator. This occurs in following cases:

- The load drives the motor (at constant output frequency from the frequency converter), ie. the load generates energy.
- 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.
- Incorrect slip compensation setting may cause higher DC-link voltage.
- Back-EMF from PM motor operation. If coasted at high RPM, the PM motor back-EMF may potentially exceed the maximum voltage tolerance of the frequency converter and cause damage. To help prevent this, the value of *4-19 Max Output Frequency* is automatically limited based on an internal calculation based on the value of *1-40 Back EMF at 1000 RPM*, *1-25 Motor Nominal Speed* and *1-39 Motor Poles*. If it is possible that the motor may overspeed (e.g. due to excessive windmilling effects), Danfoss recommends using a brake resistor.

WARNING

The frequency converter must be equipped with a brake chopper.

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

NOTICE

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

Mains drop-out
During a mains drop-out, the frequency converter keeps running until the intermediate circuit voltage drops below the minimum stop level, 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 reduces the output frequency to reduce the load.
If the overload is excessive, a current may occur that makes the frequency converter cut out after approx. 5-10 s.

Operation within the torque limit is limited in time (0-60 s) in *14-25 Trip Delay at Torque Limit*.

2.13.1 Motor Thermal Protection

This is the way Danfoss is protecting the motor from being overheated. It is an electronic feature that simulates a bimetal relay based on internal measurements. The characteristic is shown in *Illustration 2.40*

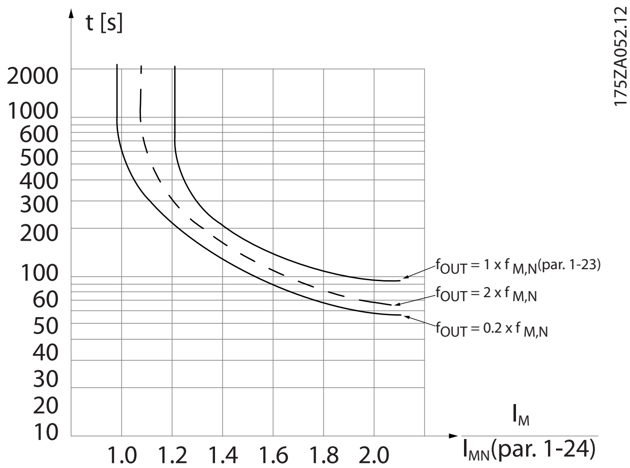


Illustration 2.40 The X-axis is showing the ratio between I_{motor} and I_{motor} nominal. The Y-axis is showing the time in seconds before the ETR cuts off and trips the frequency converter. The curves are showing the characteristic nominal speed at twice the nominal speed and at 0,2x the nominal speed.

It is clear that at lower speed, the ETR cuts of at lower heat due to less cooling of the motor. In that way the motor are 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 frequency converter.

The thermistor cut-out value is > 3 kΩ.

Integrate a thermistor (PTC sensor) in the motor for winding protection.

Motor protection can be implemented using a range of techniques: PTC sensor in motor windings; mechanical thermal switch (Klixon type); or Electronic Thermal Relay (ETR).

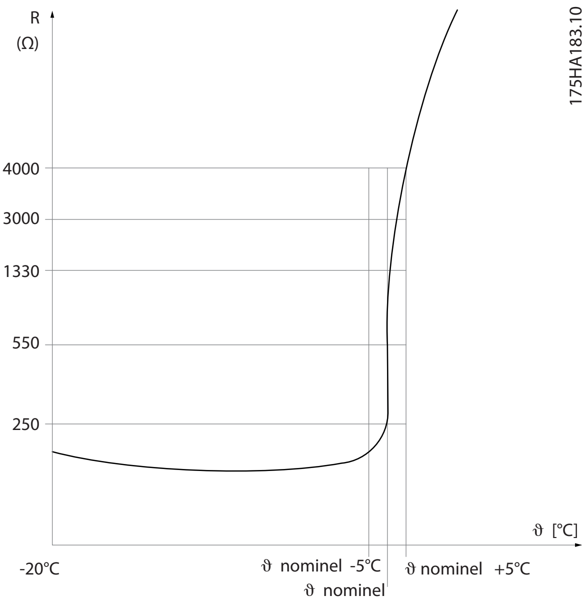


Illustration 2.41 The Thermistor Cut-out

Using a digital input and 24 V as power supply:
Example: The frequency converter trips when the motor temperature is too high.
Parameter set-up:
Set *1-90 Motor Thermal Protection* to *[2] Thermistor Trip*
Set *1-93 Thermistor Source* to *[6] Digital Input 33*

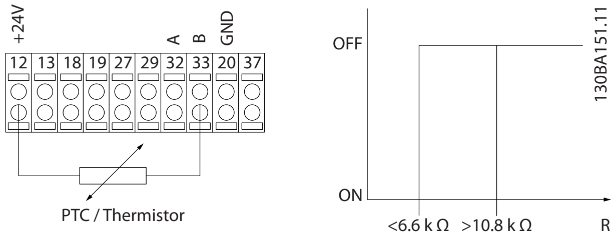


Illustration 2.42 Using a Digital Input and 24 V as Power Supply

Using a digital input and 10 V as power supply:
Example: The frequency converter trips when the motor temperature is too high.
Parameter set-up:
Set *1-90 Motor Thermal Protection* to *[2] Thermistor Trip*

Set *1-93 Thermistor Source* to *[6] Digital Input 33*

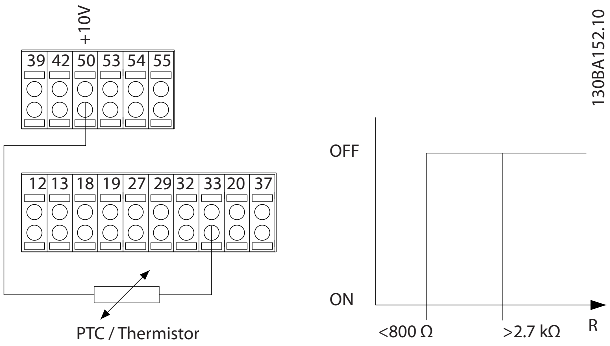


Illustration 2.43 Using a Digital Input and 10 V as Power Supply

Using an analog input and 10 V as power supply:
Example: The frequency converter trips when the motor temperature is too high.
Parameter set-up:
Set *1-90 Motor Thermal Protection* to *[2] Thermistor Trip*
Set *1-93 Thermistor Source* to *[2] Analog Input 54*
Do not select a reference source.

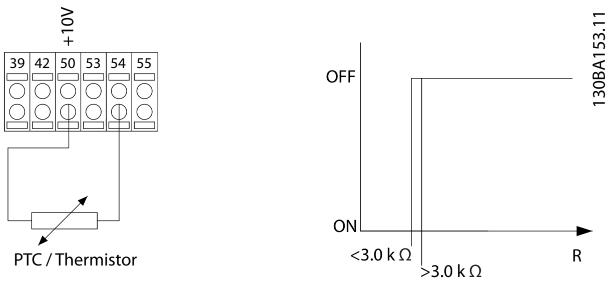


Illustration 2.44 Using an Analog Input and 10 V as Power Supply

Input Digital/analog	Supply Voltage V Cut-out Values	Threshold Cut-out Values
Digital	24	< 6.6 kΩ - > 10.8 kΩ
Digital	10	< 800 Ω - > 2.7 kΩ
Analog	10	< 3.0 kΩ - > 3.0 kΩ

Table 2.26 Threshold Cut-out Values

NOTICE

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

Summary
With the torque limit feature the motor is protected for being overloaded independent of the speed. With the ETR, the motor is protected for being over heated and there is no need for any further motor protection. That means when the motor is heated up, the ETR timer controls for how long time the motor can be running at the high temperature, before it is stopped to prevent overheating. If the motor is overloaded without reaching the temperature where the ETR shuts of the motor, the torque limit is protecting the motor and application for being overloaded.

ETR is activated in *1-90 Motor Thermal Protection* and is controlled in *4-16 Torque Limit Motor Mode*. The time before the torque limit warning trips the frequency converter is set in *14-25 Trip Delay at Torque Limit*.

3 Selection

3.1 Options and Accessories

Danfoss offers a wide range of options and accessories for the frequency converters.

3.1.1 Mounting of Option Modules in Slot B

Disconnect power to the frequency converter.

For A2 and A3 enclosure types:

1. Remove the LCP, the terminal cover, and the LCP frame from the frequency converter.
2. Fit the MCB1xx option card into slot B.
3. Connect the control cables and relieve the cable by the enclosed cable strips.
   Remove the knockout in the extended LCP frame delivered in the option set, so that the option fits under the extended LCP frame.
4. Fit the extended LCP frame and terminal cover.
5. Fit the LCP or blind cover in the extended LCP frame.
6. Connect power to the frequency converter.
7. Set up the input/output functions in the corresponding parameters, as mentioned in *chapter 9.2 General Specifications*.

For B1, B2, C1 and C2 enclosure types:

1. Remove the LCP and the LCP cradle.
2. Fit the MCB 1xx option card into slot B.
3. Connect the control cables and relieve the cable by the enclosed cable strips.
4. Fit the cradle.
5. Fit the LCP.

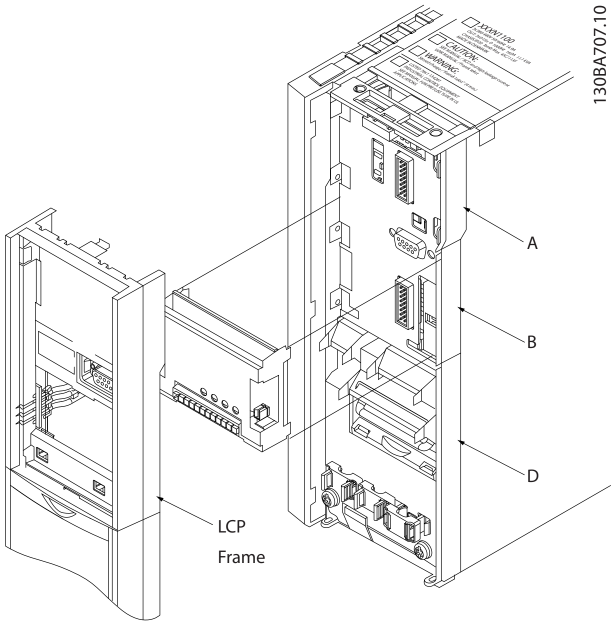


Illustration 3.1 A2, A3 and B3 Enclosure Types

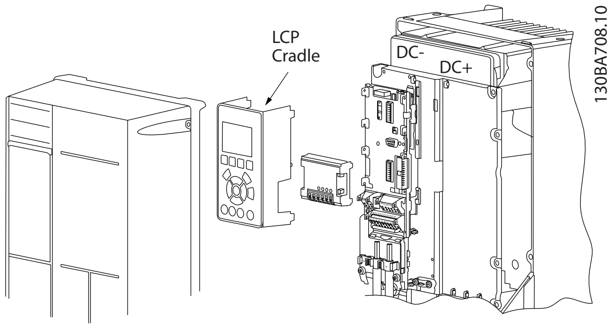


Illustration 3.2 A5, B1, B2, B4, C1, C2, C3 and C4 Enclosure Types

3.1.2 General Purpose I/O Module MCB 101

MCB 101 is used for extension of the number of digital and analog inputs and outputs of the frequency converter.

MCB 101 must be fitted into slot B in the frequency converter. Contents:

- MCB 101 option module
- Extended LCP frame
- Terminal cover

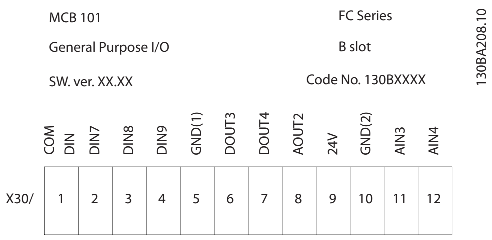


Illustration 3.3

Galvanic isolation in the MCB 101
Digital/analog inputs are galvanically isolated from other inputs/outputs on the MCB 101 and in the control card of the frequency converter. Digital/analog outputs in the MCB 101 are galvanically isolated from other inputs/outputs on the MCB 101, but not from these 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 shown in *Illustration 3.4* has to be established.

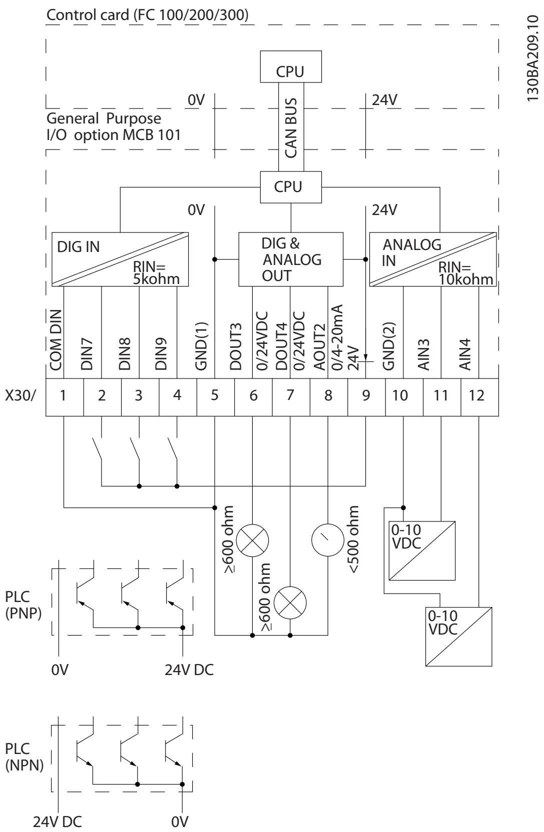


Illustration 3.4 Principle Diagram

3.1.3 Digital Inputs - Terminal X30/1-4

Number of digital inputs	Voltage level	Voltage levels	Tolerance	Max. Input impedance
3	0-24 V DC	PNP type: Common = 0 V Logic "0": Input < 5 V DC Logic "0": Input > 10 V DC NPN type: Common = 24 V Logic "0": Input > 19 V DC Logic "0": Input < 14 V DC	± 28 V continuous ± 37 V in minimum 10 s	Approx. 5 kΩ

Table 3.1 Parameters for set-up: 5-16, 5-17 and 5-18

3.1.4 Analog Voltage Inputs - Terminal X30/10-12

Number of analog voltage inputs	Standardised input signal	Tolerance	Resolution	Max. Input impedance
2	0-10 V DC	± 20 V continuously	10 bits	Approx. 5 KΩ

Table 3.2 Parameters for set-up: 6-3*, 6-4* and 16-76

3.1.5 Digital Outputs - Terminal X30/5-7

Number of digital outputs	Output level	Tolerance	Max.impedance
2	0 or 2 V DC	± 4 V	≥ 600 Ω

Table 3.3 Parameters for set-up: 5-32 and 5-33

3.1.6 Analog Outputs - Terminal X30/5+8

Number of analog outputs	Output signal level	Tolerance	Max. impedance
1	0/4 - 20 mA	±0.1 mA	< 500 Ω

Table 3.4 Parameters for set-up: 6-6* and 16-77

3

3.1.7 Relay Option MCB 105

The MCB 105 option 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 2A
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 s^{-1}

1) IEC 947 part 4 and 5

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

- Relay Module MCB 105
- Extended LCP frame and enlarged terminal cover
- Label for covering access to switches S201, S202 and S801
- Cable strips for fastening cables to relay module

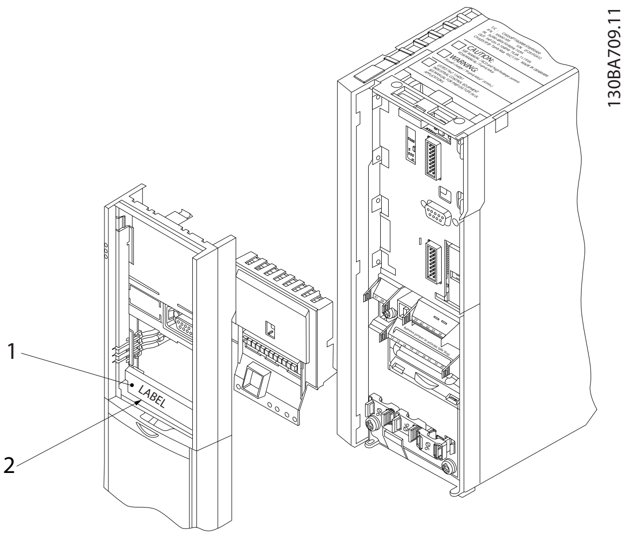


Illustration 3.5 Relay Option MCB 105

A2-A3-A4-B3	A5-B1-B2-B4-C1-C2-C3-C4
1) **IMPORTANT**! The label MUST be placed on the LCP frame as shown (UL approved).	

Table 3.5 Legend to *Illustration 3.5* and *Illustration 3.6*

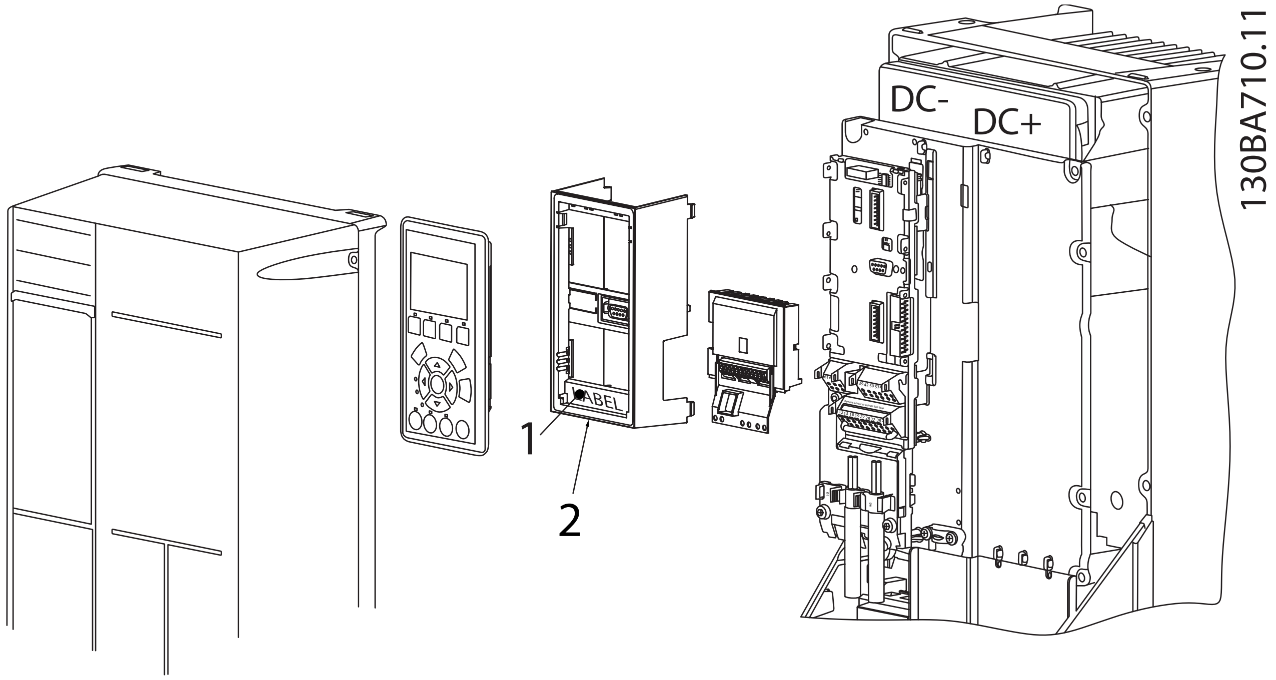


Illustration 3.6 Relay Option Kit

WARNING

Warning Dual supply.

How to add the MCB 105 option:

- See mounting instructions in the beginning of section *Options and Accessories*
- Disconnec power to the live part connections on relay terminals.
- Do not mix live parts with control signals (PELV).
- Select the relay functions in *5-40 Function Relay* [6-8], *5-41 On Delay, Relay* [6-8] and *5-42 Off Delay, Relay* [6-8].

NOTICE

Index [6] is relay 7, index [7] is relay 8, and index [8] is relay 9

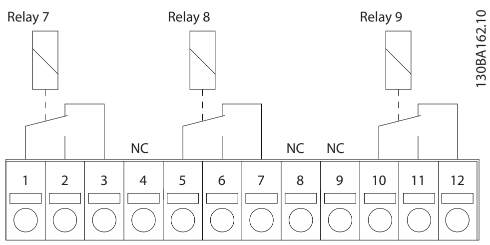


Illustration 3.7 Relay 7, Relay 8, and Relay 9

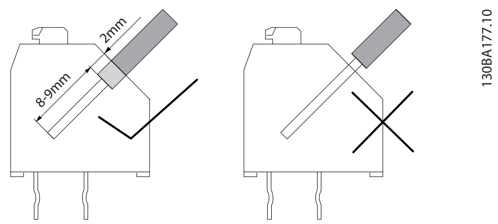


Illustration 3.8 Mounting

3

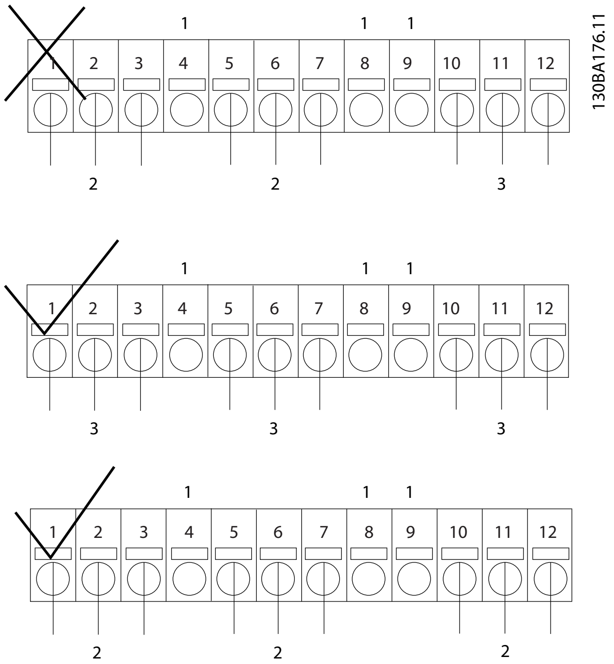


Illustration 3.9 Connection

1	NC
2	Live part
3	PELV

Table 3.6 Legend to *Illustration 3.9*

⚠WARNING

Do not combine low voltage parts and PELV systems. At a single fault the whole system might become dangerous to touch, and it could result in death or serious injury.

3.1.8 24 V Back-Up Option MCB 107 (Option D)

External 24 V DC Supply

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) and fieldbusses without mains supplied to the power section.

Input voltage range	24 V DC ±15% (max. 37 V in 10 s)
Max. input current	2.2 A
Average input current for the frequency converter	0.9 A
Max cable length	75 m
Input capacitance load	<10 uF
Power-up delay	<0.6 s

Table 3.7 External 24 V DC Supply Specification

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 de-coupling plate and the plastic cover underneath.
4. Insert the 24 V DC back-up external supply option in the option slot.
5. Mount the cable de-coupling plate.
6. Attach the terminal cover and the LCP or blind cover.

When , 24 V back-up option MCB 107 supplies the control circuit, the internal 24 V supply is automatically disconnected.

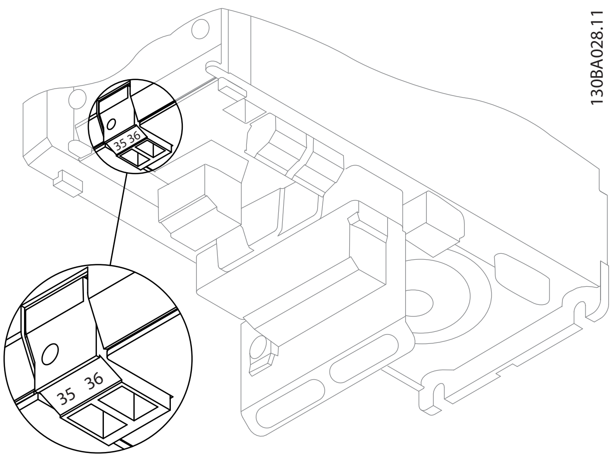


Illustration 3.10 Connection to 24 V Back-up Supplier (A2-A3).

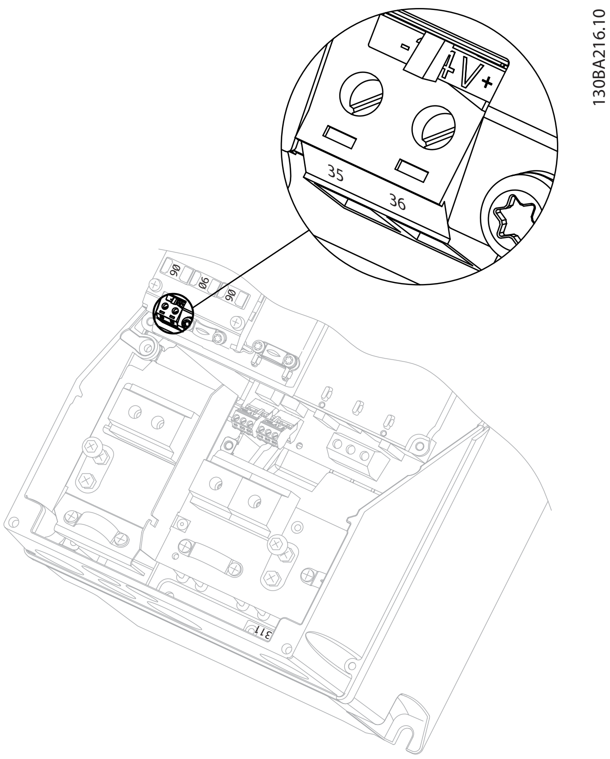


Illustration 3.11 Connection to 24 V Back-up Supplier (A5-C2).

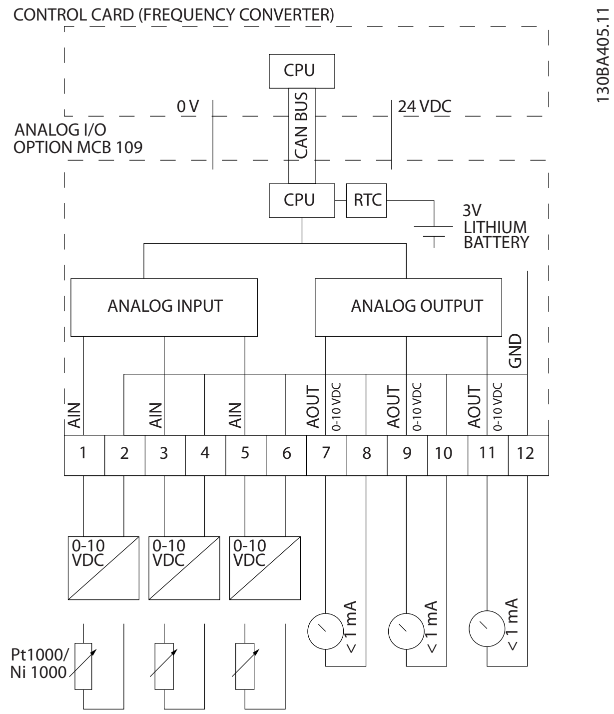


Illustration 3.12 Principle Diagram for Analog I/O Mounted in Frequency Converter.

3.1.9 Analog I/O option MCB 109

The Analog I/O card is to be used in e.g. the following cases:

- Providing battery back-up of clock function on control card
- As general extension of analog I/O selection available on control card, e.g. for multi-zone control with 3 pressure transmitters
- Turning frequency converter into de-central I/O block supporting Building Management System with inputs for sensors and outputs for operating dampers and valve actuators
- Support Extended PID controllers with I/Os for set point inputs, transmitter/sensor inputs and outputs for actuators.

Analog I/O configuration
3 x analog inputs, capable of handling following:

- 0-10 V DC

OR

- 0-20 mA (voltage input 0-10 V) by mounting a 510 Ω resistor across terminals (see **NOTICE**)
- 4-20 mA (voltage input 2-10 V) by mounting a 510 Ω resistor across terminals (see **NOTICE**)
- Ni1000 temperature sensor of 1000 Ω at 0° C. Specifications according to DIN43760
- Pt1000 temperature sensor of 1000 Ω at 0° C. Specifications according to IEC 60751

3 x Analog Outputs supplying 0-10 V DC.

3

NOTICE

Note the values available within the different standard groups of resistors:
E12: Closest standard value is 470 Ω, creating an input of 449.9 Ω and 8.997 V.
E24: Closest standard value is 510 Ω, creating an input of 486.4Ω and 9.728 V.
E48: Closest standard value is 511 Ω, creating an input of 487.3 Ω and 9.746 V.
E96: Closest standard value is 523 Ω, creating an input of 498.2 Ω and 9.964 V.

Analog inputs - terminal X42/1-6
Parameter group: 18-3*. See also *VLT® HVAC Drive Programming Guide*.

Parameter groups for set-up: 26-0*, 26-1*, 26-2* and 26-3*. See also *VLT® HVAC Drive Programming Guide*.

3 x Analog inputs	Used as temperature sensor input	Used as voltage input
Operating range	-50 to +150 °C	0 - 10 V DC
Resolution	11 bits	10 bits
Accuracy	-50 °C ±1 Kelvin +150 °C ±2 Kelvin	0.2% of full scale at cal. temperature
Sampling	3 Hz	2.4 Hz
Max load	-	± 20 V continuously
Impedance	-	Approximately 5 kΩ

Table 3.8 Analog inputs - terminal X42/1-6

When used for voltage, analog inputs are scalable by parameters for each input.

When used for temperature sensor, analog inputs scaling is preset to necessary signal level for specified temperature span.

When analog inputs are used for temperature sensors, it is possible to read out feedback value in both °C and °F.

When operating with temperature sensors, maximum cable length to connect sensors is 80 m non-screened/non-twisted wires.

Analog outputs - terminal X42/7-12
Parameter group: 18-3*. See also *VLT® HVAC Drive Programming Guide*.
Parameter groups for set-up: 26-4*, 26-5* and 26-6*. See also *VLT® HVAC Drive Programming Guide*.

3 x Analog outputs	Output signal level	Resolution	Linearity	Max load
Volt	0-10 V DC	11 bits	1% of full scale	1 mA

Table 3.9 Analog outputs - terminal X42/7-12

Analog outputs are scalable by parameters for each output.

The function assigned is selectable via a parameter and have same options as for analog outputs on control card.

For a more detailed description of parameters, refer to the *VLT® HVAC Drive Programming Guide*.

Real-time clock (RTC) with back-up
The data format of RTC includes year, month, date, hour, minutes and weekday.

Accuracy of clock is better than ± 20 ppm at 25 °C.

The built-in lithium back-up battery lasts on average for minimum 10 years, when frequency converter is operating at 40 °C ambient temperature. If battery pack back-up fails, analog I/O option must be exchanged.

3.1.10 PTC Thermistor Card MCB 112

The MCB 112 option makes it possible to monitor the temperature of an electrical motor through a galvanically isolated PTC thermistor input. It is a B option for frequency converter with Safe Torque Off.

For information on mounting and installation of the option, see *chapter 3.1.1 Mounting of Option Modules in Slot B*. See also *chapter 7 Application Examples* for different application possibilities.

X44/1 and X44/2 are the thermistor inputs. X44/12 enables Safe Torque Off of the frequency converter (T-37), if the thermistor values make it necessary, and X44/10 informs the frequency converter that a request for safe torque off came from the MCB 112 to ensure a suitable alarm handling. One of the digital inputs parameters (or a digital input of a mounted option) must be set to *[80] PTC Card 1* to use the information from X44/10. Configure *5-19 Terminal 37 Safe Stop* to the desired Safe Torque Off functionality (default is Safe Stop Alarm).

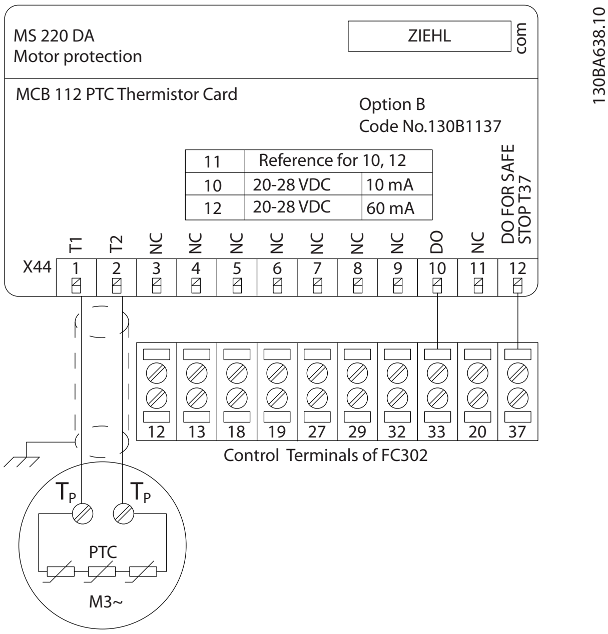


Illustration 3.13 Installation of MCB 112

ATEX Certification with FC 102

The MCB 112 has been certified for ATEX, which means that the frequency converter with the MCB 112 can now be used with motors in potentially explosive atmospheres. See the Operating Instructions for the MCB 112 for more information.

Illustration 3.14 ATmosphère EXplosive (ATEX)

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	

3.1.11 Sensor Input Option MCB 114

The sensor input option card MCB 114 can be used in the following cases:

- Sensor input for temperature transmitters PT100 and PT1000 for monitoring bearing temperatures
- As general extension of analog inputs with one additional input for multi-zone control or differential pressure measurements
- Support extended PID controllers with I/Os for set point, transmitter/sensor inputs

Typical motors, designed with temperature sensors for protecting bearings from being overloaded, are fitted with 3 PT100/1000 temperature sensors. One in front, one in the back-end bearing, and one in the motor windings. The sensor input Option MCB 114 supports 2- or 3-wire sensors with individual temperature limits for under/over temperature. An auto detection of sensor type, PT100 or PT1000 takes place at power up.

The option can generate an alarm if the measured temperature is either below low limit or above high limit specified by the user. The individual measured temperature on each sensor input can be read out in the display or by readout parameters. If an alarm occurs, the relays or digital outputs can be programmed to be active high by selecting *[21] Thermal Warning* in parameter group 5-**.

A fault condition has a common warning/alarm number associated with it, which is Alarm/Warning 20, Temp. input error. Any present output can be programmed to be active in case the warning or alarm appears.

3.1.11.1 Ordering Code Numbers and Parts Delivered

Standard version code no: 130B1172.
Coated version code no: 130B1272.

3.1.11.2 Electrical and Mechanical Specifications

Analog Input	
Number of analog inputs	1
Format	0-20 mA or 4-20 mA
Wires	2
Input impedance	<200 Ω
Sample rate	1 kHz
3rd order filter	100 Hz at 3 dB
The option is able to supply the analog sensor with 24V DC (terminal 1).	

Temperature Sensor Input	
Number of analog inputs supporting PT100/1000	3
Signal type	PT100/1000
Connection	PT 100 2 or 3 wire/PT1000 2 or 3 wire
Frequency PT100 and PT1000 input	1Hz for each channel
Resolution	10 bit
Temperature range	-50 - 204 °C -58 - 399 °F

Galvanic Isolation	
The sensors to be connected are expected to be galvanically isolated from the mains voltage level	IEC 61800-5-1 and UL508C

Cabling	
Maximum signal cable length	500 m

3.1.11.3 Electrical Wiring

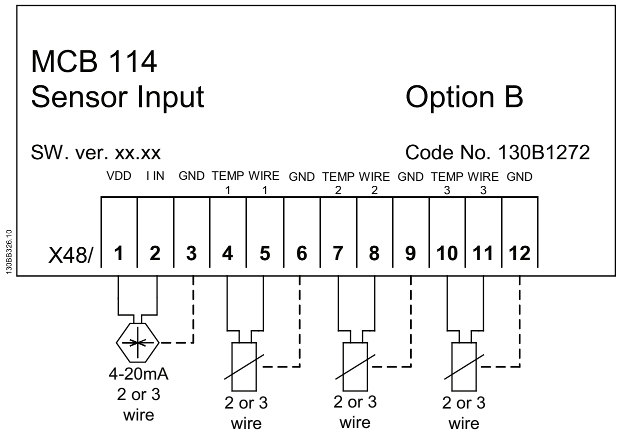


Illustration 3.15 Electrical Wiring

Terminal	Name	Function
1	VDD	24V DC to supply 4-20mA sensor
2	I in	4-20mA input
3	GND	Analog input GND
4, 7, 10	Temp 1, 2, 3	Temperature input
5, 8, 11	Wire 1, 2, 3	3rd wire input if 3 wire sensors are used
6, 9, 12	GND	Temp. input GND

Table 3.10 Terminals

3.1.12 Remote Mounting Kit for LCP

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. 1 Nm.

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

Table 3.11 Technical Data

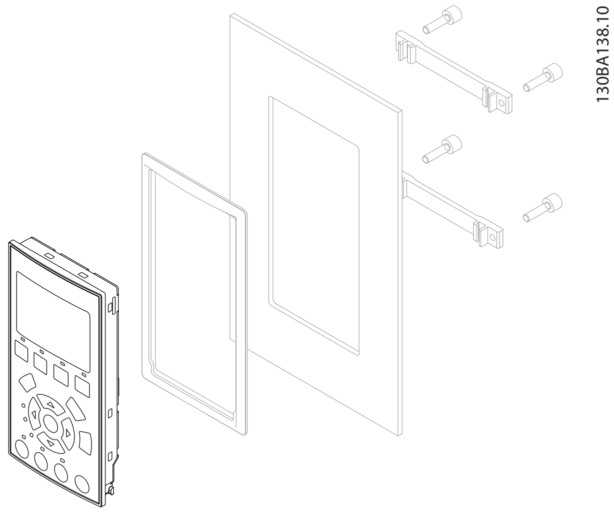


Illustration 3.16 LCP Kit with Graphical LCP, Fasteners, 3 m Cable and Gasket
Ordering No. 130B1113

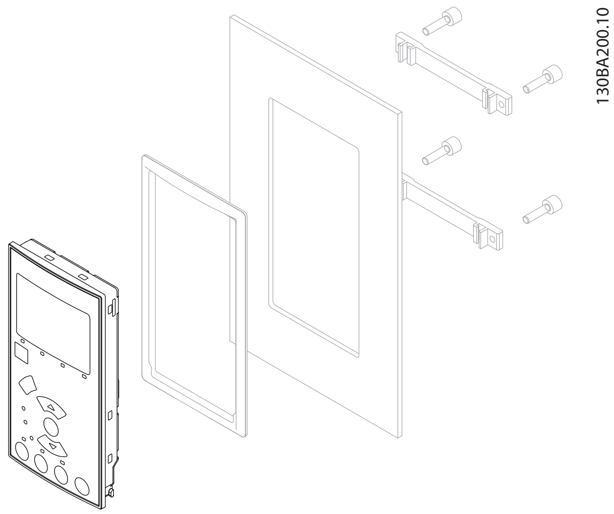


Illustration 3.17 LCP Kit with Numerical LCP, Fasteners and Gasket
Ordering no. 130B1114

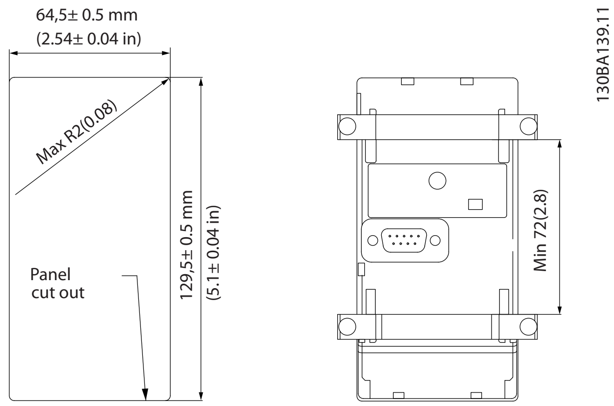


Illustration 3.18 Dimensions

3

3.1.13 IP21/IP41/ TYPE1 Enclosure Kit

IP21/IP41 top/ TYPE 1 is an optional enclosure element available for IP20 compact units, enclosure size A2-A3, B3+B4 and C3+C4.
If the enclosure kit is used, an IP20 unit is upgraded to comply with enclosure IP21/41 top/TYPE 1.

The IP41 top can be applied to all standard IP20 VLT® HVAC Drive variants.

3.1.14 IP21/Type 1 Enclosure Kit

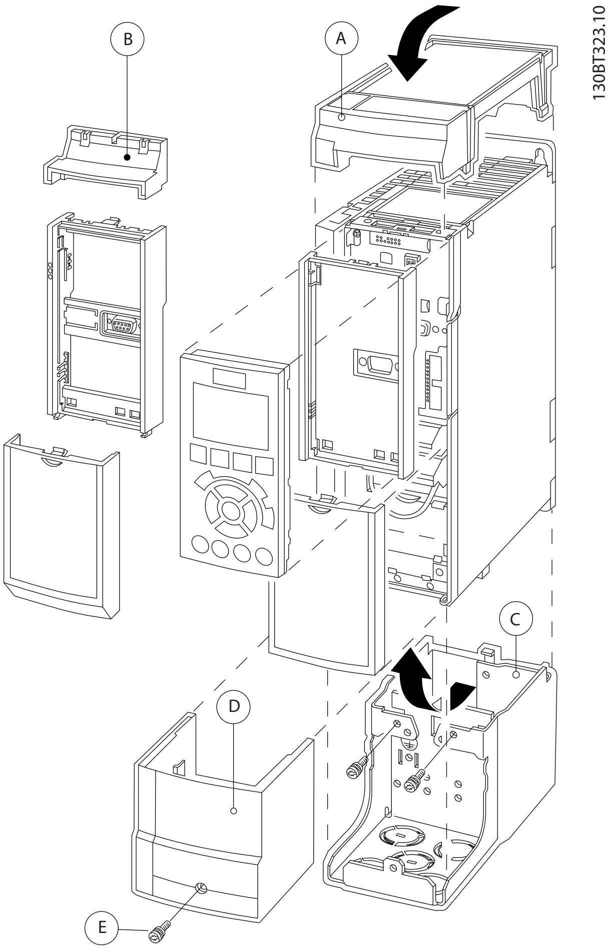


Illustration 3.19 Enclosure Type A2

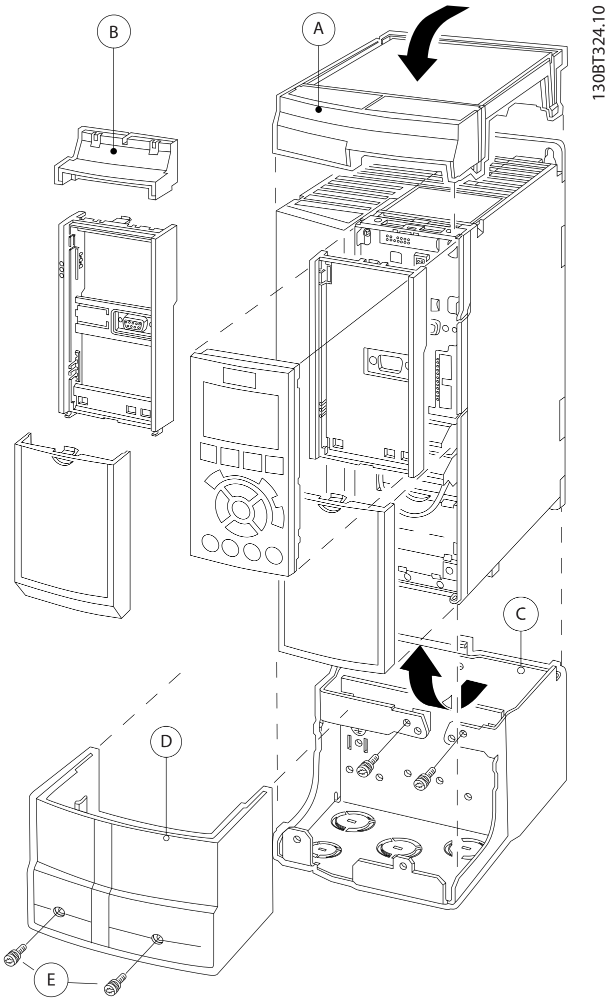


Illustration 3.20 Enclosure Type A3

A	Top cover
B	Brim
C	Base part
D	Base cover
E	Screw(s)

Table 3.12 Legend to *Illustration 3.19* and *Illustration 3.20*

Place the top cover as shown. If an A or B option is used the brim must be fitted to cover the top inlet. Place the base part C at the bottom of the frequency converter and use the clamps from the accessory bag to correctly fasten the cables. Holes for cable glands:
Size A2: 2x M25 and 3xM32
Size A3: 3xM25 and 3xM32

Enclosure type	Height A [mm]	Width B [mm]	Depth C* [mm]
A2	372	90	205
A3	372	130	205
B3	475	165	249
B4	670	255	246
C3	755	329	337
C4	950	391	337

Table 3.13 Dimensions

** If option A/B is used, the depth increases (see chapter 5.1.2 Mechanical Dimensions for details)*

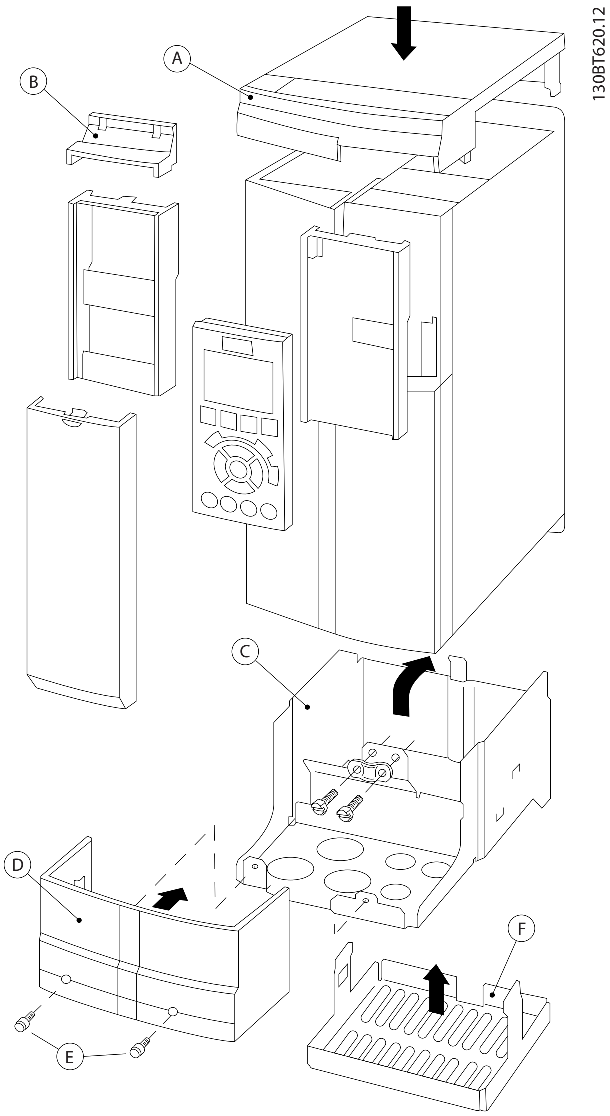


Illustration 3.21 Enclosure Type B3

Illustration 3.22 Enclosure Types B4 - C3 - C4

A	Top cover
B	Brim
C	Base part
D	Base cover
E	Screw(s)
F	Fan cover
G	Top clip

Table 3.14 Legend to *Illustration 3.21* and *Illustration 3.21*

When option module A and/or option module B is/are used, the brim (B) must be fitted to the top cover (A).

NOTICE

Side-by-side installation is not possible when using the *IP21/IP4X/TYPE 1 Enclosure Kit*

3.1.15 Output Filters

The high speed switching of the frequency converter produces some secondary effects, which influence the motor and the enclosed environment. These side effects are addressed by 2 different filter types, the dU/dt and the sine-wave filter.

dU/dt filters
Motor insulation stresses are often caused by the combination of rapid voltage and current increase. The rapid energy changes can also be reflected back to the DC-line in the inverter and cause shut down. The dU/dt filter is designed to reduce the voltage rise time/the rapid energy change in the motor and by that intervention avoid premature aging and flashover in the motor insulation. dU/dt filters have a positive influence on the radiation of magnetic noise in the cable that connects the frequency converter to the motor. The voltage wave form is still pulse shaped but the dU/dt ratio is reduced in comparison with the installation without filter.

Sine-wave filters
Sine-wave filters are designed to let only low frequencies pass. High frequencies are consequently shunted away which results in a sinusoidal phase to phase voltage waveform and sinusoidal current waveforms.
With the sinusoidal waveforms the use of special frequency converter motors with reinforced insulation is no longer needed. The acoustic noise from the motor is also damped as a consequence of the wave condition.
Besides the features of the dU/dt filter, the sine-wave filter also reduces insulation stress and bearing currents in the motor thus leading to prolonged motor lifetime and longer periods between services. Sine-wave filters enable use of longer motor cables in applications where the motor is installed far from the frequency converter. The length is unfortunately limited because the filter does not reduce leakage currents in the cables.

4 How to Order

4.1 Ordering Form

4.1.1 Drive Configurator

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

Order the frequency converter as either standard or with integral options by sending a type code string describing the product a to the local Danfoss sales office, i.e.:

FC-102P18KT4E21H1XGCXXXSXXXXAGBKCXXXXDX

The meaning of the characters in the string can be located in the pages containing the ordering numbers in *chapter 3 Selection*. In the example above, a Profibus LON works option and a General purpose I/O option is included in the frequency converter.

Ordering numbers for frequency converter standard variants can also be located in *chapter 4 How to Order*.

Configure the right frequency converter for the right application and generate the type code string in the Internet-based Drive Configurator. The Drive Configurator automatically generates an 8-digit sales number to be delivered to the local sales office.
Furthermore, establish a project list with several products and send it to a Danfoss sales representative.

Example of Drive Configurator interface set-up:
The numbers shown in the boxes refer to the letter/figure number of the Type Code String - read from left to right.

Product groups	1-3	
Frequency converter series	4-6	
Power rating	8-10	
Phases	11	
Mains Voltage	12	
Enclosure	13-15	
Enclosure type		
Enclosure class		
Control supply voltage		
Hardware configuration		
RFI filter	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 4.1 Example of Drive Configurator Interface Set-up

4.1.2 Type Code String Low and Medium Power

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	-		0		P				T					H						X	X	S	X	X	X	X	A		B		C					D	

130BA052.14

Illustration 4.1 Type Code String

Description	Pos.	Possible choice
Product group & FC Series	1-6	FC 102
Power rating	8-10	1.1- 90 kW (P1K1 - P90K)
Number of phases	11	3 phases (T)
Mains voltage	11-12	T 2: 200-240 V AC T 4: 380-480 V AC T 6: 525-600 V AC T 7: 525-690 V AC
Enclosure	13-15	E20: IP20 E21: IP21/NEMA Type 1 E55: IP55/NEMA Type 12 E66: IP66 P21: IP21/NEMA Type 1 w/ backplate P55: IP55/NEMA Type 12 w/ backplate Z55: A4 Frame IP55 Z66: A4 Frame IP66
RFI filter	16-17	H1: RFI filter class A1/B H2: RFI filter class A2 H3: RFI filter class A1/B (reduced cable length) Hx: No RFI filter
Brake	18	X: No brake chopper included B: Brake chopper included T: Safe Stop U: Safe + brake
Display	19	G: Graphical Local Control Panel (GLCP) N: Numeric Local Control Panel (NLCP) X: No Local Control Panel
Coating PCB	20	X. No coated PCB C: Coated PCB
Mains option	21	X: No Mains disconnect switch and Load Sharing 1: With Mains disconnect switch (IP55 only) 8: Mains disconnect and Load Sharing D: Load Sharing See Chapter 9 for max. cable sizes.

Description	Pos.	Possible choice
Adaptation	22	X: Standard cable entries O: European metric thread in cable entries (A4, A5, B1, B2 only) S: Imperial cable entries (A5, B1, B2 only)
Adaptation	23	Reserved
Software release	24-27	Actual software
Software language	28	
A options	29-30	AX: No options A0: MCA 101 Profibus DP V1 A4: MCA 104 DeviceNet AG: MCA 108 Lonworks AJ: MCA 109 BACnet gateway AL: MCA 120 Profinet AN: MCA 121 EtherNet/IP AQ: MCA 122 Modbus TCP
B options	31-32	BX: No option BK: MCB 101 General purpose I/O option BP: MCB 105 Relay option BO: MCB 109 Analog I/O option B2: MCB 112 PTC Thermistor Card B4: MCB 114 Sensor input option
C0 options MCO	33-34	CX: No options
C1 options	35	X: No options
C option software	36-37	XX: Standard software
D options	38-39	DX: No option D0: 24 V back- up

Table 4.2 Type Code Description

4.2 Ordering Numbers

4.2.1 Ordering Numbers: Options and Accessories

Type	Description	Ordering no.
Miscellaneous hardware I		
DC-link connector	Terminal block for DC-link connnection on A2/A3	130B1064
IP 21/4X top/TYPE 1 kit	IP21/NEMA1 Top + bottom A2	130B1122
IP 21/4X top/TYPE 1 kit	IP21/NEMA1 Top + bottom A3	130B1123
IP 21/4X top/TYPE 1 kit	IP21/NEMA1 Top + bottom B3	130B1187
IP 21/4X top/TYPE 1 kit	IP21/NEMA1 Top + bottom B4	130B1189
IP 21/4X top/TYPE 1 kit	IP21/NEMA1 Top + bottom C3	130B1191
IP 21/4X top/TYPE 1 kit	IP21/NEMA1 Top + bottom C4	130B1193
IP21/4X top	IP21 Top Cover A2	130B1132
IP21/4X top	IP21 Top Cover A3	130B1133
IP 21/4X top	IP21 Top Cover B3	130B1188
IP 21/4X top	IP21 Top Cover B4	130B1190
IP 21/4X top	IP21 Top Cover C3	130B1192
IP 21/4X top	IP21 Top Cover C4	130B1194
Panel Through Mount Kit	Enclosure, enclosure type A5	130B1028
Panel Through Mount Kit	Enclosure, enclosure type B1	130B1046
Panel Through Mount Kit	Enclosure, enclosure type B2	130B1047
Panel Through Mount Kit	Enclosure, enclosure type C1	130B1048
Panel Through Mount Kit	Enclosure, enclosure type C2	130B1049
Profibus D-Sub 9	Connector kit for IP20	130B1112
Profibus top entry kit	Top entry kit for Profibus connection - D + E enclosure types	176F1742
Terminal blocks	Screw terminal blocks for replacing spring loaded terminals 1 pc 10 pin 1 pc 6 pin and 1 pc 3 pin connectors	130B1116
Backplate	A5 IP55/NEMA 12	130B1098
Backplate	B1 IP21/IP55 / NEMA 12	130B3383
Backplate	B2 IP21/IP55 / NEMA 12	130B3397
Backplate	C1 IP21/IP55 / NEMA 12	130B3910
Backplate	C2 IP21/IP55 / NEMA 12	130B3911
Backplate	A5 IP66	130B3242
Backplate	B1 IP66	130B3434
Backplate	B2 IP66	130B3465
Backplate	C1 IP66	130B3468
Backplate	C2 IP66	130B3491
LCPs and kits		
LCP 101	Numerical Local Control Panel (NLCP)	130B1124
102	Graphical Local Control Panel (GLCP)	130B1107
cable	Separate cable, 3 m	175Z0929
kit	Panel mounting kit including graphical LCP, fasteners, 3 m cable and gasket	130B1113
LCP kit	Panel mounting kit including numerical LCP, fasteners and gasket	130B1114
kit	Panel mounting kit for all LCPs including fasteners, 3 m cable and gasket	130B1117
kit	Front mounting kit, IP55 enclosures	130B1129
kit	Panel mounting kit for all LCPs including fasteners and gasket - without cable	130B1170

Table 4.3 Options can be ordered as factory built-in options, see ordering information.

Type	Description	Comments
Options for Slot A		**Ordering no. Coated**
MCA 101	Profibus option DP V0/V1	130B1200
MCA 104	DeviceNet option	130B1202
MCA 108	Lonworks	130B1206
MCA 109	BACnet gateway for build-in. Not to be used with Relay Option MCB 105 card	130B1244
MCA 120	Profinet	130B1135
MCA 121	Ethernet	130B1219
Options for Slot B		
MCB 101	General purpose Input Output option	
MCB 105	Relay option	
MCB 109	Analog I/O option and battery back-up for real-time clock	130B1243
MCB 112	ATEX PTC	130B1137
MCB 114	Sensor input - unocated	130B1172
	Sensor input - coated	130B1272
Option for Slot D		
MCB 107	24 V DC back-up	130B1208
External Options		
Ethernet IP	Ethernet master	

Table 4.4 Options Ordering Information

For information on fieldbus and application option compatibility with older software versions, contact your Danfoss supplier.

Type	Description		
Spare Parts		**Ordering no.**	**Comments**
Control board FC	With Safe Stop Function	130B1150	
Control board FC	Without Safe Stop Function	130B1151	
Fan A2	Fan, enclosure type A2	130B1009	
Fan A3	Fan, enclosure type A3	130B1010	
Fan A5	Fan, enclosure type A5	130B1017	
Fan B1	Fan external, enclosure type B1	130B3407	
Fan B2	Fan external, enclosure type B2	130B3406	
Fan B3	Fan external, enclosure type B3	130B3563	
Fan B4	Fan external, 18.5/22 kW	130B3699	
Fan B4	Fan external 22/30 kW	130B3701	
Fan C1	Fan external, enclosure type C1	130B3865	
Fan C2	Fan external, enclosure type C2	130B3867	
Fan C3	Fan external, enclosure type C3	130B4292	
Fan C4	Fan external, enclosure type C4	130B4294	
Miscellaneous hardware II			
Accessory bag A2	Accessory bag,enclosure type A2	130B1022	
Accessory bag A3	Accessory bag, enclosure type A3	130B1022	
Accessory bag A4	Accessory bag for frame A4 w/o thread	130B0536	
Accessory bag A5	Accessory bag, enclosure type A5	130B1023	
Accessory bag B1	Accessory bag, enclosure type B1	130B2060	
Accessory bag B2	Accessory bag, enclosure type B2	130B2061	
Accessory bag B3	Accessory bag, enclosure type B3	130B0980	
Accessory bag B4	Accessory bag, enclosure type B4	130B1300	Small
Accessory bag B4	Accessory bag, enclosure type B4	130B1301	Big
Accessory bag C1	Accessory bag, enclosure type C1	130B0046	
Accessory bag C2	Accessory bag, enclosure type C2	130B0047	
Accessory bag C3	Accessory bag, enclosure type C3	130B0981	
Accessory bag C4	Accessory bag, enclosure type C4	130B0982	Small
Accessory bag C4	Accessory bag, enclosure type C4	130B0983	Big

Table 4.5 Accessories Ordering Information

4.2.2 Ordering Numbers: Harmonic Filters

Harmonic filters are used to reduce mains harmonics.

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

4

$I_{AHF,N}$ [A]	Typical Motor Used [kW]	Danfoss Ordering Number		Frequency converter size
		AHF 005	AHF 010	
10	1.1-4	175G6600	175G6622	P1K1, P4K0
19	5.5-7.5	175G6601	175G6623	P5K5-P7K5
26	11	175G6602	175G6624	P11K
35	15-18.5	175G6603	175G6625	P15K-P18K
43	22	175G6604	175G6626	P22K
72	30-37	175G6605	175G6627	P30K-P37K
101	45-55	175G6606	175G6628	P45K-P55K
144	75	175G6607	175G6629	P75K
180	90	175G6608	175G6630	P90K
217	110	175G6609	175G6631	P110
289	132	175G6610	175G6632	P132-P160
324	160	175G6611	175G6633	
370	200	175G6688	175G6691	P200
506	250	175G6609 + 175G6610	175G6631 + 175G6632	P250
578	315	2x 175G6610	2x 175G6632	P315
648	355	2x175G6611	2x175G6633	P355
694	400	175G6611 + 175G6688	175G6633 + 175G6691	P400
740	450	2x175G6688	2x175G6691	P450

Table 4.6 380-415 V AC, 50 Hz

$I_{AHF,N}$ [A]	Typical Motor Used [hp]	Danfoss Ordering Number		Frequency converter size
		AHF 005	AHF 010	
10	1.1-4	130B2540	130B2541	P1K1-P4K0
19	5.5-7.5	130B2460	130B2472	P5K5-P7K5
26	11	130B2461	130B2473	P11K
35	15-18.5	130B2462	130B2474	P15K, P18K
43	22	130B2463	130B2475	P22K
72	30-37	130B2464	130B2476	P30K-P37K
101	45-55	130B2465	130B2477	P45K-P55K
144	75	130B2466	130B2478	P75K
180	90	130B2467	130B2479	P90K
217	110	130B2468	130B2480	P110
289	132	130B2469	130B2481	P132
324	160	130B2470	130B2482	P160
370	200	130B2471	130B2483	P200
506	250	130B2468 + 130B2469	130B2480 + 130B2481	P250
578	315	2x 130B2469	2x 130B2481	P315
648	355	2x130B2470	2x130B2482	P355
694	400	130B2470 + 130B2471	130B2482 + 130B2483	P400
740	450	2x130B2471	130B2483	P450

Table 4.7 380-415 V AC, 60 Hz

$I_{AHF,N}$ [A]	Typical Motor Used [hp]	Danfoss Ordering Number		Frequency converter size
		AHF 005	AHF 010	
10	1.5-7.5	130B2538	130B2539	P1K1-P5K5
19	10-15	175G6612	175G6634	P7K5-P11K
26	20	175G6613	175G6635	P15K
35	25-30	175G6614	175G6636	P18K-P22K
43	40	175G6615	175G6637	P30K
72	50-60	175G6616	175G6638	P37K-P45K
101	75	175G6617	175G6639	P55K
144	100-125	175G6618	175G6640	P75K-P90K
180	150	175G6619	175G6641	P110
217	200	175G6620	175G6642	P132
289	250	175G6621	175G6643	P160
370	350	175G6690	175G6693	P200
434	350	2x175G6620	2x175G6642	P250
506	450	175G6620 + 175G6621	175G6642 + 175G6643	P315
578	500	2x 175G6621	2x 175G6643	P355
648	550-600	2x175G6689	2x175G6692	P400
694	600	175G6689 + 175G6690	175G6692 + 175G6693	P450
740	650	2x175G6690	2x175G6693	P500

Table 4.8 440-480 V AC, 60 Hz

Matching the frequency converter and filter is pre-calculated based on 400 V/480 V and on a typical motor load (4 pole) and 110 % torque.

$I_{AHF,N}$ [A]	Typical Motor Used [kW]	Danfoss Ordering Number		Frequency converter size
		AHF 005	AHF 010	
10	1.1-7.5	175G6644	175G6656	P1K1-P7K5
19	11	175G6645	175G6657	P11K
26	15-18.5	175G6646	175G6658	P15K-P18K
35	22	175G6647	175G6659	P22K
43	30	175G6648	175G6660	P30K
72	37-45	175G6649	175G6661	P45K-P55K
101	55	175G6650	175G6662	P75K
144	75-90	175G6651	175G6663	P90K-P110
180	110	175G6652	175G6664	P132
217	132	175G6653	175G6665	P160
289	160-200	175G6654	175G6666	P200-P250
324	250	175G6655	175G6667	P315
397	315	175G6652 + 175G6653	175G6641 + 175G6665	P400
434	355	2x175G6653	2x175G6665	P450
506	400	175G6653 + 175G6654	175G6665 + 175G6666	P500
578	450	2X 175G6654	2X 175G6666	P560
613	500	175G6654 + 175G6655	175G6666 + 175G6667	P630

Table 4.9 500-525 V AC, 50 Hz

$I_{AHF,N}$ [A]	Typical Motor Used [kW]	Danfoss Ordering Number		Frequency converter size
		AHF 005	AHF 010	
43	45	130B2328	130B2293	
72	45-55	130B2330	130B2295	P37K-P45K
101	75-90	130B2331	130B2296	P55K-P75K
144	110	130B2333	130B2298	P90K-P110
180	132	130B2334	130B2299	P132
217	160	130B2335	130B2300	P160
288	200-250	2x130B2333	130B2301	P200-P250
324	315	130B2334 + 130B2335	130B2302	P315
397	400	130B2334 + 130B2335	130B2299 + 130B2300	P400
434	450	2x130B2335	2x130B2300	P450
505	500	*	130B2300 + 130B2301	P500
576	560	*	2x130B2301	P560
612	630	*	130B2301 + 130B2300	P630
730	710	*	2x130B2302	P710

Table 4.10 690 VAC, 50 Hz

** For higher currents, contact Danfoss.*

4.2.3 Ordering Numbers: Sine Wave Filter Modules, 200-500 V AC

Frequency Converter Size			Minimum switching frequency [kHz]	Maximum output frequency [Hz]	Part No. IP20	Part No. IP00	Rated filter current at 50 Hz [A]
200-240 [V AC]	380-440 [V AC]	440-480 [V AC]					
	P1K1	P1K1	5	120	130B2441	130B2406	4.5
	P1K5	P1K5	5	120	130B2441	130B2406	4.5
	P2K2	P2K2	5	120	130B2443	130B2408	8
P1K5	P3K0	P3K0	5	120	130B2443	130B2408	8
	P4K0	P4K0	5	120	130B2444	130B2409	10
P2K2	P5K5	P5K5	5	120	130B2446	130B2411	17
P3K0	P7K5	P7K5	5	120	130B2446	130B2411	17
P4K0			5	120	130B2446	130B2411	17
P5K5	P11K	P11K	4	100	130B2447	130B2412	24
P7K5	P15K	P15K	4	100	130B2448	130B2413	38
	P18K	P18K	4	100	130B2448	130B2413	38
P11K	P22K	P22K	4	100	130B2307	130B2281	48
P15K	P30K	P30K	3	100	130B2308	130B2282	62
P18K	P37K	P37K	3	100	130B2309	130B2283	75
P22K	P45K	P55K	3	100	130B2310	130B2284	115
P30K	P55K	P75K	3	100	130B2310	130B2284	115
P37K	P75K	P90K	3	100	130B2311	130B2285	180
P45K	P90K	P110	3	100	130B2311	130B2285	180
	P110	P132	3	100	130B2312	130B2286	260
	P132	P160	3	100	130B2313	130B2287	260
	P160	P200	3	100	130B2313	130B2287	410
	P200	P250	3	100	130B2314	130B2288	410
	P250	P315	3	100	130B2314	130B2288	480
	P315	P315	2	100	130B2315	130B2289	660
	P355	P355	2	100	130B2315	130B2289	660
	P400	P400	2	100	130B2316	130B2290	750
		P450	2	100	130B2316	130B2290	750
	P450	P500	2	100	130B2317	130B2291	880
	P500	P560	2	100	130B2317	130B2291	880
	P560	P630	2	100	130B2318	130B2292	1200
	P630	P710	2	100	130B2318	130B2292	1200
	P710	P800	2	100	2x130B2317	2x130B2291	1500
	P800	P1M0	2	100	2x130B2317	2x130B2291	1500
	P1M0		2	100	2x130B2318	2x130B2292	1700

Table 4.11 Mains Supply 3x200 to 480 V AC

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

NOTICE

See also *Output Filter Design Guide*.

4.2.4 Ordering Numbers: Sine-Wave Filter Modules, 525-600/690 V AC

Frequency Converter Size		Minimum switching frequency [kHz]	Maximum output frequency [Hz]	Part No. IP20	Part No. IP00	Rated filter current at 50 Hz [A]
525-600 [V AC]	690 [V AC]					
P1K1		2	100	130B2341	130B2321	13
P1K5		2	100	130B2341	130B2321	13
P2k2		2	100	130B2341	130B2321	13
P3K0		2	100	130B2341	130B2321	13
P4K0		2	100	130B2341	130B2321	13
P5K5		2	100	130B2341	130B2321	13
P7K5		2	100	130B2341	130B2321	13
P11K		2	100	130B2342	130B2322	28
P15K		2	100	130B2342	130B2322	28
P18K		2	100	130B2342	130B2322	28
P22K		2	100	130B2342	130B2322	28
P30K		2	100	130B2343	130B2323	45
P37K	P45K	2	100	130B2344	130B2324	76
P45K	P55K	2	100	130B2344	130B2324	76
P55K	P75K	2	100	130B2345	130B2325	115
P75K	P90K	2	100	130B2345	130B2325	115
P90K	P110	2	100	130B2346	130B2326	165
	P132	2	100	130B2346	130B2326	165
	P160	2	100	130B2347	130B2327	260
	P200	2	100	130B2347	130B2327	260
	P250	2	100	130B2348	130B2329	303
	P315	2	100	130B2370	130B2341	430
	P355	1.5	100	130B2370	130B2341	430
	P400	1.5	100	130B2370	130B2341	430
	P450	1.5	100	130B2371	130B2342	530
	P500	1.5	100	130B2371	130B2342	530
	P560	1.5	100	130B2381	130B2337	660
	P630	1.5	100	130B2381	130B2337	660
	P710	1.5	100	130B2382	130B2338	765
	P800	1.5	100	130B2383	130B2339	940
	P900	1.5	100	130B2383	130B2339	940
	P1M0	1.5	100	130B2384	130B2340	1320
	P1M2	1.5	100	130B2384	130B2340	1320
	P1M4	1.5	100	2x130B2382	2x130B2338	1479

Table 4.12 Mains Supply 3x525-690 V AC

NOTICE

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

NOTICE

See also *Output Filter Design Guide*.

4.2.5 Ordering Numbers: dU/dt Filters, 380-480 V AC

Frequency converter Size		Minimum switching frequency [kHz]	Maximum output frequency [Hz]	Part No. IP20	Part No. IP00	Rated filter current at 50 Hz [A]
380-439 [V AC]	440-480 [V AC]					
P11K	P11K	4	100	130B2396	130B2385	24
P15K	P15K	4	100	130B2397	130B2386	45
P18K	P18K	4	100	130B2397	130B2386	45
P22K	P22K	4	100	130B2397	130B2386	45
P30K	P30K	3	100	130B2398	130B2387	75
P37K	P37K	3	100	130B2398	130B2387	75
P45K	P45K	3	100	130B2399	130B2388	110
P55K	P55K	3	100	130B2399	130B2388	110
P75K	P75K	3	100	130B2400	130B2389	182
P90K	P90K	3	100	130B2400	130B2389	182
P110	P110	3	100	130B2401	130B2390	280
P132	P132	3	100	130B2401	130B2390	280
P160	P160	3	100	130B2402	130B2391	400
P200	P200	3	100	130B2402	130B2391	400
P250	P250	3	100	130B2277	130B2275	500
P315	P315	2	100	130B2278	130B2276	750
P355	P355	2	100	130B2278	130B2276	750
P400	P400	2	100	130B2278	130B2276	750
	P450	2	100	130B2278	130B2276	750
P450	P500	2	100	130B2405	130B2393	910
P500	P560	2	100	130B2405	130B2393	910
P560	P630	2	100	130B2407	130B2394	1500
P630	P710	2	100	130B2407	130B2394	1500
P710	P800	2	100	130B2407	130B2394	1500
P800	P1M0	2	100	130B2407	130B2394	1500
P1M0		2	100	130B2410	130B2395	2300

Table 4.13 Mains supply 3x380 to 3x480 V AC

NOTICE

See also *Output Filter Design Guide*.

4

4.2.6 Ordering Numbers: dU/dt Filters, 525-600/690 V AC

Frequency converter Size		Minimum switching frequency [kHz]	Maximum output frequency [Hz]	Part No. IP20	Part No. IP00	Rated filter current at 50 Hz [A]
525-600 [V AC]	690 [V AC]					
P1K1		4	100	130B2423	130B2414	28
P1K5		4	100	130B2423	130B2414	28
P2K2		4	100	130B2423	130B2414	28
P3K0		4	100	130B2423	130B2414	28
P4K0		4	100	130B2424	130B2415	45
P5K5		4	100	130B2424	130B2415	45
P7K5		3	100	130B2425	130B2416	75
P11K		3	100	130B2425	130B2416	75
P15K		3	100	130B2426	130B2417	115
P18K		3	100	130B2426	130B2417	115
P22K		3	100	130B2427	130B2418	165
P30K		3	100	130B2427	130B2418	165
P37K	P45K	3	100	130B2425	130B2416	75
P45K	P55K	3	100	130B2425	130B2416	75
P55K	P75K	3	100	130B2426	130B2417	115
P75K	P90K	3	100	130B2426	130B2417	115
P90K	P110	3	100	130B2427	130B2418	165
	P132	2	100	130B2427	130B2418	165
	P160	2	100	130B2428	130B2419	260
	P200	2	100	130B2428	130B2419	260
	P250	2	100	130B2429	130B2420	310
	P315	2	100	130B2238	130B2235	430
	P400	2	100	130B2238	130B2235	430
	P450	2	100	130B2239	130B2236	530
	P500	2	100	130B2239	130B2236	530
	P560	2	100	130B2274	130B2280	630
	P630	2	100	130B2274	130B2280	630
	P710	2	100	130B2430	130B2421	765
	P800	2	100	130B2431	130B2422	1350
	P900	2	100	130B2431	130B2422	1350
	P1M0	2	100	130B2431	130B2422	1350
	P1M2	2	100	130B2431	130B2422	1350
	P1M4	2	100	2x130B2430	2x130B2421	1530

Table 4.14 Mains supply 3x525 to 3x690 V AC

NOTICE

See also *Output Filter Design Guide*.

4.2.7 Ordering Numbers: Brake Resistors

NOTICE

See *Brake Resistor Design Guide*.

5 Mechanical Installation

5.1 Mechanical Installation

5.1.1 Safety Requirements of Mechanical Installation

WARNING

Pay attention to the requirements that apply to integration and field mounting kit. Observe the information in the list to avoid serious injury or equipment damage, especially when installing large units.

CAUTION

The frequency converter is cooled by means of air circulation.
To protect the unit from overheating, it must be ensured that the ambient temperature *does not exceed the maximum temperature stated for the frequency converter* and that the 24-hour average temperature *is not exceeded*. Locate the maximum temperature and 24-hour average in *chapter 9.6.2 Derating for Ambient Temperature*.
If the ambient temperature is in the range of 45 °C - 55 °C, derating of the frequency converter becomes relevant, see *chapter 9.6.2 Derating for Ambient Temperature*.
The service life of the frequency converter is reduced if derating for ambient temperature is not taken into account.

5.1.2 Mechanical Dimensions

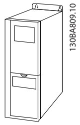
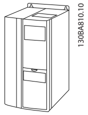
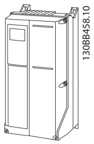
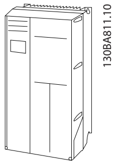
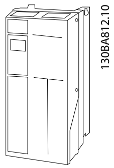
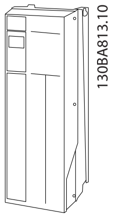
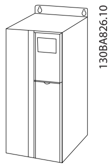
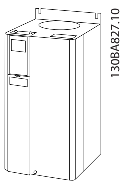
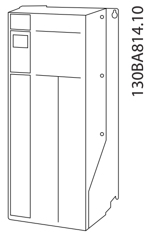
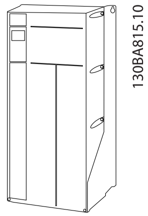
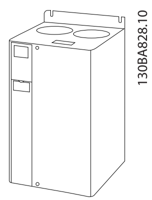
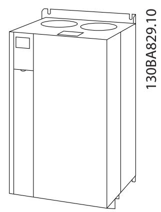
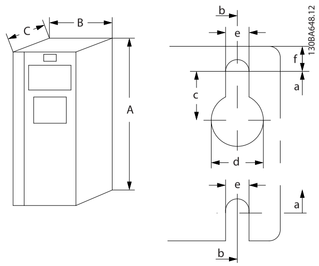
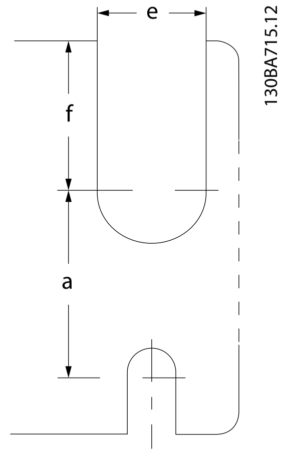
A2	A3	A4	A5	B1	B2	B3	B4	C1	C2	C3	C4
											
IP20/21	IP20/21	IP55/66	IP55/66	IP21/55/66	IP21/55/66	IP20	IP20	IP21/55/66	IP21/55/66	IP20	IP20
											
Accessory bags containing necessary brackets, screws and connectors are included with the frequency converters upon delivery.										Top and bottom mounting holes (B4, C3 and C4 only)	
* A5 in IP55/66 only											

Table 5.1 Mechanical Dimensions

Enclosure Type		A2		A3		A4	A5	B1	B2	B3	B4	C1	C2	C3	C4
Rated Power [kW] 200-240 V		1.1-2.2		3-3.7		1.1-2.2	1.1-3.7	5.5-11	15	5.5-11	15-18	18-30	37-45	22-30	37-45
380-480/500 V		1.1-4.0		5.5-7.5		1.1-4	1.1-7.5	11-18	22-30	11-18	22-37	37-55	75-90	45-55	75-90
525-600 V				1.1-7.5			1.1-7.5	11-18	22-30	11-18	22-37	37-55	75-90	45-55	75-90
525-690 V									11-30				37-90		
IP NEMA		20 Chassis	21 Type 1	20 Chassis	21 Type 1	55/66 Type 12	55/66 Type 12	21/ 55/66 Type 1/Type 12	21/55/66 Type 1/ Type 12	20 Chassis	20 Chassis	21/55/66 Type 1/ Type 12	21/55/66 Type 1/ Type 12	20 Chassis	20 Chassis
Height [mm]															
Height of back plate	A	268	375	268	375	390	420	480	650	399	520	680	770	550	660
Height with de-coupling plate for Fieldbus cables	A	374		374	-	-	-	-	-	420	595			630	800
Distance between mounting holes	a	257	350	257	350	401	402	454	624	380	495	648	739	521	631
Width [mm]															
Width of back plate	B	90	90	130	130	200	242	242	242	165	230	308	370	308	370
Width of back plate with one C option	B	130	130	170	170		242	242	242	205	230	308	370	308	370
Width of back plate with 2 C options	B	150	150	190	190		242	242	242	225	230	308	370	308	370
Distance between mounting holes	b	70	70	110	110	171	215	210	210	140	200	272	334	270	330
Depth [mm]															
Depth without option A/B	C	205	207	205	207	175	200	260	260	249	242	310	335	333	333
With option A/B	C	220	222	220	222	175	200	260	260	262	242	310	335	333	333
Screw holes [mm]															
	c	8.0	8.0	8.0	8.0	8.25	8.25	12	12	8		12.5	12.5		
	d	ø11	ø11	ø11	ø11	ø12	ø12	ø19	ø19	12		ø19	ø19		
	e	ø5.5	ø5.5	ø5.5	ø5.5	ø6.5	ø6.5	ø9	ø9	6.8	8.5	ø9	ø9	8.5	8.5
	f	9	9	6.5	6.5	6	9	9	9	7.9	15	9.8	9.8	17	17
Max weight [kg]		4.9	5.3	6.6	7.0	9.7	13.5/14.2	23	27	12	23.5	45	65	35	50
Front cover tightening torque [Nm]															
Plastic cover (low IP)		Click		Click		-	-	Click	Click	Click	Click	Click	Click	2.0	2.0
Metal cover (IP55/66)		-		-		1.5	1.5	2.2	2.2	-	-	2.2	2.2	2.0	2.0

Table 5.2 Weight and Dimensions

5

5.1.3 Accessory Bags

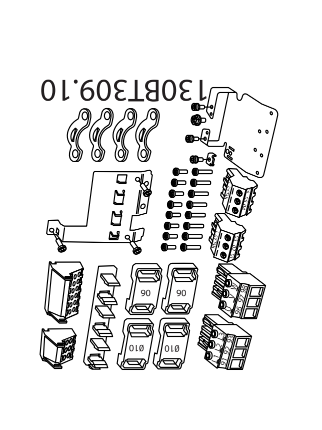
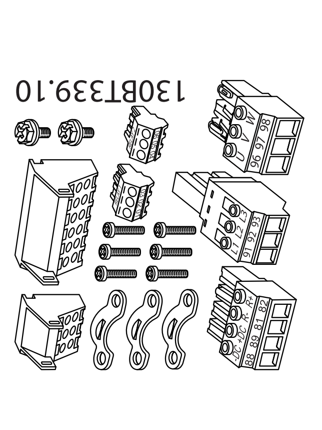
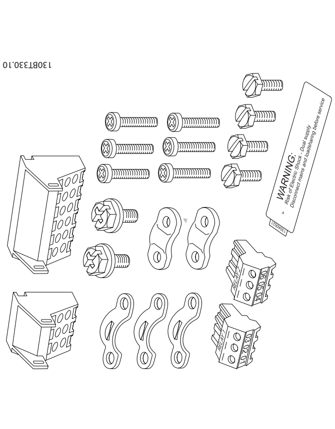
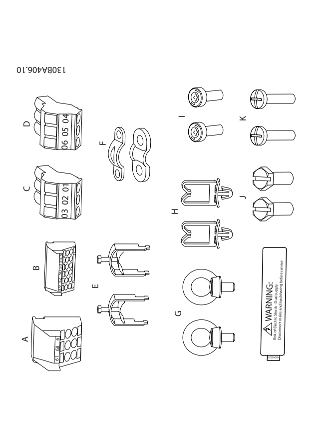
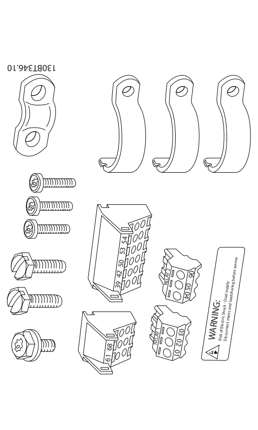
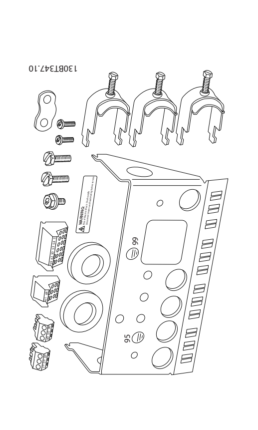
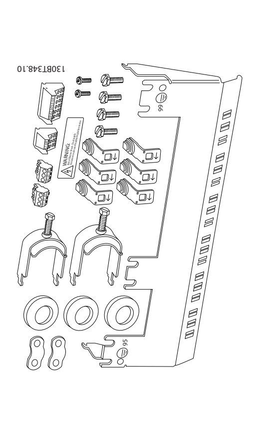
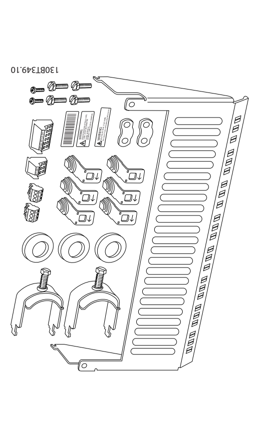
			
Enclosure type A1, A2 and A3	Enclosure type A5	Enclosure type B1 and B2	Enclosure type C1 and C2
			
Enclosure type B3	Enclosure type B4	Enclosure type C3	Enclosure type C4
1 + 2 only available in units with brake chopper. For DC-link connection (Load sharing), connector 1 can be ordered separately (Code no. 130B1064)			
An 8-pole connector is included in accessory bag for FC 102 without Safe Torque Off.			

Table 5.3 Parts included in Accessory Bags

5.1.4 Mechanical Mounting

All enclosure types allow side-by-side installation except when a *IP21/IP4X/TYPE 1 Enclosure Kit* is used (see *chapter 3.1 Options and Accessories*).

Side-by-side mounting
IP20 A and B enclosures can be arranged side-by-side with no clearance required between them, but the mounting order is important. *Illustration 5.1* shows how to mount the frames correctly.

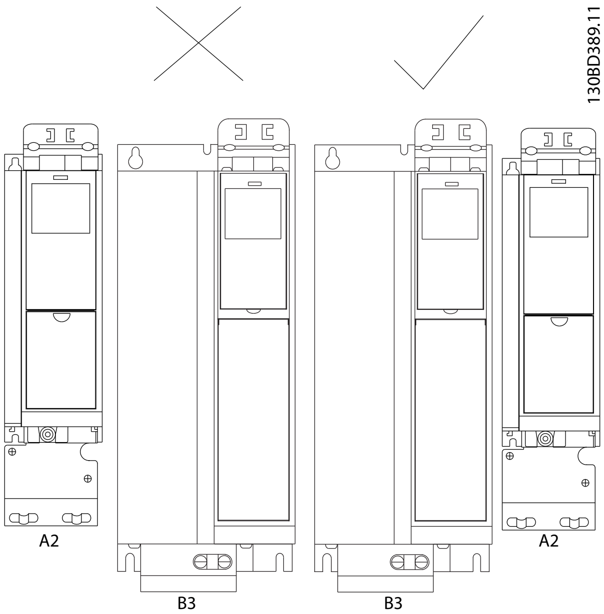


Illustration 5.1 Correct Side-by-side Mounting

If the IP 21 Enclosure kit is used on enclosure type A2 or A3, there must be a clearance between the frequency converters of min. 50 mm.

For optimal cooling conditions, allow a free-air passage above and below the frequency converter. See *Table 5.4*.

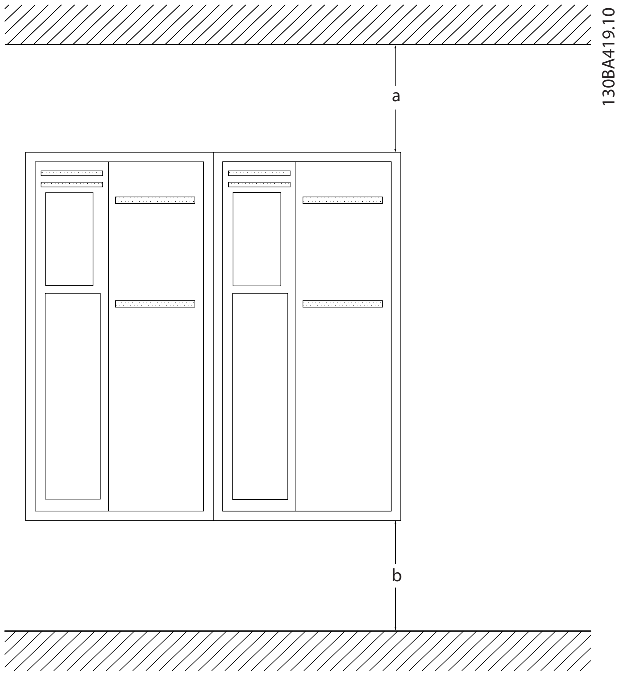


Illustration 5.2 Clearance

Enclosure type	A2/A3/A4/A5/B1	B2/B3/B4/C1/C3	C2/C4
a [mm]	100	200	225
b [mm]	100	200	225

Table 5.4 Air Passage for Different Enclosure Types

1. Drill holes in accordance with the measurements given.
2. Provide screws suitable for the surface for mounting the frequency converter. Retighten all 4 screws.

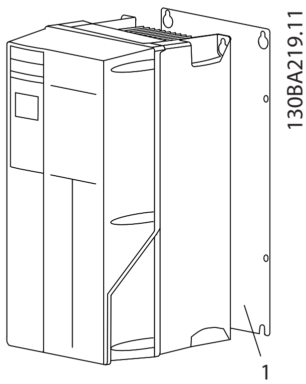


Illustration 5.3 Proper Mounting with Back Plate

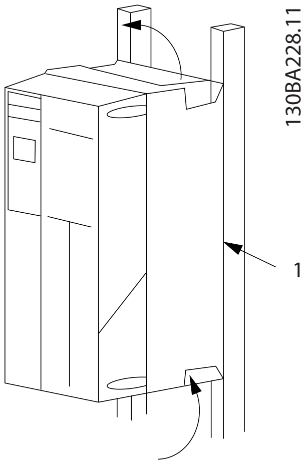


Illustration 5.4 Proper Mounting with Railings

Item	Description
1	Back plate

Table 5.5 Legend to *Illustration 5.4*

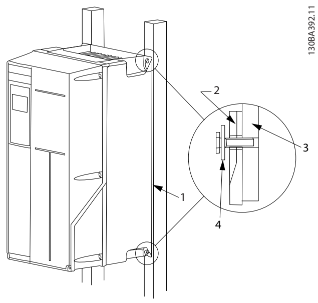


Illustration 5.5 Mounting on a Non-solid Back Wall

Mounting enclosure types A4, A5, B1, B2, C1 and C2 on a non-solid back wall, the frequency converter must be provided with a back plate, “1”, due to insufficient cooling air over the heat sink.

Enclosure	IP20	IP21	IP55	IP66
A2	*	*	-	-
A3	*	*	-	-
A4/A5	-	-	2	2
B1	-	*	2.2	2.2
B2	-	*	2.2	2.2
B3	*	-	-	-
B4	2	-	-	-
C1	-	*	2.2	2.2
C2	-	*	2.2	2.2
C3	2	-	-	-
C4	2	-	-	-
* = No screws to tighten				
- = Does not exist				

Table 5.6 Tightening Torque for Covers (Nm)

5.1.5 Field Mounting

For field mounting the IP21/IP4X top/TYPE 1 kits or IP54/55 units are recommended.

6 Electrical Installation

6.1 Connections - Enclosure Types A, B and C

6.1.1 Torque

NOTICE

Cables General
All cabling must comply with national and local regulations on cable cross-sections and ambient temperature. Copper (75 °C) conductors are recommended.

Aluminium Conductors
Terminals can accept aluminium conductors, but the conductor surface has to be clean and the oxidation must be removed and sealed by neutral acid-free Vaseline grease before the conductor is connected.
Furthermore the terminal screw must be retightened after 2 days due to softness of the aluminium. It is crucial to keep the connection a gas tight joint, otherwise the aluminium surface oxidises again.

Enclosure type	200-240 V [kW]	380-480 V [kW]	525-690 V [kW]	Cable for	Tightening up torque [Nm]
A2	1.1-2.2	1.1-4	-		
A3	3-3.7	5.5-7.5	-		
A4	1.1-2.2	1.1-4			
A5	1.1-3.7	1.1-7.5	-		
B1	5.5-11	11-18	-	Mains, Brake resistor, load sharing, Motor cables	1.8
				Relay	0.5-0.6
				Ground	2-3
B2	15	22-30	11-30	Mains, Brake resistor, load sharing cables	4.5
				Motor cables	4.5
				Relay	0.5-0.6
				Ground	2-3
B3	5.5-11	11-18	-	Mains, Brake resistor, load sharing, Motor cables	1.8
				Relay	0.5-0.6
				Ground	2-3
B4	15-18	22-37	-	Mains, Brake resistor, load sharing, Motor cables	4.5
				Relay	0.5-0.6
				Ground	2-3
C1	18-30	37-55	-	Mains, Brake resistor, load sharing cables	10
				Motor cables	10
				Relay	0.5-0.6
				Ground	2-3
C2	37-45	75-90	37-90	Mains, motor cables	14 (up to 9 5mm^2) 24 (over 95 mm^2)
				Load Sharing, brake cables	14
				Relay	0.5-0.6
				Ground	2-3
C3	22-30	45-55	-	Mains, Brake resistor, load sharing, Motor cables	10
				Relay	0.5-0.6
				Ground	2-3
C4	37-45	75-90	-	Mains, motor cables	14 (up to 95 mm^2) 24 (over 95 mm^2)
				Load Sharing, brake cables	14
				Relay	0.5-0.6
				Ground	2-3

Table 6.1 Tightening-up Torque

6.1.2 Removal of Knockouts for Extra Cables

1. Remove cable entry from the frequency converter (Avoiding foreign parts falling into the frequency converter when removing knockouts).
2. Cable entry has to be supported around the knockout to be removed.
3. The knockout can now be removed with a strong mandrel and a hammer.
4. Remove burrs from the hole.
5. Mount cable entry on frequency converter.

6.1.3 Connection to Mains and Earthing

NOTICE

The plug connector for power is plugable on frequency converters up to 7.5 kW.

1. Fit the 2 screws in the de-coupling plate, slide it into place and tighten the screws.
2. Make sure the frequency converter is properly grounded. Connect to ground connection (terminal 95). Use screw from the accessory bag.
3. Place plug connector 91 (L1), 92 (L2), 93 (L3) from the accessory bag onto the terminals labelled MAINS at the bottom of the frequency converter.
4. Attach mains wires to the mains plug connector.
5. Support the cable with the supporting enclosed brackets.

NOTICE

Check that mains voltage corresponds to the mains voltage of the name plate.

CAUTION

IT Mains
Do not connect 400 V frequency converters with RFI-filters to mains supplies with a voltage between phase and earth of more than 440 V.

CAUTION

The earth connection cable cross section must be at least 10 mm² or 2 x rated mains wires terminated separately according to EN 50178.

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

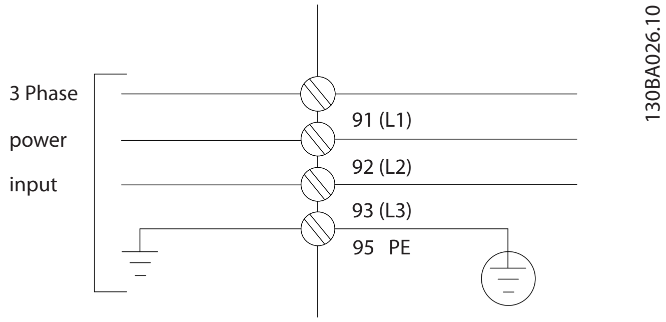


Illustration 6.1 Mains Connection

Mains connection for enclosure types A1, A2 and A3:

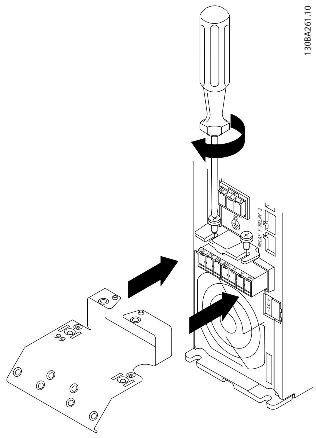


Illustration 6.2 Fitting the Mounting Plate

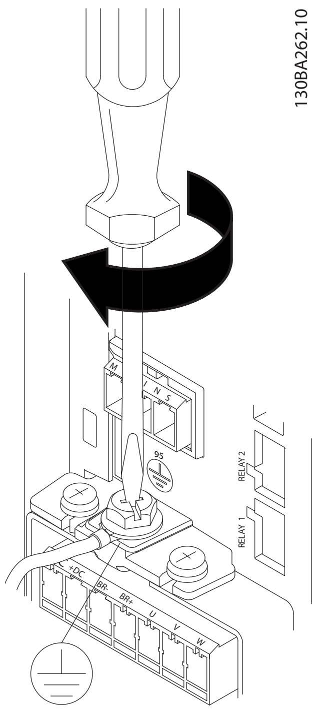


Illustration 6.3 Tightening the Earth Cable

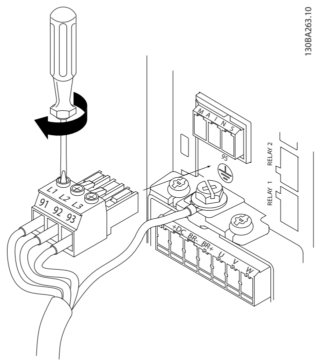


Illustration 6.4 Mounting Mains Plug and Tightening Wires

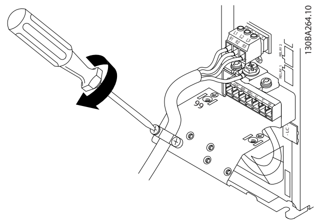


Illustration 6.5 Tighten Support Bracket

Mains connector enclosure type A4/A5 (IP55/66)

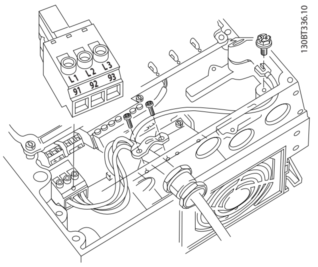


Illustration 6.6 Connecting to Mains and Earthing without Disconnector

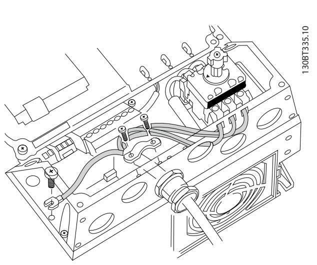


Illustration 6.7 Connecting to Mains and Earthing with Disconnector

When disconnector is used (enclosure type A4/A5) the PE must be mounted on the left side of the frequency converter.

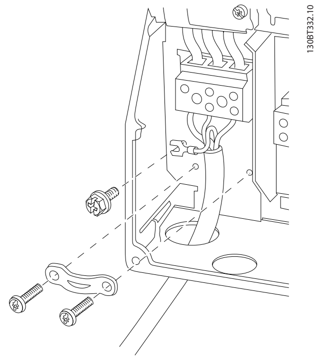


Illustration 6.8 Mains Connection Enclosure Types B1 and B2 (IP21/NEMA Type 1 and IP55/66/ NEMA Type 12)

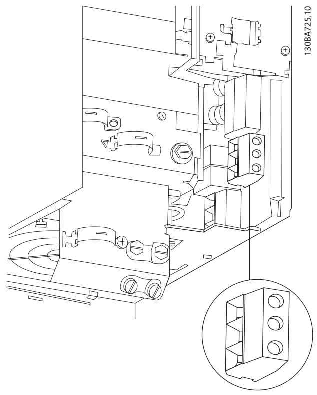


Illustration 6.9 Mains Connection Enclosure Type B3 (IP20)

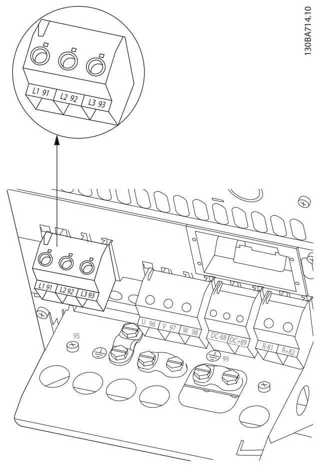


Illustration 6.10 Mains Connection Enclosure Type B4 (IP20)

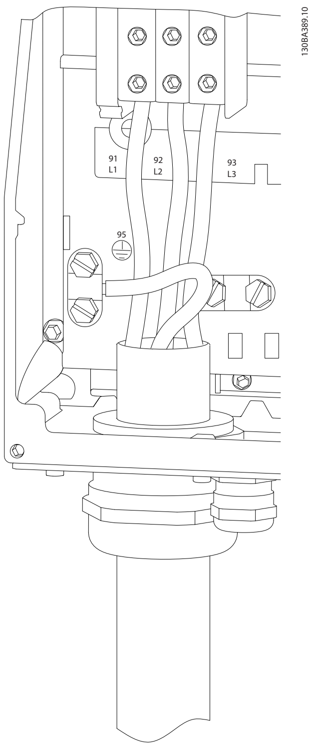


Illustration 6.11 Mains Connection Enclosure Types C1 and C2 (IP21/NEMA Type 1 and IP55/66/NEMA Type 12).

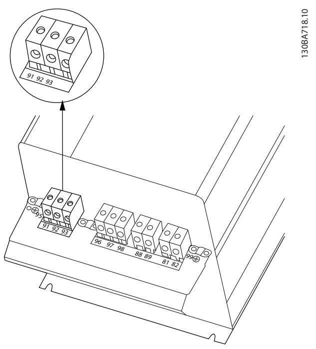


Illustration 6.12 Mains Connection Enclosure Type C3 (IP20).

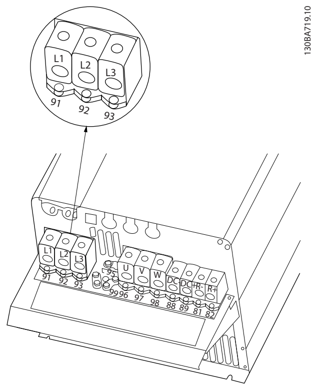


Illustration 6.13 Mains Connection Enclosure Type C4 (IP20).

Usually the power cables for mains are unscreened cables.

6.1.4 Motor Connection

NOTICE

To comply with EMC emission specifications, screened/ armoured cables are required. For more information, see *chapter 2.9.2 EMC Test Results*.

See *chapter 9 General Specifications and Troubleshooting* 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 decoupling 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 in the frequency converter.
If it is necessary to split the screen to install a motor isolator or motor relay, continue the screen with the lowest possible HF impedance.

Cable-length and cross-section

The frequency converter has been tested with a given length of cable and a given cross-section of that cable. If the cross-section is increased, the cable capacitance - and thus the leakage current - may increase, and the cable length must be reduced correspondingly. Keep the motor cable as short as possible to reduce the noise level and leakage currents.

Switching frequency

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

1. Fasten decoupling plate to the bottom of the frequency converter with screws and washers from the accessory bag.
2. Attach motor cable to terminals 96 (U), 97 (V), 98 (W).
3. Connect to earth connection (terminal 99) on decoupling plate with screws from the accessory bag.
4. Insert plug connectors 96 (U), 97 (V), 98 (W) (up to 7.5 kW) and motor cable to terminals labelled MOTOR.
5. Fasten screened cable to decoupling plate with screws and washers from the accessory bag.

All types of 3-phase asynchronous standard motors can be connected to the frequency converter. Normally, small motors are star-connected (230/400 V, Y). Large motors are normally delta-connected (400/690 V, Δ). Refer to the motor name plate for correct connection mode and voltage.

Procedure

1. Strip a section of the outer cable insulation.
2. Position the stripped wire under the cable clamp to establish mechanical fixation and electrical contact between cable screen and ground.
3. Connect ground wire to the nearest grounding terminal in accordance with grounding instructions.
4. Connect the 3-phase motor wiring to terminals 96 (U), 97 (V), and 98 (W), see *Illustration 6.14*.
5. Tighten terminals in accordance with the information provided in *chapter 6.1.1 Torque*.

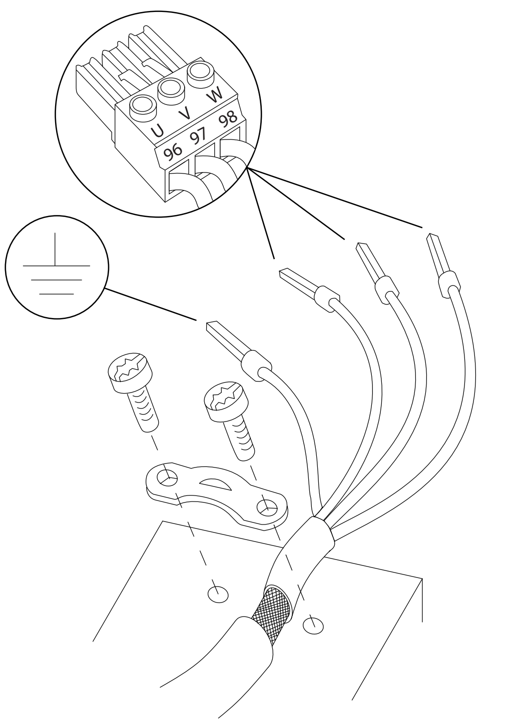


Illustration 6.14 Motor Connection

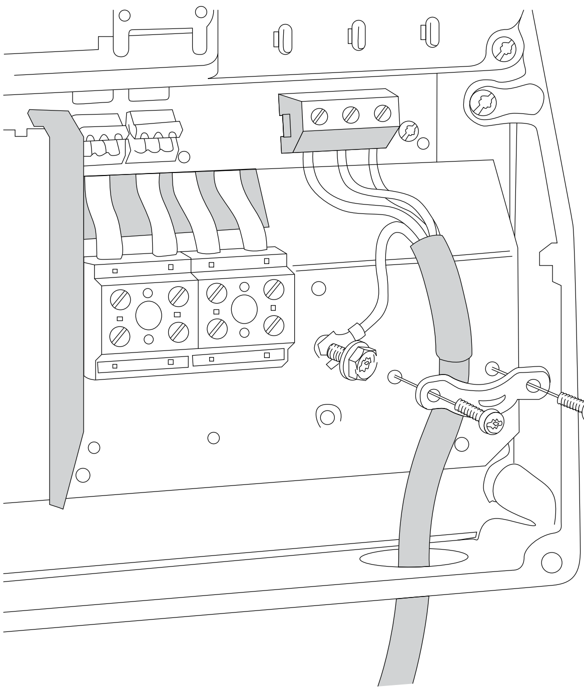


Illustration 6.15 Motor Connection for Enclosure Type B1 and B2 (IP21/NEMA Type 1, IP55/NEMA Type 12 and IP66/NEMA Type 4X)

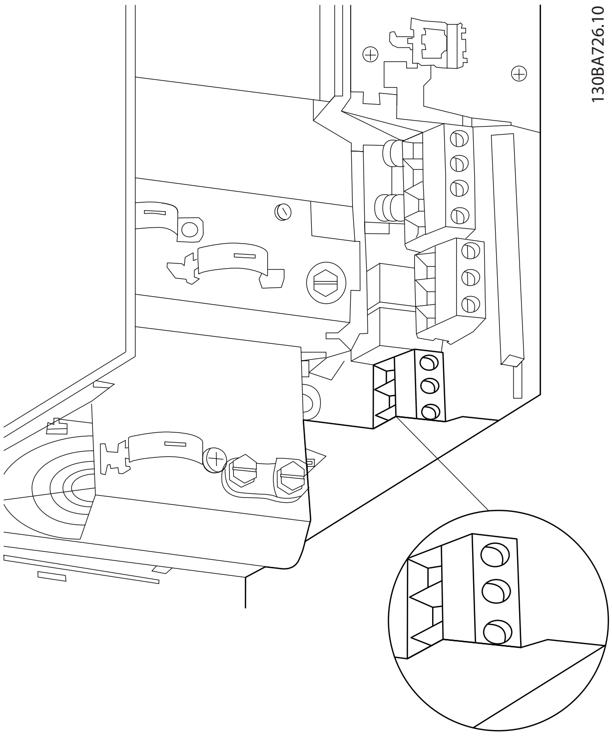


Illustration 6.16 Motor Connection for Enclosure Type B3

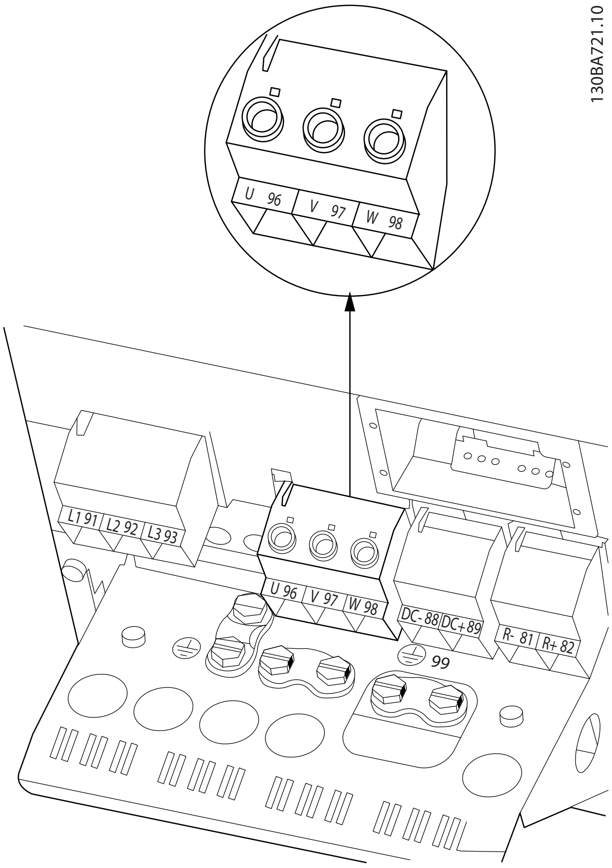


Illustration 6.17 Motor Connection for Enclosure Type B4

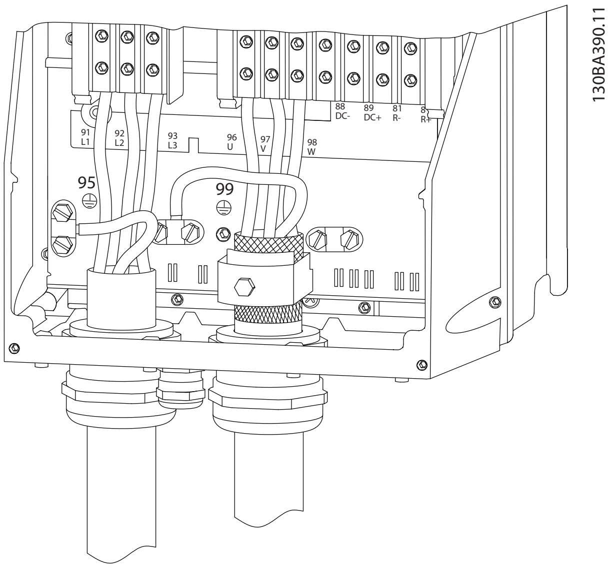


Illustration 6.18 Motor Connection Enclosure Typee C1 and C2 (IP21/NEMA Type 1 and IP55/66/NEMA Type 12)

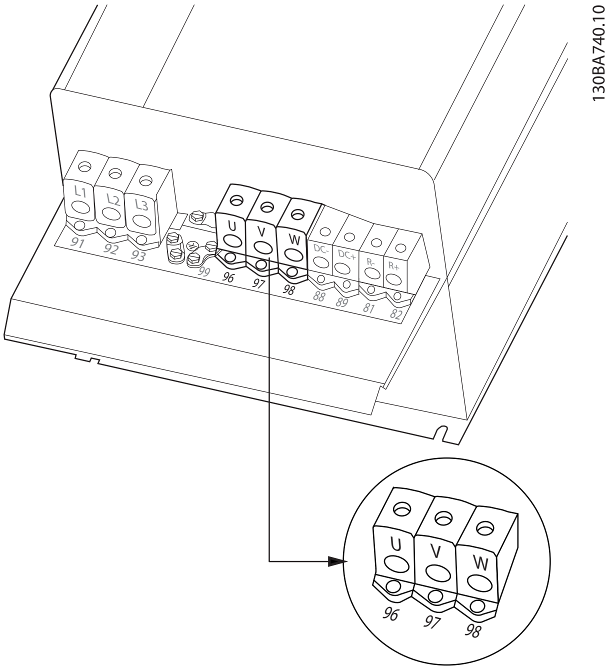


Illustration 6.19 Motor Connection for Enclosure Type C3 and C4

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 6.2 Terminal Descriptions

[1] *Protected Earth Connection*

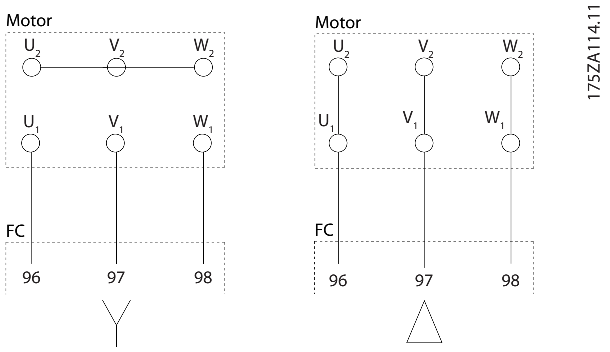


Illustration 6.20 Star and Delta Connections

NOTICE

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.

Cable entry holes

The suggested use of the holes are purely recommendations and other solutions are possible. Unused cable entry holes can be sealed with rubber grommets (for IP21).

* Tolerance ± 0.2 mm

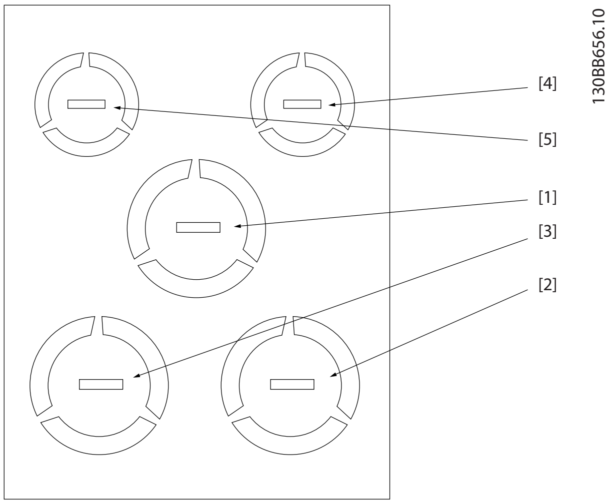


Illustration 6.21 A2 - IP21

Hole Number and recommended use	Dimensions[1] UL [in]	[mm]	Nearest metric
1) Mains	3/4	28.4	M25
2) Motor	3/4	28.4	M25
3) Brake/Load S	3/4	28.4	M25
4) Control Cable	1/2	22.5	M20
5) Control Cable	1/2	22.5	M20

Table 6.3 Legend to *Illustration 6.21*

[1] *Tolerance ± 0.2 mm*

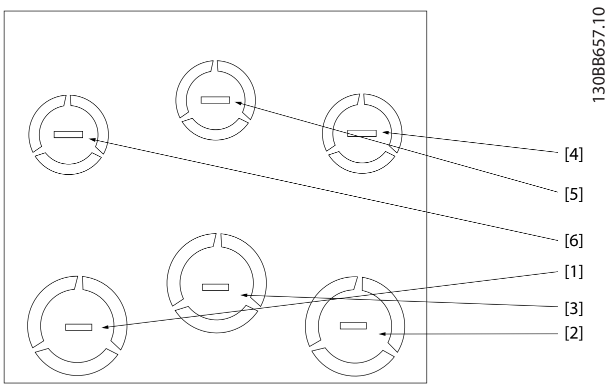


Illustration 6.22 A3 - IP21

Hole Number and recommended use	Dimensions[1] UL [in]	[mm]	Nearest metric
1) Mains	3/4	28.4	M25
2) Motor	3/4	28.4	M25
3) Brake/Load Sharing	3/4	28.4	M25
4) Control Cable	1/2	22.5	M20
5) Control Cable	1/2	22.5	M20
6) Control Cable	1/2	22.5	M20

Table 6.4 Legend to *Illustration 6.22*

[1] *Tolerance ± 0.2 mm*

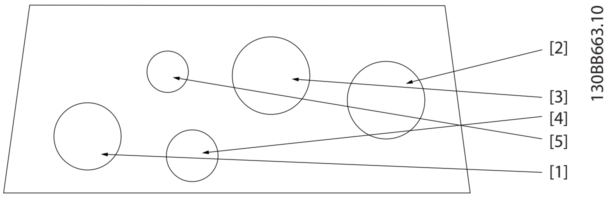


Illustration 6.23 A4 - IP55

Hole Number and recommended use	Dimensions[1)]		Nearest metric
	UL [in]	[mm]	
1) Mains	3/4	28.4	M25
2) Motor	3/4	28.4	M25
3) Brake/Load Sharing	3/4	28.4	M25
4) Control Cable	1/2	22.5	M20
5) Removed	-	-	-

Table 6.5 Legend to *Illustration 6.23*

[1)] *Tolerance ± 0.2 mm*

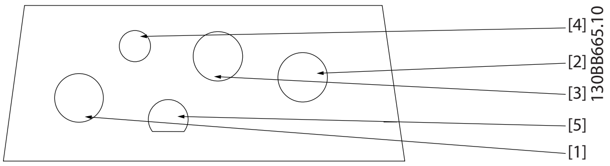


Illustration 6.24 A4 - IP55 Threaded Gland Holes

Hole Number and recommended use	Nearest metric
1) Mains	M25
2) Motor	M25
3) Brake/Load Sharing	M25
4) Control Cable	M16
5) Control Cable	M20

Table 6.6 Legend to *Illustration 6.24*

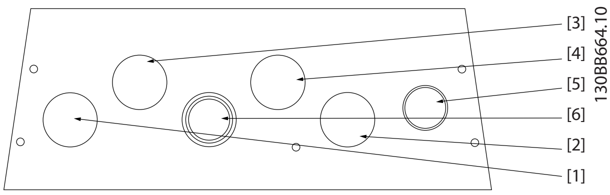


Illustration 6.25 A5 - IP55

Hole Number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Mains	3/4	28.4	M25
2) Motor	3/4	28.4	M25
3) Brake/Load Sharing	3/4	28.4	M25
4) Control Cable	3/4	28.4	M25
5) Control Cable[2]	3/4	28.4	M25
6) Control Cable [2]	3/4	28.4	M25

Table 6.7 Legend to *Illustration 6.25*

[1] Tolerance ± 0.2 mm

[2] Knock-out hole

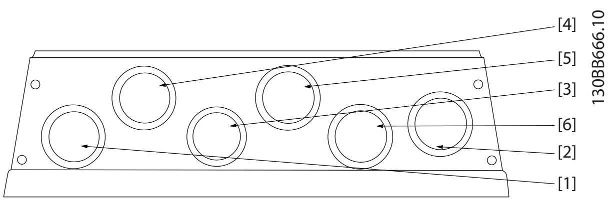


Illustration 6.26 A5- IP55 Threaded Gland Holes

Hole Number and recommended use	Nearest metric
1) Mains	M25
2) Motor	M25
3) Brake/Load S	28.4 mm[1]
4) Control Cable	M25
5) Control Cable	M25
6) Control Cable	M25

Table 6.8 Legend to *Illustration 6.26*

[1] Knock-out hole

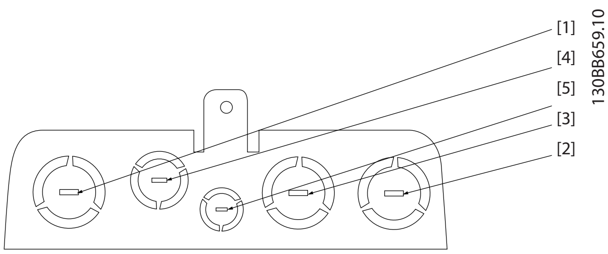


Illustration 6.27 B1 - IP21

Hole Number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Mains	1	34.7	M32
2) Motor	1	34.7	M32
3) Brake/Load Sharing	1	34.7	M32
4) Control Cable	1	34.7	M32
5) Control Cable	1/2	22.5	M20

Table 6.9 Legend to *Illustration 6.27*

[1] Tolerance ± 0.2 mm

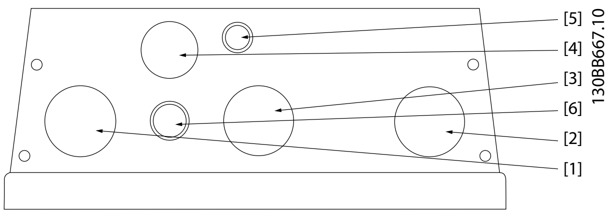


Illustration 6.28 B1 - IP55

Hole Number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Mains	1	34.7	M32
2) Motor	1	34.7	M32
3) Brake/Load Sharing	1	34.7	M32
4) Control Cable	3/4	28.4	M25
5) Control Cable	1/2	22.5	M20
5) Control Cable[2]	1/2	22.5	M20

Table 6.10 Legend to *Illustration 6.28*

[1] Tolerance ± 0.2 mm

[2] Knock-out hole

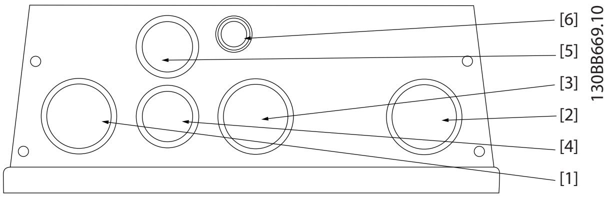


Illustration 6.29 B1 - IP55 Threaded Gland Holes

Hole Number and recommended use	Nearest metric
1) Mains	M32
2) Motor	M32
3) Brake/Load Sharing	M32
4) Control Cable	M25
5) Control Cable	M25
6) Control Cable	22.5 mm [1]

Table 6.11 Legend to *Illustration 6.29*

[1] *Knock-out hole*

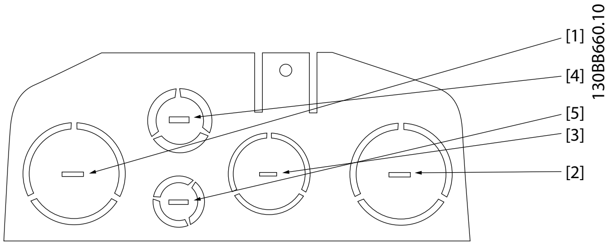


Illustration 6.30 B2 - IP21

Hole Number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Mains	1 1/4	44.2	M40
2) Motor	1 1/4	44.2	M40
3) Brake/Load Sharing	1	34.7	M32
4) Control Cable	3/4	28.4	M25
5) Control Cable	1/2	22.5	M20

Table 6.12 Legend to *Illustration 6.30*

[1] *Tolerance ± 0.2 mm*

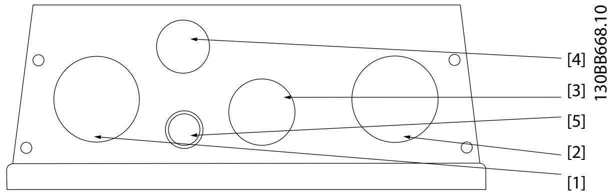


Illustration 6.31 B2 - IP55

Hole Number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Mains	1 1/4	44.2	M40
2) Motor	1 1/4	44.2	M40
3) Brake/Load Sharing	1	34.7	M32
4) Control Cable	3/4	28.4	M25
5) Control Cable[2]	1/2	22.5	M20

Table 6.13 Legend to *Illustration 6.31*

[1] *Tolerance ± 0.2 mm*

[2] *Knock-out hole*

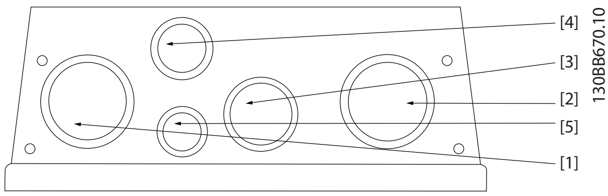


Illustration 6.32 B2 - IP55 Threaded Gland Holes

Hole Number and recommended use	Nearest metric
1) Mains	M40
2) Motor	M40
3) Brake/Load Sharing	M32
4) Control Cable	M25
5) Control Cable	M20

Table 6.14 Legend to *Illustration 6.32*

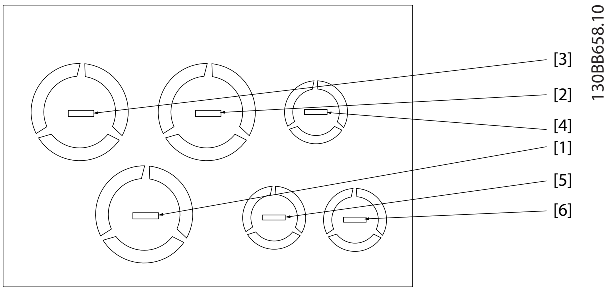


Illustration 6.33 B3 - IP21

Hole Number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Mains	1	34.7	M32
2) Motor	1	34.7	M32
3) Brake/Load Sharing	1	34.7	M32
4) Control Cable	1/2	22.5	M20
5) Control Cable	1/2	22.5	M20
6) Control Cable	1/2	22.5	M20

Table 6.15 Legend to *Illustration 6.33*

[1]) *Tolerance ± 0.2 mm*

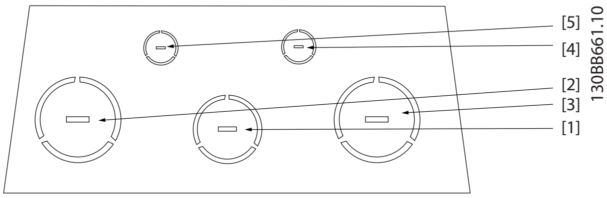


Illustration 6.34 C1 - IP21

Hole Number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Mains	2	63.3	M63
2) Motor	2	63.3	M63
3) Brake/Load Sharing	1 1/2	50.2	M50
4) Control Cable	3/4	28.4	M25
5) Control Cable	1/2	22.5	M20

Table 6.16 Legend to *Illustration 6.34*

[1]) *Tolerance ± 0.2 mm*

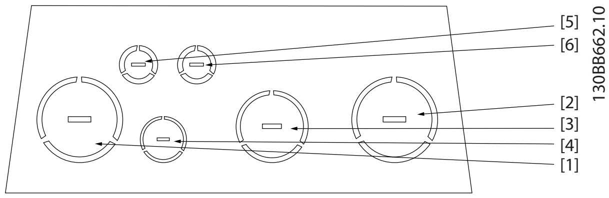


Illustration 6.35 C2 - IP21

Hole Number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Mains	2	63.3	M63
2) Motor	2	63.3	M63
3) Brake/Load Sharing	1 1/2	50.2	M50
4) Control Cable	3/4	28.4	M25
5) Control Cable	1/2	22.5	M20
6) Control Cable	1/2	22.5	M20

Table 6.17 Legend to *Illustration 6.35*

[1]) *Tolerance ± 0.2 mm*

6

6.1.5 Relay Connection

To set relay output, see parameter group *5-4* Relays*.

No.		
	01 - 02	make (normally open)
	01 - 03	break (normally closed)
	04 - 05	make (normally open)
	04 - 06	break (normally closed)

Table 6.18 Description of Relays

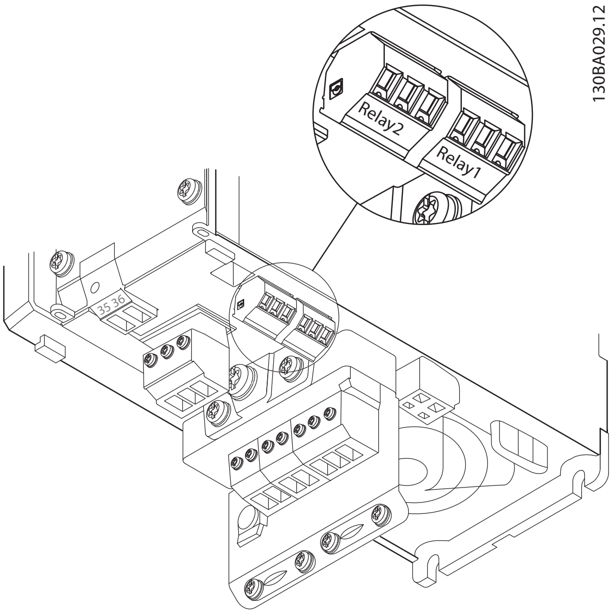


Illustration 6.36 Terminals for Relay Connection (Enclosure Types A1, A2 and A3).

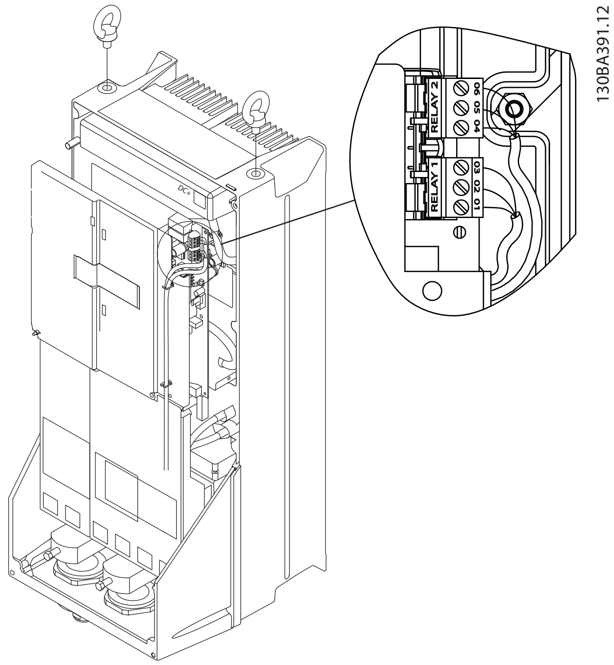


Illustration 6.37 Terminals for Relay Connection (Enclosure Types C1 and C2).

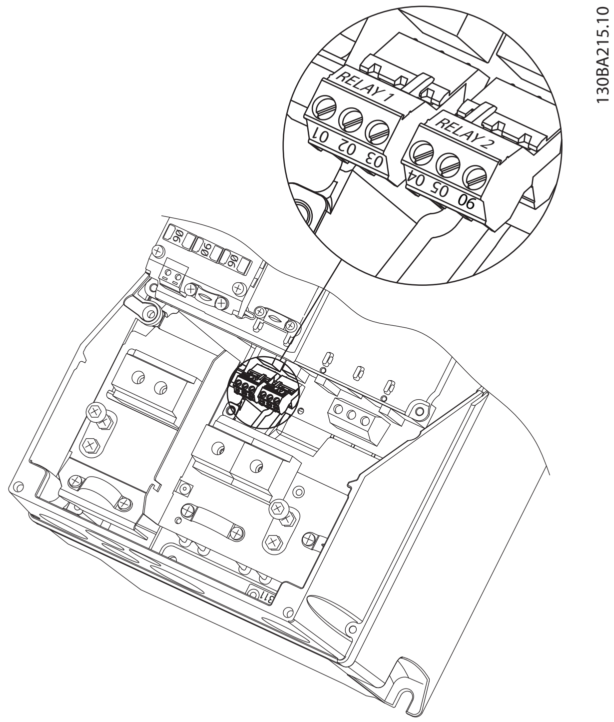


Illustration 6.38 Terminals for Relay Connection (Enclosure Types A5, B1 and B2).

6.2 Fuses and Circuit Breakers

6.2.1 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).

NOTICE

Using fuses and/or circuit breakers on the supply side is mandatory to ensure compliance with IEC 60364 for CE or NEC 2009 for UL.

⚠WARNING

Protect personnel and property against the consequence of component break-down internally in the frequency converter.

Branch Circuit Protection
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.

NOTICE

The recommendations given do not cover branch circuit protection for UL.

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

6.2.2 Recommendations

⚠WARNING

In case of malfunction, not following the recommen-dation may result in personnel risk and damage to the frequency converter and other equipment.

The tables in *chapter 6.2.4 Fuse 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 are recommended. 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.

If fuses/circuit breakers according to recommendations are selected, possible damage on the frequency converter is mainly limited to damages inside the unit.

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

6.2.3 CE Compliance

Fuses or circuit breakers are mandatory to comply with IEC 60364. Danfoss recommend using a selection of the following.

The fuses below are suitable for use on a circuit capable of delivering 100,000 Arms (symmetrical), 240 V, 480 V, 600 V, or 690 V depending on the frequency converter voltage rating. With the proper fusing the frequency converter, short-circuit current rating (SCCR) is 100,000 Arms.

The following UL listed fuses are suitable:

- UL248-4 class CC fuses
- UL248-8 class J fuses
- UL248-12 class R fuses (RK1)
- UL248-15 class T fuses

The following max. fuse size and type have been tested:

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6.2.4 Fuse Tables

Enclosure type	Power [kW]	Recommended fuse size	Recommended Max. fuse	Recommended circuit breaker Moeller	Max trip level [A]
A2	1.1-2.2	gG-10 (1.1-1.5) gG-16 (2.2)	gG-25	PKZM0-25	25
A3	3.0-3.7	gG-16 (3) gG-20 (3.7)	gG-32	PKZM0-25	25
B3	5.5-11	gG-25 (5.5-7.5) gG-32 (11)	gG-63	PKZM4-50	50
B4	15-18	gG-50 (15) gG-63 (18)	gG-125	NZMB1-A100	100
C3	22-30	gG-80 (22) aR-125 (30)	gG-150 (22) aR-160 (30)	NZMB2-A200	150
C4	37-45	aR-160 (37) aR-200 (45)	aR-200 (37) aR-250 (45)	NZMB2-A250	250
A4	1.1-2.2	gG-10 (1.1-1.5) gG-16 (2.2)	gG-32	PKZM0-25	25
A5	0.25-3.7	gG-10 (0.25-1.5) gG-16 (2.2-3) gG-20 (3.7)	gG-32	PKZM0-25	25
B1	5.5-11	gG-25 (5.5) gG-32 (7.5-11)	gG-80	PKZM4-63	63
B2	15	gG-50	gG-100	NZMB1-A100	100
C1	18-30	gG-63 (18.5) gG-80 (22) gG-100 (30)	gG-160 (18.5-22) aR-160 (30)	NZMB2-A200	160
C2	37-45	aR-160 (37) aR-200 (45)	aR-200 (37) aR-250 (45)	NZMB2-A250	250

Table 6.19 200-240 V, Enclosure Types A, B and C

Enclosure type	Power [kW]	Recommended fuse size	Recommended Max. fuse	Recommended circuit breaker Moeller	Max trip level [A]
A2	1.1-4.0	gG-10 (1.1-3) gG-16 (4)	gG-25	PKZM0-25	25
A3	5.5-7.5	gG-16	gG-32	PKZM0-25	25
B3	11-18	gG-40	gG-63	PKZM4-50	50
B4	22-37	gG-50 (22) gG-63 (30) gG-80 (37)	gG-125	NZMB1-A100	100
C3	45-55	gG-100 (45) gG-160 (55)	gG-150 (45) gG-160 (55)	NZMB2-A200	150
C4	75-90	aR-200 (75) aR-250 (90)	aR-250	NZMB2-A250	250
A4	1.1-4	gG-10 (1.1-3) gG-16 (4)	gG-32	PKZM0-25	25
A5	1.1-7.5	gG-10 (1.1-3) gG-16 (4-7.5)	gG-32	PKZM0-25	25
B1	11-18.5	gG-40	gG-80	PKZM4-63	63
B2	22-30	gG-50 (22) gG-63 (30)	gG-100	NZMB1-A100	100
C1	37-55	gG-80 (37) gG-100 (45) gG-160 (55)	gG-160	NZMB2-A200	160
C2	75-90	aR-200 (75) aR-250 (90)	aR-250	NZMB2-A250	250

Table 6.20 380-480 V, Enclosure Types A, B and C

Enclosure type	Power [kW]	Recommended fuse size	Recommended Max. fuse	Recommended circuit breaker Moeller	Max trip level [A]
A3	5.5-7.5	gG-10 (5.5) gG-16 (7.5)	gG-32	PKZM0-25	25
B3	11-18	gG-25 (11) gG-32 (15-18)	gG-63	PKZM4-50	50
B4	22-37	gG-40 (22) gG-50 (30) gG-63 (37)	gG-125	NZMB1-A100	100
C3	45-55	gG-63 (45) gG-100 (55)	gG-150	NZMB2-A200	150
C4	75-90	aR-160 (75) aR-200 (90)	aR-250	NZMB2-A250	250
A5	1.1-7.5	gG-10 (1.1-5.5) gG-16 (7.5)	gG-32	PKZM0-25	25
B1	11-18	gG-25 (11) gG-32 (15) gG-40 (18.5)	gG-80	PKZM4-63	63
B2	22-30	gG-50 (22) gG-63 (30)	gG-100	NZMB1-A100	100
C1	37-55	gG-63 (37) gG-100 (45) aR-160 (55)	gG-160 (37-45) aR-250 (55)	NZMB2-A200	160
C2	75-90	aR-200 (75-90)	aR-250	NZMB2-A250	250

Table 6.21 525-600 V, Enclosure Types A, B and C

Enclosure type	Power [kW]	Recommended fuse size	Recommended Max. fuse	Recommended circuit breaker Moeller	Max trip level [A]
A3	1.1 1.5 2.2 3 4 5.5 7.5	gG-6 gG-6 gG-6 gG-10 gG-10 gG-16 gG-16	gG-25 gG-25 gG-25 gG-25 gG-25 gG-25 gG-25	-	-
B2	11 15 18 22 30	gG-25 (11) gG-32 (15) gG-32 (18) gG-40 (22) gG-63 (30)	gG-63 gG-80 (30)	-	-
C2	37 45 55 75	gG-63 (37) gG-80 (45) gG-100 (55) gG-125 (75)	gG-100 (37) gG-125 (45) gG-160 (55-75)	-	-
C3	45 55	gG-80 gG-100	gG-100 gG-125	-	-

Table 6.22 525-690 V, Enclosure Types A, B and C

UL Compliance

Fuses or circuit breakers are mandatory to comply with NEC 2009. Danfoss recommends using a selection of the following

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.

	Recommended max. fuse					
Power [kW]	Bussmann Type RK1 [1)]	Bussmann Type J	Bussmann Type T	Bussmann Type CC	Bussmann Type CC	Bussmann Type CC
1.1	KTN-R-10	JKS-10	JJN-10	FNQ-R-10	KTK-R-10	LP-CC-10
1.5	KTN-R-15	JKS-15	JJN-15	FNQ-R-15	KTK-R-15	LP-CC-15
2.2	KTN-R-20	JKS-20	JJN-20	FNQ-R-20	KTK-R-20	LP-CC-20
3.0	KTN-R-25	JKS-25	JJN-25	FNQ-R-25	KTK-R-25	LP-CC-25
3.7	KTN-R-30	JKS-30	JJN-30	FNQ-R-30	KTK-R-30	LP-CC-30
5.5-7.5	KTN-R-50	KS-50	JJN-50	-	-	-
11	KTN-R-60	JKS-60	JJN-60	-	-	-
15	KTN-R-80	JKS-80	JJN-80	-	-	-
18.5-22	KTN-R-125	JKS-125	JJN-125	-	-	-
30	KTN-R-150	JKS-150	JJN-150	-	-	-
37	KTN-R-200	JKS-200	JJN-200	-	-	-
45	KTN-R-250	JKS-250	JJN-250	-	-	-

Table 6.23 200-240 V, Enclosure Types A, B and C

	Recommended max. fuse			
Power [kW]	SIBA Type RK1	Littel fuse Type RK1	Ferraz-Shawmut Type CC	Ferraz-Shawmut Type RK1[3)]
1.1	5017906-010	KLN-R-10	ATM-R-10	A2K-10-R
1.5	5017906-016	KLN-R-15	ATM-R-15	A2K-15-R
2.2	5017906-020	KLN-R-20	ATM-R-20	A2K-20-R
3.0	5017906-025	KLN-R-25	ATM-R-25	A2K-25-R
3.7	5012406-032	KLN-R-30	ATM-R-30	A2K-30-R
5.5-7.5	5014006-050	KLN-R-50	-	A2K-50-R
11	5014006-063	KLN-R-60	-	A2K-60-R
15	5014006-080	KLN-R-80	-	A2K-80-R
18.5-22	2028220-125	KLN-R-125	-	A2K-125-R
30	2028220-150	KLN-R-150	-	A2K-150-R
37	2028220-200	KLN-R-200	-	A2K-200-R
45	2028220-250	KLN-R-250	-	A2K-250-R

Table 6.24 200-240 V, Enclosure Types A, B and C

	Recommended max. fuse			
Power [kW]	Bussmann Type JFHR2[2)]	Littel fuse JFHR2	Ferraz-Shawmut JFHR2[4)]	Ferraz-Shawmut J
1.1	FWX-10	-	-	HSJ-10
1.5	FWX-15	-	-	HSJ-15
2.2	FWX-20	-	-	HSJ-20
3.0	FWX-25	-	-	HSJ-25
3.7	FWX-30	-	-	HSJ-30
5.5-7.5	FWX-50	-	-	HSJ-50
11	FWX-60	-	-	HSJ-60
15-18.5	FWX-80	-	-	HSJ-80
22	FWX-125	-	-	HSJ-125
30	FWX-150	L25S-150	A25X-150	HSJ-150
37	FWX-200	L25S-200	A25X-200	HSJ-200
45	FWX-250	L25S-250	A25X-250	HSJ-250

Table 6.25 200-240 V, Enclosure Types A, B and C

1) KTS-fuses from Bussmann may substitute KTN for 240 V frequency converters.

2) FWH-fuses from Bussmann may substitute FWX for 240 V frequency converters.

3) A6KR fuses from FERRAZ SHAWMUT may substitute A2KR for 240 V frequency converters.

4) A50X fuses from FERRAZ SHAWMUT may substitute A25X for 240 V frequency converters.

	Recommended max. fuse					
Power [kW]	Bussmann Type RK1	Bussmann Type J	Bussmann Type T	Bussmann Type CC	Bussmann Type CC	Bussmann Type CC
1.1	KTS-R-6	JKS-6	JJS-6	FNQ-R-6	KTK-R-6	LP-CC-6
1.5-2.2	KTS-R-10	JKS-10	JJS-10	FNQ-R-10	KTK-R-10	LP-CC-10
3	KTS-R-15	JKS-15	JJS-15	FNQ-R-15	KTK-R-15	LP-CC-15
4	KTS-R-20	JKS-20	JJS-20	FNQ-R-20	KTK-R-20	LP-CC-20
5.5	KTS-R-25	JKS-25	JJS-25	FNQ-R-25	KTK-R-25	LP-CC-25
7.5	KTS-R-30	JKS-30	JJS-30	FNQ-R-30	KTK-R-30	LP-CC-30
11-15	KTS-R-40	JKS-40	JJS-40	-	-	-
18	KTS-R-50	JKS-50	JJS-50	-	-	-
22	KTS-R-60	JKS-60	JJS-60	-	-	-
30	KTS-R-80	JKS-80	JJS-80	-	-	-
37	KTS-R-100	JKS-100	JJS-100	-	-	-
45	KTS-R-125	JKS-125	JJS-125	-	-	-
55	KTS-R-150	JKS-150	JJS-150	-	-	-
75	KTS-R-200	JKS-200	JJS-200	-	-	-
90	KTS-R-250	JKS-250	JJS-250	-	-	-

Table 6.26 380-480 V, Enclosure Types A, B and C

	Recommended max. fuse			
Power [kW]	SIBA Type RK1	Littel fuse Type RK1	Ferraz-Shawmut Type CC	Ferraz-Shawmut Type RK1
1.1-2.2	5017906-010	KLS-R-10	ATM-R-10	A6K-10-R
3	5017906-016	KLS-R-15	ATM-R-15	A6K-15-R
4	5017906-020	KLS-R-20	ATM-R-20	A6K-20-R
5.5	5017906-025	KLS-R-25	ATM-R-25	A6K-25-R
7.5	5012406-032	KLS-R-30	ATM-R-30	A6K-30-R
11-15	5014006-040	KLS-R-40	-	A6K-40-R
18	5014006-050	KLS-R-50	-	A6K-50-R
22	5014006-063	KLS-R-60	-	A6K-60-R
30	2028220-100	KLS-R-80	-	A6K-80-R
37	2028220-125	KLS-R-100	-	A6K-100-R
45	2028220-125	KLS-R-125	-	A6K-125-R
55	2028220-160	KLS-R-150	-	A6K-150-R
75	2028220-200	KLS-R-200	-	A6K-200-R
90	2028220-250	KLS-R-250	-	A6K-250-R

Table 6.27 380-500 V, Enclosure Types A, B and C

	Recommended max. fuse			
Power [kW]	Bussmann JFHR2	Ferraz- Shawmut J	Ferraz- Shawmut JFHR2[1)]	Littel fuse JFHR2
1.1-2.2	FWH-10	HSJ-10	-	-
3	FWH-15	HSJ-15	-	-
4	FWH-20	HSJ-20	-	-
5.5	FWH-25	HSJ-25	-	-
7.5	FWH-30	HSJ-30	-	-
11-15	FWH-40	HSJ-40	-	-
18	FWH-50	HSJ-50	-	-
22	FWH-60	HSJ-60	-	-
30	FWH-80	HSJ-80	-	-
37	FWH-100	HSJ-100	-	-
45	FWH-125	HSJ-125	-	-
55	FWH-150	HSJ-150	-	-
75	FWH-200	HSJ-200	A50-P-225	L50-S-225
90	FWH-250	HSJ-250	A50-P-250	L50-S-250

Table 6.28 380-480 V, Enclosure Types A, B and C

[1)] Ferraz-Shawmut A50QS fuses may substitute for A50P fuses.

	Recommended max. fuse					
Power [kW]	Bussmann Type RK1	Bussmann Type J	Bussmann Type T	Bussmann Type CC	Bussmann Type CC	Bussmann Type CC
1.1	KTS-R-5	JKS-5	JJS-6	FNQ-R-5	KTK-R-5	LP-CC-5
1.5-2.2	KTS-R-10	JKS-10	JJS-10	FNQ-R-10	KTK-R-10	LP-CC-10
3	KTS-R15	JKS-15	JJS-15	FNQ-R-15	KTK-R-15	LP-CC-15
4	KTS-R20	JKS-20	JJS-20	FNQ-R-20	KTK-R-20	LP-CC-20
5.5	KTS-R-25	JKS-25	JJS-25	FNQ-R-25	KTK-R-25	LP-CC-25
7.5	KTS-R-30	JKS-30	JJS-30	FNQ-R-30	KTK-R-30	LP-CC-30
11-15	KTS-R-35	JKS-35	JJS-35	-	-	-
18	KTS-R-45	JKS-45	JJS-45	-	-	-
22	KTS-R-50	JKS-50	JJS-50	-	-	-
30	KTS-R-60	JKS-60	JJS-60	-	-	-
37	KTS-R-80	JKS-80	JJS-80	-	-	-
45	KTS-R-100	JKS-100	JJS-100	-	-	-
55	KTS-R-125	JKS-125	JJS-125	-	-	-
75	KTS-R-150	JKS-150	JJS-150	-	-	-
90	KTS-R-175	JKS-175	JJS-175	-	-	-

Table 6.29 525-600 V, Enclosure Types A, B and C

	Recommended max. fuse			
Power [kW]	SIBA Type RK1	Littel fuse Type RK1	Ferraz-Shawmut Type RK1	Ferraz-Shawmut J
1.1	5017906-005	KLS-R-005	A6K-5-R	HSJ-6
1.5-2.2	5017906-010	KLS-R-010	A6K-10-R	HSJ-10
3	5017906-016	KLS-R-015	A6K-15-R	HSJ-15
4	5017906-020	KLS-R-020	A6K-20-R	HSJ-20
5.5	5017906-025	KLS-R-025	A6K-25-R	HSJ-25
7.5	5017906-030	KLS-R-030	A6K-30-R	HSJ-30
11-15	5014006-040	KLS-R-035	A6K-35-R	HSJ-35
18	5014006-050	KLS-R-045	A6K-45-R	HSJ-45
22	5014006-050	KLS-R-050	A6K-50-R	HSJ-50
30	5014006-063	KLS-R-060	A6K-60-R	HSJ-60
37	5014006-080	KLS-R-075	A6K-80-R	HSJ-80
45	5014006-100	KLS-R-100	A6K-100-R	HSJ-100
55	2028220-125	KLS-R-125	A6K-125-R	HSJ-125
75	2028220-150	KLS-R-150	A6K-150-R	HSJ-150
90	2028220-200	KLS-R-175	A6K-175-R	HSJ-175

Table 6.30 525-600 V, Enclosure Types A, B and C

[1)] 170M fuses shown from Bussmann 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.

	Recommended max. fuse					
Power [kW]	Bussmann Type RK1	Bussmann Type J	Bussmann Type T	Bussmann Type CC	Bussmann Type CC	Bussmann Type CC
[kW]						
1.1	KTS-R-5	JKS-5	JJS-6	FNQ-R-5	KTK-R-5	LP-CC-5
1.5-2.2	KTS-R-10	JKS-10	JJS-10	FNQ-R-10	KTK-R-10	LP-CC-10
3	KTS-R15	JKS-15	JJS-15	FNQ-R-15	KTK-R-15	LP-CC-15
4	KTS-R20	JKS-20	JJS-20	FNQ-R-20	KTK-R-20	LP-CC-20
5.5	KTS-R-25	JKS-25	JJS-25	FNQ-R-25	KTK-R-25	LP-CC-25
7.5	KTS-R-30	JKS-30	JJS-30	FNQ-R-30	KTK-R-30	LP-CC-30
11-15	KTS-R-35	JKS-35	JJS-35	-	-	-
18	KTS-R-45	JKS-45	JJS-45	-	-	-
22	KTS-R-50	JKS-50	JJS-50	-	-	-
30	KTS-R-60	JKS-60	JJS-60	-	-	-
37	KTS-R-80	JKS-80	JJS-80	-	-	-
45	KTS-R-100	JKS-100	JJS-100	-	-	-
55	KTS-R-125	JKS-125	JJS-125	-	-	-
75	KTS-R-150	JKS-150	JJS-150	-	-	-
90	KTS-R-175	JKS-175	JJS-175	-	-	-

Table 6.31 525-690 V, Enclosure Types A, B and C

	Recommended max. fuse							
Power [kW]	Max. prefuse	Bussmann E52273 RK1/JDDZ	Bussmann E4273 J/JDDZ	Bussmann E4273 T/JDDZ	SIBA E180276 RK1/JDDZ	LittelFuse E81895 RK1/JDDZ	Ferraz-Shawmut E163267/E2137 RK1/JDDZ	Ferraz-Shawmut E2137 J/HSJ
11-15	30 A	KTS-R-30	JKS-30	JKJS-30	5017906-030	KLS-R-030	A6K-30-R	HST-30
18.5	45 A	KTS-R-45	JKS-45	JJS-45	5014006-050	KLS-R-045	A6K-45-R	HST-45
30	60 A	KTS-R-60	JKS-60	JJS-60	5014006-063	KLS-R-060	A6K-60-R	HST-60
37	80 A	KTS-R-80	JKS-80	JJS-80	5014006-080	KLS-R-075	A6K-80-R	HST-80
45	90 A	KTS-R-90	JKS-90	JJS-90	5014006-100	KLS-R-090	A6K-90-R	HST-90
55	100 A	KTS-R-100	JKS-100	JJS-100	5014006-100	KLS-R-100	A6K-100-R	HST-100
75	125 A	KTS-R-125	JKS-125	JJS-125	2028220-125	KLS-150	A6K-125-R	HST-125
90	150 A	KTS-R-150	JKS-150	JJS-150	2028220-150	KLS-175	A6K-150-R	HST-150

Table 6.32 *525-690 V, Enclosure Types B and C

** UL compliance only 525-600 V*

6.3 Disconnectors and Contactors

6.3.1 Mains Disconnectors

Assembling of IP55/NEMA Type 12 (enclosure type A5) with mains disconnector

Mains switch is placed on left side on enclosure types B1, B2, C1 and C2. Mains switch on A5 enclosures is placed on right side

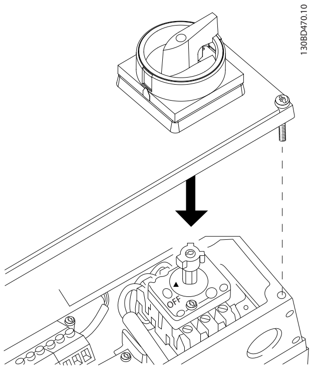


Illustration 6.39 Location of Mains Switch

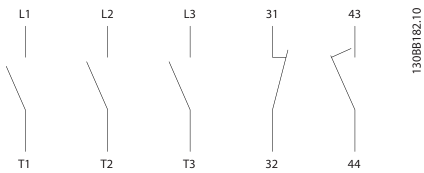
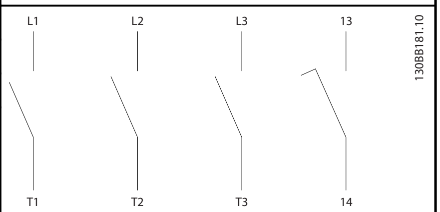
Enclosure type	Type	Terminal connections
A5	Kraus&Naimer KG20A T303	
B1	Kraus&Naimer KG64 T303	
B2	Kraus&Naimer KG64 T303	
C1 37 kW	Kraus&Naimer KG100 T303	
C1 45-55 kW	Kraus&Naimer KG105 T303	
C2 75 kW	Kraus&Naimer KG160 T303	
C2 90 kW	Kraus&Naimer KG250 T303	

Table 6.33 Terminal Connections for Various Enclosure Types

6.4 Additional Motor Information

6.4.1 Motor Cable

The motor must be connected to terminals U/T1/96, V/T2/97, W/T3/98. Ground to terminal 99. All types of 3-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 Ground

Table 6.34 Terminal Functions

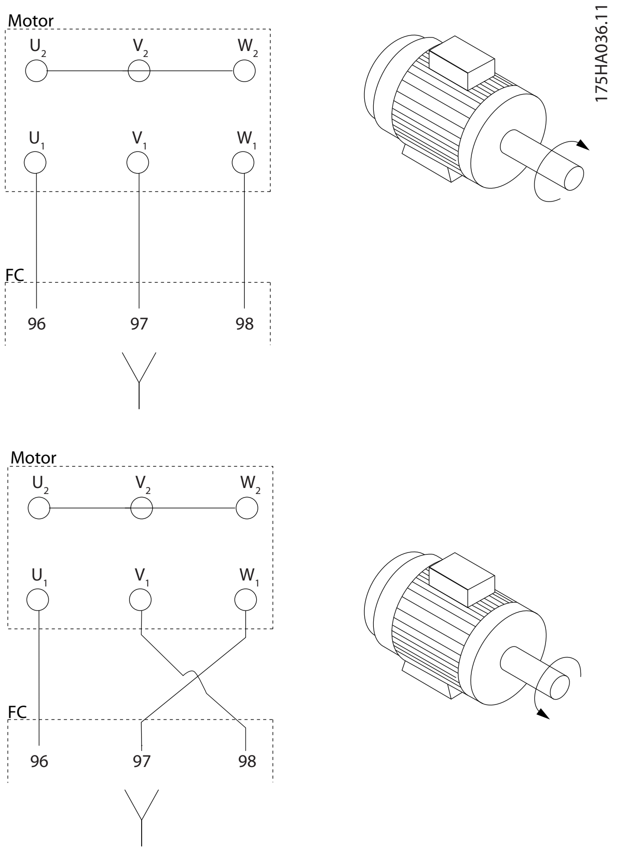


Illustration 6.40 Terminal Connection for Clockwise and Counter-clockwise Rotation

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

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

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

NOTICE

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

6.4.2 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 the motor name plate).
For thermal motor protection it is also possible to use the PTC Thermistor Card option MCB 112. 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.

6.4.3 Parallel Connection of Motors

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

- Recommended to run applications with parallel motors in U/F mode *1-01 Motor Control Principle*. 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 speed.
- The electronic thermal relay (ETR) of the frequency inverter cannot be used as motor protection for the individual motor. Provide further motor protection by e.g. thermistors in each motor winding or individual thermal relays. (Circuit breakers are not suitable as protection device).

6

NOTICE

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

NOTICE

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)*.

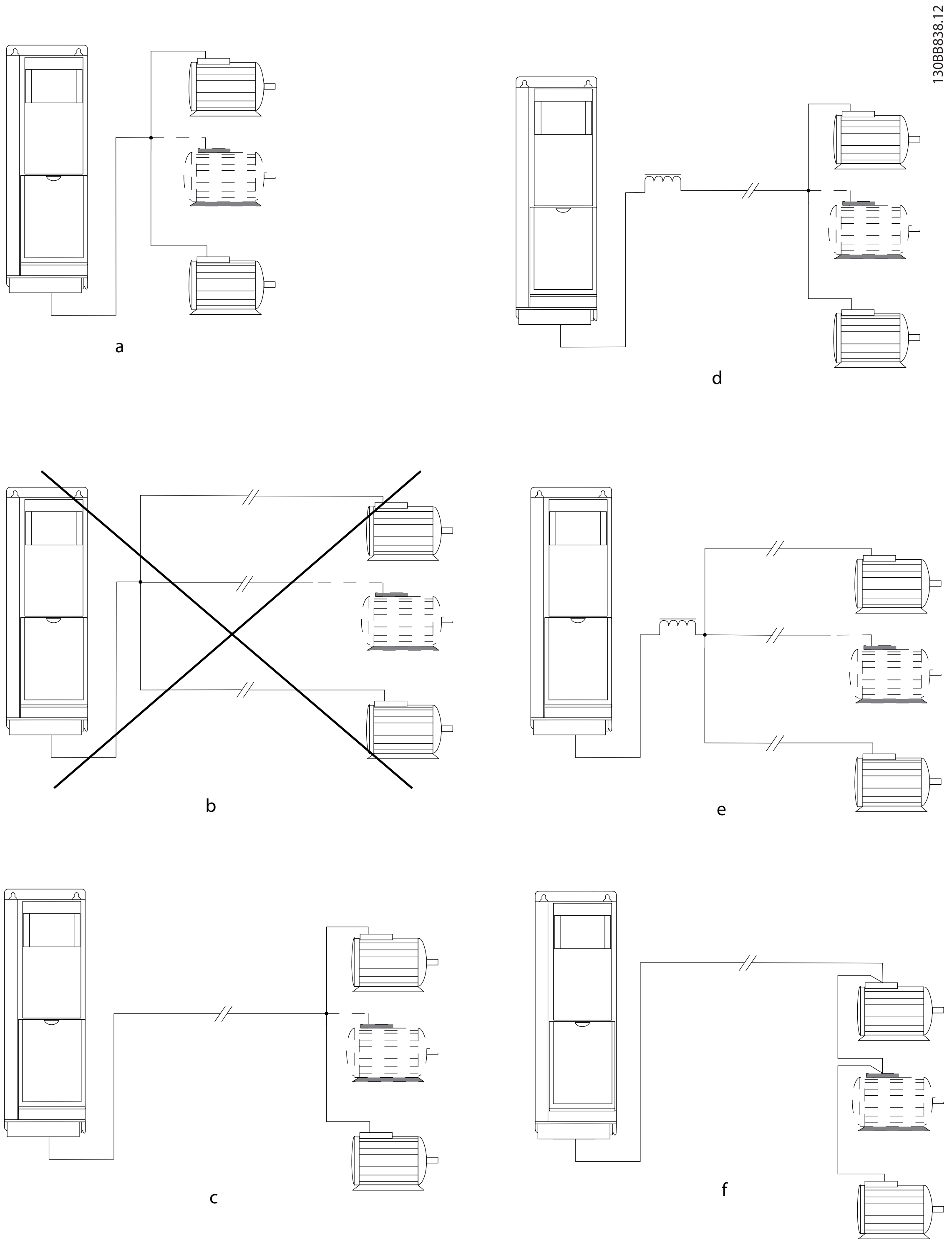


Illustration 6.41 Parallel Motor Connection

c, d) The total motor cable length specified in section 4.5, *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.
e) Be aware of the maximum motor cable length specified in *Table 6.35*.
e) Use LC filter for long parallel cables.

Enclosure Type	Power Size [kW]	Voltage [V]	1 cable [m]	2 cables [m]	3 cables [m]	4 cables [m]
A5	5	400	150	45	8	6
		500	150	7	4	3
A2, A5	1.1-1.5	400	150	45	20	8
		500	150	45	5	4
A2, A5	2.2-4	400	150	45	20	11
		500	150	45	20	6
A3, A5	5.5-7.5	400	150	45	20	11
		500	150	45	20	11
B1, B2, B3, B4, C1, C2, C3, C4	11-90	400	150	75	50	37
		500	150	75	50	37

Table 6.35 Max. Cable Length for Each Parallel Cable, Depending on Quantity of Parallel 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).

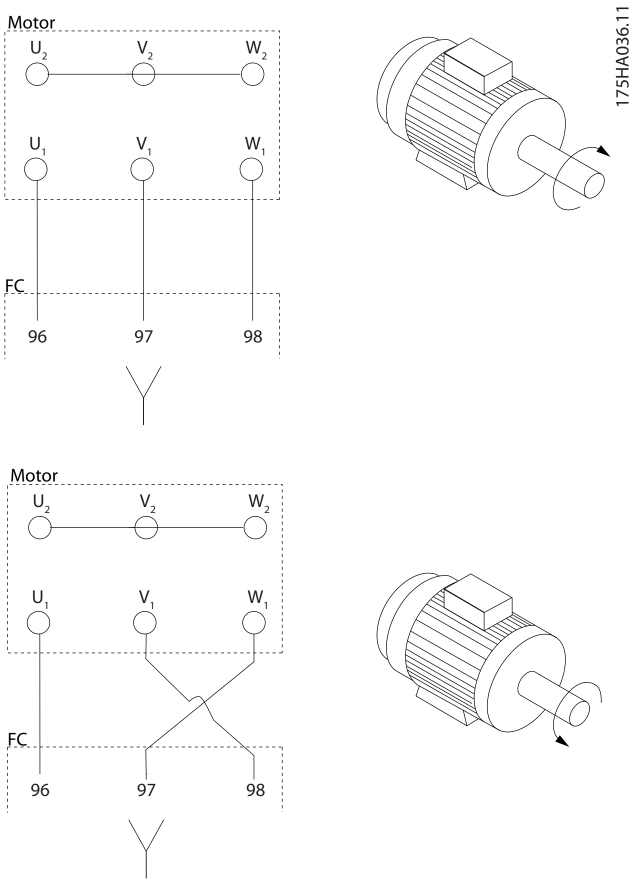


Illustration 6.42 Motor Rotation Check Steps

6.4.4 Direction of Motor Rotation

The default setting is clockwise rotation with the frequency converter output connected as follows.

Terminal 96 connected to U-phase
Terminal 97 connected to V-phase
Terminal 98 connected to W-phase

The direction of motor rotation is changed by switching 2 motor phases.

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

6.4.5 Motor Insulation

For motor cable lengths ≤ the maximum cable length listed in *chapter 9 General Specifications and Trouble-shooting*, the motor insulation ratings listed in *Table 6.36* are recommended. If a motor has lower insulation rating, it is recommended to use a dU/dt or sine-wave filter.

Nominal Mains Voltage [V]	Motor Insulation [V]
$U_N \leq 420$	Standard U_{LL} = 1300
420 V < $U_N \leq 500$	Reinforced U_{LL} = 1600
500 V < $U_N \leq 600$	Reinforced U_{LL} = 1800
600 V < $U_N \leq 690$	Reinforced U_{LL} = 2000

Table 6.36 Motor Insulation

6

6.4.6 Motor Bearing Currents

All motors installed with FC 102 90 kW or higher power frequency converter should have NDE (Non-Drive End) insulated bearings installed to eliminate circulating bearing currents. To minimise 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
   - 2a Ensure the motor and load motor are aligned.
   - 2b Strictly follow the EMC Installation guideline.
   - 2c Reinforce the PE so the high frequency impedance is lower in the PE than the input power leads.
   - 2d 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.
   - 2e Make sure that the impedance from frequency converter to building ground is lower that the grounding impedance of the machine. This can be difficult for pumps.
   - 2f Make a direct ground 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 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.

6.5 Control Cables and Terminals

6.5.1 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 by means of a screwdriver (see *Illustration 6.43*).

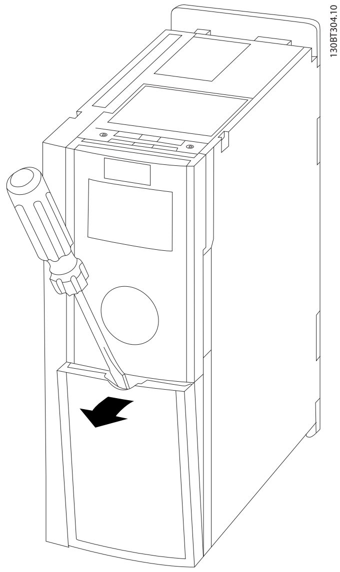


Illustration 6.43 Enclosure Types A1, A2, A3, B3, B4, C3 and C4

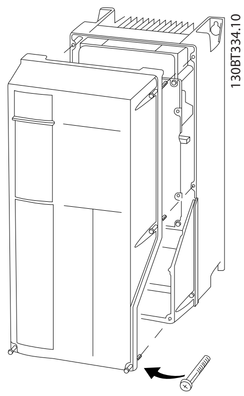


Illustration 6.44 Enclosure Types A5, B1, B2, C1 and C2

6.5.2 Control Cable Routing

Tie down all control wires to the designated control cable routing as shown in the picture. 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 6.45*).

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 *Illustration 6.46* and *Illustration 6.47*. On the NEMA 1 unit remove a cover plate.
Kit number for fieldbus top connection: 176F1742

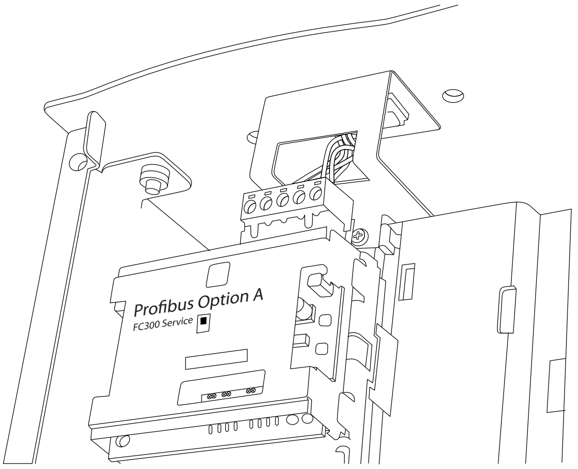


Illustration 6.45 Inside Location of Fieldbus

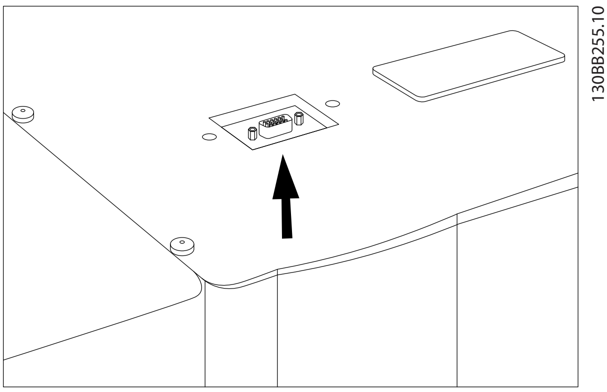


Illustration 6.46 Top Connection for Fieldbus on IP00

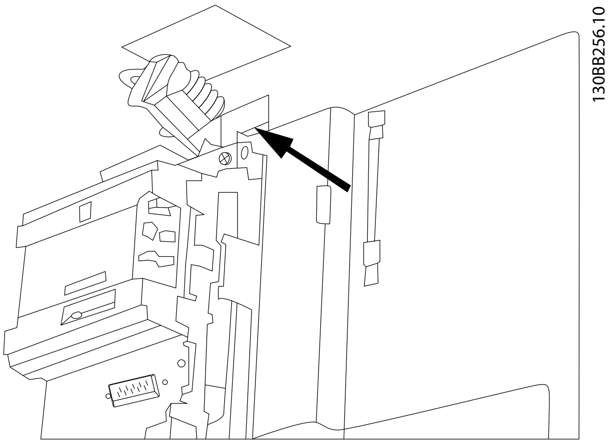


Illustration 6.47 Top Connection for Fieldbus NEMA 1 Units

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 6.37 24 V External DC Supply

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.

NOTICE

A warning of low voltage is given when 24 V DC has been connected; however, there is 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.

6.5.3 Control Terminals

Item	Description
1	8 pole plug digital I/O
2	3 pole plug RS-485 Bus
3	6 pole analog I/O
4	USB Connection

Table 6.38 Legend Table to *Illustration 6.48*, for FC 102

Item	Description
1	10 pole plug digital I/O
2	3 pole plug RS-485 Bus
3	6 pole analog I/O
4	SB Connection

Table 6.39 Legend Table to *Illustration 6.48*, for FC 102

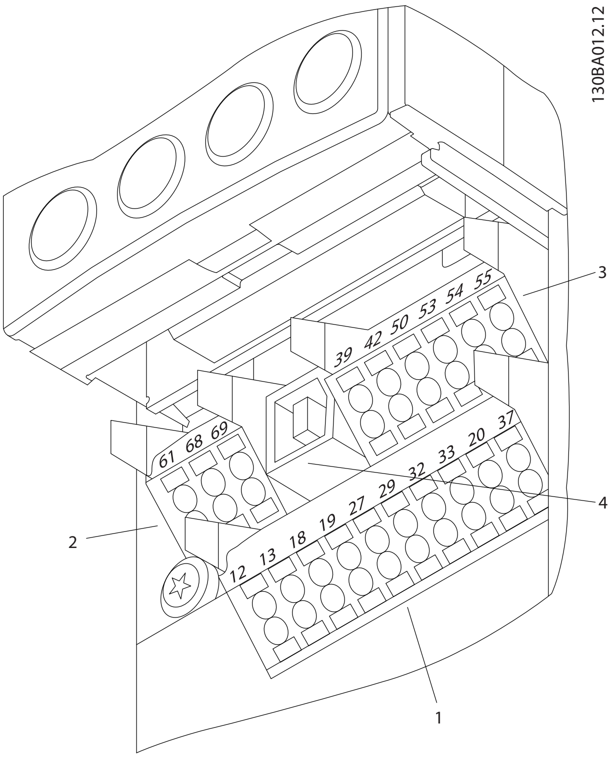


Illustration 6.48 Control Terminals (all Enclosure Types)

6.5.4 Switches S201, S202, and S801

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

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

Default setting

S201 (A53) = OFF (voltage input)

S202 (A54) = OFF (voltage input)

S801 (Bus termination) = OFF

NOTICE

When changing the function of S201, S202 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.

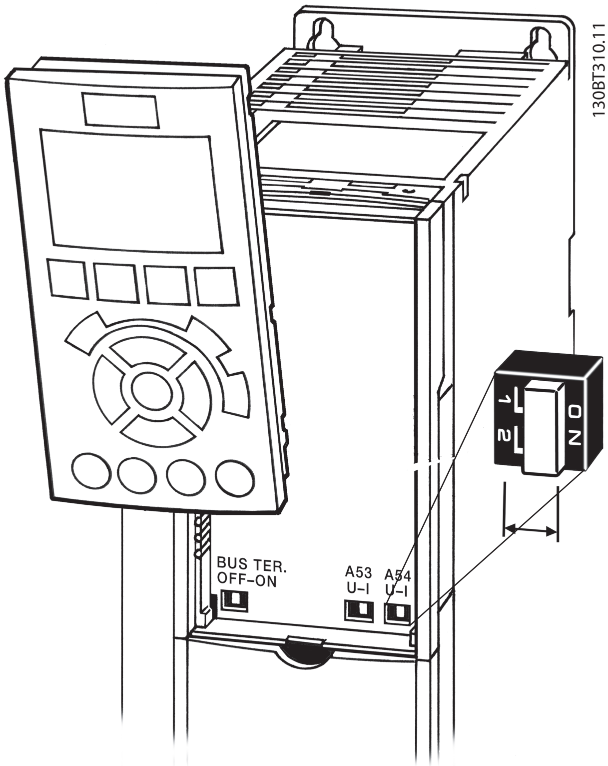


Illustration 6.49 Location of S201, S202 and S801 Switches

6.5.5 Electrical Installation, Control Terminals

To mount the cable to the terminal

1. Strip insulation of 9-10 mm

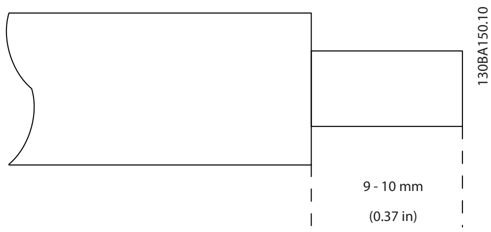


Illustration 6.50 Strip Cable

2. Insert a screwdriver1) in the square hole.

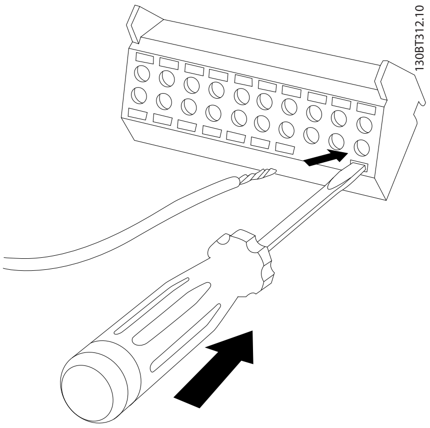


Illustration 6.51 Insert Screwdriver

3. Insert the cable in the adjacent circular hole.

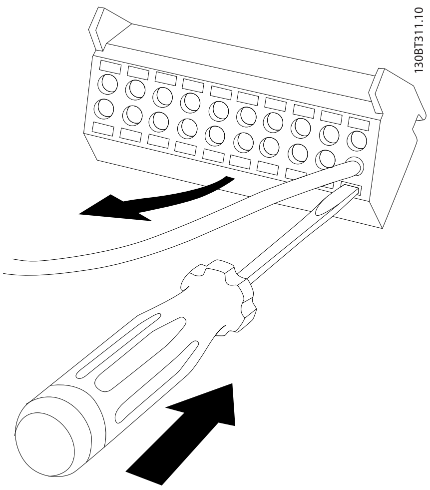


Illustration 6.52 Insert Cable

4. Remove the screwdriver. The cable is now mounted to the terminal.

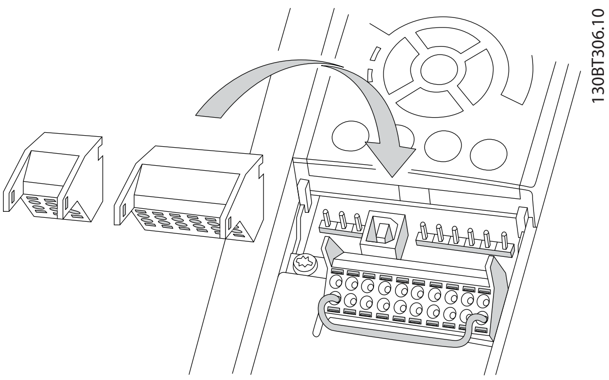


Illustration 6.53 Remove Screwdriver

To remove the cable from the terminal

1. Insert a screwdriver[1)] in the square hole.
2. Pull out the cable.

1) Max. 0.4 x 2.5 mm

6.5.6 Basic Wiring Example

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

Default settings
18 = Start, *5-10 Terminal 18 Digital Input* [9]
27 = Stop inverse, *5-12 Terminal 27 Digital Input* [6]
37 = Safe Torque Off inverse

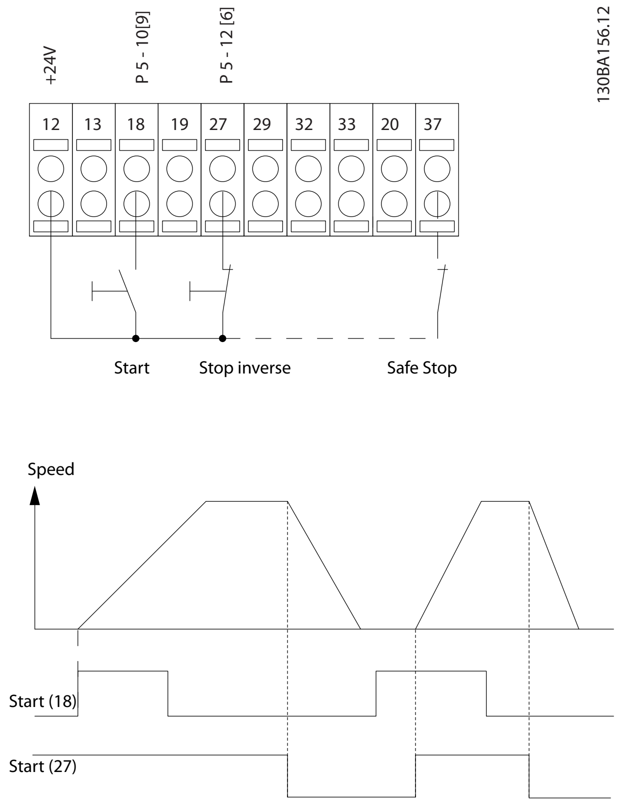


Illustration 6.54 Basic Wiring

6

6.5.7 Electrical Installation, Control Cables

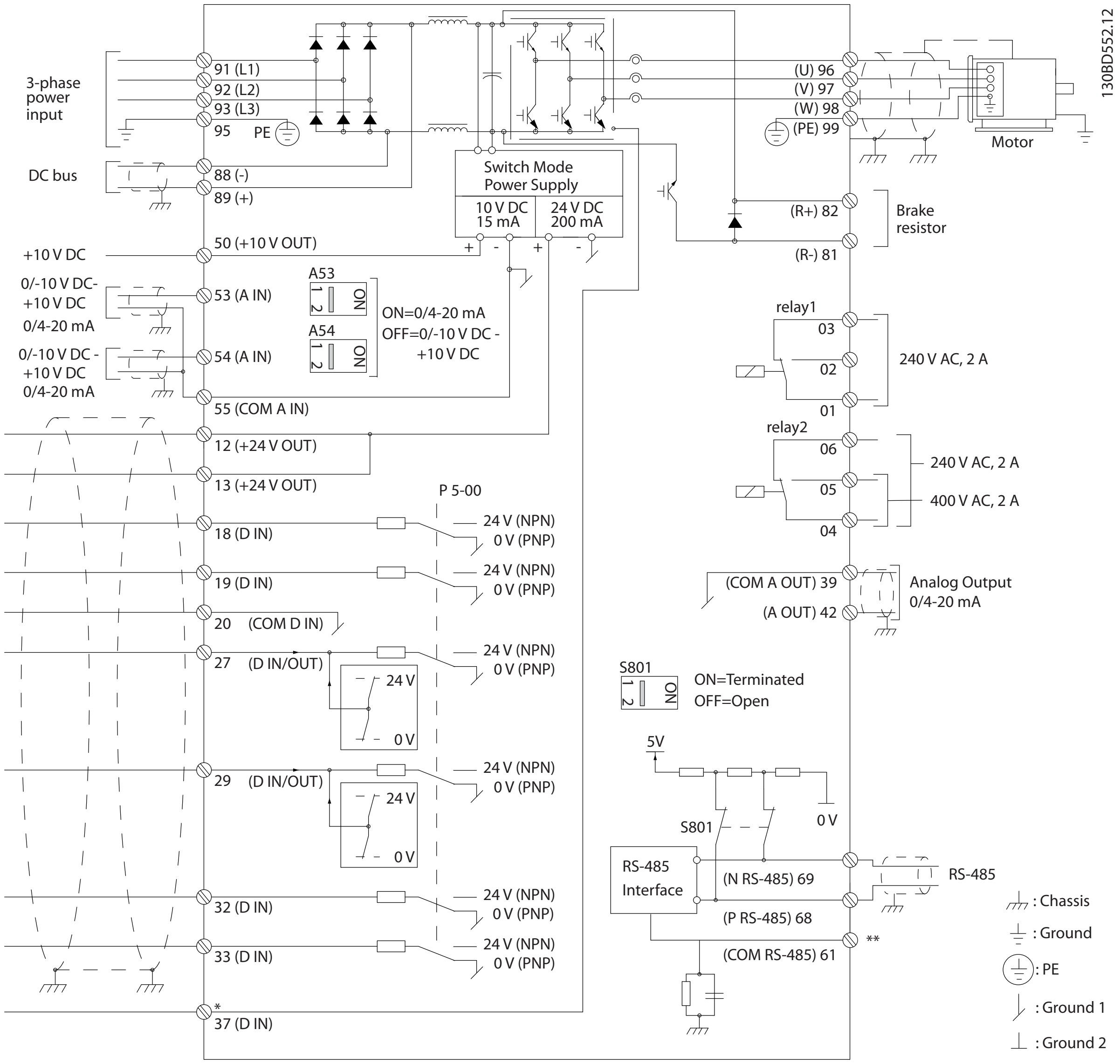


Illustration 6.55 Basic Wiring Schematic

A=Analog, D=Digital
*Terminal 37 (optional) is used for Safe Torque Off. For Safe Torque Off installation instructions, refer to the *Safe Torque Off Operating Instructions for Danfoss VLT® Frequency Converters*.
**Do not connect cable screen.

Very long control cables and analog signals may in rare cases and depending on installation, result in 50/60 Hz ground 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 analog 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 analog input signal.

Input polarity of control terminals

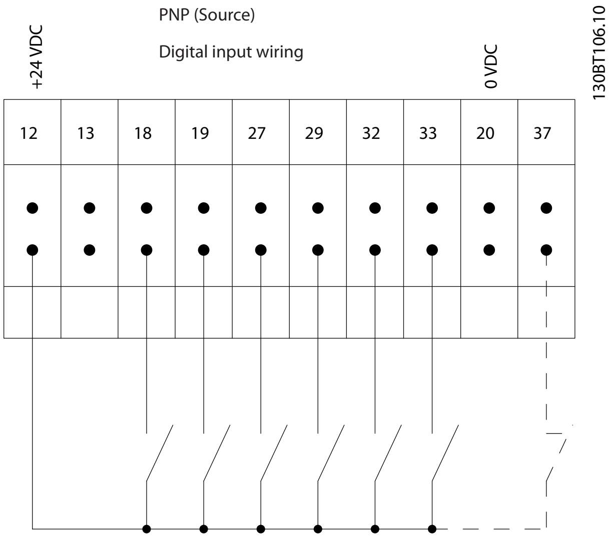


Illustration 6.56 Input Polarity PNP (Source)

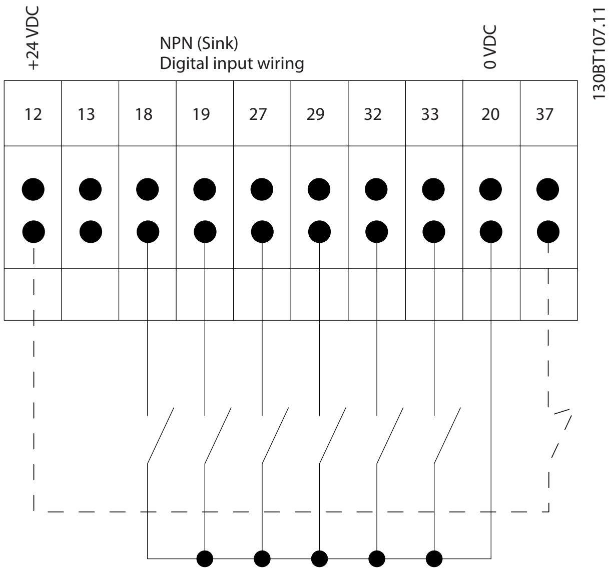


Illustration 6.57 Input Polarity NPN (Sink)

NOTICE

To comply with EMC emission specifications, screened/armoured cables are recommended. If an unscreened/unarmoured cable is used, see *chapter 2.9.2 EMC Test Results*.

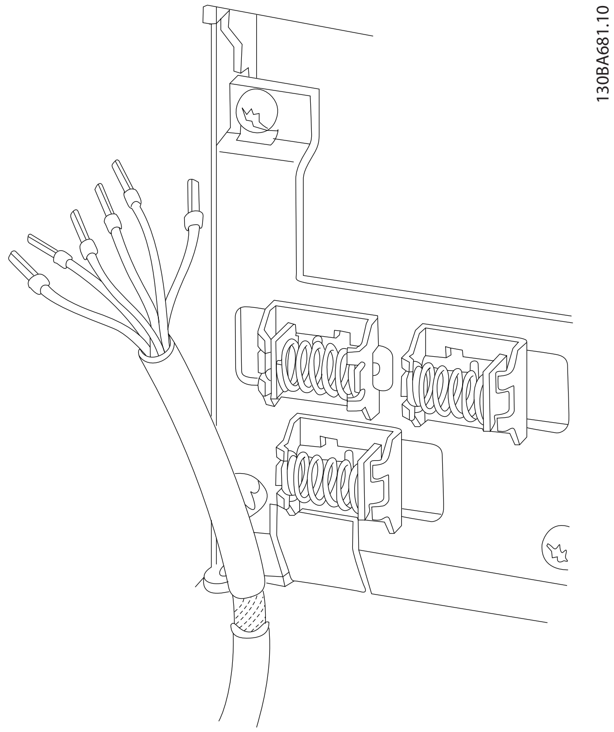


Illustration 6.58 Grounding of Screened/Armoured Control Cables

6

6.5.8 Relay Output

Relay 1

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

Relay 2 (Not FC 301)

- 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 Relay Option Module MCB 105.

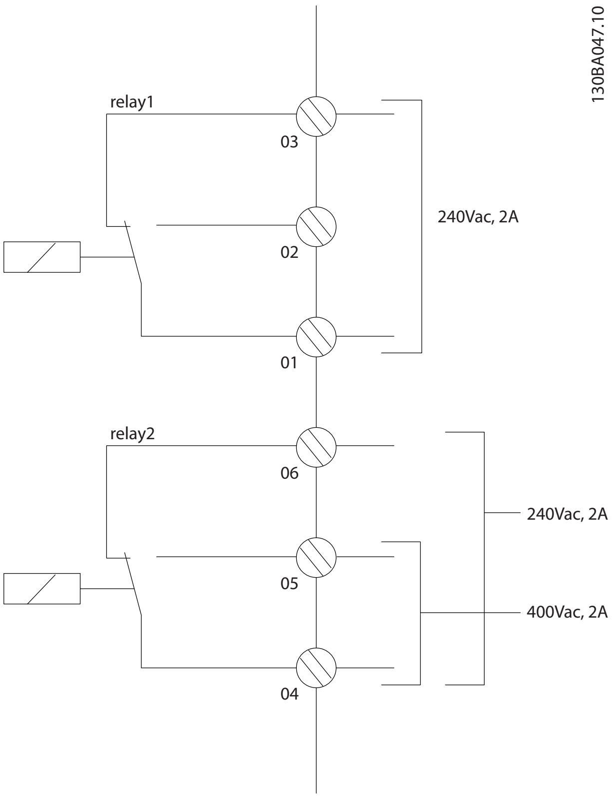


Illustration 6.59 Relay Outputs 1 and 2

6.6 Additional Connections

6.6.1 DC Bus Connection

The DC bus terminal is used for DC back-up, with the intermediate circuit being supplied from an external source. It uses terminals 88 and 89.

For further information, contact Danfoss.

6.6.2 Load Sharing

Use terminals 88 and 89 for load sharing.

The connection cable must be screened and the max. 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.

⚠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

6.6.3 Installation of Brake Cable

The connection cable to the brake resistor must be screened and the max. length from the frequency converter to the DC bar is limited to 25 m (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.

Terminals 81 and 82 are brake resistor terminals.

See Brake instructions for more information about safe installation.

NOTICE

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

⚠CAUTION

Note that voltages up to 1099 V DC, depending on the supply voltage, may occur on the terminals.

6

6.6.4 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.

USB is a serial bus utilising 4 shielded wires with Ground pin 4 connected to the shield in the PC USB port. By 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 ground potential difference caused by not following the recommendations described in *AC Mains Connection* in the *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 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 ground potential difference, but does not eliminate all potential differences due to the ground and shield connected in the PC USB port.

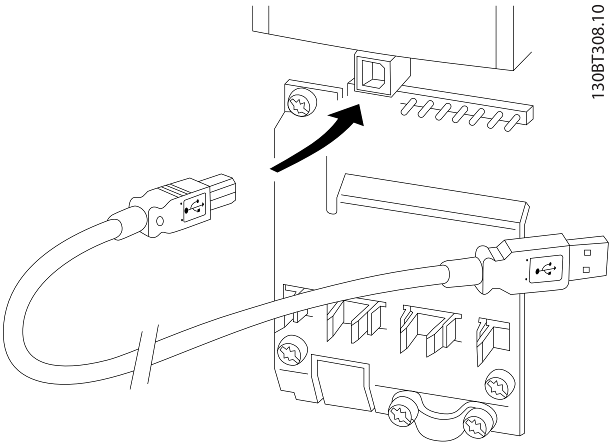


Illustration 6.60 USB Connection

6.6.5 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. Select *copy*.
5. Select the *project* section.
6. Select *paste*.
7. Select *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. Select *Open* – stored files are shown.
4. Open the appropriate file.
5. Select *Write to drive*.

All parameters are now transferred to the frequency converter.

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

6.6.6 MCT 31

The MCT 31 harmonic calculation PC tool enables easy estimation of the harmonic distortion in a given application. Both the harmonic distortion of Danfoss frequency converters as well as non-Danfoss frequency converters with additional harmonic reduction devices, such as Danfoss AHF filters and 12-18-pulse rectifiers, can be calculated.

Ordering number:
Order the CD containing the MCT 31 PC tool using code number 130B1031.

6.7 Safety

6.7.1 High Voltage Test

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

⚠WARNING

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

6

6.7.2 Grounding

The following basic issues need to be considered when installing a frequency converter, so as to obtain electro-magnetic compatibility (EMC).

- Safety grounding: The frequency converter has a high leakage current and must be grounded appropriately for safety reasons. Apply local safety regulations.
- High-frequency grounding: Keep the ground wire connections as short as possible.

Connect the different ground 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 have been reduced.
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 from the fastening points.

6.7.3 Safety Ground Connection

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

⚠WARNING

The ground leakage current from the frequency converter exceeds 3.5 mA. To ensure a good mechanical connection from the ground cable to the ground connection (terminal 95), the cable cross-section must be at least 10 mm^2 or 2 rated ground wires terminated separately.

6.7.4 ADN-compliant Installation

Units with ingress protection rating IP55 (NEMA 12) or higher prevent spark formation, and are classified as limited explosion risk electrical apparatus in accordance with the European Agreement concerning International Carriage of Dangerous Goods by Inland Waterways (ADN).

For units with ingress protection rating IP20, IP21, or IP54, prevent risk of spark formation as follows:

- Do not install a mains switch
- Ensure that *14-50 RFI Filter* is set to *[1] On*.
- Remove all relay plugs marked “RELAY”. See *Illustration 6.61*.
- Check which relay options are installed, if any. The only permitted relay option is Extended Relay Card MCB 113.

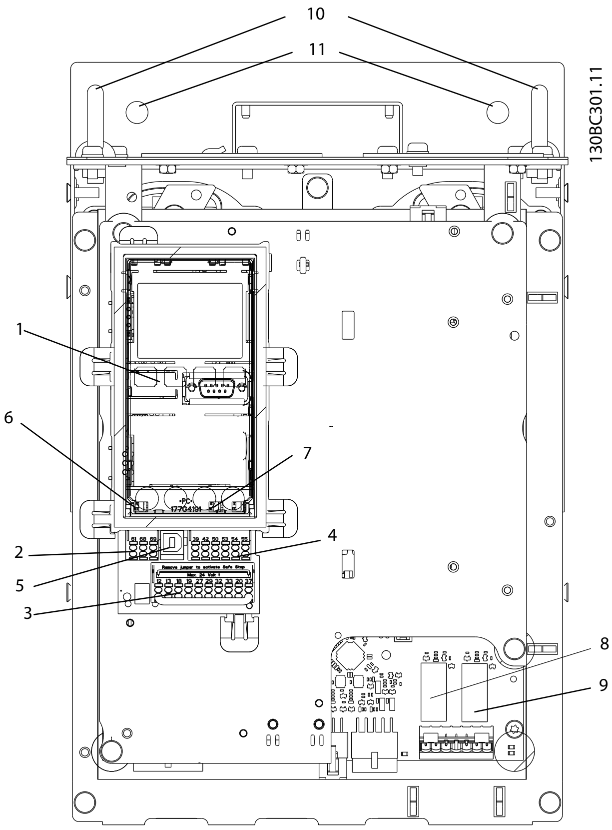


Illustration 6.61 Location of Relay Plugs, Pos. 8 and 9

Manufacturer declaration is available upon request.

6.8 EMC-correct Installation

6.8.1 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 *chapter 2.2 CE Labelling*, *chapter 2.9 General Aspects of EMC* and *chapter 2.9.2 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 should provide a minimum coverage of 80%. The screen material must be metal, not limited to, but typically copper, aluminium, steel or lead. There are no special requirements for the mains cable.

- Installations using rigid metal conduits are not required to use screened cable, but the motor cable must be installed in conduit separate from the control and mains cables. Full connection of the conduit from the frequency converter to the motor is required. The EMC performance of flexible conduits varies a lot and information from the manufacturer must be obtained.
- Connect the screen/armour/conduit to ground 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 *chapter 6.8.3 Grounding of Screened Control Cables*.
- 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).

Leave the screen as close to the connectors as possible.

Illustration 6.62 shows an example of an EMC-correct electrical installation of an IP20 frequency converter. The frequency converter is fitted in an installation cabinet with an output contactor and connected to a PLC, which is installed in a separate cabinet. Other ways of doing the installation may have just as good an EMC performance, provided the above guide lines 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 *chapter 2.9.2 EMC Test Results*.

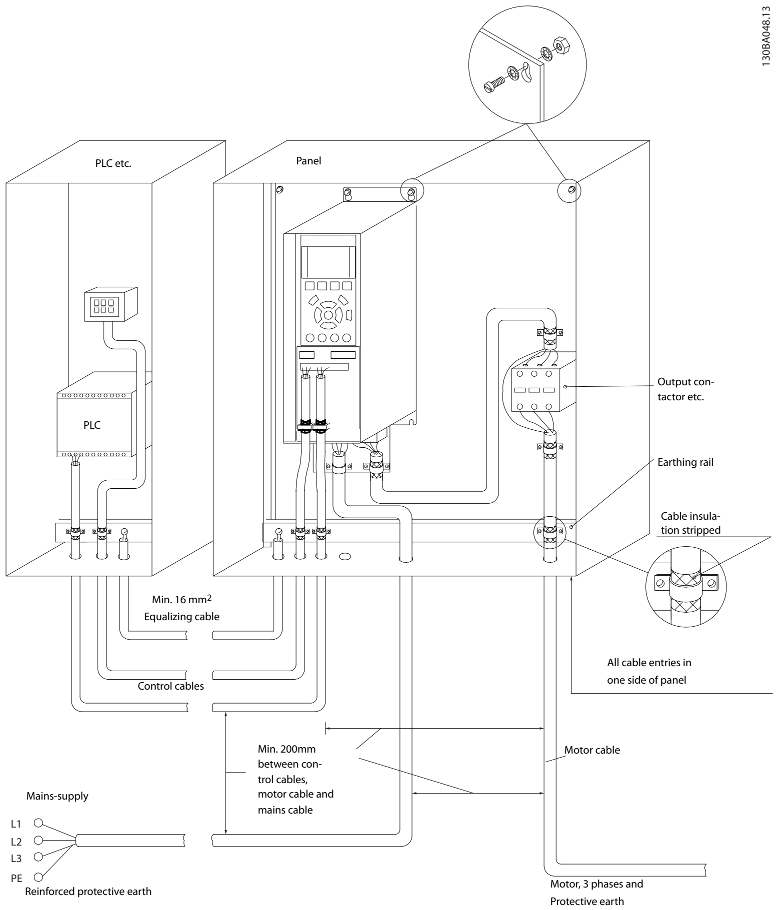


Illustration 6.62 EMC-correct Electrical Installation of a Frequency Converter in Cabinet

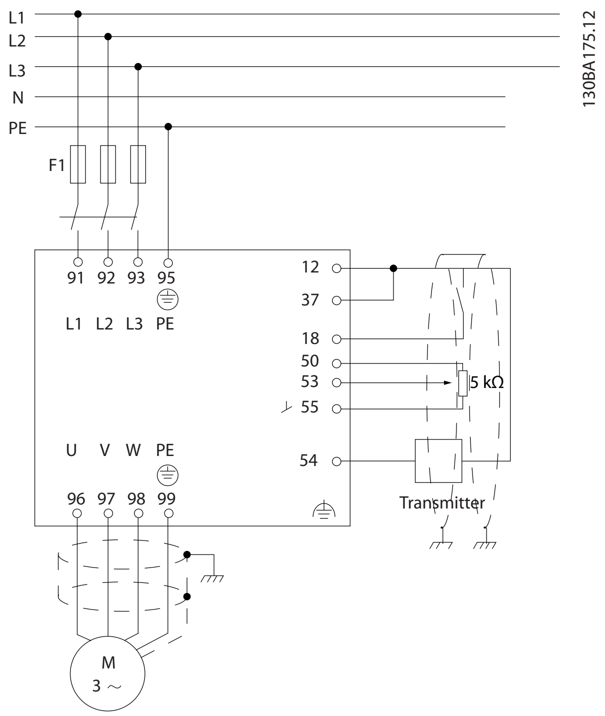


Illustration 6.63 Electrical Connection Diagram

6.8.2 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 in- 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).

Transfer impedance (Z_T) is rarely stated by cable manufacturers, 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 on the basis of 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. Aluminium-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

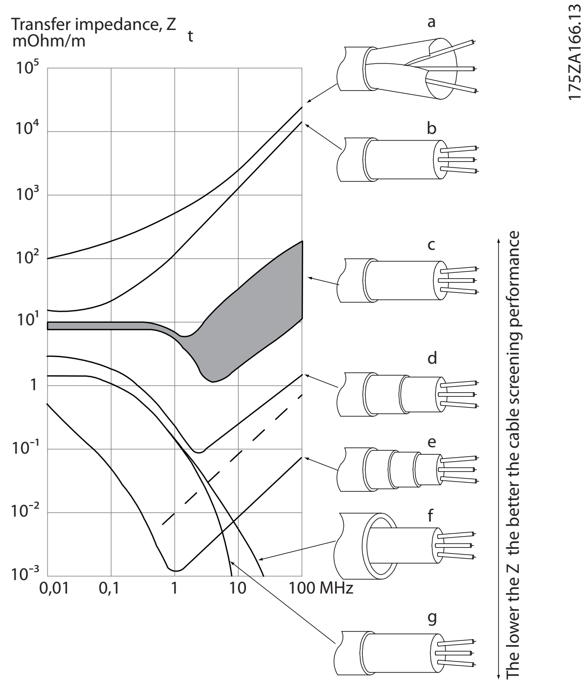


Illustration 6.64 Transfer Impedance

6.8.3 Grounding of Screened Control Cables

Correct screening
The preferred method in most cases is to secure control and cables with screening clamps provided at both ends to ensure best possible high frequency cable contact.
If the ground potential between the frequency converter and the PLC is different, electric noise may occur that disturbs the entire system. Solve this problem by fitting an equalising cable next to the control cable. Minimum cable cross section: 16 mm².

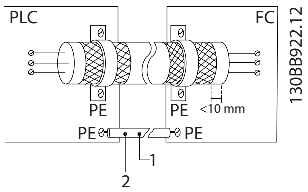


Illustration 6.65 Control Cable with Equalising Cable

1	Min. 16 mm²
2	Equalizing cable

Table 6.40 Legend to *Illustration 6.65*

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 100 nF capacitor (keeping leads short).

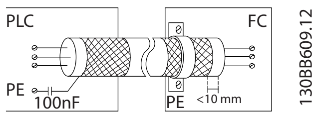


Illustration 6.66 Screen-to-ground Connected to a 100 nF Capacitor

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

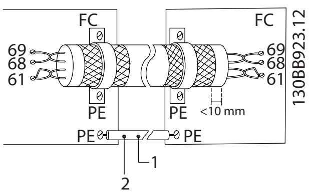


Illustration 6.67 Twisted-pair Cables

1	Min. 16 mm²
2	Equalizing cable

Table 6.41 Legend to *Illustration 6.67*

Alternatively, the connection to terminal 61 can be omitted:

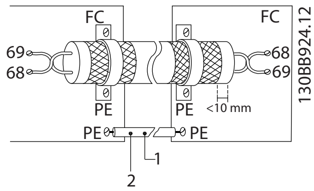


Illustration 6.68 Terminal 61 not Connected

1	Min. 16 mm²
2	Equalizing cable

Table 6.42 Legend to *Illustration 6.68*

6.8.4 RFI Switch

Mains supply isolated from ground
If the frequency converter is supplied from an isolated mains source (IT mains, floating delta) or TT/TN-S mains with grounded leg (grounded delta), turn off the RFI switch via *14-50 RFI Filter*.
In OFF, the internal capacitors between the chassis (ground), the input RFI filter and the intermediate circuit are cut off. As the RFI switch is turned off, the frequency converter is not be able to meet optimum EMC performance.
By opening the RFI filter switch, the ground leakage currents are also reduced, but not the high-frequency leakage currents caused by the switching of the inverter. It is important to use isolation monitors that are capable for use with power electronics (IEC61557-8). E.g. Deif type SIM-Q, Bender type IRDH 275/375 or similar.
Also refer to the application note *VLT on IT mains.*

NOTICE

If the RFI switch is not turned off, and the frequency converter is running on isolated grids, ground faults can potentially lead to charge-up of the intermediate circuit and cause DC capacitor damage or result in reduced product life.

6.9 Residual Current Device

Use RCD relays, multiple protective grounding as extra protection, provided that local safety regulations are complied with.
If a ground fault appears, a DC content may develop in the faulty current.
If RCD relays are used, observe local regulations. Relays must be suitable for protection of 3-phase equipment with a bridge rectifier and for a brief discharge on power-up see *chapter 2.11 Earth Leakage Current* for further information.

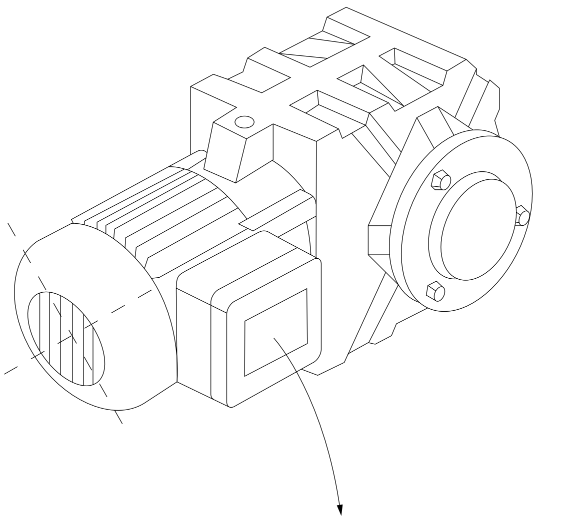
6.10 Final Set-up and Test

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

Step 1. Locate the motor name plate

NOTICE

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 6.69 Motor Name Plate

Step 2. Enter the motor name plate data in this parameter list.
To access this list, press [Quick Menu] and 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 ensures 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 function*.
3. Activate the AMA *1-29 Automatic Motor Adaptation (AMA)*.
4. Select between complete or reduced AMA. 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

1. Press [Off] - the frequency converter enters 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 alarm mode. A description of the alarm can be found in the *Warnings and Alarms* chapter in product related *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 assist in troubleshooting. If contacting Danfoss for service, make sure to mention number and alarm description.

NOTICE

Unsuccessful AMA is often caused by incorrectly registered motor name plate data, or a too big 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.

7 Application Examples

7.1 Application Examples

7.1.1 Start/Stop

Terminal 18 = start/stop *5-10 Terminal 18 Digital Input* [8] *Start*
Terminal 27 = No operation *5-12 Terminal 27 Digital Input* [0] *No operation* (Default *coast inverse*

5-10 Terminal 18 Digital Input = *Start* (default)

5-12 Terminal 27 Digital Input = *coast inverse* (default)

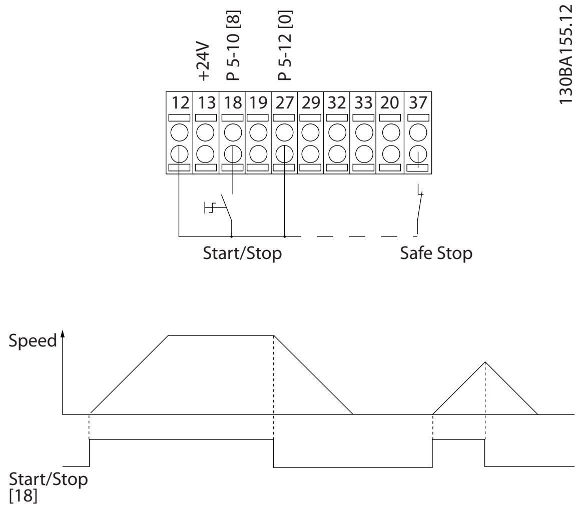


Illustration 7.1 Terminal 37: Available only with Safe Stop Function

7.1.2 Pulse Start/Stop

Terminal 18 = start/stop *5-10 Terminal 18 Digital Input [9] Latched start*
Terminal 27= Stop *5-12 Terminal 27 Digital Input [6] Stop inverse*

5-10 Terminal 18 Digital Input = Latched start

5-12 Terminal 27 Digital Input = Stop inverse

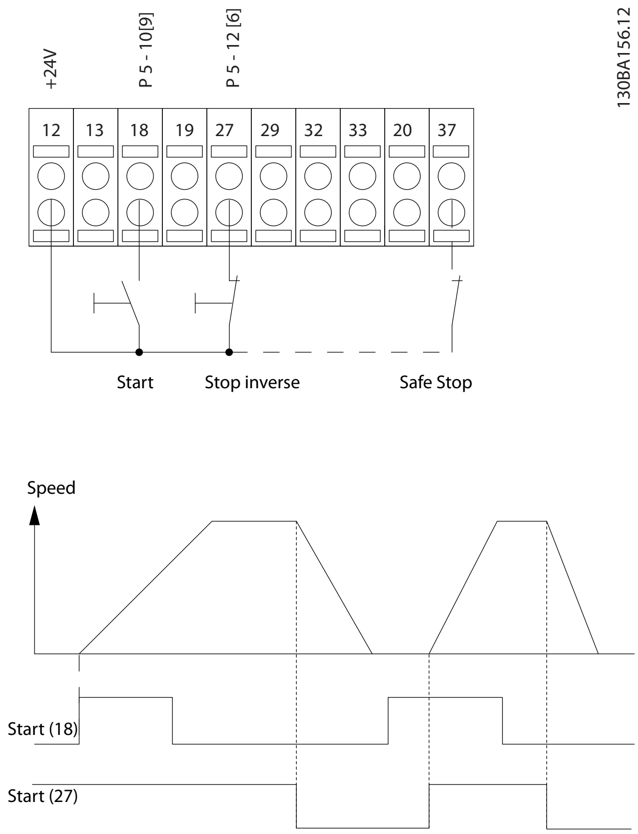


Illustration 7.2 Terminal 37: Available Only with Safe Torque Off Function

7.1.3 Potentiometer Reference

Voltage reference via a potentiometer.

3-15 Reference 1 Source [1] = Analog Input 53

6-10 Terminal 53 Low Voltage = 0 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 = 1.500 RPM

Switch S201 = OFF (U)

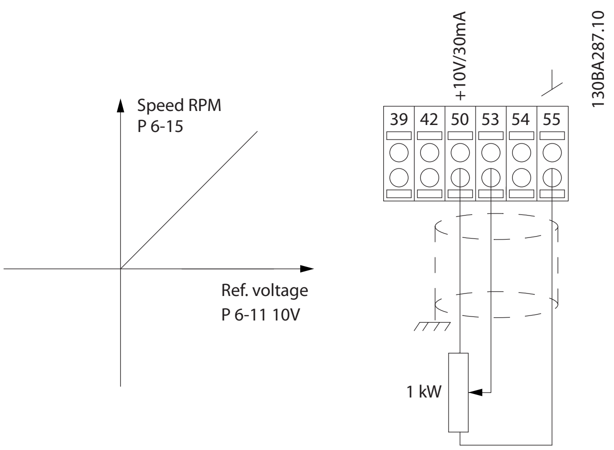


Illustration 7.3 Voltage Reference via a Potentiometer

7.1.4 Automatic Motor Adaptation (AMA)

AMA is an algorithm to measure the electrical motor parameters on a motor at standstill. This means that AMA itself does not supply any torque.
AMA is useful when commissioning systems and optimising the adjustment of the frequency converter to the applied motor. This feature is particularly used where the default setting does not apply to the connected motor.
1-29 Automatic Motor Adaptation (AMA) allows a choice of complete AMA with determination of all electrical motor parameters or reduced AMA with determination of the stator resistance Rs only.
The duration of a total AMA varies from a few minutes on small motors to more than 15 minutes on large motors.

Limitations and preconditions:

- For the AMA to determine the motor parameters optimally, enter the correct motor nameplate data in *1-20 Motor Power [kW]* to *1-28 Motor Rotation Check*.
- For the best adjustment of the frequency converter, carry out AMA on a cold motor. Repeated AMA runs may lead to a heating of the motor, which results in an increase of the stator resistance, Rs. Normally, this is not critical.
- AMA can only be carried out if the rated motor current is minimum 35% of the rated output current of the frequency converter. AMA can be carried out on up to one oversize motor.
- It is possible to carry out a reduced AMA test with a Sine-wave filter installed. Avoid carrying out a complete AMA with a Sine-wave filter. If an overall setting is required, remove the Sine-wave filter while running a total AMA. After completion of the AMA, reinsert the Sine-wave filter.
- If motors are coupled in parallel, use only reduced AMA if any.
- Avoid running a complete AMA when using synchronous motors. If synchronous motors are applied, run a reduced AMA and manually set the extended motor data. The AMA function does not apply to permanent magnet motors.
- The frequency converter does not produce motor torque during an AMA. During an AMA, it is imperative that the application does not force the motor shaft to run, which is known to happen with e.g. wind milling in ventilation systems. This disturbs the AMA function.
- AMA cannot be activated when running a PM motor (when *1-10 Motor Construction* is set to *[1] PM non salient SPM*).

7.1.5 Smart Logic Control

A useful facility in the frequency converter is the Smart Logic Control (SLC).
In applications where a PLC is generating a simple sequence the SLC may take over elementary tasks from the main control.
SLC is designed to act from event send to or generated in the frequency converter. The frequency converter then performs the pre-programmed action.

7.1.6 Smart Logic Control Programming

The Smart Logic Control (SLC) is essentially a sequence of user-defined actions (see *13-52 SL Controller Action*) executed by the SLC when the associated user-defined *event* (see *13-51 SL Controller Event*) is evaluated as TRUE by the SLC.
Events and *actions* are each numbered and are linked in pairs called states. This means that when *event [1]* is fulfilled (attains the value TRUE), *action [1]* is executed. After this, the conditions of *event [2]* is evaluated, and if evaluated TRUE, *action [2]* is executed and so on. Events and actions are placed in array parameters.

Only one *event* will be evaluated at any time. If an *event* is evaluated as FALSE, nothing happens (in the SLC) during

7

the present scan interval and no other *events* are evaluated. This means that when the SLC starts, it evaluates *event [1]* (and only *event [1]*) each scan interval. Only when *event [1]* is evaluated TRUE, the SLC executes *action [1]* and starts evaluating *event [2]*.

It is possible to program from 0 to 20 *events* and *actions*. When the last *event/action* has been executed, the sequence starts over again from *event [1]/action [1]*. *Illustration 7.4* shows an example with three *events/actions*:

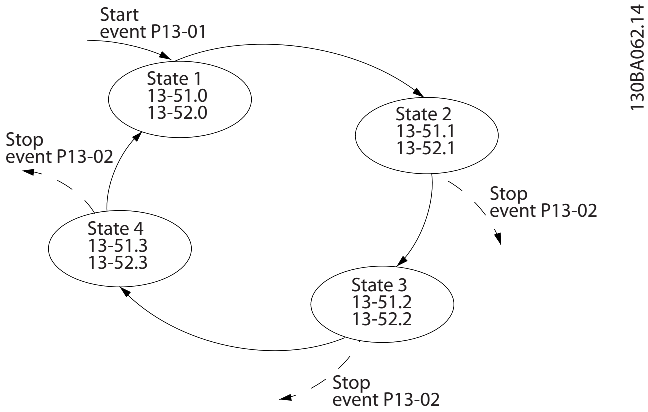


Illustration 7.4 An Example with Three Events/Actions

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7.1.7 SLC Application Example

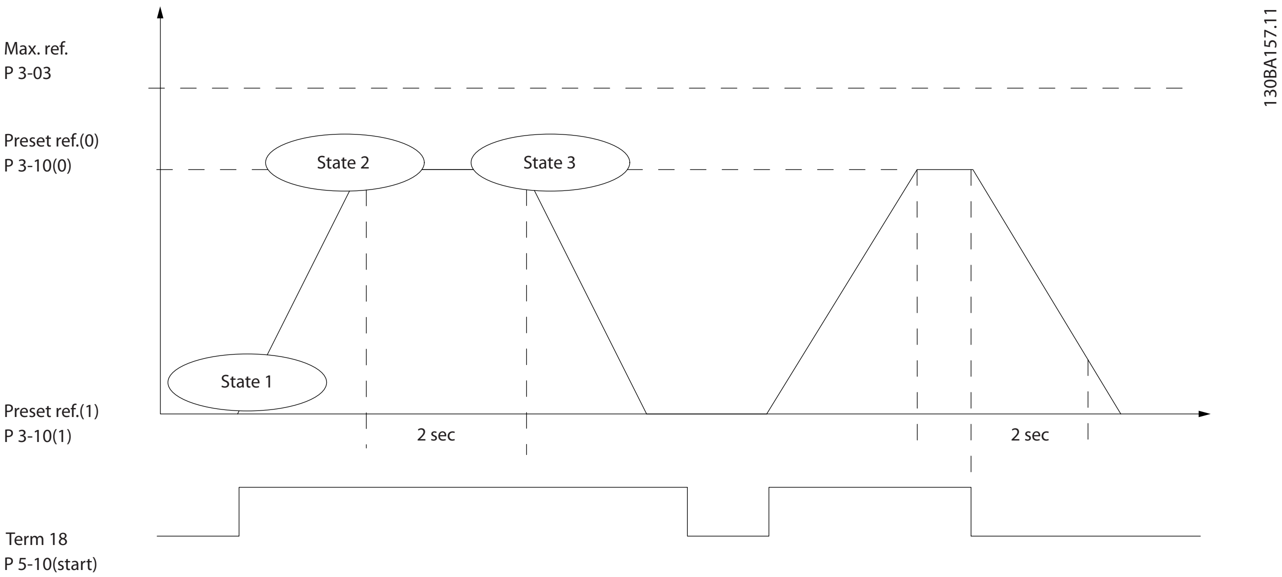

Illustration 7.5 One sequence 1: Start – ramp up – run at reference speed 2 sec – ramp down and hold shaft until stop

Set the ramping times in *3-41 Ramp 1 Ramp Up Time* and *3-42 Ramp 1 Ramp Down Time* to the wanted times

$$tramp = \frac{tacc \times nnorm\,(par.\ 1 - 25)}{ref\,[RPM]}$$

Set term 27 to *No Operation* (*5-12 Terminal 27 Digital Input*)
Set Preset reference 0 to first preset speed (*3-10 Preset Reference* [0]) in percentage of Max reference speed (*3-03 Maximum Reference*). Ex.: 60%
Set preset reference 1 to second preset speed (*3-10 Preset Reference* [1] Ex.: 0 % (zero).
Set the timer 0 for constant running speed in *13-20 SL Controller Timer* [0]. Ex.: 2 sec.

Set Event 1 in *13-51 SL Controller Event* [1] to *True* [1]
Set Event 2 in *13-51 SL Controller Event* [2] to *On Reference* [4]
Set Event 3 in *13-51 SL Controller Event* [3] to *Time Out 0* [30]
Set Event 4 in *13-51 SL Controller Event* [4] to *False* [0]

Set Action 1 in *13-52 SL Controller Action* [1] to *Select preset 0* [10]
Set Action 2 in *13-52 SL Controller Action* [2] to *Start Timer 0* [29]
Set Action 3 in *13-52 SL Controller Action* [3] to *Select preset 1* [11]
Set Action 4 in *13-52 SL Controller Action* [4] to *No Action* [1]

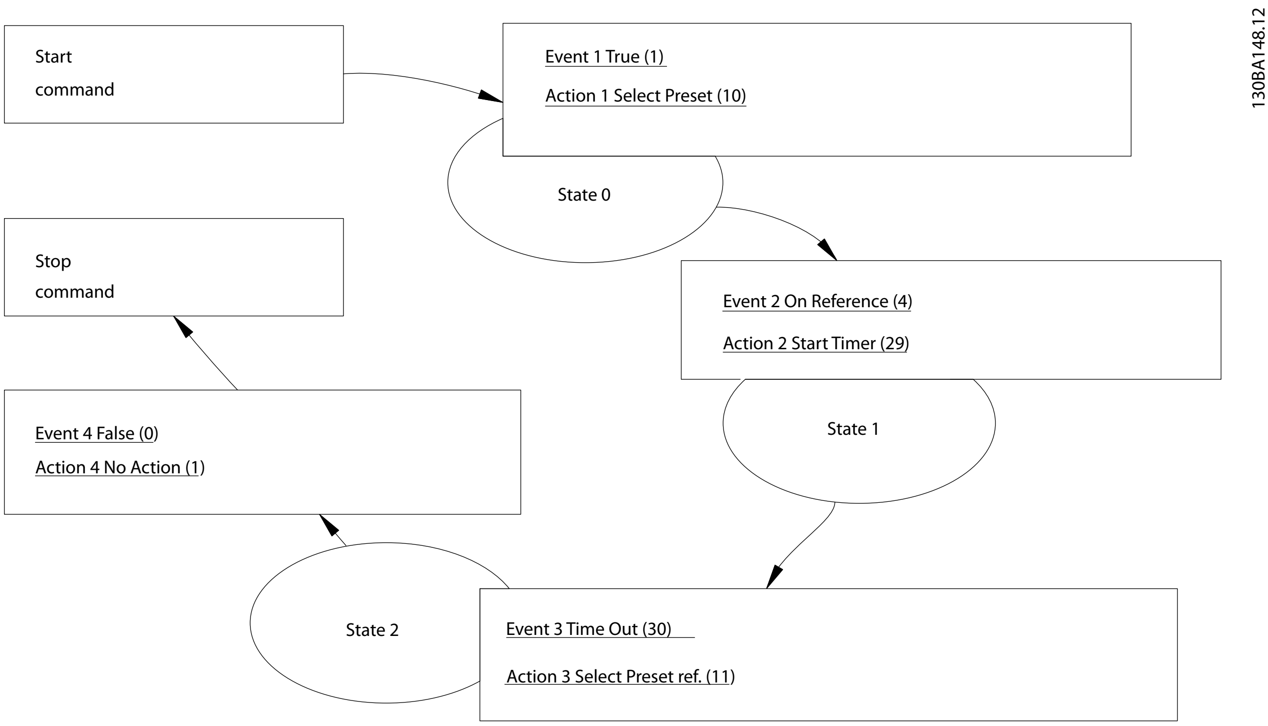

Illustration 7.6 Set Event and Action

Set the Smart Logic Control in *13-00 SL Controller Mode* to ON.

Start/stop command is applied on terminal 18. If stop signal is applied the frequency converter will ramp down and go into free mode.

7.1.8 Cascade Controller

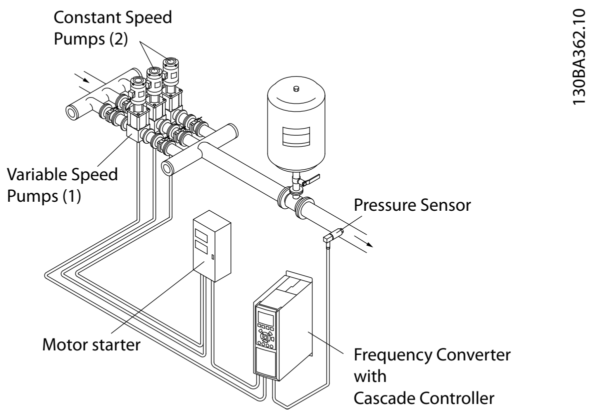

Illustration 7.7 A Pump Application

The Cascade Controller is used for pump applications where a certain pressure ("head") or level needs to be maintained over a wide dynamic range. Running a large pump at variable speed over a wide for range is not an ideal solution because of low pump efficiency and because there is a practical limit of about 25% rated full load speed for running a pump.

In the Cascade Controller the frequency converter controls a variable speed motor as the variable speed pump (lead) and can stage up to 2 additional constant speed pumps on and off. By varying the speed of the initial pump, variable speed control of the entire system is provided. This maintains constant pressure while eliminating pressure surges, resulting in reduced system stress and quieter operation in pumping systems.

Fixed Lead Pump
The motors must be of equal size. The Cascade Controller allows the frequency converter to control up to 5 equal size pumps using the frequency converters 2 built-in relays and terminal 27, 29 (DI/DO). When the variable pump (lead) is connected directly to the frequency converter, the other 4 pumps are controlled by the two built-in relays and terminal 27, 29 (DI/DO). Lead pump alternation cannot be selected when lead pump is fixed.

Lead Pump Alternation
The motors must be of equal size. This function makes it possible to cycle the frequency converter between the pumps in the system (when *25-57 Relays per Pump* =1, maximum pump is 4. When *25-57 Relays per Pump* =2, maximum pump is 3). In this operation, the run time between pumps is equalized reducing the required pump maintenance and increasing reliability and lifetime of the

system. The alternation of the lead pump can take place at a command signal or at staging (adding lag pump).

The command can be a manual alternation or an alternation event signal. If the alternation event is selected, the lead pump alternation takes place every time the event occurs. Selections include whenever an alternation timer expires, when the lead pump goes into sleep mode. Staging is determined by the actual system load.

25-55 Alternate if Load <= *50%*= 1, if load >50% alternation does not happen. If load <=50% Alternation happens. When *25-55 Alternate if Load* <= *50%* = 0, Alternation happens no matter with Load. Total pump capacity is determined as lead pump plus lag speed pumps capacities.

Bandwidth Management
In cascade control systems, to avoid frequent switching of fixed speed pumps, the desired system pressure is kept within a bandwidth rather than at a constant level. The staging bandwidth provides the required bandwidth for operation. When a large and quick change in system pressure occurs, the override bandwidth overrides the staging bandwidth to prevent immediate response to a short duration pressure change. An override bandwidth timer can be programmed to prevent staging until the system pressure has stabilised and normal control established.

When the Cascade Controller is enabled and running normally, and the frequency converter issues a trip alarm, the system head is maintained by staging and destaging fixed speed pumps. To prevent frequent staging and destaging and minimise pressure fluxuations, a wider fixed speed bandwidth is used instead of the staging bandwidth.

7.1.9 Pump Staging with Lead Pump Alternation

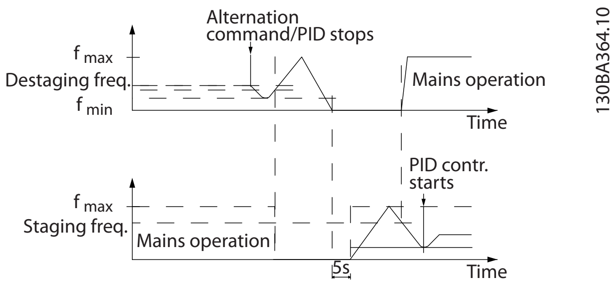

Illustration 7.8 Pump Staging with Lead Pump Alternation

With lead pump alternation enabled, a maximum of 2 pumps are controlled. At an alternation command, the lead pump ramps to minimum frequency (f_{min}) and after a delay will ramp to maximum frequency (f_{max}. When the speed of the lead pump reaches the destaging frequency, the fixed speed pump is cut out (de-staged). The lead pump continues to ramp up and then ramps down to a stop and the 2 relays are cut out.

After a time delay, the relay for the fixed speed pump cuts in (staged) and this pump becomes the new lead pump. The new lead pump ramps up to maximum speed and then down to minimum speed. When ramping down and reaching the staging frequency, the old lead pump is now cut in (staged) on the mains as the new fixed speed pump.

If the lead pump has been running at minimum frequency (f_{min}) for a programmed amount of time, with a fixed speed pump running, the lead pump contributes little to the system. When the programmed value of the timer expires, the lead pump is removed, avoiding a deal heat water circulation problem.

7.1.10 System Status and Operation

If the lead pump goes into Sleep Mode, the function is displayed on the LCP. It is possible to alternate the lead pump on a Sleep Mode condition.

When the Cascade Controller is enabled, the operation status for each pump and the Cascade Controller is displayed on the LCP. Information displayed includes:

- Pumps Status, is a readout of the status for the relays assigned to each pump. The display shows pumps that are disabled, off, running on the frequency converter or running on the mains/ motor starter.
- Cascade Status, is a readout of the status for the Cascade Controller. The display shows the Cascade Controller is disabled, all pumps are off, and emergency has stopped all pumps, all pumps are running, fixed speed pumps are being staged/de-staged and lead pump alternation is occurring.
- De-stage at No-Flow ensures that all fixed speed pumps are stopped individually until the no-flow status disappears.

7.1.11 Fixed Variable Speed Pump Wiring Diagram

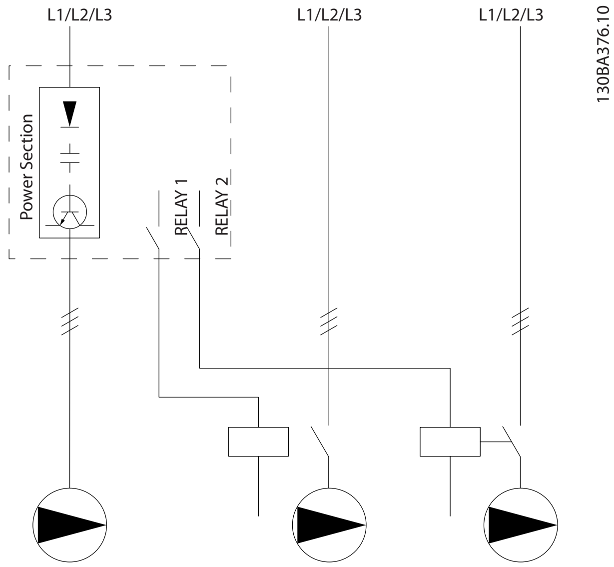

Illustration 7.9 Fixed Variable Speed Pump Wiring Diagram

- K1 blocks for K2 via the mechanical interlock preventing mains to be connected to the output of the frequency converter. (via K1).
- Auxiliary break contact on K1 prevents K3 to cut in.
- RELAY 2 controls contactor K4 for on/off control of the fixed speed pump.
- At alternation both relays de-energises and now RELAY 2 is energised as the first relay.

7.1.12 Lead Pump Alternation Wiring Diagram

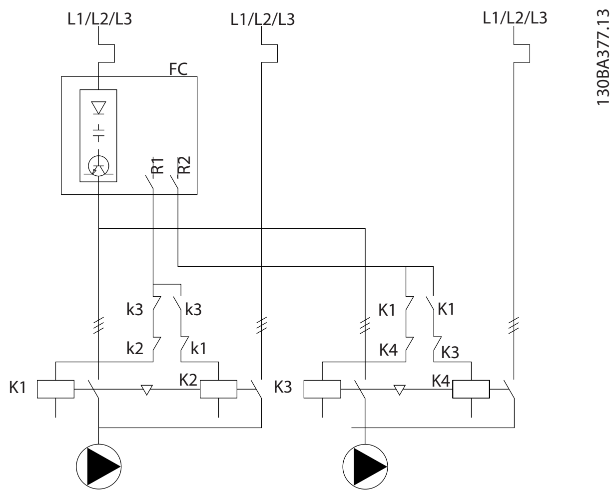

Illustration 7.10 Lead Pump Alternation Wiring Diagram

Every pump must be connected to 2 contactors (K1/K2 and K3/K4) with a mechanical interlock. Thermal relays or other motor protection devices must be applied according to local regulation and/or individual demands.

- RELAY 1 (R1) and RELAY 2 (R2) are the built-in relays in the frequency converter.
- When all relays are de-energised, the first built in relay to be energised cuts in the contactor corresponding to the pump controlled by the relay. E.g. RELAY 1 cuts in contactor K1, which becomes the lead pump.

7.1.13 Cascade Controller Wiring Diagram

The wiring diagram shows an example with the built-in BASIC Cascade Controller with one variable speed pump (lead) and 2 fixed speed pumps, a 4-20 mA transmitter and System Safety Interlock.

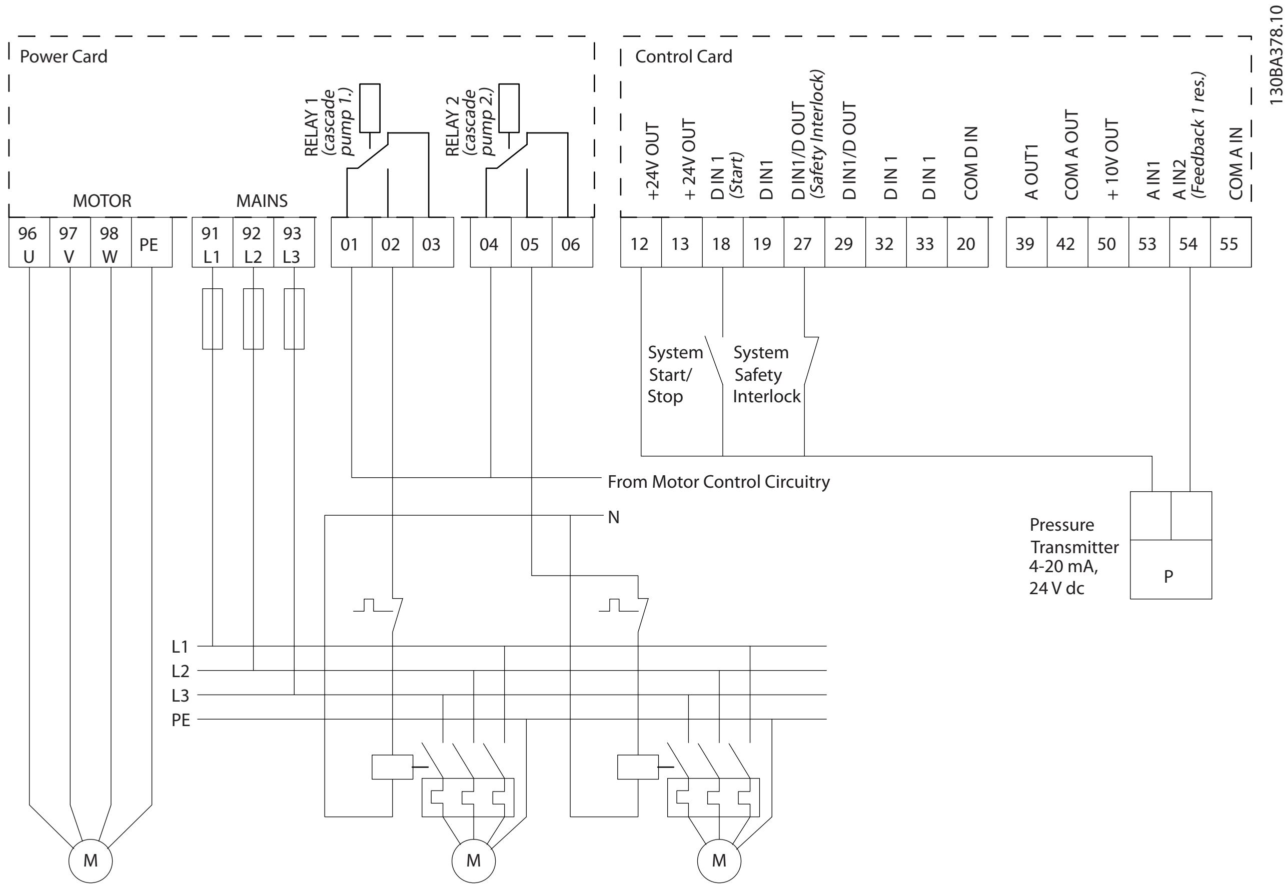

Illustration 7.11 Cascade Controller Wiring Diagram

7.1.14 Start/Stop Conditions

See *5-1* Digital Inputs*.

Digital input commands	Variable speed pump (lead)	Fixed speed pumps (lag)
Start (SYSTEM START/STOP)	Ramps up (if stopped and there is a demand)	Staging (if stopped and there is a demand)
Lead Pump Start	Ramps up if SYSTEM START is active	Not affected
Coast (EMERGENCY STOP)	Coast to stop	Cut out (correspond relays, terminal 27/29 and 42/45)
External Interlock	Coast to stop	Cut out (built-in relays are de-energised)

Table 7.1 Commands Assigned to Digital Inputs

LCP keys	Variable speed pump (lead)	Fixed speed pumps (lag)
[Hand On]	Ramps up (if stopped by a normal stop command) or stays in operation if already running	Destaging (if running)
[Off]	Ramps down	Destaging
[Auto On]	Starts and stops according to commands via terminals or serial bus cascade controller only can work when drive in "Auto ON" mode	Staging/Destaging

Table 7.2 LCP Key Functions

8 Installation and Set-up

8.1 Installation and Set-up

8.1.1 Overview

RS-485 is a 2-wire bus interface compatible with multi-drop network topology, that is, 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.

NOTICE

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

Terminate each segment at both ends, using either the termination switch (S801) of the 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 ground connection of the screen at every node is important, including at high frequencies. Thus, connect a large surface of the screen to ground, for example with a cable clamp or a conductive cable gland. It may be necessary to apply potential-equalising 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 [Ω]	120
Cable length [m]	Max. 1200 (including drop lines) Max. 500 station-to-station

Table 8.1 Cable Specifications

One or more frequency converters can be connected to a control (or master) using the RS-485 standardised interface. Terminal 68 is connected to the P signal (TX+, RX+), while terminal 69 is connected to the N signal (TX-,RX-). See drawings in *chapter 6.8.3 Grounding of Screened Control Cables*.

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

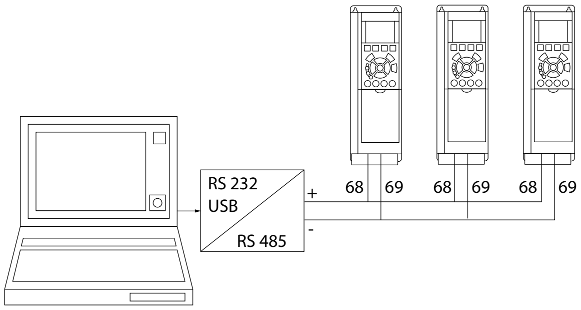

Illustration 8.1 Parallel Connections

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

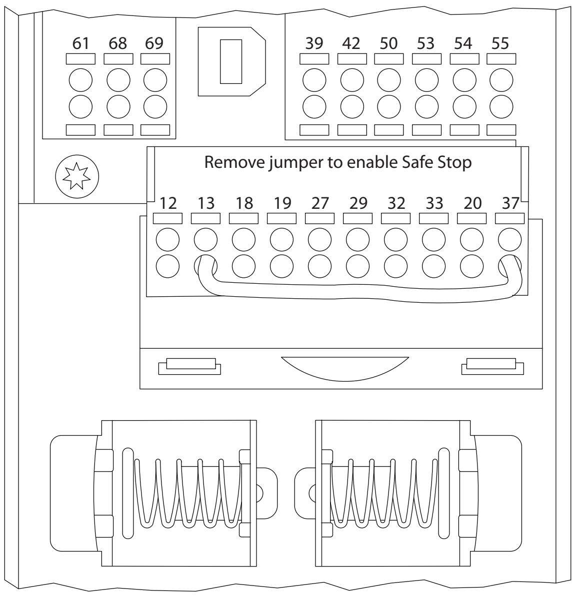

Illustration 8.2 Control Card Terminals

8.1.2 Frequency Converter Hardware Setup

Use the terminator dip switch on the main control board of the frequency converter to terminate the RS-485 bus.

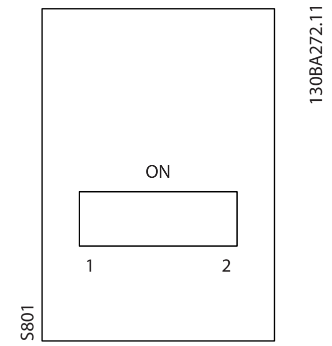

Illustration 8.3 Terminator Switch Factory Setting

The factory setting for the dip switch is OFF.

8.1.3 Frequency Converter Parameter Settings for Modbus Communication

The following parameters apply to the RS-485 interface (FC-port):

Parameter	Function
8-30 Protocol	Select the application protocol to run on the RS-485 interface
8-31 Address	Set the node address. Note: The address range depends on the protocol selected in *8-30 Protocol*
8-32 Baud Rate	Set the baud rate. Note: The default baud rate depends on the protocol selected in *8-30 Protocol*
8-33 Parity / Stop Bits	Set the parity and number of stop bits. Note: The default selection depends on the protocol selected in *8-30 Protocol*
8-35 Minimum Response Delay	Specify a minimum delay time between receiving a request and transmitting a response. This can be used for overcoming modem turnaround delays.
8-36 Maximum Response Delay	Specify a maximum delay time between transmitting a request and receiving a response.
8-37 Maximum Inter-Char Delay	Specify a maximum delay time between two received bytes to ensure time-out if transmission is interrupted.

Table 8.2 Parameters Apply to the RS-485 Interface (FC-port)

8.1.4 EMC Precautions

The following EMC precautions are recommended to achieve interference-free operation of the RS-485 network.

Observe relevant national and local regulations, for example regarding protective earth connection. Keep the RS-485 communication cable 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 inches) 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°.

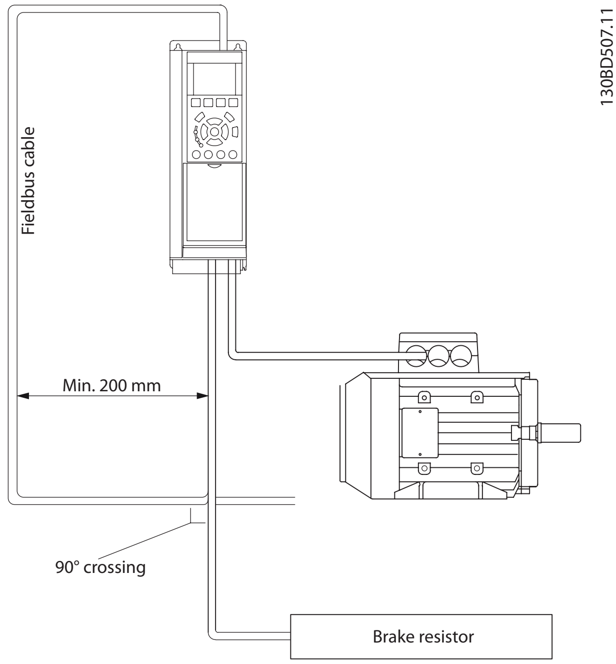

Illustration 8.4 Cable Routing

8.2 FC Protocol Overview

The FC protocol, also referred to as FC bus or Standard bus, is the Danfoss standard fieldbus. It defines an access technique according to the master-follower principle for communications via a serial bus.
One master and a maximum of 126 followers can be connected to the bus. The master selects the individual followers via an address character in the telegram. A follower itself can never transmit without first being requested to do so, and direct message transfer between the individual followers is not possible. Communications occur in the half-duplex mode.
The master function cannot be transferred to another node (single-master system).

The physical layer is RS-485, thus utilising the RS-485 port built into the frequency converter. The FC protocol supports different telegram formats:

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

8.2.1 FC with Modbus RTU

The FC protocol 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 a variety of preset speeds
- Run in reverse
- Change of the active set-up
- Control of the 2 relays built into 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 PID controller is used.

8.3 Network Configuration

8.3.1 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 Baud Rate	2400 - 115200
8-33 Parity / Stop Bits	Even parity, 1 stop bit (default)

Table 8.3 Parameters Enable the FC Protocol

8.4 FC Protocol Message Framing Structure

8.4.1 Content of a Character (byte)

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

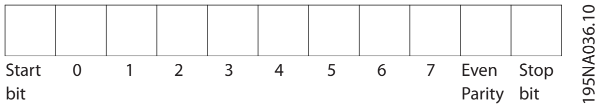

Illustration 8.5 Content of a Character

8.4.2 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.

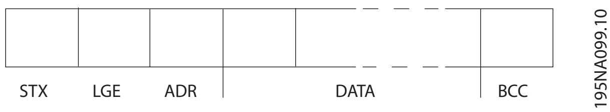

Illustration 8.6 Telegram Structure

8.4.3 Telegram Length (LGE)

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

4 data bytes	LGE=4+1+1=6 bytes
12 data bytes	LGE=12+1+1=14 bytes
Telegramscontaining texts	10[1)]+n bytes

Table 8.4 Length of Telegrams

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

8.4.4 Frequency Converter Address (ADR)

2 different address formats are used.
The address range of the frequency converter is either 1-31 or 1-126.

1. Address format 1-31:

Bit 7 = 0 (address format 1-31 active)

Bit 6 is not used

Bit 5 = 1: Broadcast, address bits (0-4) are not used

Bit 5 = 0: No Broadcast

Bit 0-4 = frequency converter address 1-31

2. Address format 1-126:

Bit 7 = 1 (address format 1-126 active)

Bit 0-6 = frequency converter address 1-126

Bit 0-6 = 0 Broadcast

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

8.4.5 Data Control Byte (BCC)

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

8.4.6 The Data Field

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

The 3 types of telegram are:

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

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

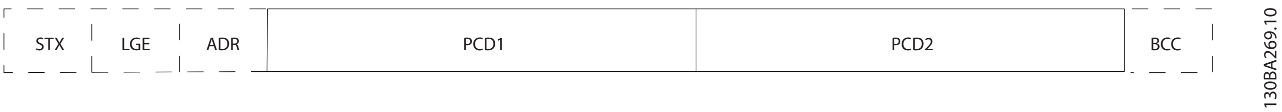

Illustration 8.7 Process Block

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

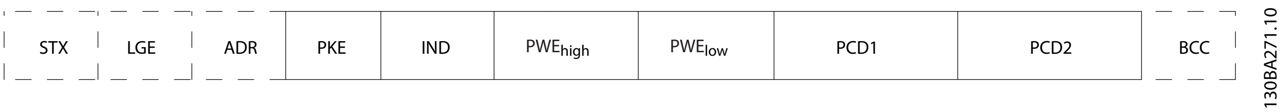

Illustration 8.8 Parameter Block

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

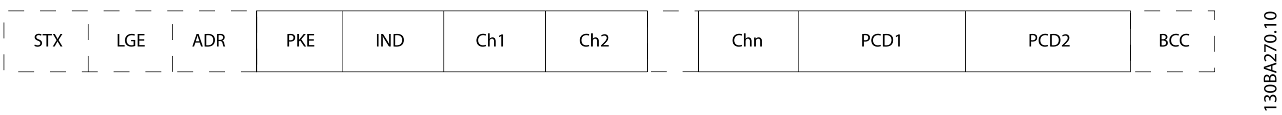

Illustration 8.9 Text Block

8.4.7 The PKE Field

The PKE field contains 2 sub-fields: Parameter command and response AK, and Parameter number PNU:

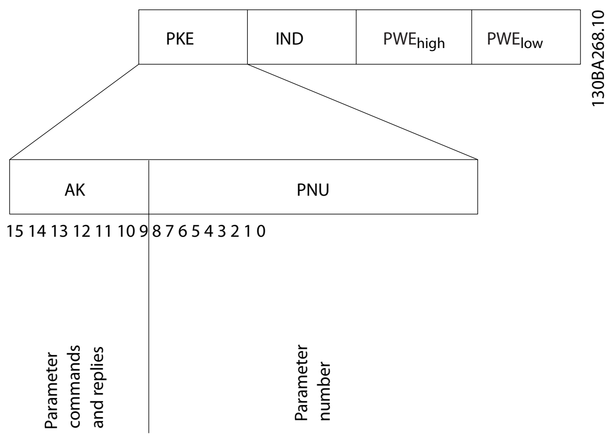

Illustration 8.10 PKE Field

Bits no. 12-15 transfer parameter commands from master to follower and return processed follower responses to the master.

Bit no.				Parameter command
15	14	13	12	
0	0	0	0	No command
0	0	0	1	Read parameter value
0	0	1	0	Write parameter value in RAM (word)
0	0	1	1	Write parameter value in RAM (double word)
1	1	0	1	Write parameter value in RAM and EEprom (double word)
1	1	1	0	Write parameter value in RAM and EEprom (word)
1	1	1	1	Read/write text

Table 8.5 Parameter Commands Master ⇒ Follower

Bit no.				Response
15	14	13	12	
0	0	0	0	No response
0	0	0	1	Parameter value transferred (word)
0	0	1	0	Parameter value transferred (double word)
0	1	1	1	Command cannot be performed
1	1	1	1	text transferred

Table 8.6 Response Follower⇒ Master

If the command cannot be performed, the follower sends this response:
0111 Command cannot be performed

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

PWE low (Hex)	Fault Report
0	The parameter number used does not exit
1	There is no write access to the defined parameter
2	Data value exceeds the parameter's limits
3	The sub index used does not exit
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 frequency converter's present mode. 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 8.7 Parameter Value Fault Report

8.4.8 Parameter Number (PNU)

Bits no. 0-11 transfer parameter numbers. The function of the relevant parameter is defined in the parameter description in *chapter 8.11.1 Control Word According to FC Profile (8-10 Control Profile = FC profile)*.

8.4.9 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.

8.4.10 Parameter Value (PWE)

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

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

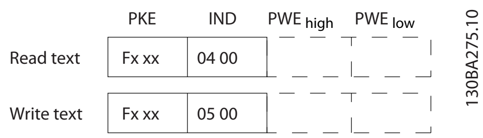

Illustration 8.11 Text via PWE Block

8.4.11 Data Types Supported by the Frequency Converter

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 8.8 Data Types and Description

8.4.12 Conversion

The various attributes of each parameter are displayed in factory setting. 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 therefore read as 10.0.

Examples:
0 s ⇒ conversion index 0
0.00 s ⇒ conversion index -2
0 ms ⇒ conversion index -3
0.00 ms ⇒ conversion index -5

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

Table 8.9 Conversion Table

8.4.13 Process Words (PCD)

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

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

Table 8.10 Process Words (PCD)

8.5 Examples

8.5.1 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
PWEHIGH = 0000 Hex
PWELOW = 03E8 Hex - Data value 1000, corresponding to 100 Hz, see *chapter 8.4.12 Conversion*.

The telegram looks like this:

PKE	IND	PWE high	PWE low
E19E H	0000 H	0000 H	03E8 H

130BA092.10

Illustration 8.12 Write Data in EEPROM

NOTICE

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

The response from the follower to the master is:

PKE	IND	PWE high	PWE low
119E H	0000 H	0000 H	03E8 H

130BA093.10

Illustration 8.13 Response from Follower

8.5.2 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
PWEHIGH = 0000 Hex
PWELOW = 0000 Hex

PKE	IND	PWE high	PWE low
1155 H	0000 H	0000 H	0000 H

130BA094.10

Illustration 8.14 Parameter Value

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

PKE	IND	PWE high	PWE low
1155 H	0000 H	0000 H	03E8 H

130BA267.10

Illustration 8.15 Response from Follower

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*.

8.6 Modbus RTU Overview

8.6.1 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.

8.6.2 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.

8.6.3 Modbus RTU Overview

Regardless of the type of physical communication networks, the Modbus RTU Overview describes the process a controller uses to request access to another device. This process includes how the Modbus RTU responds to requests from another device, and how errors are detected and reported. It also establishes a common format for the layout and contents of message fields.
During communications over a Modbus RTU network, the protocol determines:

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

If a reply is required, the controller constructs the reply message and sends it.
Controllers communicate using a master-follower technique in which only the master can initiate transactions (called queries). Followers respond by supplying the requested data to the master, or by taking the action requested in the query.
The master can address individual followers, or initiate a broadcast message to all followers. Followers return a response to queries that are addressed to them individually. No responses are returned to broadcast queries from the master. The Modbus RTU protocol establishes the format for the master's query by providing the device (or broadcast) address, a function code defining the requested action, any data to be sent, and an error-checking field. The follower's response message is also constructed using Modbus protocol. It contains fields confirming the action taken, any data to be returned, and

an error-checking field. If an error occurs in receipt of the message, or if the follower is unable to perform the requested action, the follower constructs an error message, and send it in response, or a time-out occurs.

8.6.4 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 a variety of preset speeds
- Run in reverse
- Change the active set-up
- Control the frequency converter's built-in relay

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.

8.7 Network Configuration

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 8.11 Modbus RTU Parameters

8.8 Modbus RTU Message Framing Structure

8.8.1 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 8.12*.

Start bit	Data byte								Stop/ parity	Stop

Table 8.12 Format for Each Byte

Coding System	8-bit binary, hexadecimal 0-9, A-F. 2 hexadecimal characters contained in each 8-bit field of the message
Bits Per Byte	1 start bit 8 data bits, least significant bit sent first 1 bit for even/odd parity; no bit for no parity 1 stop bit if parity is used; 2 bits if no parity
Error Check Field	Cyclical Redundancy Check (CRC)

8.8.2 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 8.13*.

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 8.13 Typical Modbus RTU Message Structure

8

8.8.3 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 field to be transmitted is the device address. Following the last transmitted character, a similar period of at least 3.5 character intervals marks the end of the message. A new message can begin after this period. The entire message frame must be transmitted as a continuous stream. If a silent period of more than 1.5 character intervals occurs before completion of the frame, the receiving device flushes the incomplete message and assumes that the next byte is the address field of a new message. Similarly, if a new message begins before 3.5 character intervals after a previous message, the receiving device considers it a continuation of the previous message. This causes a time-out (no response from the follower), since the value in the final CRC field is not valid for the combined messages.

8.8.4 Address Field

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

8.8.5 Function Field

The function field of a message frame contains 8 bits. Valid codes are in the range of 1-FF. Function fields are used to send messages between master and follower. When a message is sent from a master to a follower device, the function code field tells the follower what kind of action to perform. When the follower responds to the master, it uses the function code field to indicate either a normal (error-free) response, or that some kind of error occurred (called an exception response). For a normal response, the follower simply echoes the original function code. For an exception response, the follower returns a code that is equivalent to the original function code with its most significant bit set to logic 1. In addition, the follower places a unique code into the data field of the response message. This tells the master what kind of error occurred, or the reason for the exception. Also refer to *chapter 8.8.10 Function Codes Supported by Modbus RTU* and *chapter 8.8.11 Modbus Exception Codes*

8.8.6 Data Field

The data field is constructed using sets of 2 hexadecimal digits, in the range of 00 to FF hexadecimal. These are made up of one RTU character. The data field of messages sent from a master to follower device contains additional information which the follower must use to take the action defined by the function code. This can include items such as coil or register addresses, the quantity of items to be handled, and the count of actual data bytes in the field.

8.8.7 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 2 values are unequal, a bus time-out results. The error-checking field contains a 16-bit binary value implemented as 2 8-bit bytes. When this is done, 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.

8.8.8 Coil Register Addressing

In Modbus, all data are organised in coils and holding registers. Coils hold a single bit, whereas holding registers hold a 2-byte word (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	Master to follower
17-32	Frequency converter speed or set-point reference Range 0x0 – 0xFFFF (-200% ... ~200%)	Master to follower
33-48	Frequency converter status word (see *Table 8.16*)	Follower to master
49-64	Open loop mode: Frequency converter output frequency Closed loop mode: Frequency converter feedback signal	Follower to master
65	Parameter write control (master to follower) 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.	Master to follower
66-65536	Reserved	

Table 8.14 Coil Descriptions

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 8.15 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 8.16 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 8.17 Holding Registers

** Used to specify the index number to be used when accessing an indexed parameter.*

8

8.8.9 How to Control the Frequency Converter

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

8.8.10 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 follower ID	11 Hex

Table 8.18 Function Codes

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

Table 8.19 Function Codes

8.8.11 Modbus Exception Codes

For a full explanation of the structure of an exception code response, refer to *chapter 8.8.5 Function Field*.

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

Table 8.20 Modbus Exception Codes

8.9 How to Access Parameters

8.9.1 Parameter Handling

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

Reading *3-14 Preset Relative Reference* (32bit): The holding registers 3410 & 3411 holds the parameters value. A value of 11300 (Decimal), means that the parameter is set to 1113.00 S.

For information on the parameters, size and converting index, consult the product relevant programming guide.

8.9.2 Storage of Data

The Coil 65 decimal determines whether data written to the frequency converter are stored in EEPROM and RAM (coil 65=1) or only in RAM (coil 65= 0).

8.9.3 IND

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

8.9.4 Text Blocks

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

8.9.5 Conversion Factor

The different attributes for each parameter can be seen in the section on factory settings. Since a parameter value can only be transferred as a whole number, a conversion factor must be used to transfer decimals.

8.9.6 Parameter Values

Standard data types
Standard data types are int 16, int 32, uint 8, uint 16 and uint 32. They are stored as 4x registers (40001–4FFFF). The parameters are read using function 03HEX "Read Holding Registers." Parameters are written using the function 6HEX "Preset Single Register" for 1 register (16 bits), and the function 10 HEX "Preset Multiple Registers" for 2 registers (32 bits). Readable sizes range from 1 register (16 bits) up to 10 registers (20 characters).

Non-standard data types
Non-standard data types are text strings and are stored as 4x registers (40001–4FFFF). The parameters are read using function 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).

8.10 Examples

The following examples illustrate various Modbus RTU commands.

8.10.1 Read Coil Status (01 HEX)

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

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

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

Field Name	Example (HEX)
Follower Address	01 (frequency converter address)
Function	01 (read coils)
Starting Address HI	00
Starting Address LO	20 (32 decimals) Coil 33
No. of Points HI	00
No. of Points LO	10 (16 decimals)
Error Check (CRC)	-

Table 8.21 Query

Response
The coil status in the response message is packed as one coil per bit of the data field. Status is indicated as: 1=ON; 0=OFF. The LSB of the first data byte contains the coil addressed in the query. The other coils follow toward the high order end of this byte, and from 'low-order to high-order' in subsequent bytes.
If the returned coil quantity is not a multiple of 8, the remaining bits in the final data byte is padded with zeros (toward the high order end of the byte). The byte count field specifies the number of complete bytes of data.

Field Name	Example (HEX)
Follower Address	01 (frequency converter address)
Function	01 (read coils)
Byte Count	02 (2 bytes of data)
Data (Coils 40-33)	07
Data (Coils 48-41)	06 (STW=0607hex)
Error Check (CRC)	-

Table 8.22 Response

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NOTICE

Coils and registers are addressed explicitly with an off-set of -1 in Modbus.
I.e. Coil 33 is addressed as Coil 32.

8.10.2 Force/Write Single Coil (05 HEX)

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

Query
The query message specifies the coil 65 (parameter write control) to be forced. Coil addresses start at zero, that is, coil 65 is addressed as 64. Force Data=00 00HEX (OFF) or FF 00HEX (ON).

Field Name	Example (HEX)
Follower Address	01 (Frequency converter address)
Function	05 (write single coil)
Coil Address HI	00
Coil Address LO	40 (64 decimal) Coil 65
Force Data HI	FF
Force Data LO	00 (FF 00=ON)
Error Check (CRC)	-

Table 8.23 Query

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

Field Name	Example (HEX)
Follower Address	01
Function	05
Force Data HI	FF
Force Data LO	00
Quantity of Coils HI	00
Quantity of Coils LO	01
Error Check (CRC)	-

Table 8.24 Response

8.10.3 Force/Write Multiple Coils (0F HEX)

Description
This function forces each coil in a sequence of coils to either ON or OFF. When broadcasting the function forces the same coil references in all attached followers.

Query
The query message specifies the coils 17 to 32 (speed set-point) to be forced.

Field Name	Example (HEX)
Follower Address	01 (frequency converter address)
Function	0F (write multiple coils)
Coil Address HI	00
Coil Address LO	10 (coil address 17)
Quantity of Coils HI	00
Quantity of Coils LO	10 (16 coils)
Byte Count	02
Force Data HI (Coils 8-1)	20
Force Data LO (Coils 16-9)	00 (ref.=2000 hex)
Error Check (CRC)	-

Table 8.25 Query

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

Field Name	Example (HEX)
Follower Address	01 (frequency converter address)
Function	0F (write multiple coils)
Coil Address HI	00
Coil Address LO	10 (coil address 17)
Quantity of Coils HI	00
Quantity of Coils LO	10 (16 coils)
Error Check (CRC)	-

Table 8.26 Response

8.10.4 Read Holding Registers (03 HEX)

Description
This function reads the contents of holding registers in the following.

Query
The query message specifies the starting register and quantity of registers to be read. Register addresses start at zero, i.e. registers 1-4 are addressed as 0-3.

Field Name	Example (HEX)
Slave Address	01
Function	03 (read holding registers)
Starting Address HI	0B (Register address 3029)
Starting Address LO	D5 (Register address 3029)
No. of Points HI	00
No. of Points LO	02 - (Par. 3-03 is 32 bits long, i.e. 2 registers)
Error Check (CRC)	-

Table 8.27 Example: Read *3-03 Maximum Reference*, register 03030

Response
The register data in the response message are packed as 2two bytes per register, with the binary contents right justified within each byte. For each register, the first byte contains the high-order bits and the second contains the low-order bits.

Field Name	Example (HEX)
Slave Address	01
Function	03
Byte Count	04
Data HI (Register 3030)	00
Data LO (Register 3030)	16
Data HI (Register 3031)	E3
Data LO (Register 3031)	60
Error Check (CRC)	-

Table 8.28 Example: Hex 0016E360=1.500.000=1500 RPM

8.10.5 Preset Single Register (06 HEX)

Description
This function presets a value into a single holding register.

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

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

Field Name	Example (HEX)
Follower Address	01
Function	06
Register Address HI	03 (Register address 999)
Register Address LO	E7 (Register address 999)
Preset Data HI	00
Preset Data LO	01
Error Check (CRC)	-

Table 8.29 Query

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

Field Name	Example (HEX)
Follower Address	01
Function	06
Register Address HI	03
Register Address LO	E7
Preset Data HI	00
Preset Data LO	01
Error Check (CRC)	-

Table 8.30 Response

8.10.6 Preset Multiple Registers (10 HEX)

Description
This function presets values into a sequence of holding registers.

Query
The query message specifies the register references to be preset. Register addresses start at zero, i.e. register 1 is addressed as 0. Example of a request to preset 2 registers (set parameter 1-24=738 (7.38 A))

Field Name	Example (HEX)
Slave Address	01
Function	10
Starting Address HI	04
Starting Address LO	D7
No. of Registers HI	00
No. of registers LO	02
Byte Count	04
Write Data HI (Register 4: 1049)	00
Write Data LO (Register 4: 1049)	00
Write Data HI (Register 4: 1050)	02
Write Data LO (Register 4: 1050)	E2
Error Check (CRC)	-

Table 8.31 Query

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

Field Name	Example (HEX)
Slave Address	01
Function	10
Starting Address HI	04
Starting Address LO	D7
No. of Registers HI	00
No. of registers LO	02
Error Check (CRC)	-

Table 8.32 Response

8.11 Danfoss FC Control Profile

8.11.1 Control Word According to FC Profile (*8-10 Control Profile* = FC profile)

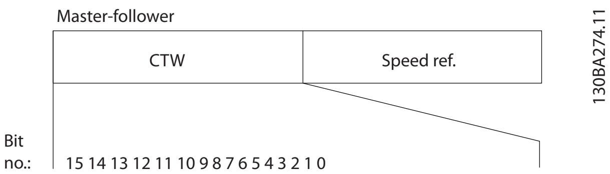

Illustration 8.16 Control Word

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 8.33 Control Word Bits

Explanation of the Control Bits

Bits 00/01
Bits 00 and 01 are used to select between the 4 reference values, which are pre-programmed in *3-10 Preset Reference* according to *Table 8.34*.

Programmed ref. value	Parameter	Bit 01	Bit 00
1	*3-10 Preset Reference* [0]	0	0
2	*3-10 Preset Reference* [1]	0	1
3	*3-10 Preset Reference* [2]	1	0
4	*3-10 Preset Reference* [3]	1	1

Table 8.34 Reference Values

NOTICE

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

Bit 02, DC brake
Bit 02 = ’0’ leads to DC braking and stop. Set braking current and duration in *2-01 DC Brake Current* and *2-02 DC Braking Time*. Bit 02 = ’1’ leads to ramping.

Bit 03, Coasting
Bit 03 = ’0’: The frequency converter immediately "lets go" of the motor, (the output transistors are "shut off") and it coasts to a standstill. Bit 03 = ’1’: The frequency converter starts the motor, if the other starting conditions are met.

Make a selection in *8-50 Coasting Select* to define how Bit 03 gates with the corresponding function on a digital input.

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

Bit 05, Hold output frequency
Bit 05 = ’0’: The present output frequency (in Hz) freezes. Change the frozen output frequency only with the digital inputs (*5-10 Terminal 18 Digital Input* to *5-15 Terminal 33 Digital Input*) programmed to *Speed up* and *Slow down*.

NOTICE

If Freeze output is active, the frequency converter can only be stopped by the following:

- **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 signal’s leading edge, 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. Turn off the control word, if it should not be used when updating or reading parameters.

Bit 11, Relay 01
Bit 11 = "0": Relay not activated. Bit 11 = "1": Relay 01 activated provided that *Control word bit 11* is selected in *5-40 Function Relay*.

Bit 12, Relay 04
Bit 12 = "0": Relay 04 is not activated. Bit 12 = "1": Relay 04 is activated provided that *Control word bit 12* is selected in *5-40 Function Relay*.

Bit 13/14, Selection of set-up
Use bits 13 and 14 to select from the 4 menu set-ups according to *Table 8.35*.

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

Table 8.35 4 Menu Set-ups

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 or Logic and is selected.

8.11.2 Status Word According to FC Profile (STW) (*8-10 Control Profile* = FC profile)

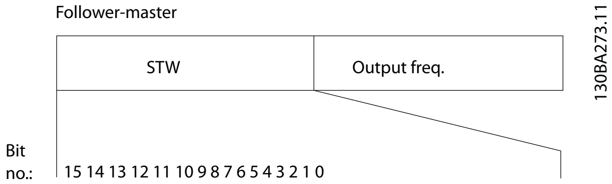

Illustration 8.17 Status Word

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 8.36 Status Word Bits

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].

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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 might 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 activated on the control unit or *Local control* in *3-13 Reference Site* is selected. Control via serial communication is not possible. 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 overtemperature on the inverter. Bit 12 = ’1’: The inverter stops because of overtemperature, but the unit does not trip and resumes operation once the overtemperature stops.

Bit 13, Voltage OK/limit exceeded
Bit 13 = ’0’: There are no voltage warnings. Bit 13 = ’1’: The DC-voltage in the frequency converter’s 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.

8.11.3 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 by means of 2’s complement. The Actual Output frequency (MAV) is scaled in the same way as the bus reference.

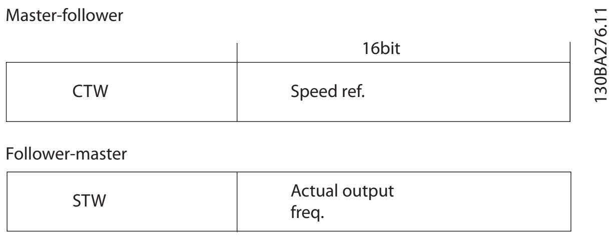


Illustration 8.18 Actual Output Frequency (MAV)

The reference and MAV are scaled as follows:

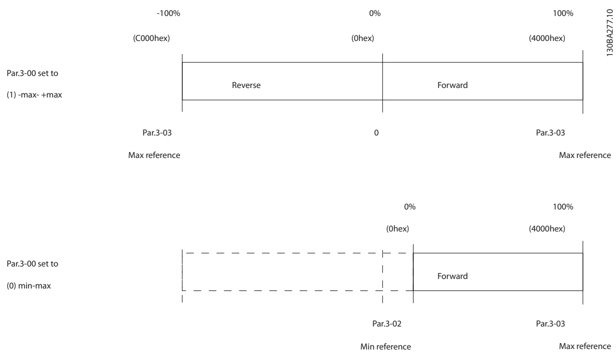


Illustration 8.19 Reference and MAV

8

9 General Specifications and Troubleshooting

9.1 Mains Supply Tables

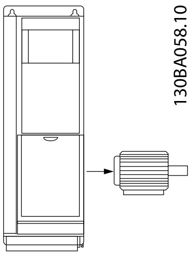
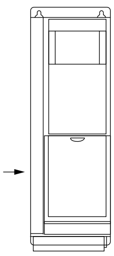
Mains supply 3x200-240 V AC - Normal overload 110% for 1 minute						
Frequency Converter Typical Shaft Output [kW]		P1K1 1.1	P1K5 1.5	P2K2 2.2	P3K0 3	P3K7 3.7
IP20/Chassis (A2+A3 may be converted to IP21 using a conversion kit)		A2	A2	A2	A3	A3
IP55/NEMA 12		A4/A5	A4/A5	A4/A5	A5	A5
IP66/NEMA 12		A5	A5	A5	A5	A5
Typical Shaft Output [hp] at 208 V		1.5	2.0	2.9	4.0	4.9
Output current						
 130BA058.10	Continuous (3x200-240 V) [A]	6.6	7.5	10.6	12.5	16.7
	Intermittent (3x200-240 V) [A]	7.3	8.3	11.7	13.8	18.4
	Continuous kVA (208 V AC) [kVA]	2.38	2.70	3.82	4.50	6.00
	Max. cable size:					
	(mains, motor, brake) [mm^2/AWG][2)]	4/10				
Max. input current						
 130BA057.10	Continuous (3x200-240 V) [A]	5.9	6.8	9.5	11.3	15.0
	Intermittent (3x200-240 V) [A]	6.5	7.5	10.5	12.4	16.5
	Max. pre-fuses[1)] [A]	20	20	20	32	32
	Environment					
	Estimated power loss at rated max. load [W] [4)]	63	82	116	155	185
	Weight enclosure IP20 [kg]	4.9	4.9	4.9	6.6	6.6
	Weight enclosure IP21 [kg]	5.5	5.5	5.5	7.5	7.5
	Weight enclosure IP55 [kg]	9.7/13.5	9.7/13.5	9.7/13.5	13.5	13.5
	Weight enclosure IP66 [kg]	9.7/13.5	9.7/13.5	9.7/13.5	13.5	13.5
	Efficiency [3)]	0.96	0.96	0.96	0.96	0.96

Table 9.1 Mains Supply 3x200-240 V AC

Mains supply 3x200-240 V AC - Normal overload 110% for 1 minute									
IP20/Chassis (B3+4 and C3+4 may be converted to IP21 using a conversion kit)	B3	B3	B3	B4	B4	C3	C3	C4	C4
IP21/NEMA 1	B1	B1	B1	B2	C1	C1	C1	C2	C2
IP55/NEMA 12	B1	B1	B1	B2	C1	C1	C1	C2	C2
IP66/NEMA 12	B1	B1	B1	B2	C1	C1	C1	C2	C2
	P5K5	P7K5	P11K	P15K	P18K	P22K	P30K	P37K	P45K
Typical Shaft Output [kW]	5.5	7.5	11	15	18.5	22	30	37	45
Typical Shaft Output [hp] at 208 V	7.5	10	15	20	25	30	40	50	60
Output current									
Continuous (3x200-240 V) [A]	24.2	30.8	46.2	59.4	74.8	88.0	115	143	170
	16/6			35/2	35/2			70/3/0	185/ kcmil350
Continuous (3x200-240 V) [A]	22.0	28.0	42.0	54.0	68.0	80.0	104.0	130.0	154.0
Intermittent (3x200-240 V) [A]	24.2	30.8	46.2	59.4	74.8	88.0	114.0	143.0	169.0
Max. pre-fuses[1] [A]	63	63	63	80	125	125	160	200	250
Environment:									
Estimated power loss at rated max. load [W] [4]	269	310	447	602	737	845	1140	1353	1636
Weight enclosure IP20 [kg]	12	12	12	23.5	23.5	35	35	50	50
Weight enclosure IP21 [kg]	23	23	23	27	45	45	45	65	65
Weight enclosure IP55 [kg]	23	23	23	27	45	45	45	65	65
Weight enclosure IP66 [kg]	23	23	23	27	45	45	45	65	65
Efficiency [3]	0.96	0.96	0.96	0.96	0.96	0.97	0.97	0.97	0.97
Intermittent (3x200-240 V) [A]	26.6	33.9	50.8	65.3	82.3	96.8	127	157	187
Continuous kVA (208 V AC) [kVA]	8.7	11.1	16.6	21.4	26.9	31.7	41.4	51.5	61.2
Max. cable size:									
(mains, motor, brake) [mm²/AWG] [2]	10/7			35/2	50/1/0 (B4=35/2)			95/4/0	120/250 MCM

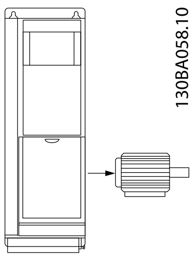


Table 9.2 Mains Supply 3x200-240 V AC

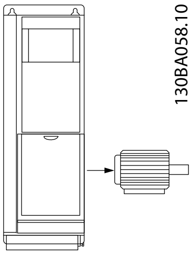
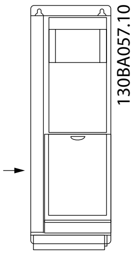
Mains Supply 3x380-480 V AC - Normal overload 110% for 1 minute								
Frequency converter Typical Shaft Output [kW]		P1K1 1.1	P1K5 1.5	P2K2 2.2	P3K0 3	P4K0 4	P5K5 5.5	P7K5 7.5
Typical Shaft Output [hp] at 460 V		1.5	2.0	2.9	4.0	5.0	7.5	10
IP20/Chassis (A2+A3 may be converted to IP21 using a conversion kit)		A2	A2	A2	A2	A2	A3	A3
IP55/NEMA 12		A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A5	A5
IP66/NEMA 12		A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A5	A5
Output current								
 130BA058.10	Continuous (3x380-440V) [A]	3	4.1	5.6	7.2	10	13	16
	Intermittent (3x380-440V) [A]	3.3	4.5	6.2	7.9	11	14.3	17.6
	Continuous (3x441-480V) [A]	2.7	3.4	4.8	6.3	8.2	11	14.5
	Intermittent (3x441-480V) [A]	3.0	3.7	5.3	6.9	9.0	12.1	15.4
	Continuous kVA (400 V AC) [kVA]	2.1	2.8	3.9	5.0	6.9	9.0	11.0
	Continuous kVA (460 V AC) [kVA]	2.4	2.7	3.8	5.0	6.5	8.8	11.6
	Max. cable size:							
	(mains, motor, brake) [[mm^2/AWG] 2)	4/10						
Max. input current								
 130BA057.10	Continuous (3x380-440 V) [A]	2.7	3.7	5.0	6.5	9.0	11.7	14.4
	Intermittent (3x380-440 V) [A]	3.0	4.1	5.5	7.2	9.9	12.9	15.8
	Continuous (3x441-480 V) [A]	2.7	3.1	4.3	5.7	7.4	9.9	13.0
	Intermittent (3x441-480 V) [A]	3.0	3.4	4.7	6.3	8.1	10.9	14.3
	Max. pre-fuses1)[A]	10	10	20	20	20	32	32
	Environment							
	Estimated power loss at rated max. load [W] 4)	58	62	88	116	124	187	255
	Weight enclosure IP20 [kg]	4.8	4.9	4.9	4.9	4.9	6.6	6.6
	Weight enclosure IP21 [kg]							
	Weight enclosure IP55 [kg]	9.7/13.5	9.7/13.5	9.7/13.5	9.7/13.5	9.7/13.5	14.2	14.2
	Weight enclosure IP66 [kg]	9.7/13.5	9.7/13.5	9.7/13.5	9.7/13.5	9.7/13.5	14.2	14.2
	Efficiency 3)	0.96	0.97	0.97	0.97	0.97	0.97	0.97

Table 9.3 Mains Supply 3x380-480 V AC

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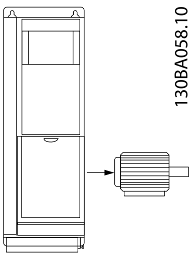
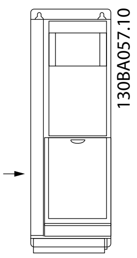
Mains Supply 3x380-480 V AC - Normal overload 110% for 1 minute											
Frequency converter Typical Shaft Output [kW]		P11K 11	P15K 15	P18K 18.5	P22K 22	P30K 30	P37K 37	P45K 45	P55K 55	P75K 75	P90K 90
Typical Shaft Output [hp] at 460 V		15	20	25	30	40	50	60	75	100	125
IP20/Chassis (B3+4 and C3+4 may be converted to IP21 using a conversion kit (Contact Danfoss)		B3	B3	B3	B4	B4	B4	C3	C3	C4	C4
IP21/NEMA 1		B1	B1	B1	B2	B2	C1	C1	C1	C2	C2
IP55/NEMA 12		B1	B1	B1	B2	B2	C1	C1	C1	C2	C2
IP66/NEMA 12		B1	B1	B1	B2	B2	C1	C1	C1	C2	C2
Output current											
	Continuous (3x380-439 V) [A]	24	32	37.5	44	61	73	90	106	147	177
	Intermittent (3x380-439 V) [A]	26.4	35.2	41.3	48.4	67.1	80.3	99	117	162	195
	Continuous (3x440-480 V) [A]	21	27	34	40	52	65	80	105	130	160
	Intermittent (3x440-480 V) [A]	23.1	29.7	37.4	44	61.6	71.5	88	116	143	176
	Continuous kVA (400 V AC) [kVA]	16.6	22.2	26	30.5	42.3	50.6	62.4	73.4	102	123
	Continuous kVA 460 V AC) [kVA]	16.7	21.5	27.1	31.9	41.4	51.8	63.7	83.7	104	128
	Max. cable size:										
	(mains, motor, brake) [mm²/ AWG] 2)	10/7			35/2		50/1/0 (B4=35/2)			95/ 4/0	120/ MCM250
	With mains disconnect switch included:	16/6					35/2	35/2		70/3/0	185/ kcmil350
Max. input current											
	Continuous (3x380-439 V) [A]	22	29	34	40	55	66	82	96	133	161
	Intermittent (3x380-439 V) [A]	24.2	31.9	37.4	44	60.5	72.6	90.2	106	146	177
	Continuous (3x440-480 V) [A]	19	25	31	36	47	59	73	95	118	145
	Intermittent (3x440-480 V) [A]	20.9	27.5	34.1	39.6	51.7	64.9	80.3	105	130	160
	Max. pre-fuses1)[A]	63	63	63	63	80	100	125	160	250	250
	Environment										
	Estimated power loss at rated max. load [W] 4)	278	392	465	525	698	739	843	1083	1384	1474
	Weight enclosure IP20 [kg]	12	12	12	23.5	23.5	23.5	35	35	50	50
	Weight enclosure IP21 [kg]	23	23	23	27	27	45	45	45	65	65
	Weight enclosure IP55 [kg]	23	23	23	27	27	45	45	45	65	65
	Weight enclosure IP66 [kg]	23	23	23	27	27	45	45	45	65	65
	Efficiency 3)	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.99

Table 9.4 Mains Supply 3x380-480 V AC

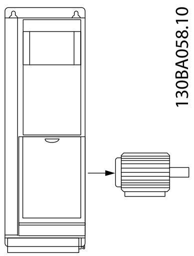
Mains supply 3x525 - 600 VAC Normal overload 110% for 1 minute																			
Size:		P1K1	P1K5	P2K2	P3K0	P3K7	P4K0	P5K5	P7K5	P11K	P15K	P18K	P22K	P30K	P37K	P45K	P55K	P75K	P90K
Typical Shaft Output [kW]		1.1	1.5	2.2	3	3.7	4	5.5	7.5	11	15	18.5	22	30	37	45	55	75	90
IP20 / Chassis		A3	A3	A3	A3	A2	A3	A3	A3	B3	B3	B3	B4	B4	B4	C3	C3	C4	C4
IP21 / NEMA 1		A3	A3	A3	A3	A2	A3	A3	A3	B1	B1	B1	B2	B2	C1	C1	C1	C2	C2
IP55 / NEMA 12		A5	A5	A5	A5	A5	A5	A5	A5	B1	B1	B1	B2	B2	C1	C1	C1	C2	C2
IP66 / NEMA 12		A5	A5	A5	A5	A5	A5	A5	A5	B1	B1	B1	B2	B2	C1	C1	C1	C2	C2
Output current																			
	Continuous (3x525-550 V) [A]	2.6	2.9	4.1	5.2	-	6.4	9.5	11.5	19	23	28	36	43	54	65	87	105	137
	Intermittent (3x525-550 V) [A]	2.9	3.2	4.5	5.7	-	7.0	10.5	12.7	21	25	31	40	47	59	72	96	116	151
	Continuous (3x525-600 V) [A]	2.4	2.7	3.9	4.9	-	6.1	9.0	11.0	18	22	27	34	41	52	62	83	100	131
	Intermittent (3x525-600 V) [A]	2.6	3.0	4.3	5.4	-	6.7	9.9	12.1	20	24	30	37	45	57	68	91	110	144
	Continuous kVA (525 V AC) [kVA]	2.5	2.8	3.9	5.0	-	6.1	9.0	11.0	18.1	21.9	26.7	34.3	41	51.4	61.9	82.9	100	130.5
	Continuous kVA (575 V AC) [kVA]	2.4	2.7	3.9	4.9	-	6.1	9.0	11.0	17.9	21.9	26.9	33.9	40.8	51.8	61.7	82.7	99.6	130.5
	Max. cable size, IP21/55/66 (mains, motor, brake) [mm²]/[AWG] [2)]	4/ 10								10/ 7			25/ 4		50/ 1/0			95/ 4/0	120/ MCM2 50
	Max. cable size, IP20 (mains, motor, brake) [mm²]/[AWG] [2)]	4/ 10								16/ 6			35/ 2		50/ 1/0			95/ 4/0	150/ MCM2 50 [5)]
	With mains disconnect switch included:	4/10								16/6					35/2			70/3/0	185/ kcmil3 50

Table 9.5 [5)] **With Brake and Load Sharing 95/4/0**

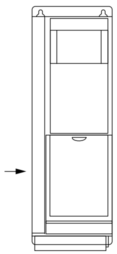
Mains supply 3x525-600 VAC Normal overload 110% for 1 minute - continued																			
Size:		P1K1	P1K5	P2K2	P3K0	P3K7	P4K0	P5K5	P7K5	P11K	P15K	P18K	P22K	P30K	P37K	P45K	P55K	P75K	P90K
Max. input current																			
 130BA057.10	Continuous (3x525-600 V) [A]	2.4	2.7	4.1	5.2	-	5.8	8.6	10.4	17.2	20.9	25.4	32.7	39	49	59	78.9	95.3	124.3
	Intermittent (3x525-600 V) [A]	2.7	3.0	4.5	5.7	-	6.4	9.5	11.5	19	23	28	36	43	54	65	87	105	137
	Max. pre-fuses[1] [A]	10	10	20	20	-	20	32	32	63	63	63	63	80	100	125	160	250	250
	Environment:																		
	Estimated power loss at rated max. load [W] [4]	50	65	92	122	-	145	195	261	300	400	475	525	700	750	850	1100	1400	1500
	Weight enclosure IP20 [kg]	6.5	6.5	6.5	6.5	-	6.5	6.6	6.6	12	12	12	23.5	23.5	23.5	35	35	50	50
	Weight enclosure IP21/55 [kg]	13.5	13.5	13.5	13.5	13.5	13.5	14.2	14.2	23	23	23	27	27	27	45	45	65	65
	Efficiency [4]	0.97	0.97	0.97	0.97	-	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98

Table 9.6 [5] With Brake and Load Sharing 95/ 4/0

Mains Supply 3x525-690 V AC							
Frequency Converter Typical Shaft Output [kW]	**P1K1** **1.1**	**P1K5** **1.5**	**P2K2** **2.2**	**P3K0** **3**	**P4K0** **4**	**P5K5** **5.5**	**P7K5** **7.5**
Enclosure IP20 (only)	A3	A3	A3	A3	A3	A3	A3
Output current High overload 110% for 1 min							
Continuous (3x525-550 V) [A]	2.1	2.7	3.9	4.9	6.1	9	11
Intermittent (3x525-550 V) [A]	2.3	3.0	4.3	5.4	6.7	9.9	12.1
Continuous kVA (3x551-690 V) [A]	1.6	2.2	3.2	4.5	5.5	7.5	10
Intermittent kVA (3x551-690 V) [A]	1.8	2.4	3.5	4.9	6.0	8.2	11
Continuous kVA 525 V AC	1.9	2.6	3.8	5.4	6.6	9	12
Continuous kVA 690 V AC	1.9	2.6	3.8	5.4	6.6	9	12
Max. input current							
Continuous (3x525-550 V) [A]	1.9	2.4	3.5	4.4	5.5	8	10
Intermittent (3x525-550 V) [A]	2.1	2.6	3.8	8.4	6.0	8.8	11
Continuous kVA (3x551-690 V) [A]	1.4	2.0	2.9	4.0	4.9	6.7	9
Intermittent kVA (3x551-690 V) [A]	1.5	2.2	3.2	4.4	5.4	7.4	9.9
Additional specifications							
IP20 max. cable cross section[5)] (mains, motor, brake and load sharing) [mm^2]/(AWG)	[0.2-4]/(24-10)						
Estimated power loss at rated max. load [W] [4)]	44	60	88	120	160	220	300
Weight, enclosure IP20 [kg]	6.6	6.6	6.6	6.6	6.6	6.6	6.6
Efficiency [4)]	0.96	0.96	0.96	0.96	0.96	0.96	0.96

Table 9.7 Mains Supply 3x525-690 V AC IP20

Normal overload 110% for 1 minute										
Frequency converter TypicalShaft Output [kW]	**P11K** **11**	**P15K** **15**	**P18K** **18.5**	**P22K** **22**	**P30K** **30**	**P37K** **37**	**P45K** **45**	**P55K** **55**	**P75K** **75**	**P90K** **90**
Typical Shaft Output [HP] at 575 V	10	16.4	20.1	24	33	40	50	60	75	100
IP21/NEMA 1	B2	B2	B2	B2	B2	C2	C2	C2	C2	C2
IP55/NEMA 12	B2	B2	B2	B2	B2	C2	C2	C2	C2	C2
Output current										
Continuous (3x525-550 V) [A]	14	19	23	28	36	43	54	65	87	105
Intermittent (3x525-550 V) [A]	15.4	20.9	25.3	30.8	39.6	47.3	59.4	71.5	95.7	115.5
Continuous (3x551-690 V) [A]	13	18	22	27	34	41	52	62	83	100
Intermittent (3x551-690 V) [A]	14.3	19.8	24.2	29.7	37.4	45.1	57.2	68.2	91.3	110
Continuous kVA (550 V AC) [kVA]	13.3	18.1	21.9	26.7	34.3	41	51.4	61.9	82.9	100
Continuous kVA (575 V AC) [kVA]	12.9	17.9	21.9	26.9	33.8	40.8	51.8	61.7	82.7	99.6
Continuous kVA (690 V AC) [kVA]	15.5	21.5	26.3	32.3	40.6	49	62.1	74.1	99.2	119.5
Max. input current										
Continuous (3x525-690 V) [A]	15	19.5	24	29	36	49	59	71	87	99
Intermittent (3x525-690 V) [A]	16.5	21.5	26.4	31.9	39.6	53.9	64.9	78.1	95.7	108.9
Max. pre-fuses[1] [A]	63	63	63	63	80	100	125	160	160	160
Additional specifications										
Estimated power loss at rated max. load [W] [4]	201	285	335	375	430	592	720	880	1200	1440
Max. cable size (mains, motor, brake) [mm^2]/(AWG) [2]	[35]/(1/0)					[95]/(4/0)				
Weight IP21 [kg]	27	27	27	27	27	65	65	65	65	65
Weight IP55 [kg]	27	27	27	27	27	65	65	65	65	65
Efficiency [4]	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98

Table 9.8 Mains Supply 3x525-690 V AC IP21-IP55/NEMA 1-NEMA 12

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Normal overload 110% for 1 minute		
Frequency converter Typical Shaft Output [kW]	**P45K** **45**	**P55K** **55**
Typical Shaft Output [HP] at 575 V	60	75
IP20/Chassis	C3	C3
Output current		
Continuous (3x525-550 V) [A]	54	65
Intermittent (3x525-550 V) [A]	59.4	71.5
Continuous (3x551-690 V) [A]	52	62
Intermittent (3x551-690 V) [A]	57.2	68.2
Continuous kVA (550 V AC) [kVA]	51.4	62
Continuous kVA (575 V AC) [kVA]	62.2	74.1
Continuous kVA (690 V AC) [kVA]	62.2	74.1
Max. input current		
Continuous (3x525-550 V) [A]	52	63
Intermittent (3x525-550 V) [A]	57.2	69.3
Continuous (3x551-690 V) [A]	50	60
Intermittent (3x551-690 V) [A]	55	66
Max. pre-fuses[1)] [A]	100	125
Additional specifications		
Estimated power loss at rated max. load [W] [4)]	592	720
Max. cable size (mains, motor, brake) [mm2]/(AWG) [2)]	50 (1)	
Weight IP20 [kg]	35	35
Efficiency [4)]	0.98	0.98

Table 9.9 Mains Supply 3x525-690 V IP20

1) For type of fuse, see chapter 6.2 Fuses and Circuit Breakers

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 normal load conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions).

Values are based on a typical motor efficiency (IE1/IE2 border line). Lower efficiency motors will also add to the power loss in the frequency converter and vice versa.

If the switching frequency is raised from nominal 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 typically 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) Motor and mains cable: 300 MCM/150 mm^2

9

9.2 General Specifications

Mains supply (L1, L2, L3)

Supply voltage	200-240 V ±10%, 380-480 V ±10%, 525-690 V ±10%

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

Supply frequency	50/60 Hz ±5%
Max. imbalance temporary between mains phases	3.0 % of rated supply voltage
True Power Factor ()	≥ 0.9 nominal at rated load
Displacement Power Factor (cos) near unity	(> 0.98)
Switching on input supply L1, L2, L3 (power-ups) ≤ enclosure type A	maximum twice/min.
Switching on input supply L1, L2, L3 (power-ups) ≥ enclosure type B, C	maximum once/min.
Switching on input supply L1, L2, L3 (power-ups) ≥ enclosure type D, E, F	maximum once/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, 480/600 V maximum.

Motor output (U, V, W)

Output voltage	0 - 100% of supply voltage
Output frequency	0 - 590 Hz*
Switching on output	Unlimited
Ramp times	1 - 3600 s

** Dependent on power size.*

Torque characteristics

Starting torque (Constant torque)	maximum 110% for 1 min.*
Starting torque	maximum 135% up to 0.5 s*
Overload torque (Constant torque)	maximum 110% for 1 min.*

**Percentage relates to the frequency converter's nominal torque.*

Cable lengths and cross sections

Max. motor cable length, screened/armoured	VLT® HVAC Drive: 150 m
Max. motor cable length, unscreened/unarmoured	VLT® HVAC Drive: 300 m
Max. cross section to motor, mains, load sharing and brake *	
Maximum cross section to control terminals, rigid wire	1.5 mm^2/16 AWG (2 x 0.75 mm^2)
Maximum cross section to control terminals, flexible cable	1 mm^2/18 AWG
Maximum cross section to control terminals, cable with enclosed core	0.5 mm^2/20 AWG
Minimum cross section to control terminals	0.25 mm^2

** See Mains Supply tables for more information!*

Digital inputs

Programmable digital inputs	4 (6)
Terminal number	18, 19, 27 1), 29 1), 32, 33,
Logic	PNP or NPN
Voltage level	0-24 V DC
Voltage level, logic'0' PNP	<5 V DC
Voltage level, logic'1' PNP	>10 V DC
Voltage level, logic '0' NPN	>19 V DC
Voltage level, logic '1' NPN	<14 V DC
Maximum voltage on input	28 V DC
Input resistance, R_i	approx. 4 kΩ

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

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

Analog inputs	
Number of analog inputs	2
Terminal number	53, 54
Modes	Voltage or current
Mode select	Switch S201 and switch S202
Voltage mode	Switch S201/switch S202 = OFF (U)
Voltage level	0 to +10 V (scaleable)
Input resistance, R_i	approx. 10 kΩ
Max. voltage	±20 V
Current mode	Switch S201/switch S202 = ON (I)
Current level	0/4 to 20 mA (scaleable)
Input resistance, R_i	approx. 200 Ω
Max. current	30 mA
Resolution for analog inputs	10 bit (+ sign)
Accuracy of analog inputs	Max. error 0.5% of full scale
Bandwidth	200 Hz

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

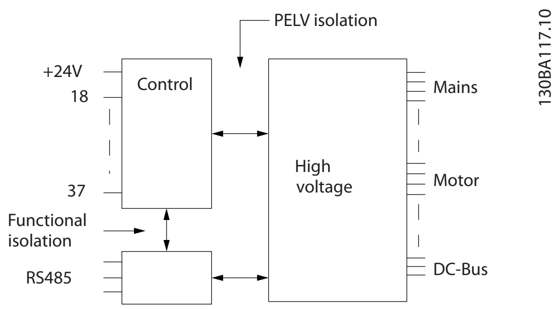


Illustration 9.1 PELV Isolation of Analog Inputs

Pulse inputs	
Programmable pulse inputs	2
Terminal number pulse	29, 33
Max. frequency at terminal, 29, 33	110 kHz (Push-pull driven)
Max. frequency at terminal, 29, 33	5 kHz (open collector)
Min. frequency at terminal 29, 33	4 Hz
Voltage level	see *chapter 9.2.1*
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

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

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

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

9

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
Max. load	200 mA

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

Relay outputs	
Programmable relay outputs	2
Relay 01 Terminal number	1-3 (break), 1-2 (make)
Max. terminal load (AC-1)[1] on 1-3 (NC), 1-2 (NO) (Resistive load)	240 V AC, 2 A
Max. terminal load (AC-15)[1] (Inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Max. terminal load (DC-1)[1] on 1-2 (NO), 1-3 (NC) (Resistive load)	60 V DC, 1 A
Max. terminal load (DC-13)[1] (Inductive load)	24 V DC, 0.1 A
Relay 02 Terminal number	4-6 (break), 4-5 (make)
Max. terminal load (AC-1)[1] on 4-5 (NO) (Resistive load)[2][3]	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 parts 4 and 5
The relay contacts are galvanically isolated from the rest of the circuit by reinforced isolation (PELV).
2) Overvoltage Category II
3) UL applications 300 V AC 2 A

Control card, 10 V DC output	
Terminal number	50
Output voltage	10.5 V ±0.5 V
Max. load	25 mA

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

Control characteristics	
Resolution of output frequency at 0 - 590 Hz	±0.003 Hz
System response time (terminals 18, 19, 27, 29, 32, 33)	≤ 2 ms
Speed control range (open loop)	1:100 of synchronous speed

Speed accuracy (open loop)	30-4000 rpm: Maximum error of ±8 rpm

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

Surroundings	
Enclosure type A	IP 20/Chassis, IP 21kit/Type 1, IP55/Type12, IP 66/Type12
Enclosure type B1/B2	IP 21/Type 1, IP55/Type12, IP 66/12
Enclosure type B3/B4	IP20/Chassis
Enclosure type C1/C2	IP 21/Type 1, IP55/Type 12, IP66/12
Enclosure type C3/C4	IP20/Chassis
Enclosure kit available	IP21/NEMA 1/IP 4_X on top of enclosure
Vibration test enclosure A, B, C	1.0 g
Relative humidity	5% - 95% (IEC 721-3-3; Class 3K3 (non-condensing) during operation
Aggressive environment (IEC 60068-2-43) H_2S test	class Kd
Test method according to IEC 60068-2-43 H2S (10 days)	
Ambient temperature (at 60 AVM switching mode)	
- with derating	max. 55° C[1)]
- with full output power of typical IE2 motors (up to 90% output current)	max. 50 ° C[1)]
- at full continuous FC output current	max. 45 ° C[1)]

[1)] For more information on derating see chapter 9.6 Special Conditions

Minimum ambient temperature during full-scale operation	0 °C
Minimum ambient temperature at reduced performance	- 10 °C
Temperature during storage/transport	-25 - +65/70 °C
Maximum altitude above sea level without derating	1000 m
Maximum altitude above sea level with derating	3000 m

Derating for high altitude, see chapter 9.6 Special Conditions

EMC standards, Emission	EN 61800-3, EN 61000-6-3/4, EN 55011, IEC 61800-3
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 chapter 9.6 Special Conditions

Control card performance	
Scan interval	5 ms

Control card, USB serial communication	
USB standard	1.1 (Full speed)
USB plug	USB type B “device” plug

CAUTION

Connection to PC is carried out via a standard host/device USB cable.
The USB connection is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.
The USB connection is <u>not</u> galvanically isolated from protection earth. Use only isolated laptop/PC as connection to the USB connector on or an isolated USB cable/converter.

9

Protection and Features

- Electronic thermal motor protection against overload.
- Temperature monitoring of the heatsink ensures that the frequency converter trips, if the temperature reaches 95 °C ± 5 °C. An overload temperature cannot be reset until the temperature of the heatsink is below 70 °C ± 5 °C (Guideline - these temperatures may vary for different power sizes, enclosures etc.). The has an auto derating function to avoid it's heatsink reaching 95°C.
- 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 is protected against earth faults on motor terminals U, V, W.

9.3 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.

This also means that 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 a little when the switching frequency is set to a value of above 5 kHz. The efficiency will also be slightly reduced if the mains voltage is 480V.

Frequency converter efficiency calculation
Calculate the efficiency of the frequency converter at different loads based on *Illustration 9.2*. The factor in this graph must be multiplied with the specific efficiency factor listed in the specification tables:

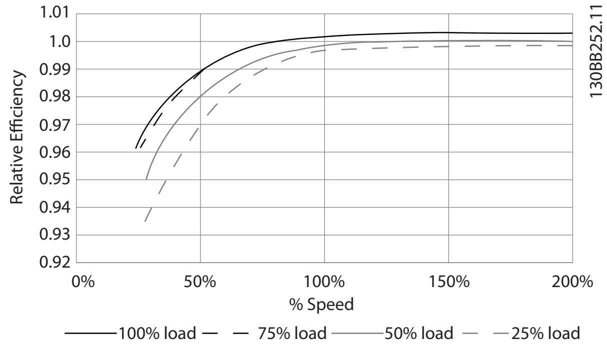


Illustration 9.2 Typical Efficiency Curves

Example: Assume a 22 kW, 380-480V AC frequency converter runs at 25% load at 50% speed. The graph shows 0.97 - rated efficiency for a 22 kW FC is 0.98. The actual efficiency is then: 0.97x0.98=0.95.

Efficiency of the motor (η_{MOTOR})
The efficiency of a motor connected to the frequency converter depends on the magnetizing level. In general, the efficiency is just 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 it is controlled by the frequency converter 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%). This is because the sine shape of the motor current 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}):
$\eta_{SYSTEM} = \eta_{VLT} \times \eta_{MOTOR}$

9.4 Acoustic Noise

The acoustic noise from the frequency converter originates from 3 sources:

- DC intermediate circuit coils.
- Integral fan.
- RFI filter choke.

The typical values measured at a distance of 1 m from the unit:

Enclosure type	At reduced fan speed (50%) [dBA]	Full fan speed [dBA]
A2	51	60
A3	51	60
A4	50	55
A5	54	63
B1	61	67
B2	58	70
B3	59.4	70.5
B4	53	62.8
C1	52	62
C2	55	65
C3	56.4	67.3
C4	-	-

Table 9.10 Measured Values

9.5 Peak Voltage on Motor

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 increases.

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.

To obtain approximate values for cable lengths and voltages not mentioned below, use the following rules of thumb:

1. Rise time increases/decreases proportionally with cable length.
2. U_{PEAK} = DC link voltage x 1.9
(DC link voltage = Mains voltage x 1.35).
3. $dU/dt = \frac{0.8 \times UPEAK}{Risetime}$

Data are measured according to IEC 60034-17.
Cable lengths are in metres.

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
36	240	0.226	0.616	2.142
50	240	0.262	0.626	1.908
100	240	0.650	0.614	0.757
150	240	0.745	0.612	0.655

Table 9.11 Frequency converter, P5K5, T2

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
5	230	0.13	0.510	3.090
50	230	0.23	0.590	2.034
100	230	0.54	0.580	0.865
150	230	0.66	0.560	0.674

Table 9.12 Frequency converter, P7K5, T2

Cable length [m]		Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
36	240	0.264	0.624	1.894
136	240	0.536	0.596	0.896
150	240	0.568	0.568	0.806

Table 9.13 Frequency converter, P11K, T2

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
30	240	0.556	0.650	0.935
100	240	0.592	0.594	0.807
150	240	0.708	0.575	0.669

Table 9.14 Frequency converter, P15K, T2

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
36	240	0.244	0.608	1.993
136	240	0.568	0.580	0.832
150	240	0.720	0.574	0.661

Table 9.15 Frequency converter, P18K, T2

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
36	240	0.244	0.608	1.993
136	240	0.560	0.580	0.832
150	240	0.720	0.574	0.661

Table 9.16 Frequency converter, P22K, T2

9

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
15	240	0.194	0.626	2.581
50	240	0.252	0.574	1.929
150	240	0.444	0.538	0.977

Table 9.17 Frequency converter, P30K, T2

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
30	240	0.300	0.598	1.593
100	240	0.536	0.566	0.843
150	240	0.776	0.546	0.559

Table 9.18 Frequency converter, P37K, T2

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
30	240	0.300	0.598	1.593
100	240	0.536	0.566	0.843
150	240	0.776	0.546	0.559

Table 9.19 Frequency converter, P45K, T2

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
5	400	0.640	0.690	0.862
50	400	0.470	0.985	0.985
150	400	0.760	1.045	0.947

Table 9.20 Frequency converter, P1K5, T4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
5	400	0.172	0.890	4.156
50	400	0.310		2.564
150	400	0.370	1.190	1.770

Table 9.21 Frequency converter, P4K0, T4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
5	400	0.04755	0.739	8.035
50	400	0.207	1.040	4.548
150	400	0.6742	1.030	2.828

Table 9.22 Frequency converter, P7K5, T4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
15	400	0.408	0.718	1.402
100	400	0.364	1.050	2.376
150	400	0.400	0.980	2.000

Table 9.23 Frequency converter, P11K, T4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
36	400	0.422	1.060	2.014
100	400	0.464	0.900	1.616
150	400	0.896	1.000	0.915

Table 9.24 Frequency converter, P15K, T4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
36	400	0.344	1.040	2.442
100	400	1.000	1.190	0.950
150	400	1.400	1.040	0.596

Table 9.25 Frequency converter, P18K, T4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
36	400	0.232	0.950	3.534
100	400	0.410	0.980	1.927
150	400	0.430	0.970	1.860

Table 9.26 Frequency converter, P22K, T4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
15	400	0.271	1.000	3.100
100	400	0.440	1.000	1.818
150	400	0.520	0.990	1.510

Table 9.27 Frequency converter, P30K, T4

Cable length [m]	Mains voltage	Rise time [µsec]	Vpeak [kV]	dU/dt [kV/µsec]
5	480	0.270	1.276	3.781
50	480	0.435	1.184	2.177
100	480	0.840	1.188	1.131
150	480	0.940	1.212	1.031

Table 9.28 Frequency converter, P37K, T4

Cable length [m]	Mains voltage [V]	Rise time [µsec]	Vpeak [kV]	dU/dt [kV/µsec]
36	400	0.254	1.056	3.326
50	400	0.465	1.048	1.803
100	400	0.815	1.032	1.013
150	400	0.890	1.016	0.913

Table 9.29 Frequency converter, P45K, T4

Cable length [m]	Mains voltage [V]	Rise time [µsec]	Vpeak [kV]	dU/dt [kV/µsec]
10	400	0.350	0.932	2.130

Table 9.30 Frequency converter, P55K, T4

Cable length [m]	Mains voltage [V]	Rise time [µsec]	Vpeak [kV]	dU/dt [kV/µsec]
5	480	0.371	1.170	2.466

Table 9.31 Frequency converter, P75K, T4

Cable length [m]	Mains voltage [V]	Rise time [µsec]	Vpeak [kV]	dU/dt [kV/µsec]
5	400	0.364	1.030	2.264

Table 9.32 Frequency converter, P90K, T4

9.6 Special Conditions

9.6.1 Purpose of Derating

Take derating into account when using the frequency converter at low air pressure (high altitudes), at low speeds, with long motor cables, cables with a large cross section or at high ambient temperature. This section describes the actions required.

9.6.2 Derating for Ambient Temperature

90% frequency converter output current can be maintained up to max. 50 °C ambient temperature.

With a typical full load current of IE2 motors, full output shaft power can be maintained up to 50 °C.
For more specific data and/or derating information for other motors or conditions, contact Danfoss.

9.6.3 Derating for Ambient Temperature, Enclosure Type A

60° AVM - Pulse Width Modulation

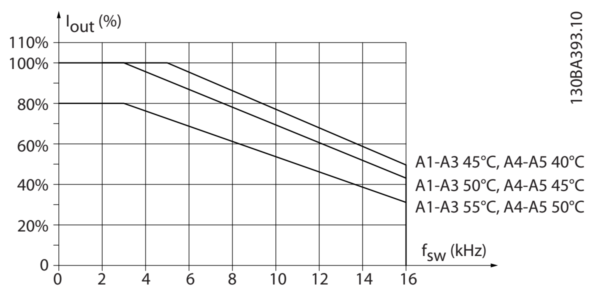


Illustration 9.3 Derating of I_{out} for Different $T_{AMB, MAX}$ for Enclosure Type A, using 60° AVM

SFAVM - Stator Frequency Asyncron Vector Modulation

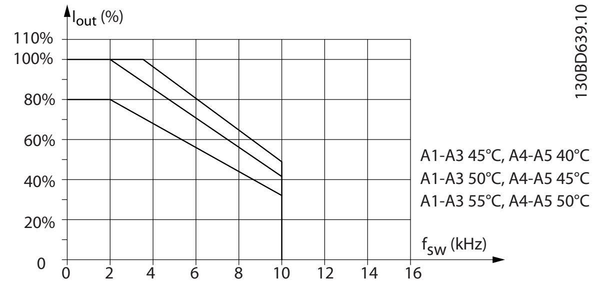


Illustration 9.4 Derating of I_{out} for Different $T_{AMB,\ MAX}$ for Enclosures Type A, using SFAVM

When using only 10 m motor cable or less in enclosure type A, less derating is necessary. This is due to the fact that the length of the motor cable has a relatively high impact on the recommended derating.

60° AVM

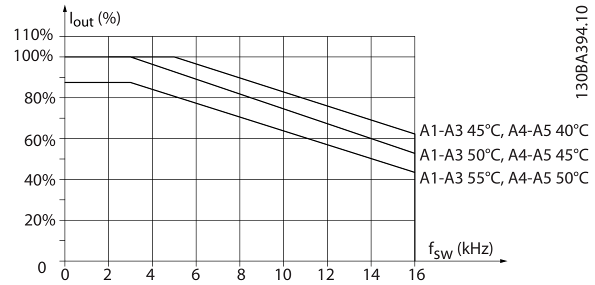


Illustration 9.5 Derating of I_{out} for Different $T_{AMB,\ MAX}$ for Enclosures Type A, using 60° AVM and maximum 10 m motor cable

SFAVM

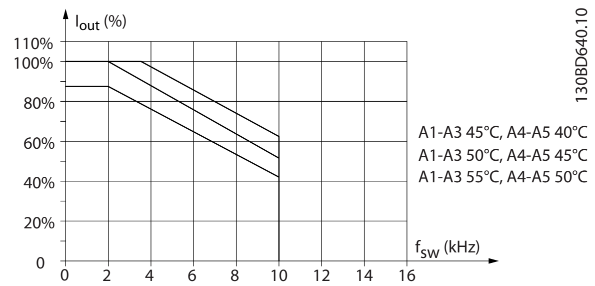


Illustration 9.6 Derating of I_{out} for Different $T_{AMB,\ MAX}$ for Enclosures Type A, using SFAVM and maximum 10 m motor cable

9.6.3.1 Enclosure Type A3, T7

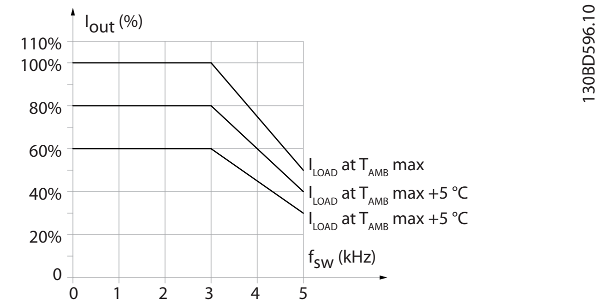


Illustration 9.7 Derating of I_{out} for Different $T_{AMB,\ MAX}$ for Enclosure Type A3

9.6.4 Derating for Ambient Temperature, Enclosure Type B

9.6.4.1 Enclosure Type B, T2, T4 and T5

For the B and C enclosure types the derating also depends on the overload mode selected in *1-04 Overload Mode*

60° AVM - Pulse Width Modulation

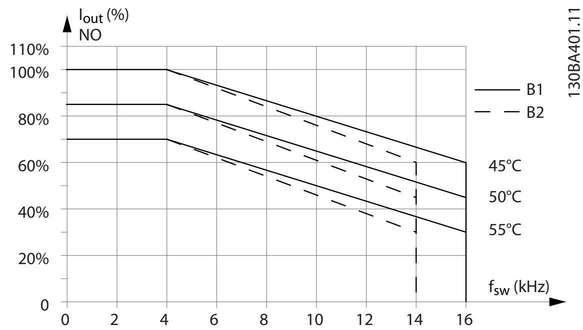


Illustration 9.8 Derating of I_{out} for different $T_{AMB,\ MAX}$ for enclosure types B1 and B2, using 60° AVM in Normal overload mode (110% over torque)

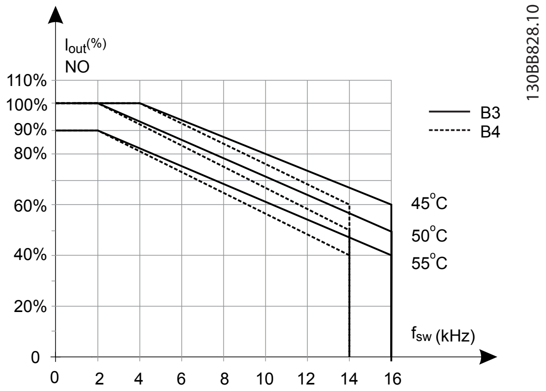


Illustration 9.9 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types B3 and B4, using 60° AVM in Normal overload mode (110% over torque)

SFAVM - Stator Frequency Asyncron Vector Modulation

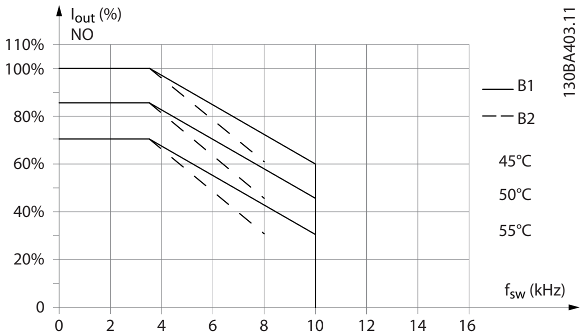


Illustration 9.10 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types B1 and B2, using SFAVM in Normal overload mode (110% over torque)

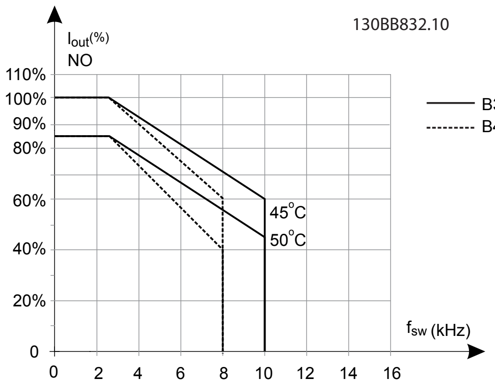


Illustration 9.11 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types B3 and B4, using SFAVM in Normal overload mode (110% over torque)

9.6.4.2 Enclosure Type B, T6

60° AVM - Pulse Width Modulation

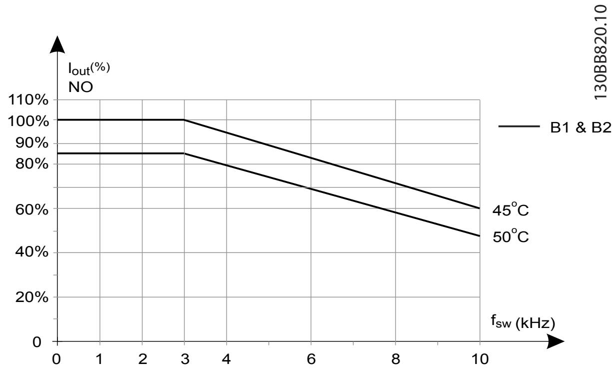


Illustration 9.12 Output current derating with switching frequency and ambient temperature for 600 V frequency converters, enclosure type B, 60 AVM, NO

SFAVM - Stator Frequency Asyncron Vector Modulation

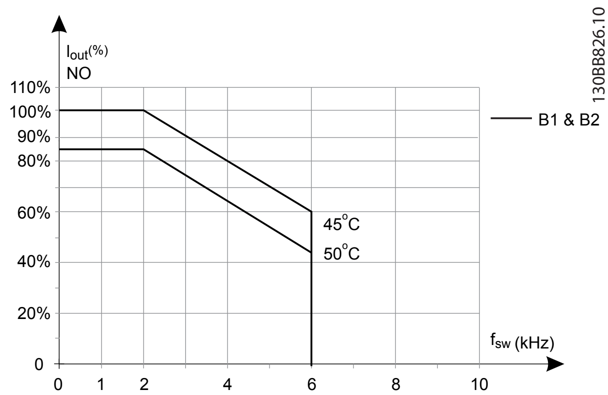


Illustration 9.13 Output current derating with switching frequency and ambient temperature for 600 V frequency converters, enclosure type B, SFAVM, NO

9

9.6.4.3 Enclosure Type B, T7

Enclosure Type B2, 525-690 V

60° AVM - Pulse Width Modulation

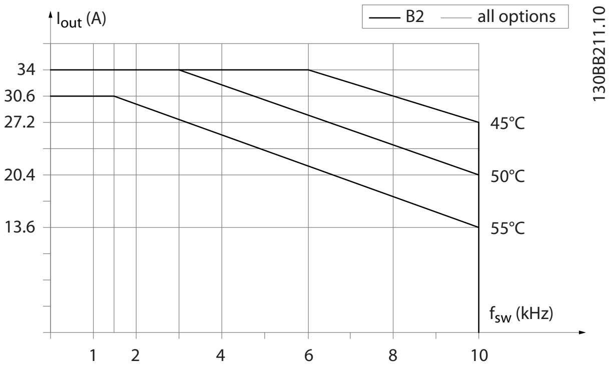


Illustration 9.14 Output current derating with switching frequency and ambient temperature for enclosure typeB2, 60° AVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.

SFAVM - Stator Frequency Asyncron Vector Modulation

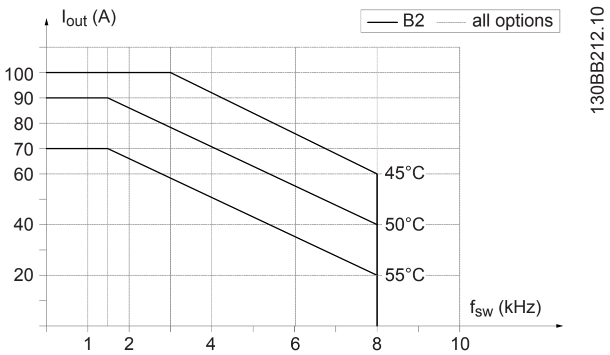


Illustration 9.15 Output current derating with switching frequency and ambient temperature for enclosure typeB2, SFAVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.

9.6.5 Derating for Ambient Temperature, Enclosure Type C

9.6.5.1 Enclosure Type C, T2, T4 and T5

60° AVM - Pulse Width Modulation

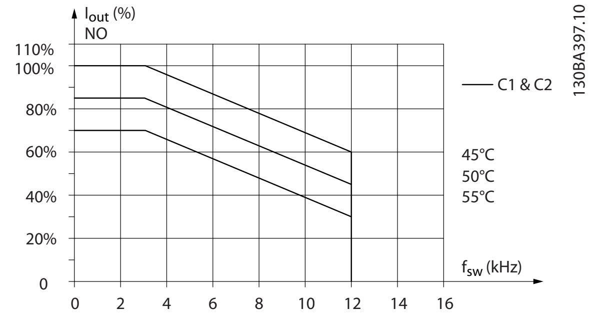


Illustration 9.16 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types C1 and C2, using 60° AVM in Normal overload mode (110% over torque)

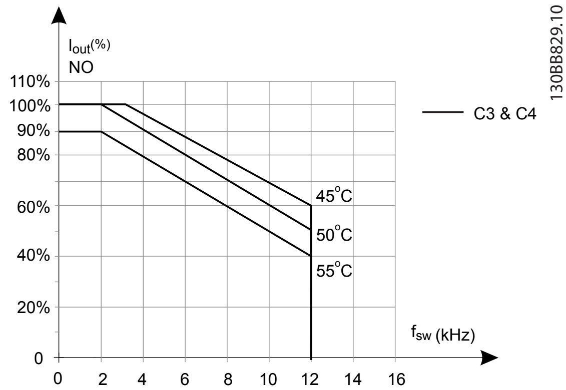


Illustration 9.17 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types C3 and C4, using 60° AVM in Normal overload mode (110% over torque)

SFAVM - Stator Frequency Asyncron Vector Modulation

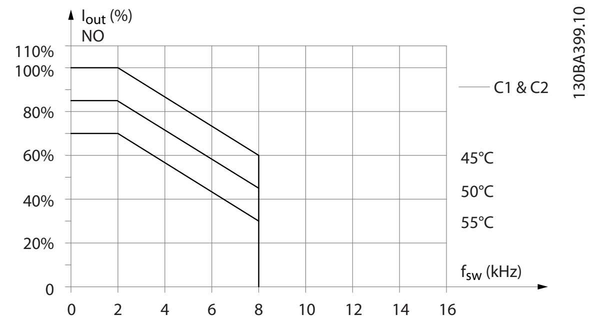


Illustration 9.18 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types C1 and C2, using SFAVM in Normal overload mode (110% over torque)

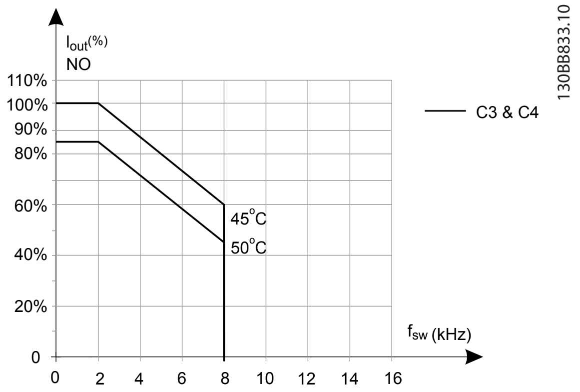


Illustration 9.19 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types C3 and C4, using SFAVM in Normal overload mode (110% over torque)

SFAVM - Stator Frequency Asyncron Vector Modulation

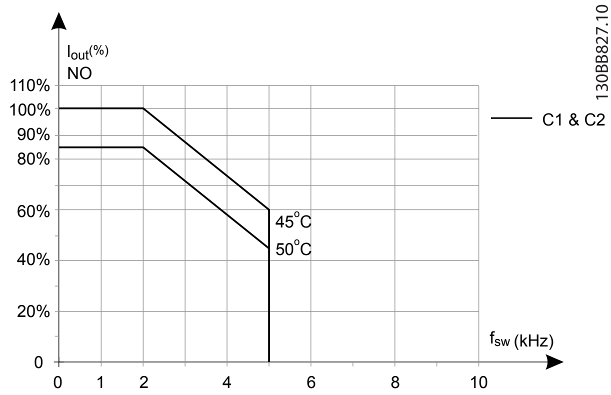


Illustration 9.21 Output current derating with switching frequency and ambient temperature for 600 V frequency converters, enclosure type C, SFAVM, NO

9.6.5.2 Enclosure Type C, T6

60° AVM - Pulse Width Modulation

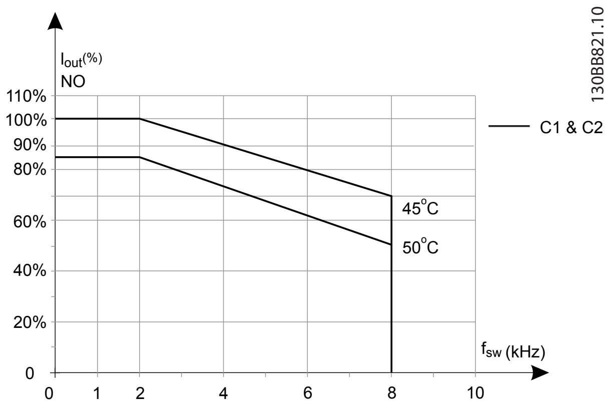


Illustration 9.20 Output current derating with switching frequency and ambient temperature for 600 V frequency converters, enclosure type C, 60 AVM, NO

9.6.5.3 Enclosure Type C, T7

60° AVM - Pulse Width Modulation

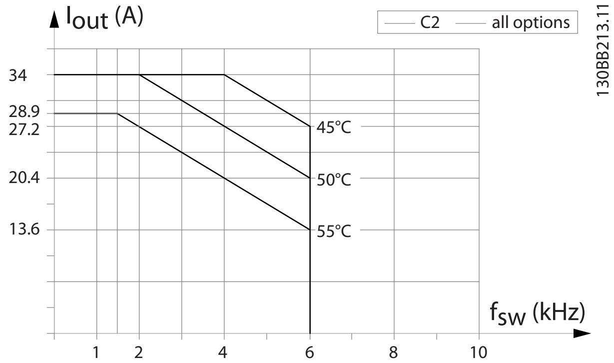


Illustration 9.22 Output current derating with switching frequency and ambient temperature for enclosure type C2, 60° AVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.

SFAVM - Stator Frequency Asyncron Vector Modulation

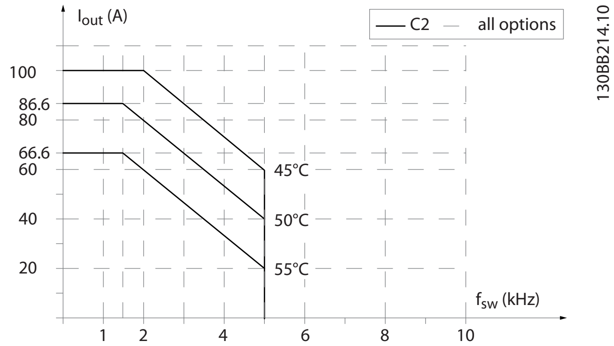


Illustration 9.23 Output current derating with switching frequency and ambient temperature for enclosure typeC2, SFAVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.

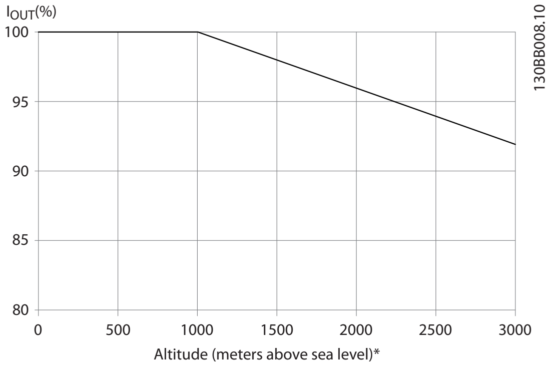


Illustration 9.25 An alternative is to lower the ambient temperature at high altitudes and thereby ensure 100% output current at high altitudes

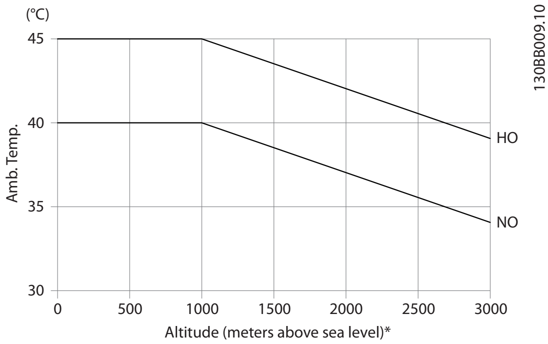


Illustration 9.26 Example: At an altitude of 2000 m and a temperature of 45 ° C ($T_{AMB, MAX}$ - 3.3 K), 91% of the rated output current is available. At a temperature of 41.7 ° C, 100% of the rated output current is available

9.6.6 Automatic Adaptations to Ensure Performance

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 to ensure the performance of the frequency converter. The capability for automatic output current reduction extends the acceptable operating conditions even further.

9.6.7 Derating for Low Air Pressure

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

Below 1000 m altitude no derating is necessary, but above 1000 m the ambient temperature (T_{AMB}) or max. output current (I_{out}) should be derated in accordance with the following diagram.

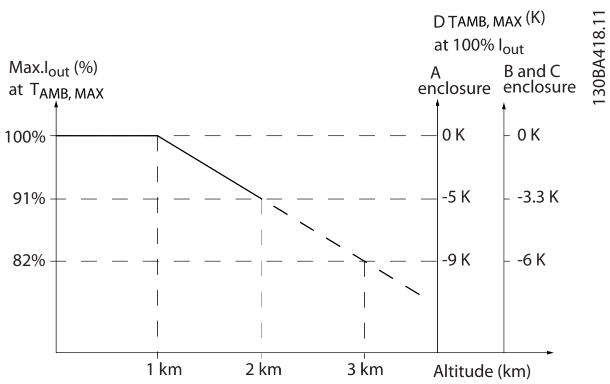


Illustration 9.24 Derating of output current versus altitude at $T_{AMB, MAX}$ for enclosure types A, B and C. At altitudes above 2000 m, contact Danfoss regarding PELV.

Derating of output current versus altitude at $T_{AMB, MAX}$ for enclosure types D, E and F.

9.6.8 Derating for Running at Low Speed

When a motor is connected to a frequency converter, it is necessary to check that the cooling of the motor is adequate.
The level of heating depends on the load on the motor, as well as the operating speed and time.

Constant torque applications (CT mode)

A problem may occur at low RPM values in constant torque applications. In a constant torque applications, a motor may over-heat at low speeds due to less cooling air from the motor integral fan.
Therefore, if the motor is to be run continuously at an RPM value lower than half of the rated value, the motor must be supplied with additional air-cooling (or a motor designed for this type of operation may be used).

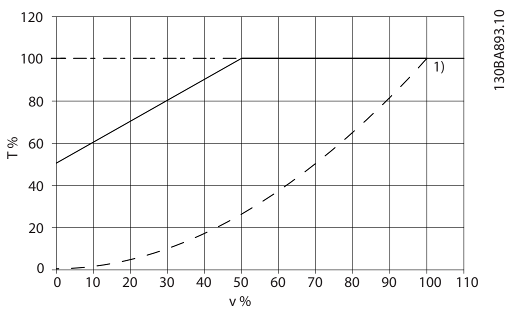
An alternative is to reduce the load level of the motor by selecting a larger motor. However, the design of the frequency converter puts a limit to the motor size.

Variable (Quadratic) torque applications (VT)

In VT applications such as centrifugal pumps and fans, where the torque is proportional to the square of the speed and the power is proportional to the cube of the speed, there is no need for additional cooling or de-rating of the motor.

In the graphs shown below, the typical VT curve is below the maximum torque with de-rating and maximum torque with forced cooling at all speeds.

Maximum load for a standard motor at 40 °C driven by a VLT frequency converter



Legend: — — — Typical torque at VT load —•—•— Max torque with forced cooling ——— Max torque

Note 1) Over-synchronous speed operation results in the available motor torque decreasing inversely proportional with the increase in speed. This must be considered during the design phase to avoid overloading the motor.

Table 9.33 Maximum load for a standard motor at 40 °C

9.7 Troubleshooting

A warning or an alarm is signalled by the relevant LED on the front of the and indicated by a code on the display.

A warning remains active until its cause is no longer present. Under certain circumstances, operation of the motor may still be continued. Warning messages may be critical, but are not necessarily so.

In the event of an alarm, the trips. Alarms must be reset to restart operation once their cause has been rectified.

This may be done in 4 ways:

1. By resetting the [RESET] on the LCP.
2. Via a digital input with the “Reset” function.
3. Via serial communication/optional fieldbus.
4. By resetting automatically using the Auto Reset function, which is a default setting for VLT® HVAC Drive, see *14-20 Reset Mode* in the *FC 102 Programming Guide*

NOTICE

After a manual reset pressing [RESET] on the LCP, press [Auto On] or [Hand On] to restart the motor.

If an alarm cannot be reset, the reason may be that its cause has not been rectified, or the alarm is trip-locked (see also *Table 9.34*).

⚠CAUTION

Alarms that are trip-locked offer additional protection, means that the mains supply must be switched off before the alarm can be reset. After being switched back on, the is no longer blocked and may be reset as described above once the cause has been rectified.
Alarms that are not trip-locked can also be reset using the automatic reset function in *14-20 Reset Mode*
(Warning: automatic wake-up is possible!)
If a warning and alarm is marked against a code in the table on the following page, this means that either a warning occurs before an alarm, or it can be specified whether it is a warning or an alarm that is to be displayed for a given fault.
This is possible, for instance, in *1-90 Motor Thermal Protection*. After an alarm or trip, the motor carries on coasting, and the alarm and warning flash on the . Once the problem has been rectified, only the alarm continues flashing.

NOTICE

No missing motorphase detection (no 30-32) and no stall detection is active when *1-10 Motor Construction* is set to [1] PM non salient SPM.

No.	Description	Warning	Alarm/ Trip	Alarm/Trip Lock	Parameter Reference
1	10 V low	X			
2	Live zero error	(X)	(X)		6-01
3	No motor	(X)			1-80
4	Mains phase loss	(X)	(X)	(X)	14-12
5	DC link voltage high	X			
6	DC link voltage low	X			

No.	Description	Warning	Alarm/ Trip	Alarm/Trip Lock	Parameter Reference
7	DC over voltage	X	X		
8	DC under voltage	X	X		
9	Inverter overloaded	X	X		
10	Motor ETR over temperature	(X)	(X)		1-90
11	Motor thermistor over temperature	(X)	(X)		1-90
12	Torque limit	X	X		
13	Over Current	X	X	X	
14	Ground fault	X	X	X	
15	Hardware mismatch		X	X	
16	Short Circuit		X	X	
17	Control word timeout	(X)	(X)		8-04
18	Start failed		X		
23	Internal Fan Fault	X			
24	External Fan Fault	X			14-53
25	Brake resistor short-circuited	X			
26	Brake resistor power limit	(X)	(X)		2-13
27	Brake chopper short-circuited	X	X		
28	Brake check	(X)	(X)		2-15
29	Drive over temperature	X	X	X	
30	Motor phase U missing	(X)	(X)	(X)	4-58
31	Motor phase V missing	(X)	(X)	(X)	4-58
32	Motor phase W missing	(X)	(X)	(X)	4-58
33	Inrush fault		X	X	
34	Fieldbus communication fault	X	X		
35	Out of frequency range	X	X		
36	Mains failure	X	X		
37	Phase Imbalance	X	X		
38	Internal fault		X	X	
39	Heatsink sensor		X	X	
40	Overload of Digital Output Terminal 27	(X)			5-00, 5-01
41	Overload of Digital Output Terminal 29	(X)			5-00, 5-02
42	Overload of Digital Output On X30/6	(X)			5-32
42	Overload of Digital Output On X30/7	(X)			5-33
46	Pwr. card supply		X	X	
47	24 V supply low	X	X	X	
48	1.8 V supply low		X	X	
49	Speed limit	X	(X)		1-86
50	AMA calibration failed		X		
51	AMA check U_{nom} and I_{nom}		X		
52	AMA low I_{nom}		X		
53	AMA motor too big		X		
54	AMA motor too small		X		
55	AMA Parameter out of range		X		
56	AMA interrupted by user		X		
57	AMA timeout		X		
58	AMA internal fault	X	X		
59	Current limit	X			
60	External Interlock	X			
62	Output Frequency at Maximum Limit	X			
64	Voltage Limit	X			
65	Control Board Over-temperature	X	X	X	
66	Heat sink Temperature Low	X			

No.	Description	Warning	Alarm/ Trip	Alarm/Trip Lock	Parameter Reference
67	Option Configuration has Changed		X		
68	Safe Stop	(X)	X1)		5-19
69	Pwr. Card Temp		X	X	
70	Illegal FC configuration			X	
71	PTC 1 Safe Stop	X	X1)		
72	Dangerous Failure			X1)	
73	Safe Stop Auto Restart				
76	Power Unit Setup	X			
79	Illegal PS config		X	X	
80	Drive Initialized to Default Value		X		
91	Analog input 54 wrong settings			X	
92	NoFlow	X	X		22-2*
93	Dry Pump	X	X		22-2*
94	End of Curve	X	X		22-5*
95	Broken Belt	X	X		22-6*
96	Start Delayed	X			22-7*
97	Stop Delayed	X			22-7*
98	Clock Fault	X			0-7*
201	Fire M was Active				
202	Fire M Limits Exceeded				
203	Missing Motor				
204	Locked Rotor				
243	Brake IGBT	X	X		
244	Heatsink temp	X	X	X	
245	Heatsink sensor		X	X	
246	Pwr.card supply		X	X	
247	Pwr.card temp		X	X	
248	Illegal PS config		X	X	
250	New spare parts			X	
251	New Type Code		X	X	

Table 9.34 Alarm/Warning Code List

(X) Dependent on parameter

1) Can not be Auto reset via 14-20 Reset Mode

A trip is the action when an alarm has appeared. The trip will coast the motor and can be reset by pressing [Reset] or make a reset by a digital input (parameter group 5-1* [1]). The original event that caused an alarm cannot damage the or cause dangerous conditions. A trip lock is an action when an alarm occurs, which may cause damage to or connected parts. A Trip Lock situation can only be reset by a power cycling.

Warning	yellow
Alarm	flashing red
Trip locked	yellow and red

Table 9.35 LED Indication

9

Alarm Word and Extended Status Word					
Bit	**Hex**	**Dec**	**Alarm Word**	**Warning Word**	**Extended Status Word**
0	00000001	1	Brake Check	Brake Check	Ramping
1	00000002	2	Pwr. Card Temp	Pwr. Card Temp	AMA Running
2	00000004	4	Earth Fault	Earth Fault	Start CW/CCW
3	00000008	8	Ctrl.Card Temp	Ctrl.Card Temp	Slow Down
4	00000010	16	Ctrl. Word TO	Ctrl. Word TO	Catch Up
5	00000020	32	Over Current	Over Current	Feedback High
6	00000040	64	Torque Limit	Torque Limit	Feedback Low
7	00000080	128	Motor Th Over	Motor Th Over	Output Current High
8	00000100	256	Motor ETR Over	Motor ETR Over	Output Current Low
9	00000200	512	Inverter Overld.	Inverter Overld.	Output Freq High
10	00000400	1024	DC under Volt	DC under Volt	Output Freq Low
11	00000800	2048	DC over Volt	DC over Volt	Brake Check OK
12	00001000	4096	Short Circuit	DC Voltage Low	Braking Max
13	00002000	8192	Inrush Fault	DC Voltage High	Braking
14	00004000	16384	Mains ph. Loss	Mains ph. Loss	Out of Speed Range
15	00008000	32768	AMA Not OK	No Motor	OVC Active
16	00010000	65536	Live Zero Error	Live Zero Error	
17	00020000	131072	Internal Fault	10V Low	
18	00040000	262144	Brake Overload	Brake Overload	
19	00080000	524288	U phase Loss	Brake Resistor	
20	00100000	1048576	V phase Loss	Brake IGBT	
21	00200000	2097152	W phase Loss	Speed Limit	
22	00400000	4194304	Fieldbus Fault	Fieldbus Fault	
23	00800000	8388608	24 V Supply Low	24V Supply Low	
24	01000000	16777216	Mains Failure	Mains Failure	
25	02000000	33554432	1.8V Supply Low	Current Limit	
26	04000000	67108864	Brake Resistor	Low Temp	
27	08000000	134217728	Brake IGBT	Voltage Limit	
28	10000000	268435456	Option Change	Unused	
29	20000000	536870912	Drive Initialized	Unused	
30	40000000	1073741824	Safe Stop	Unused	
31	80000000	2147483648	Mech. brake low (A63)	Extended Status Word	

Table 9.36 Description of Alarm Word, Warning Word and Extended Status Word

The alarm words, warning words and extended status words can be read out via serial bus or optional fieldbus for diagnosis. See also *16-90 Alarm Word*, *16-92 Warning Word* and *16-94 Ext. Status Word*.

9.7.1 Alarm Words

Bit (Hex)	Alarm Word (16-90 Alarm Word)
00000001	
00000002	Power card over temperature
00000004	Earth fault
00000008	
00000010	Control word timeout
00000020	Over current
00000040	
00000080	Motor thermistor over temp.
00000100	Motor ETR over temperature
00000200	Inverter overloaded
00000400	DC link under voltage
00000800	DC link over voltage
00001000	Short circuit
00002000	
00004000	Mains phase loss
00008000	AMA not OK
00010000	Live zero error
00020000	Internal fault
00040000	
00080000	Motor phase U is missing
00100000	Motor phase V is missing
00200000	Motor phase W is missing
00800000	Control Voltage Fault
01000000	
02000000	VDD, supply low
04000000	Brake resistor short circuit
08000000	Brake chopper fault
10000000	Earth fault DESAT
20000000	Drive initialised
40000000	Safe Stop [A68]
80000000	

Table 9.37 16-90 Alarm Word

Bit (Hex)	Alarm Word 2 (16-91 Alarm Word 2)
00000001	
00000002	Reserved
00000004	Service Trip, Typecode / Sparepart
00000008	Reserved
00000010	Reserved
00000020	
00000040	
00000080	
00000100	Broken Belt
00000200	Not used
00000400	Not used
00000800	Reserved
00001000	Reserved
00002000	Reserved
00004000	Reserved
00008000	Reserved
00010000	Reserved
00020000	Not used
00040000	Fans error
00080000	ECB error
00100000	Reserved
00200000	Reserved
00400000	Reserved
00800000	Reserved
01000000	Reserved
02000000	Reserved
04000000	Reserved
08000000	Reserved
10000000	Reserved
20000000	Reserved
40000000	PTC 1 Safe Stop [A71]
80000000	Dangerous Failure [A72]

Table 9.38 16-91 Alarm Word 2

9.7.2 Warning Words

Bit (Hex)	Warning Word (16-92 Warning Word)
00000001	
00000002	Power card over temperature
00000004	Earth fault
00000008	
00000010	Control word timeout
00000020	Over current
00000040	
00000080	Motor thermistor over temp.
00000100	Motor ETR over temperature
00000200	Inverter overloaded
00000400	DC link under voltage
00000800	DC link over voltage
00001000	
00002000	
00004000	Mains phase loss
00008000	No motor
00010000	Live zero error
00020000	
00040000	
00080000	
00100000	
00200000	
00400000	
00800000	
01000000	
02000000	Current limit
04000000	
08000000	
10000000	
20000000	
40000000	Safe Stop [W68]
80000000	Not used

Table 9.39 16-92 Warning Word

Bit (Hex)	Warning Word 2 (16-93 Warning Word 2)
00000001	
00000002	
00000004	Clock Failure
00000008	Reserved
00000010	Reserved
00000020	
00000040	
00000080	End of Curve
00000100	Broken Belt
00000200	Not used
00000400	Reserved
00000800	Reserved
00001000	Reserved
00002000	Reserved
00004000	Reserved
00008000	Reserved
00010000	Reserved
00020000	Not used
00040000	Fans warning
00080000	
00100000	Reserved
00200000	Reserved
00400000	Reserved
00800000	Reserved
01000000	Reserved
02000000	Reserved
04000000	Reserved
08000000	Reserved
10000000	Reserved
20000000	Reserved
40000000	PTC 1 Safe Stop [W71]
80000000	Reserved

Table 9.40 16-93 Warning Word 2

9

9.7.3 Extended Status Words

Bit (Hex)	Extended Status Word (16-94 Ext. Status Word)
00000001	Ramping
00000002	AMA tuning
00000004	Start CW/CCW
00000008	Not used
00000010	Not used
00000020	Feedback high
00000040	Feedback low
00000080	Output current high
00000100	Output current low
00000200	Output frequency high
00000400	Output frequency low
00000800	Brake check OK
00001000	Braking max
00002000	Braking
00004000	Out of speed range
00008000	OVC active
00010000	AC brake
00020000	Password Timelock
00040000	Password Protection
00080000	Reference high
00100000	Reference low
00200000	Local Ref./Remote Ref.
00400000	Reserved
00800000	Reserved
01000000	Reserved
02000000	Reserved
04000000	Reserved
08000000	Reserved
10000000	Reserved
20000000	Reserved
40000000	Reserved
80000000	Reserved

Table 9.41 Extended Status Word, 16-94 Ext. Status Word

Bit (Hex)	Extended Status Word 2 (16-95 Ext. Status Word 2)
00000001	Off
00000002	Hand / Auto
00000004	Not used
00000008	Not used
00000010	Not used
00000020	Relay 123 active
00000040	Start Prevented
00000080	Control ready
00000100	Drive ready
00000200	Quick Stop
00000400	DC Brake
00000800	Stop
00001000	Standby
00002000	Freeze Output Request
00004000	Freeze Output
00008000	Jog Request
00010000	Jog
00020000	Start Request
00040000	Start
00080000	Start Applied
00100000	Start Delay
00200000	Sleep
00400000	Sleep Boost
00800000	Running
01000000	Bypass
02000000	Fire Mode
04000000	Reserved
08000000	Reserved
10000000	Reserved
20000000	Reserved
40000000	Reserved
80000000	Reserved

Table 9.42 Extended Status Word 2, 16-95 Ext. Status Word 2

The warning/alarm information below defines each warning/alarm condition, provides the probable cause for the condition, and details a remedy or troubleshooting procedure.

WARNING 1, 10 Volts low
The control card voltage is below 10 V from terminal 50. Remove some of the load from terminal 50, as the 10 V supply is overloaded. Max. 15 mA or minimum 590 Ω.

A short circuit in a connected potentiometer or improper wiring of the potentiometer can cause this condition.

Troubleshooting

Remove the wiring from terminal 50. If the warning clears, the problem is with the wiring. If the warning does not clear, replace the control card.

WARNING/ALARM 2, Live zero error
This warning or alarm only appears if programmed in *6-01 Live Zero Timeout Function*. The signal on one of the analog inputs is less than 50% of the minimum value programmed for that input. Broken wiring or faulty device sending the signal can cause this condition.

Troubleshooting

Check connections on all the analog input terminals. Control card terminals 53 and 54 for signals, terminal 55 common. MCB 101 terminals 11 and 12 for signals, terminal 10 common. MCB 109 terminals 1, 3, 5 for signals, terminals 2, 4, 6 common).

Check that the frequency converter programming and switch settings match the analog signal type.

Perform Input Terminal Signal Test.

WARNING/ALARM 4, Mains phase loss
A phase is missing on the supply side, or the mains voltage imbalance is too high. This message also appears for a fault in the input rectifier on the frequency converter. Options are programmed at *14-12 Function at Mains Imbalance*.

Troubleshooting

Check the supply voltage and supply currents to the frequency converter.

WARNING 5, DC link voltage high
The intermediate circuit voltage (DC) is higher than the high-voltage warning limit. The limit is dependent on the frequency converter voltage rating. The unit is still active.

WARNING 6, DC link voltage low
The intermediate circuit voltage (DC) is lower than the low-voltage warning limit. The limit is dependent on the frequency converter voltage rating. The unit is still active.

WARNING/ALARM 7, DC overvoltage
If the intermediate circuit voltage exceeds the limit, the frequency converter trips after a time.

Troubleshooting

Connect a brake resistor

Extend the ramp time

Change the ramp type

Activate the functions in *2-10 Brake Function*

Increase *14-26 Trip Delay at Inverter Fault*

If the alarm/warning occurs during a power sag, use kinetic back-up (*14-10 Mains Failure*)

WARNING/ALARM 8, DC under voltage
If the DC-link voltage drops below the undervoltage limit, the frequency converter checks if a 24 V DC back-up supply is connected. If no 24 V DC back-up supply is connected, the frequency converter trips after a fixed time delay. The time delay varies with unit size.

Troubleshooting

Check that the supply voltage matches the frequency converter voltage.

Perform input voltage test.

Perform soft charge circuit test.

WARNING/ALARM 9, Inverter overload
The frequency converter is about to cut out because of an overload (too high current for too long). The counter for electronic, thermal inverter protection issues a warning at 98% and trips at 100%, while giving an alarm. The frequency converter *cannot* be reset until the counter is below 90%.
The fault is that the frequency converter has run with more than 100% overload for too long.

Troubleshooting

Compare the output current shown on the LCP with the frequency converter rated current.

Compare the output current shown on the LCP with measured motor current.

Display the Thermal Drive Load on the LCP and monitor the value. When running above the frequency converter continuous current rating, the counter increases. When running below the frequency converter continuous current rating, the counter decreases.

WARNING/ALARM 10, Motor overload temperature
According to the electronic thermal protection (ETR), the motor is too hot. Select whether the frequency converter issues a warning or an alarm when the counter reaches 100% in *1-90 Motor Thermal Protection*. The fault occurs when the motor runs with more than 100% overload for too long.

Troubleshooting

Check for motor overheating.

Check if the motor is mechanically overloaded

Check that the motor current set in *1-24 Motor Current* is correct.

Ensure that Motor data in parameters 1-20 to 1-25 are set correctly.

If an external fan is in use, check in *1-91 Motor External Fan* that it is selected.

Running AMA in *1-29 Automatic Motor Adaptation (AMA)* tunes the frequency converter to the motor more accurately and reduces thermal loading.

WARNING/ALARM 11, Motor thermistor over temp
Check whether the thermistor is disconnected. Select whether the frequency converter issues a warning or an alarm in *1-90 Motor Thermal Protection*.

Troubleshooting

Check for motor overheating.

Check if the motor is mechanically overloaded.

When using terminal 53 or 54, check that the thermistor is connected correctly between either terminal 53 or 54 (analog voltage input) and terminal 50 (+10 V supply). Also check that the terminal switch for 53 or 54 is set for voltage. Check *1-93 Thermistor Source* selects terminal 53 or 54.

When using digital inputs 18 or 19, check that the thermistor is connected correctly between either terminal 18 or 19 (digital input PNP only) and terminal 50. Check *1-93 Thermistor Source* selects terminal 18 or 19.

WARNING/ALARM 12, Torque limit
The torque has exceeded the value in *4-16 Torque Limit Motor Mode* or the value in *4-17 Torque Limit Generator Mode*. *14-25 Trip Delay at Torque Limit* can change this warning from a warning-only condition to a warning followed by an alarm.

Troubleshooting

If the motor torque limit is exceeded during ramp up, extend the ramp up time.

If the generator torque limit is exceeded during ramp down, extend the ramp down time.

If torque limit occurs while running, possibly increase the torque limit. Make sure that the system can operate safely at a higher torque.

Check the application for excessive current draw on the motor.

WARNING/ALARM 13, Over current
The inverter peak current limit (approximately 200% of the rated current) is exceeded. The warning lasts about 1.5 s, then the frequency converter trips and issues an alarm. Shock loading or quick acceleration with high inertia loads can cause this fault. If the acceleration during ramp up is quick, the fault can also appear after kinetic back-up. If extended mechanical brake control is selected, trip can be reset externally.

Troubleshooting

Remove power and check if the motor shaft can be turned.

Check that the motor size matches the frequency converter.

Check parameters 1-20 to 1-25 for correct motor data.

ALARM 14, Earth (ground) fault
There is current from the output phases to ground, either in the cable between the frequency converter and the motor or in the motor itself.

Troubleshooting

Remove power to the frequency converter and repair the earth fault.

Check for earth faults in the motor by measuring the resistance to ground of the motor leads and the motor with a megohmmeter.

ALARM 15, Hardware mismatch
A fitted option is not operational with the present control board hardware or software.

Record the value of the following parameters and contact your Danfoss supplier:

15-40 FC Type

15-41 Power Section

15-42 Voltage

15-43 Software Version

15-45 Actual Typecode String

15-49 SW ID Control Card

15-50 SW ID Power Card

15-60 Option Mounted

15-61 Option SW Version (for each option slot)

ALARM 16, Short circuit
There is short-circuiting in the motor or motor wiring.

Remove power to the frequency converter and repair the short circuit.

WARNING/ALARM 17, Control word timeout
There is no communication to the frequency converter.
The warning is only active when *8-04 Control Word Timeout Function* is NOT set to *[0] Off*.
If *8-04 Control Word Timeout Function* is set to *[5] Stop and Trip*, a warning appears and the frequency converter ramps down until it stops then displays an alarm.

Troubleshooting

Check connections on the serial communication cable.

Increase *8-03 Control Word Timeout Time*

Check the operation of the communication equipment.

Verify a proper installation based on EMC requirements.

ALARM 18, Start failed
The speed has not been able to exceed *1-77 Compressor Start Max Speed [RPM]* during start within the allowed time. (set in *1-79 Compressor Start Max Time to Trip*). This may be caused by a blocked motor.

WARNING 23, Internal fan fault
The fan warning function is an extra protective function that checks if the fan is running/mounted. The fan warning can be disabled in *14-53 Fan Monitor* (*[0] Disabled*).

For the D, E, and F Frame filters, the regulated voltage to the fans is monitored.

Troubleshooting

Check for proper fan operation.

Cycle power to the frequency converter and check that the fan operates briefly at start-up.

Check the sensors on the heatsink and control card.

WARNING 24, External fan fault
The fan warning function is an extra protective function that checks if the fan is running/mounted. The fan warning can be disabled in *14-53 Fan Monitor* (*[0] Disabled*).

Troubleshooting

Check for proper fan operation.

Cycle power to the frequency converter and check that the fan operates briefly at start-up.

Check the sensors on the heatsink and control card.

WARNING 25, Brake resistor short circuit
The brake resistor is monitored during operation. If a short circuit occurs, the brake function is disabled and the warning appears. The frequency converter is still operational, but without the brake function. Remove power to the frequency converter and replace the brake resistor (see *2-15 Brake Check*).

WARNING/ALARM 26, Brake resistor power limit
The power transmitted to the brake resistor is calculated as a mean value over the last 120 seconds of run time. The calculation is based on the intermediate circuit voltage and the brake resistance value set in *2-16 AC brake Max. Current*. The warning is active when the dissipated braking power is higher than 90% of the brake resistance power. If *[2] Trip* is selected in *2-13 Brake Power Monitoring*, the frequency converter trips when the dissipated braking power reaches 100%.

WARNING/ALARM 27, Brake chopper fault
The brake transistor is monitored during operation and if a short circuit occurs, the brake function is disabled and a warning is issued. The frequency converter is still operational but, since the brake transistor has short-circuited, substantial power is transmitted to the brake resistor, even if it is inactive.

Remove power to the frequency converter and remove the brake resistor.

WARNING/ALARM 28, Brake check failed
The brake resistor is not connected or not working.
Check *2-15 Brake Check*.

ALARM 29, Heatsink temp
The maximum temperature of the heatsink has been exceeded. The temperature fault does not reset until the temperature falls below a defined heatsink temperature. The trip and reset points are different based on the frequency converter power size.

Troubleshooting
Check for the following conditions.

Ambient temperature too high.

Motor cable too long.

Incorrect airflow clearance above and below the frequency converter.

Blocked airflow around the frequency converter.

Damaged heatsink fan.

Dirty heatsink.

ALARM 30, Motor phase U missing
Motor phase U between the frequency converter and the motor is missing.

Remove power from the frequency converter and check motor phase U.

ALARM 31, Motor phase V missing
Motor phase V between the frequency converter and the motor is missing.

Remove power from the frequency converter and check motor phase V.

ALARM 32, Motor phase W missing
Motor phase W between the frequency converter and the motor is missing.

Remove power from the frequency converter and check motor phase W.

ALARM 33, Inrush fault
Too many power-ups have occurred within a short time period. Let the unit cool to operating temperature.

WARNING/ALARM 34, Fieldbus communication fault
The fieldbus on the communication option card is not working.

WARNING/ALARM 36, Mains failure
This warning/alarm is only active if the supply voltage to the frequency converter is lost and *14-10 Mains Failure* is NOT set to *[0] No Function*. Check the fuses to the frequency converter and mains supply to the unit.

ALARM 38, Internal fault
When an internal fault occurs, a code number defined in *Table 9.43* is displayed.

Troubleshooting

Cycle power

Check that the option is properly installed

Check for loose or missing wiring

It may be necessary to contact your Danfoss supplier or service department. Note the code number for further troubleshooting directions.

No.	Text
0	Serial port cannot be initialised. Contact your Danfoss supplier or Danfoss Service Department.
256-258	Power EEPROM data is defective or too old. Replace power card.
512-519	Internal fault. Contact your Danfoss supplier or Danfoss Service Department.
783	Parameter value outside of min/max limits
1024-1284	Internal fault. Contact your Danfoss supplier or the Danfoss Service Department.
1299	Option SW in slot A is too old
1300	Option SW in slot B is too old
1302	Option SW in slot C1 is too old
1315	Option SW in slot A is not supported (not allowed)
1316	Option SW in slot B is not supported (not allowed)
1318	Option SW in slot C1 is not supported (not allowed)
1379-2819	Internal fault. Contact your Danfoss supplier or Danfoss Service Department.
1792	HW reset of DSP
1793	Motor derived parameters not transferred correctly to DSP
1794	Power data not transferred correctly at power up to DSP
1795	The DSP has received too many unknown SPI telegrams
1796	RAM copy error
2561	Replace control card
2820	LCP stack overflow
2821	Serial port overflow
2822	USB port overflow
3072-5122	Parameter value is outside its limits
5123	Option in slot A: Hardware incompatible with control board hardware
5124	Option in slot B: Hardware incompatible with control board hardware
5125	Option in slot C0: Hardware incompatible with control board hardware
5126	Option in slot C1: Hardware incompatible with control board hardware
5376-6231	Internal fault. Contact your Danfoss supplier or Danfoss Service Department.

Table 9.43 Internal Fault Codes

ALARM 39, Heatsink sensor
No feedback from the heat sink temperature sensor.

The signal from the IGBT thermal sensor is not available on the power card. The problem could be on the power card, on the gate drive card, or the ribbon cable between the power card and gate drive card.

WARNING 40, Overload of digital output terminal 27
Check the load connected to terminal 27 or remove short-circuit connection. Check *5-00 Digital I/O Mode* and *5-01 Terminal 27 Mode*.

WARNING 41, Overload of digital output terminal 29
Check the load connected to terminal 29 or remove short-circuit connection. Check *5-00 Digital I/O Mode* and *5-02 Terminal 29 Mode*.

WARNING 42, Overload of digital output on X30/6 or overload of digital output on X30/7
For X30/6, check the load connected to X30/6 or remove the short-circuit connection. Check *5-32 Term X30/6 Digi Out (MCB 101)*.

For X30/7, check the load connected to X30/7 or remove the short-circuit connection. Check *5-33 Term X30/7 Digi Out (MCB 101)*.

ALARM 45, Earth fault 2
Ground fault.

Troubleshooting

Check for proper grounding and loose connections.

Check for proper wire size.

Check motor cables for short-circuits or leakage currents.

ALARM 46, Power card supply
The supply on the power card is out of range.

There are 3 power supplies generated by the switch mode power supply (SMPS) on the power card: 24 V, 5 V, ±18 V. When powered with 24 V DC with the MCB 107 option, only the 24 V and 5 V supplies are monitored. When powered with 3-phase mains voltage, all 3 supplies are monitored.

Troubleshooting

Check for a defective power card.

Check for a defective control card.

Check for a defective option card.

If a 24 V DC power supply is used, verify proper supply power.

WARNING 47, 24 V supply low
The 24 V DC is measured on the control card. The external 24 V DC back-up power supply may be overloaded, otherwise contact the Danfoss supplier.

WARNING 48, 1.8 V supply low
The 1.8 V DC supply used on the control card is outside of allowable limits. The power supply is measured on the control card. Check for a defective control card. If an option card is present, check for an overvoltage condition.

WARNING 49, Speed limit
When the speed is not within the specified range in *4-11 Motor Speed Low Limit [RPM]* and *4-13 Motor Speed High Limit [RPM]*, the frequency converter shows a warning. When the speed is below the specified limit in *1-86 Trip Speed Low [RPM]* (except when starting or stopping), the frequency converter trips.

ALARM 50, AMA calibration failed
Contact your Danfoss supplier or Danfoss Service Department.

ALARM 51, AMA check U_{nom} and I_{nom}
The settings for motor voltage, motor current and motor power are wrong. Check the settings in parameters 1-20 to 1-25.

ALARM 52, AMA low I_{nom}
The motor current is too low. Check the settings.

ALARM 53, AMA motor too big
The motor is too big for the AMA to operate.

ALARM 54, AMA motor too small
The motor is too small for the AMA to operate.

ALARM 55, AMA parameter out of range
The parameter values of the motor are outside of the acceptable range. AMA cannot run.

ALARM 56, AMA interrupted by user
The user has interrupted the AMA.

ALARM 57, AMA internal fault
Try to restart AMA again. Repeated restarts can over heat the motor.

ALARM 58, AMA Internal fault
Contact your Danfoss supplier.

WARNING 59, Current limit
The current is higher than the value in *4-18 Current Limit*. Ensure that Motor data in parameters 1-20 to 1-25 are set correctly. Possibly increase the current limit. Be sure that the system can operate safely at a higher limit.

WARNING 60, External interlock
A digital input signal is indicating a fault condition external to the frequency converter. An external interlock has commanded the frequency converter to trip. Clear the external fault condition. To resume normal operation, apply 24 V DC to the terminal programmed for external interlock. Reset the frequency converter.

WARNING 62, Output frequency at maximum limit
The output frequency has reached the value set in *4-19 Max Output Frequency*. Check the application to determine the cause. Possibly increase the output frequency limit. Be sure the system can operate safely at a higher output frequency. The warning will clear when the output drops below the maximum limit.

WARNING/ALARM 65, Control card over temperature
The cut-out temperature of the control card is 80 °C.

Troubleshooting

- Check that the ambient operating temperature is within limits
- Check for clogged filters
- Check fan operation
- Check the control card

WARNING 66, Heatsink temperature low
The frequency converter is too cold to operate. This warning is based on the temperature sensor in the IGBT module.
Increase the ambient temperature of the unit. Also, a trickle amount of current can be supplied to the frequency converter whenever the motor is stopped by setting *2-00 DC Hold/Preheat Current* at 5% and *1-80 Function at Stop*

ALARM 67, Option module configuration has changed
One or more options have either been added or removed since the last power-down. Check that the configuration change is intentional and reset the unit.

ALARM 68, Safe Stop activated
Safe Torque Off has been activated. To resume normal operation, apply 24 V DC to terminal 37, then send a reset signal (via bus, digital I/O, or by pressing [Reset]).

ALARM 69, Power card temperature
The temperature sensor on the power card is either too hot or too cold.

Troubleshooting

Check that the ambient operating temperature is within limits.

Check for clogged filters.

Check fan operation.

Check the power card.

ALARM 70, Illegal FC configuration
The control card and power card are incompatible. To check compatibility, contact your supplier with the type code of the unit from the nameplate and the part numbers of the cards.

ALARM 71, PTC 1 safe stop
Safe Torque Off has been activated from the PTC Thermistor Card MCB 112 (motor too warm). Normal operation can be resumed when the MCB 112 applies 24 V DC to Terminal 37 again (when the motor temperature reaches an acceptable level) and when the Digital Input from the MCB 112 is deactivated. When that happens, a reset signal must be is be sent (via Bus, Digital I/O, or by pressing [Reset]).

ALARM 72, Dangerous failure
Safe Torque Off with trip lock. An unexpected combination of Safe Torque Off commands has occurred:

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- MCB 112 VLT PTC Thermistor Card enables X44/10, but safe stop is not enabled.
- MCB 112 is the only device using Safe Torque Off (specified through selection [4] or [5] in *5-19 Terminal 37 Safe Stop*), Safe Torque Off is activated, and X44/10 is not activated.

ALARM 80, Drive initialised to default value
Parameter settings are initialised to default settings after a manual reset. To clear the alarm, reset the unit.

ALARM 92, No flow
A no-flow condition has been detected in the system. *22-23 No-Flow Function* is set for alarm. Troubleshoot the system and reset the frequency converter after the fault has been cleared.

ALARM 93, Dry pump
A no-flow condition in the system with the frequency converter operating at high speed may indicate a dry pump. *22-26 Dry Pump Function* is set for alarm. Troubleshoot the system and reset the frequency converter after the fault has been cleared.

ALARM 94, End of curve
Feedback is lower than the set point. This may indicate leakage in the system. *22-50 End of Curve Function* is set for alarm. Troubleshoot the system and reset the frequency converter after the fault has been cleared.

ALARM 95, Broken belt
Torque is below the torque level set for no load, indicating a broken belt. *22-60 Broken Belt Function* is set for alarm. Troubleshoot the system and reset the frequency converter after the fault has been cleared.

ALARM 96, Start delayed
Motor start has been delayed due to short-cycle protection. *22-76 Interval between Starts* is enabled. Troubleshoot the system and reset the frequency converter after the fault has been cleared.

WARNING 97, Stop delayed
Stopping the motor has been delayed due to short cycle protection. *22-76 Interval between Starts* is enabled. Troubleshoot the system and reset the frequency converter after the fault has been cleared.

WARNING 98, Clock fault
Time is not set or the RTC clock has failed. Reset the clock in *0-70 Date and Time*.

WARNING 200, Fire mode
This warning indicates the frequency converter is operating in fire mode. The warning clears when fire mode is removed. See the fire mode data in the alarm log.

WARNING 201, Fire mode was active
This indicates the frequency converter had entered fire mode. Cycle power to the unit to remove the warning. See the fire mode data in the alarm log.

WARNING 202, Fire mode limits exceeded
While operating in fire mode one or more alarm conditions have been ignored which would normally trip the unit. Operating in this condition voids unit warranty. Cycle power to the unit to remove the warning. See the fire mode data in the alarm log.

WARNING 203, Missing motor
With a frequency converter operating multi-motors, an under-load condition was detected. This could indicate a missing motor. Inspect the system for proper operation.

WARNING 204, Locked rotor
With a frequency converter operating multi-motors, an overload condition was detected. This could indicate a locked rotor. Inspect the motor for proper operation.

WARNING 250, New spare part
A component in the frequency converter has been replaced. Reset the frequency converter for normal operation.

WARNING 251, New typecode
The power card or other components have been replaced and the typecode changed. Reset to remove the warning and resume normal operation.

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FAMCO
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Danfoss

Design Guide
VLT® AQUA Drive FC 202
0.25-90 kW

VLT®
THE REAL DRIVE

Contents

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1 Introduction

1.1 Purpose of the Design Guide

This design guide for Danfoss VLT® AQUA Drive frequency converters is intended for:

- Project and systems engineers
- Design consultants
- Application and product specialists

The design guide provides technical information to understand the capabilities of the frequency converter for integration into motor control and monitoring systems.

The purpose of the design guide is to provide design considerations and planning data for integration of the frequency converter into a system. The design guide caters for selection of frequency converters and options for a diversity of applications and installations.

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

VLT® is a registered trademark.

1.2 Organisation

Chapter 1 Introduction: The general purpose of the design guide and compliance with international directives.

Chapter 2 Product Overview: The internal structure and functionality of the frequency converter and operational features.

Chapter 3 System Integration: Environmental conditions; EMC, harmonics and earth leakage; mains input; motors and motor connections; other connections; mechanical planning; and descriptions of options and accessories available.

Chapter 4 Application Examples: Samples of product applications and guidelines for use.

Chapter 5 Special Conditions: Details on unusual operational environments.

Chapter 6 Typecode and Selection: Procedures for ordering equipment and options to meet the intended use of the system.

Chapter 7 Specifications: A compilation of technical data in table and graphics format.

Chapter 8 Appendix - Selected Drawings: A compilation of graphics illustrating mains and motor connections, relay terminals, and cable entries.

1.3 Additional Resources

Resources available to understand advanced frequency converter operation, programming, and directives compliance:

- The *VLT® AQUA Drive FC 202 Operating Instructions* (referenced as *Operating Instructions* in this manual) provide detailed information for the installation and start up of the frequency converter.
- The *VLT® AQUA Drive FC 202 Design Guide* provides information required for design and planning for integration of the frequency converter into a system.
- The *VLT® AQUA Drive FC 202 Programming Guide* (referenced as *Programming Guide* in this manual) provides greater detail about how to work with parameters and many application examples.
- The *VLT® Safe Torque Off Operating Instructions* describe how to use Danfoss frequency converters in functional safety applications. This manual is supplied with the frequency converter when the STO option is present.
- The *VLT® Brake Resistor Design Guide* explains optimal brake resistor selection.

NOTICE

Optional equipment is available that may change some of the information described in these publications. Be sure to see the instructions supplied with the options for specific requirements.

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1.4 Abbreviations, Symbols and Conventions

60° AVM	60° Asynchronous vector modulation
A	Ampere/AMP
AC	Alternating current
AD	Air discharge
AEO	Automatic energy optimisation
AI	Analog input
AMA	Automatic motor adaptation
AWG	American wire gauge
°C	Degrees celsius
CD	Contant discharge
CM	Common mode
CT	Constant torque
DC	Direct current
DI	Digital input
DM	Differential mode
D-TYPE	Drive dependent
EMC	Electromagnetic compatibility
EMF	Electromotive force
ETR	Electronic thermal relay
f_{JOG}	Motor frequency when jog function is activated.
f_M	Motor frequency
f_{MAX}	The maximum output frequency the frequency converter applies on its output.
f_{MIN}	The minimum motor frequency from frequency converter
$f_{M,N}$	Nominal motor frequency
FC	Frequency converter
g	Gramme
Hiperface®	Hiperface® is a registered trademark by Stegmann
hp	Horsepower
HTL	HTL encoder (10–30 V) pulses - High-voltage transistor logic
Hz	Hertz
I_{INV}	Rated inverter output current
I_{LIM}	Current limit
$I_{M,N}$	Nominal motor current
$I_{VLT,MAX}$	The maximum output current
$I_{VLT,N}$	The rated output current supplied by the frequency converter
kHz	Kilohertz
LCP	Local control panel
lsb	Least significant bit
m	Meter
mA	Milliampere
MCM	Mille circular mil
MCT	Motion control tool
mH	Inductance in milli Henry
min	Minute
ms	Millisecond
msb	Most significant bit
η_{VLT}	Efficiency of the frequency converter defined as ratio between power output and power input.
nF	Capacitance in nano Farad
NLCP	Numerical local control panel
Nm	Newton meter
n_s	Synchronous motor speed
Online/Offline Parameters	Changes to online parameters are activated immediately after the data value is changed.
$P_{br,cont.}$	Rated power of the brake resistor (average power during continuous braking).
PCB	Printed circuit board
PCD	Process data
PELV	Protective extra low voltage
P_m	Frequency converter nominal output power as high overload (HO).
$P_{M,N}$	Nominal motor power
PM motor	Permanent magnet motor
Process PID	The PID regulator maintains the desired speed, pressure, temperature, etc.
$R_{br,nom}$	The nominal resistor value that ensures a brake power on motor shaft of 150/160% for 1 minute
RCD	Residual current device
Regen	Regenerative terminals
R_{min}	Minimum permissible brake resistor value by frequency converter
RMS	Root mean square
RPM	Revolutions per minute
R_{rec}	Recommended brake resistor resistance of Danfoss brake resistors
s	Second
SFAVM	Stator flux-oriented asynchronous vector modulation
STW	Status word
SMPS	Switch mode power supply
THD	Total harmonic distortion
T_{LIM}	Torque limit
TTL	TTL encoder (5 V) pulses - transistor transistor logic
$U_{M,N}$	Nominal motor voltage
V	Volts
VT	Variable torque
VVC+	Voltage vector control

Table 1.1 Abbreviations

1

Conventions
Numbered lists indicate procedures.
Bullet lists indicate other information and description of illustrations.
Italicised text indicates:

- Cross reference
- Link
- Footnote
- Parameter name, parameter group name, parameter option

All dimensions are in mm (inch).
* indicates a default setting of a parameter.

The following symbols are used in this document:

WARNING

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

CAUTION

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

NOTICE

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

1.5 Definitions

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.

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

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

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.

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

$$\cos\varphi = \frac{P\,[\mathrm{kW}]}{P\,[\mathrm{kVA}]} = \frac{U\lambda \ x \ I\lambda \ x \cos\varphi}{U\lambda \ x \ I\lambda}$$

Cosphi is also known as displacement power factor.

Both lambda and cosphi are stated for Danfoss VLT® frequency converters in *chapter 7.2 Mains Supply*.

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.

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

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

Slip compensation
The frequency converter compensates for the motor slip by giving the frequency a supplement that follows the measured motor load, keeping the motor speed almost constant.

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

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

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

Trip
A state entered in fault situations, such as when the frequency converter is subject to an overtemperature or when it protects the motor, process or mechanism. Restart is prevented until the cause of the fault has disappeared and the trip state is cancelled. Cancel the trip state by:

- activating reset or
- programming the frequency converter to reset automatically

Do not use trip for personal safety.

Trip locked
A state entered in fault situations when the frequency converter is protecting itself and requires physical intervention, for example if the frequency converter is

subject to a short circuit on the output. 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. Do not use trip may for personal safety.

VT characteristics
Variable torque characteristics for pumps and fans.

1.6 Document and Software Version

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

Table 1.2 shows the document version and the corresponding software version.

Edition	Remarks	Software version
MG20N6xx	Replaces MG20N5xx	2.20 and later

Table 1.2 Document and Software Version

1.7 Approvals and Certifications

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

1.7.1 CE Mark

Illustration 1.1 CE

The CE mark (Communauté Européenne) indicates that the product manufacturer conforms to all applicable EU directives. The EU directives applicable to the design and manufacture of frequency converters are listed in *Table 1.3*.

NOTICE

The CE mark does not regulate the quality of the product. Technical specifications cannot be deduced from the CE mark.

NOTICE

Frequency converters with an integrated safety function must comply with the machinery directive.

EU directive	Version
Low voltage directive	2006/95/EC
EMC directive	2004/108/EC
Machinery directive[1)]	2006/42/EC
ErP directive	2009/125/EC
ATEX directive	94/9/EC
RoHS directive	2002/95/EC

Table 1.3 EU Directives Applicable to Frequency Converters

1) Machinery directive conformance is only required for frequency converters with an integrated safety function.

Declarations of conformity are available on request.

1.7.1.1 Low Voltage Directive

The low voltage directive applies to all electrical equipment in the 50–1000 V AC and the 75–1600 V DC voltage ranges.

The aim of the directive is to ensure personal safety and avoid property damage, when operating electrical equipment that is installed and maintained correctly, in its intended application.

1.7.1.2 EMC Directive

The purpose of the EMC (electromagnetic compatibility) directive is to reduce electromagnetic interference and enhance immunity of electrical equipment and installations. The basic protection requirement of the EMC Directive 2004/108/EC states that devices that generate electromagnetic interference (EMI), or whose operation could be affected by EMI, must be designed to limit the generation of electromagnetic interference and shall have a suitable degree of immunity to EMI when properly installed, maintained, and used as intended.

Electrical equipment devices used alone or as part of a system must bear the CE mark. Systems do not require the CE mark, but must comply with the basic protection requirements of the EMC directive.

1.7.1.3 Machinery Directive

The aim of the machinery directive is to ensure personal safety and avoid property damage, for mechanical equipment used in its intended application. The machinery directive applies to a machine consisting of an aggregate of interconnected components or devices of which at least one is capable of mechanical movement.

Frequency converters with an integrated safety function must comply with the machinery directive. Frequency converters without safety function do not fall under the machinery directive. If a frequency converter is integrated into a machinery system, Danfoss can provide information on safety aspects relating to the frequency converter.

1

When frequency converters are used in machines with at least one moving part, the machine manufacturer must provide a declaration stating compliance with all relevant statutes and safety measures.

1.7.1.4 ErP Directive

The ErP directive is the European Ecodesign Directive for energy-related products. The directive sets ecodesign requirements for energy-related products, including frequency converters. The aim of the directive is to increase energy efficiency and the level of protection of the environment, while at the same time increasing the security of the energy supply. Environmental impact of energy-related products includes energy consumption throughout the entire product life cycle.

1.7.2 C-tick Compliance

Illustration 1.2 C-Tick

The C-tick label indicates compliance with the applicable technical standards for Electromagnetic Compatibility (EMC), and is required for placing electrical and electronic devices on the market in Australia and New Zealand.

The C-tick regulatory is about conducted and radiated emission. For frequency converters, apply the emission limits specified in EN/IEC 61800-3.

A declaration of conformity can be provided on request.

1.7.3 UL Compliance

UL Listed

Illustration 1.3 UL

NOTICE

525-690 V frequency converters are not certified for UL.

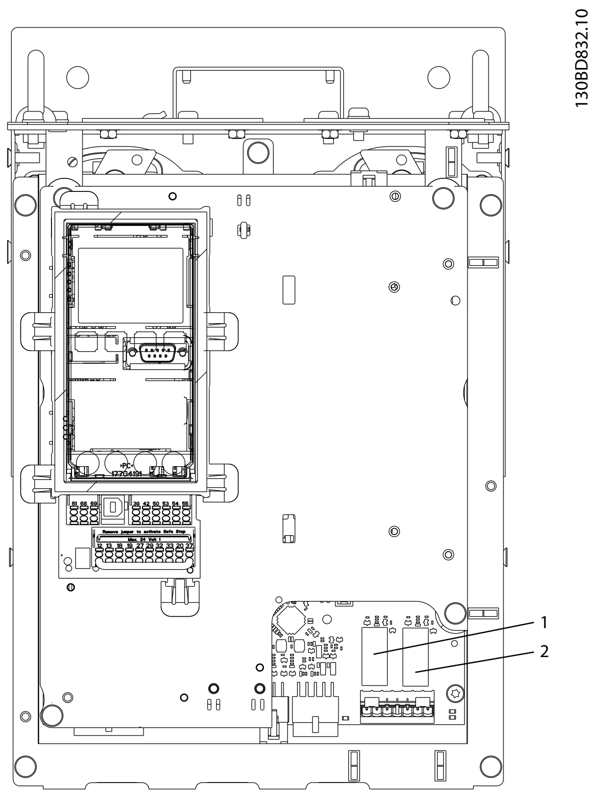
The frequency converter complies with UL508C thermal memory retention requirements. For more information, refer to *chapter 2.6.2 Motor Thermal Protection*.

1.7.4 Marine Compliance

Units with ingress protection rating IP55 (NEMA 12) or higher prevent spark formation, and are classified as limited explosion risk electrical apparatus in accordance with the European Agreement concerning International Carriage of Dangerous Goods by Inland Waterways (ADN).

For units with ingress protection rating IP20/Chassis, IP21/NEMA 1, or IP54, prevent risk of spark formation as follows:

- Do not install a mains switch
- Ensure that *14-50 RFI Filter* is set to *[1] On*.
- Remove all relay plugs marked *RELAY*. See *Illustration 1.4*.
- Check which relay options are installed, if any. The only permitted relay option is VLT® Extended Relay Card MCB 113.



1, 2	Relay plugs

Illustration 1.4 Location of Relay Plugs

Manufacturer declaration is available upon request.

1.8 Safety

1.8.1 General Safety Principles

Frequency converters contain high-voltage components and have the potential for fatal injury if handled improperly. Only trained technicians should install and operate the equipment. Do not attempt repair work without first removing power from the frequency converter and waiting the designated amount of time for stored electrical energy to dissipate.

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

1.8.2 Qualified Personnel

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

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

⚠WARNING

HIGH VOLTAGE

Frequency converters contain high voltage when connected to AC mains input, DC power supply, or load sharing. Failure to perform installation, start-up, and maintenance by qualified personnel can result in death or serious injury.

- **Installation, start-up, and maintenance must be performed by qualified personnel only.**

⚠WARNING

UNINTENDED START

When the frequency converter is connected to AC mains, DC power supply, or load sharing, the motor may start at any time. Unintended start during programming, service, or repair work can result in death, serious injury, or property damage. The motor can start via an external switch, a serial bus command, an input reference signal from the LCP, or after a cleared fault condition.
To prevent unintended motor start:

- **Disconnect the frequency converter from the mains.**
- **Press [Off/Reset] on the LCP before programming parameters.**
- **The frequency converter, motor, and any driven equipment must be fully wired and assembled when the frequency converter is connected to AC mains, DC power supply, or load sharing.**

⚠WARNING

DISCHARGE TIME

The frequency converter contains DC-link capacitors, which can remain charged even when the frequency converter is not powered. Failure to wait the specified time after power has been removed before performing service or repair work can result in death or serious injury.

- **Stop the motor.**
- **Disconnect the AC mains and remote DC-link power supplies, including battery back-ups, UPS, and DC-link connections to other frequency converters.**
- **Disconnect or lock any PM motor.**
- **Wait for the capacitors to discharge fully, before performing any service or repair work. The duration of waiting time is specified in *Table 1.4*.**

Voltage [V]	Minimum waiting time (minutes)		
	4	7	15
200-240	0.25-3.7 kW	-	5.5-45 kW
380-480	0.37-7.5 kW	-	11-90 kW
525-600	0.75-7.5 kW	-	11-90 kW
525-690	-	1.1-7.5 kW	11-90 kW
High voltage may be present even when the warning LED indicator lights are off.			

Table 1.4 Discharge Time

1

WARNING

LEAKAGE CURRENT HAZARD

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

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

WARNING

EQUIPMENT HAZARD

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

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

WARNING

UNINTENDED MOTOR ROTATION WINDMILLING

Unintended rotation of permanent magnet motors creates voltage and can charge the unit, resulting in death, serious injury, or equipment damage.

- **Ensure that permanent magnet motors are blocked to prevent unintended rotation.**

CAUTION

INTERNAL FAILURE HAZARD

An internal failure in the frequency converter can result in serious injury, when the frequency converter is not properly closed.

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

2 Product Overview

2.1 Introduction

This chapter provides an overview of the frequency converter's primary assemblies and circuitry. It describes the internal electrical and signal processing functions. A description of the internal control structure is also included.

Also described are automated and optional frequency converter functions available for designing robust operating systems with sophisticated control and status reporting performance.

2.1.1 Product Dedication to Water and Wastewater Applications

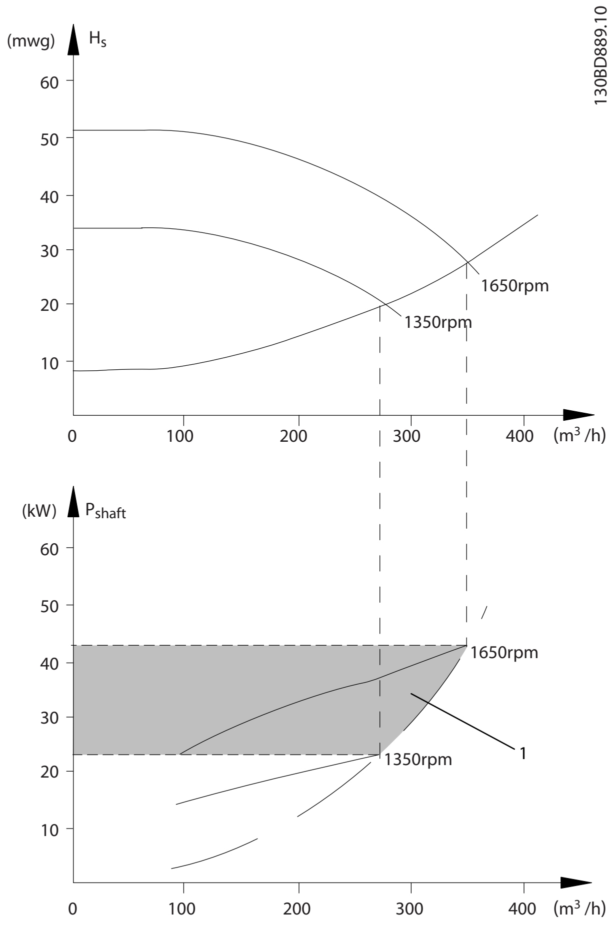
The VLT® AQUA Drive FC 202 is designed for water and wastewater applications. The integrated SmartStart wizard and the quick menu *Water and Pumps* guide the user through the commissioning process. The range of standard and optional features includes:

- Cascade control
- Dry-run detection
- End of curve detection
- Motor alternation
- Deragging
- Initial and final ramp
- Check valve ramp
- STO
- Low-flow detection
- Pre lube
- Flow confirmation
- Pipe fill mode
- Sleep mode
- Real-time clock
- Password protection
- Overload protection
- Smart logic control
- Minimum speed monitor
- Free programmable texts for information, warnings and alerts

2.1.2 Energy Savings

When comparing with alternative control systems and technologies, a frequency converter is the optimum energy control system for controlling fan and pump systems.

By using a frequency converter to control the flow, around 50% of energy savings can be achieved in typical applications, if the pump speed is reduced by 20%. *Illustration 2.1* shows an example of the achievable energy reduction.



1	Energy saving

Illustration 2.1 Example: Energy Saving

2

2.1.3 Example of Energy Savings

As shown in *Illustration 2.2*, the flow is controlled by changing the pump speed, measured in RPM. By reducing the speed only 20% from the rated speed, the flow is also reduced by 20%. This is because the flow is directly proportional to the speed. The consumption of electricity, however, is reduced by up to almost 50%.
If the system only needs to supply a flow that corresponds to 100% a few days in a year, while the average is below 80% of the rated flow for the remainder of the year, the amount of energy saved is even greater than 50%.

Illustration 2.2 describes the dependence of flow, pressure and power consumption on pump speed in RPM for centrifugal pumps.

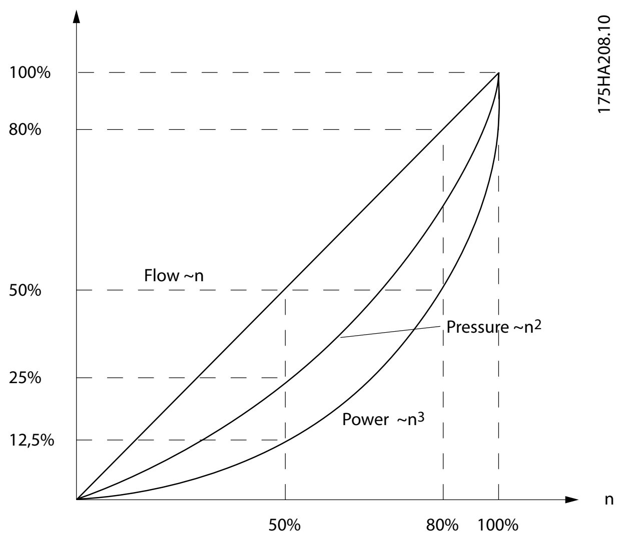


Illustration 2.2 Affinity Laws for Centrifugal Pumps

$$Flow: \frac{Q1}{Q2} = \frac{n1}{n2}$$

$$Pressure: \frac{H1}{H2} = \left(\frac{n1}{n2}\right)^2$$

$$Power: \frac{P1}{P2} = \left(\frac{n1}{n2}\right)^3$$

Assuming an equal efficiency in the speed range.

Q=Flow	P=Power
Q_1=Flow 1	P_1=Power 1
Q_2=Reduced flow	P_2=Reduced power
H=Pressure	n=Speed regulation
H_1=Pressure 1	n_1=Speed 1
H_2=Reduced pressure	n_2=Reduced speed

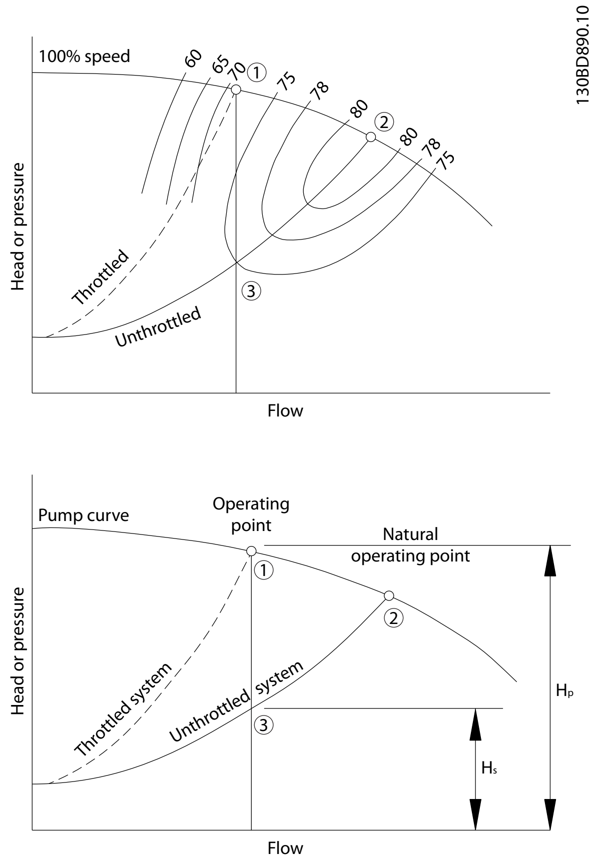
Table 2.1 Affinity Laws

2.1.4 Valve Control versus Speed Control of Centrifugal Pumps

Valve control
As the demand for process requirements in water systems varies, the flow has to be adjusted accordingly. Frequently used methods for flow adaptation are throttling or recycling using valves.

A recycle valve that is opened too wide can cause the pump to run at the end of the pump curve, with a high flow rate at a low pump head. These conditions do not only cause a waste of energy due to the high speed of the pump, but can also lead to pump cavitation with resultant pump damage.

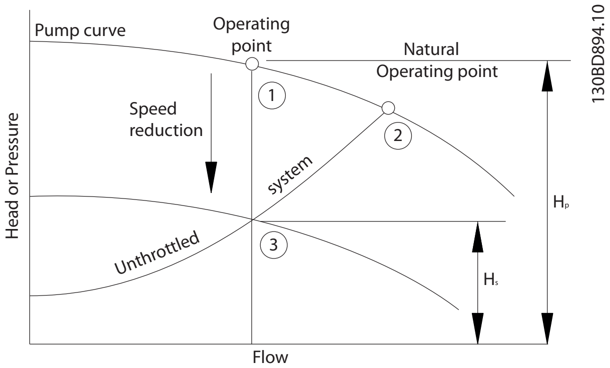
Throttling the flow with a valve, adds a pressure drop across the valve (HP-HS). This can be compared with accelerating and pulling the brake at the same time, in an attempt to reduce car speed. *Illustration 2.3* shows that throttling makes the system curve turn from point (2) on the pump curve to a point with significantly reduced efficiency (1).



1	Operating point using a throttle valve
2	Natural operating point
3	Operating point using speed control

Illustration 2.3 Flow Reduction by Valve Control (Throttling)

Speed control
The same flow can be adjusted by reducing the speed of the pump, as shown in *Illustration 2.4*. Reducing the speed moves the pump curve down. The point of operation is the new intersection point of the pump curve and the system curve (3). The energy savings can be calculated by applying the affinity laws as described in *chapter 2.1.3 Example of Energy Savings*.



1	Operating point using a throttle valve
2	Natural operating point
3	Operating point using speed control

Illustration 2.4 Flow Reduction by Speed Control

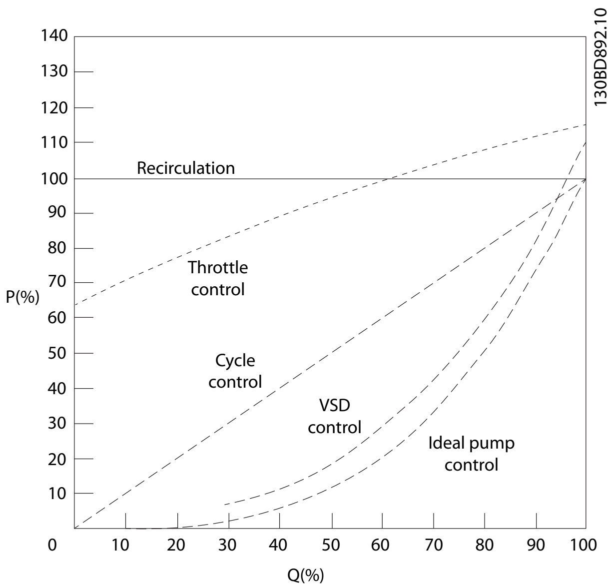
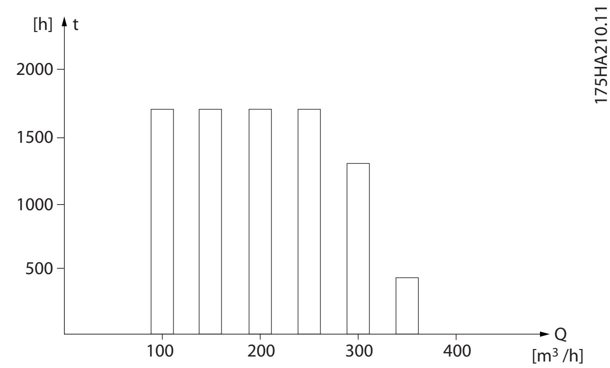


Illustration 2.5 Comparative Flow Control Curves

2.1.5 Example with Varying Flow over 1 Year

This example is calculated based on pump characteristics obtained from a pump datasheet, shown in *Illustration 2.7*.

The result obtained shows energy savings in excess of 50% at the given flow distribution over a year, see *Illustration 2.6*. The payback period depends on the price of electricity and the price of the frequency converter. In this example, payback is less than a year, when compared with valves and constant speed.



t [h]	Duration of flow. See also *Table 2.2.*
Q [m^3/h]	Flowrate

Illustration 2.6 Flow Distribution over 1 Year (Duration versus Flowrate)

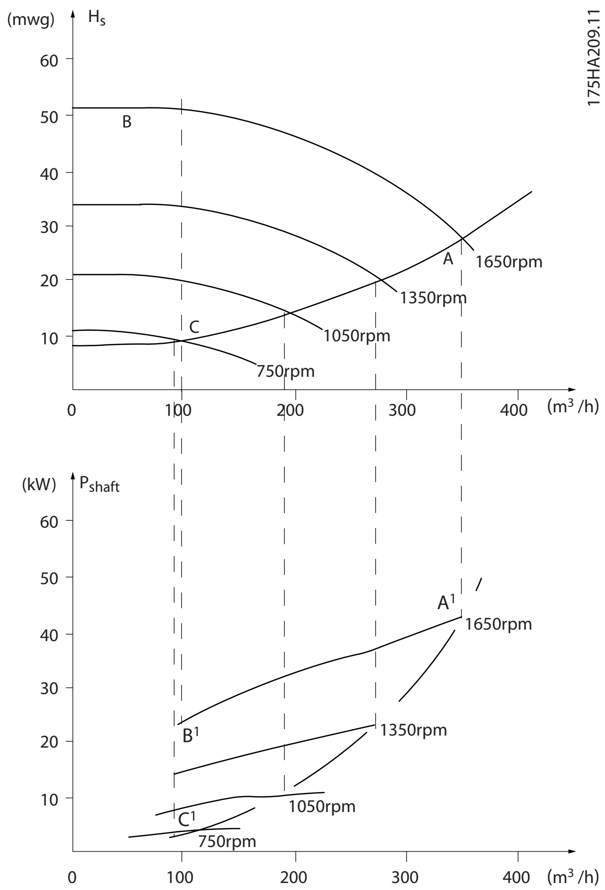


Illustration 2.7 Energy Consumption at Different Speeds

2

Flow rate	Distribution		Valve regulation		Frequency converter control	
	%	Duration	Power	Consump-tion	Power	Consump-tion
[m³/h]		[h]	[kW]	[kWh]	[kW]	[kWh]
350	5	438	42.5[1)]	18.615	42.5[1)]	18.615
300	15	1314	38.5	50.589	29.0	38.106
250	20	1752	35.0	61.320	18.5	32.412
200	20	1752	31.5	55.188	11.5	20.148
150	20	1752	28.0	49.056	6.5	11.388
100	20	1752	23.0[2)]	40.296	3.5[3)]	6.132
Σ	100	8760	–	275.064	–	26.801

Table 2.2 Result

1) Power reading at point A1

2) Power reading at point B1

3) Power reading at point C1

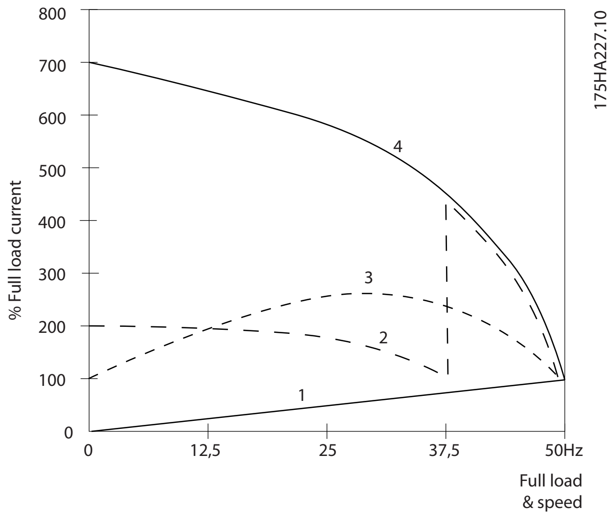
2.1.6 Improved Control

Using a frequency converter to control the flow or pressure of a system improves control.
A frequency converter can vary the speed of the fan or pump, obtaining variable control of flow and pressure.
Furthermore, a frequency converter can quickly adapt the speed of the fan or pump to new flow or pressure conditions in the system.
Obtain simple control of process (flow, level or pressure) utilising the built-in PI control.

2.1.7 Star/Delta Starter or Soft Starter

When large motors are started, it is necessary in many countries to use equipment that limits the start-up current. In more traditional systems, a star/delta starter or soft starter is widely used. Such motor starters are not required if a frequency converter is used.

As illustrated in *Illustration 2.8*, a frequency converter does not consume more than rated current.



1	VLT® AQUA Drive FC 202
2	Star/delta starter
3	Soft starter
4	Start directly on mains

Illustration 2.8 Start-up Current

2.2 Description of Operation

The frequency converter supplies a regulated amount of mains AC power to the motor to control its speed. The frequency converter supplies variable frequency and voltage to the motor.

The frequency converter is divided into 4 main modules:

- Rectifier
- Intermediate DC bus circuit
- Inverter
- Control and regulation

Illustration 2.9 is a block diagram of the internal components of the frequency converter. See *Table 2.3* for their functions.

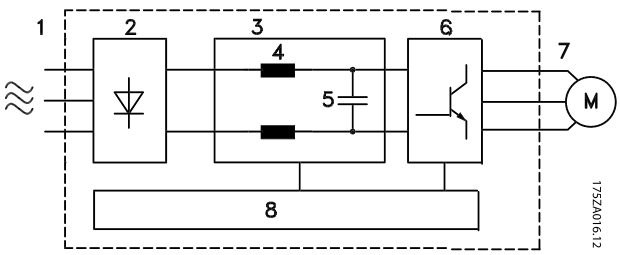


Illustration 2.9 Frequency Converter Block Diagram

Area	Title	Functions
1	Mains input	• 3-phase AC mains power supply to the frequency converter.
2	Rectifier	• The rectifier bridge converts the AC input to DC current to supply inverter power.
3	DC bus	• Intermediate DC bus circuit handles the DC current.
4	DC reactors	• Filter the intermediate DC circuit voltage. • Prove mains transient protection. • Reduce RMS current. • Raise the power factor reflected back to the line. • Reduce harmonics on the AC input.
5	Capacitor bank	• Stores the DC power. • Provides ride-through protection for short power losses.
6	Inverter	• Converts the DC into a controlled PWM AC waveform for a controlled variable output to the motor.
7	Output to motor	• Regulated 3-phase output power to the motor.
8	Control circuitry	• Input power, internal processing, output, and motor current are monitored to provide efficient operation and control. • User interface and external commands are monitored and performed. • Status output and control can be provided.

Table 2.3 Legend to *Illustration 2.9*

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

The frequency converter supplies the motor with variable voltage/current and frequency, which enables variable speed control of 3-phased, standard asynchronous motors and non-salient PM motors.

The frequency converter manages various motor control principles such as U/f special motor mode and VVC+. Short-circuit behavior of the frequency converter depends on the 3 current transducers in the motor phases.

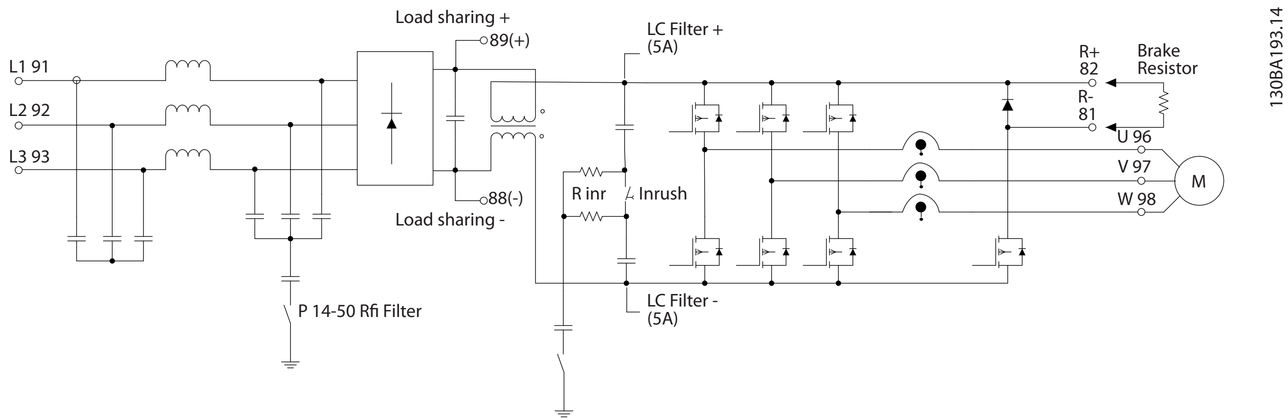


Illustration 2.10 Frequency Converter Structure

2

2.3 Sequence of Operation

2.3.1 Rectifier Section

When power is first applied to the frequency converter, it enters through the input terminals (L1, L2, and L3) and on to the disconnect and/or RFI filter option, depending on the unit's configuration.

2.3.2 Intermediate Section

Following the rectifier section, voltage passes to the intermediate section. This rectified voltage is smoothed by an sine-wave filter circuit consisting of the DC bus inductor and the DC bus capacitor bank.

The DC bus inductor provides series impedance to changing current. This aids the filtering process while reducing harmonic distortion to the input AC current waveform normally inherent in rectifier circuits.

2.3.3 Inverter Section

In the inverter section, once a run command and speed reference are present, the IGBTs begin switching to create the output waveform. This waveform, as generated by the Danfoss VVC^{+} PWM principle at the control card, provides optimal performance and minimal losses in the motor.

2.3.4 Brake Option

For frequency converters equipped with the dynamic brake option, a brake IGBT along with terminals 81(R-) and 82(R+) are included for connecting an external brake resistor.

The function of the brake IGBT is to limit the voltage in the intermediate circuit, whenever the maximum voltage limit is exceeded. It does this by switching the externally mounted resistor across the DC bus to remove excess DC voltage present on the bus capacitors.

External brake resistor placement has the advantages of selecting the resistor based on application need, dissipating the energy outside of the control panel, and protecting the converter from overheating if the brake resistor is overloaded.

The brake IGBT gate signal originates on the control card and is delivered to the brake IGBT via the power card and gate drive card. Additionally, the power and control cards monitor the brake IGBT and brake resistor connection for short-circuits and overloads. For pre-fuse specifications, refer to *chapter 7.1 Electrical Data*. See also *chapter 7.7 Fuses and Circuit Breakers*.

2.3.5 Load Sharing

Units with the built-in load sharing option contain terminals (+) 89 DC and (–) 88 DC. Within the frequency converter, these terminals connect to the DC bus in front of the DC link reactor and bus capacitors.

For more information contact Danfoss.

The load-sharing terminals can connect in 2 different configurations.

1. In the first method, the terminals tie the DC-bus circuits of multiple frequency converters together. This allows a unit that is in a regenerative mode to share its excess bus voltage with another unit that is running a motor. Load sharing in this manner can reduce the need for external dynamic brake resistors, while also saving energy. The number of units that can be connected in this way is infinite, as long as each unit has the same voltage rating. In addition, depending on the size and number of units, it may be necessary to install DC reactors and DC fuses in the DC link connections, and AC reactors on the mains.Attempting such a configuration requires specific considerations. Contact Danfoss for assistance.
2. In the second method, the frequency converter is powered exclusively from a DC source. This requires:
   - 2a A DC source.
   - 2b A means to soft charge the DC bus at power-up.

   Again, attempting such a configuration requires specific considerations. Contact Danfoss for assistance.

2.4 Control Structures

2.4.1 Control Structure Open Loop

When operating in open-loop mode, the frequency converter responds to input commands manually via the LCP keys or remotely via the analog/digital inputs or serial bus.

In the configuration shown in *Illustration 2.11*, the frequency converter operates in open-loop mode. It receives input from either the LCP (hand mode) or via a remote signal (auto mode). The signal (speed reference) is received and conditioned with programmed minimum and maximum motor speed limits (in RPM and Hz), ramp-up and ramp-down times, and the direction of motor rotation. The reference is then passed on to control the motor.

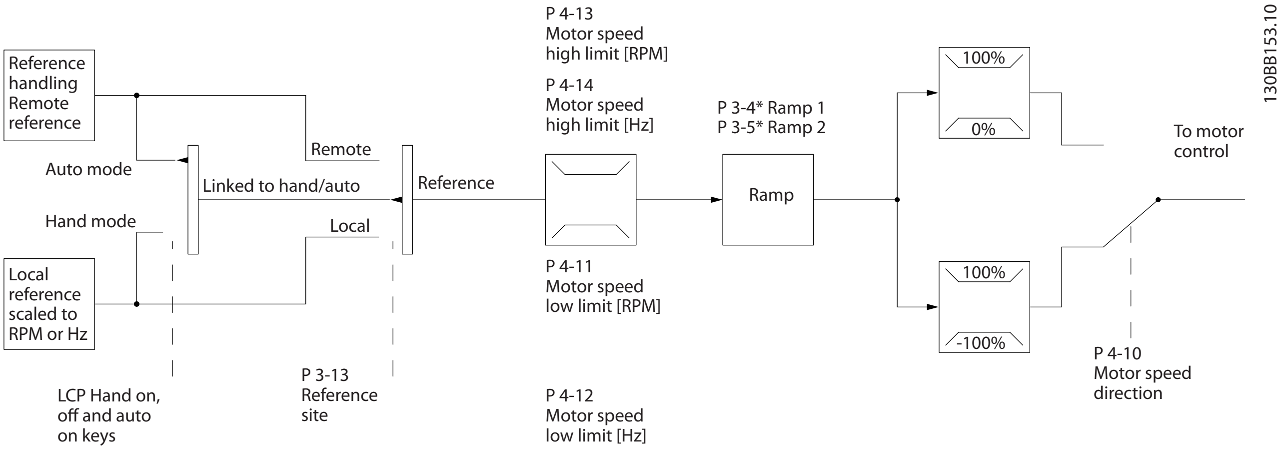


Illustration 2.11 Open-loop Mode Block Diagram

2.4.2 Control Structure Closed Loop

In closed-loop mode, an internal PID controller allows the frequency converter to process system reference and feedback signals to act as an independent control unit. The converter can provide status and alarm messages, along with many other programmable options, for external system monitoring while operating independently in closed loop.

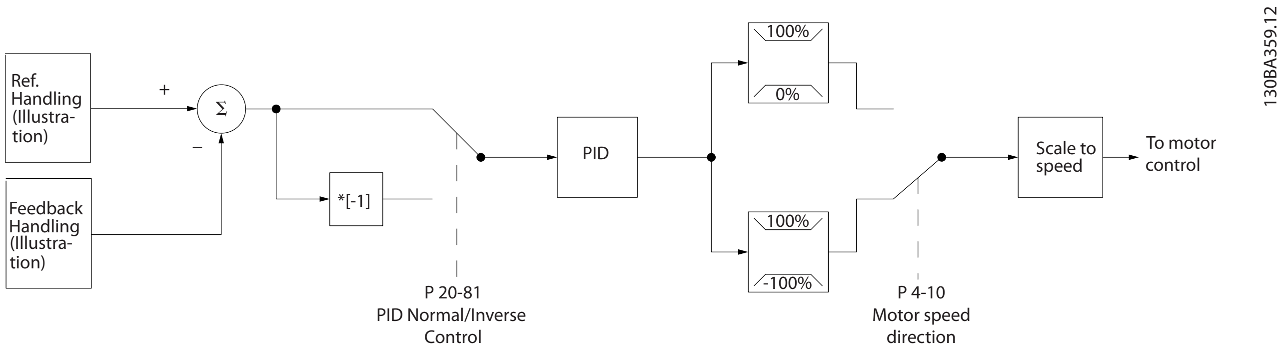


Illustration 2.12 Block Diagram of Closed-loop Controller

For example, consider a pump application in which the speed of a pump is controlled so that the static pressure in a pipe is constant (see *Illustration 2.12*). The frequency converter receives a feedback signal from a sensor in the system. It compares this feedback to a setpoint reference value and determines the error, if any, between these 2 signals. It then adjusts the speed of the motor to correct this error.

The desired static pressure setpoint is the reference signal to the frequency converter. A static pressure sensor measures the actual static pressure in the pipe and provides this information to the frequency converter as a feedback signal. If the feedback signal is greater than the setpoint reference, the frequency converter slows to reduce the pressure. In a similar way, if the pipe pressure is lower than the setpoint reference, the frequency converter speeds up to increase the pressure provided by the pump.

While the default values for the frequency converter in closed loop often provide satisfactory performance, system control can often be optimised by tuning the PID parameters. *Auto tuning* is provided for this optimisation.

2

Other programmable features include:

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

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

The frequency converter can be operated manually via the LCP, or remotely via analog and digital inputs and serial bus.

Active reference and configuration mode
The active reference is either a local reference or a remote reference. Remote reference is the default setting.

- To use the local reference, perform configuration in manual mode, known as *Hand On* mode. To enable manual mode, adapt parameter settings in parameter group *0-4* LCP Keypad*. For more information, refer to the *programming guide*.
- To use the remote reference, perform configuration in *Auto On* mode, which is the default mode. In *Auto On* mode, it is possible to control the frequency converter via the digital inputs and various serial interfaces (RS485, USB, or an optional fieldbus).
- *Illustration 2.13* illustrates the configuration mode resulting from active reference selection, either local or remote.
- *Illustration 2.14* illustrates manual configuration mode for local reference.

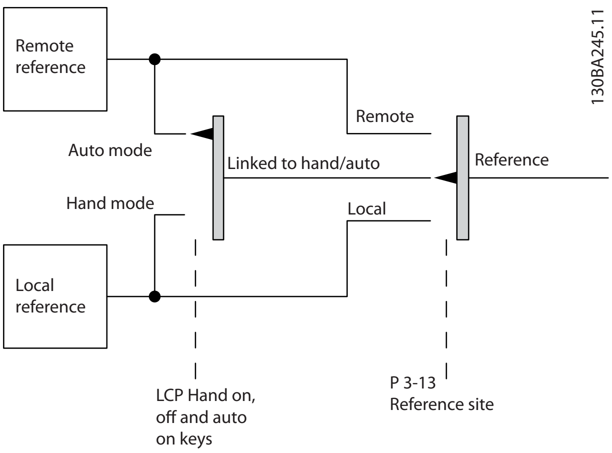


Illustration 2.13 Active Reference

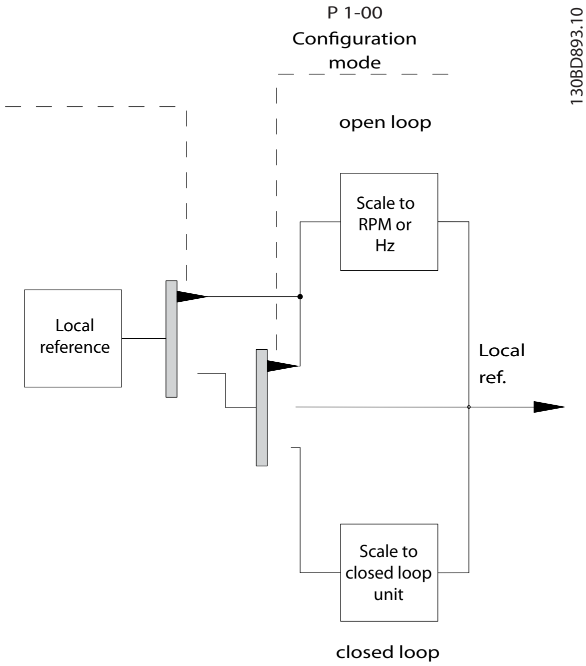


Illustration 2.14 Configuration Mode

Application control principle
Either the remote reference or the local reference is active at any time. Both cannot be active simultaneously. Set the application control principle (that is, open loop or closed loop) in *1-00 Configuration Mode*, as shown in *Table 2.4*.
When the local reference is active, set the application control principle in *1-05 Local Mode Configuration*.
Set the reference site in *3-13 Reference Site*, as shown in *Table 2.4*.

For more information refer to the *Programming Guide*.

[Hand On] [Auto On] LCP Keys	Reference Site *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 2.4 Local and Remote Reference Configurations

2.4.4 Reference Handling

Reference handling is applicable in both open and closed loop operation.

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

External references can also be supplied to the converter, most commonly through an analog control input. All reference sources and the bus reference are added to produce the total external reference. The external reference, the preset reference, the setpoint, or the sum of all 3 can be selected as the active reference. This reference can be scaled.

The scaled reference is calculated as follows:

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

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

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

Remote reference
A remote reference is comprised of the following (see *Illustration 2.15*).

- Preset references
- External references (analog inputs, pulse frequency inputs, digital potentiometer inputs, and serial communication bus references)
- A preset relative reference
- A feedback controlled setpoint

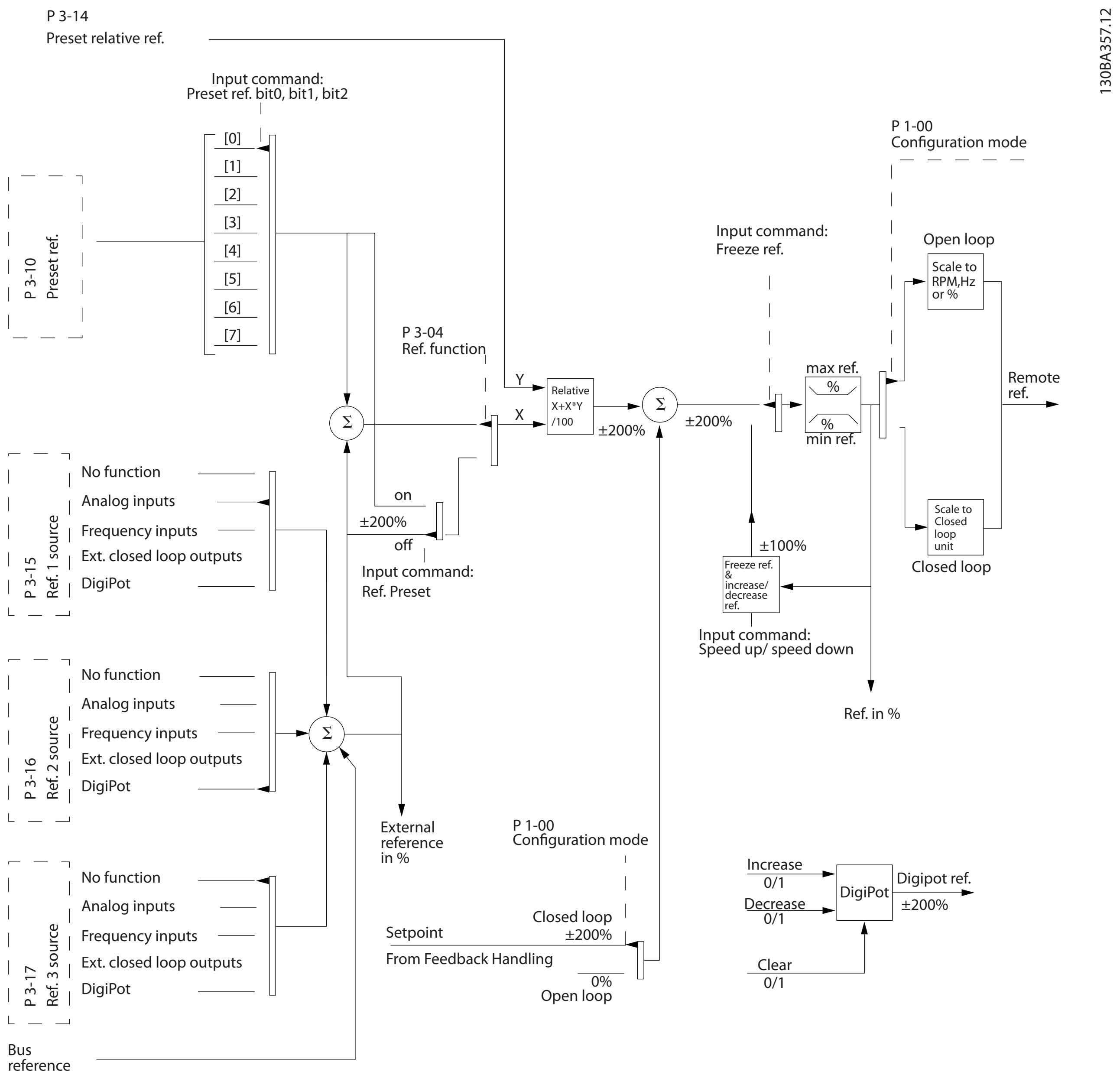


Illustration 2.15 Block Diagram Showing Remote Reference Handling

2.4.5 Feedback Handling

Feedback handling can be configured to work with applications requiring advanced control, such as multiple setpoints and multiple types of feedback (see *Illustration 2.16*. Three types of control are common:

Single zone, single setpoint
This is a basic feedback configuration. Setpoint 1 is added to any other reference (if any) and the feedback signal is selected.

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

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

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

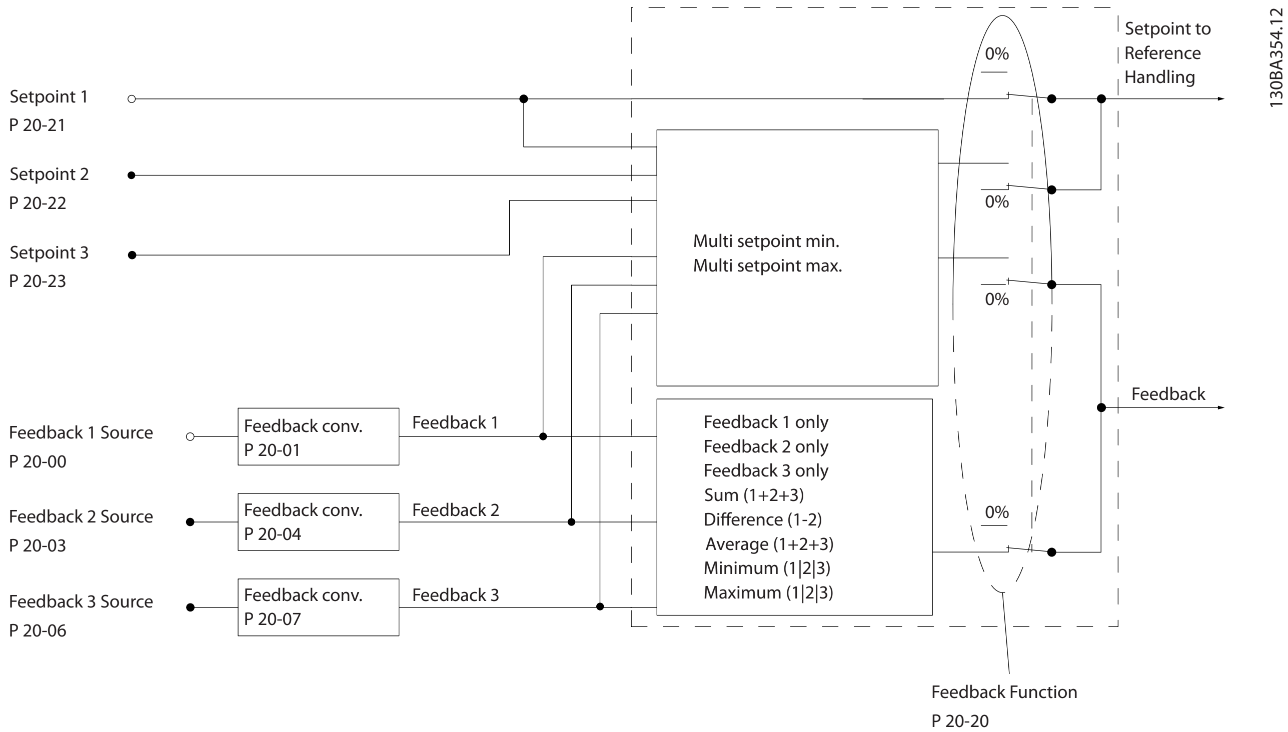


Illustration 2.16 Block Diagram of Feedback Signal Processing

2

Feedback conversion
In some applications, it is useful to convert the feedback signal. One example is using a pressure signal to provide flow feedback. Since the square root of pressure is proportional to flow, the square root of the pressure signal yields a value proportional to the flow. This is shown in *Illustration 2.17*.

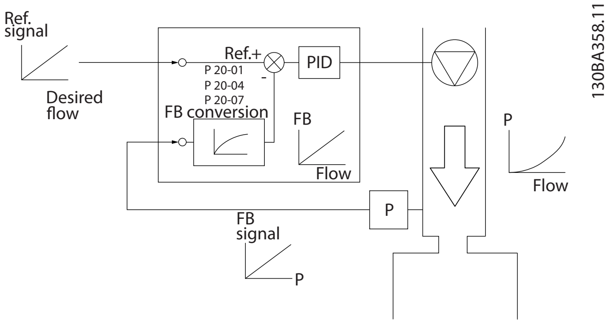


Illustration 2.17 Feedback Conversion

2.5 Automated Operational Functions

Automated operational features are active as soon as the frequency converter is operating. Most of them require no programming or set-up. Understanding that these features are present can optimise a system design and possibly avoid introducing redundant components or functionality.

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

The frequency converter has a range of built-in protection functions to protect itself and the motor it is running.

2.5.1 Short Circuit Protection

Motor (phase-phase)
The frequency converter is protected against short circuits on the motor side by current measurement in each of the 3 motor phases or in the DC link. A short circuit between 2 output phases causes an overcurrent in the inverter. The inverter is turned off when the short-circuit current exceeds the permitted value (Alarm 16 Trip Lock).

Mains side
A frequency converter that works correctly limits the current it can draw from the supply. Still, it is recommended to use fuses and/or circuit breakers on the supply side as protection in case of component breakdown inside the frequency converter (first fault). See *chapter 7.7 Fuses and Circuit Breakers* for more information.

NOTICE

To ensure compliance with IEC 60364 for CE or NEC 2009 for UL, it is mandatory to use fuses and/or circuit breakers.

Brake resistor
The frequency converter is protected from a short-circuit in the brake resistor.

Load sharing
To protect the DC bus against short-circuits and the frequency converters from overload, install DC fuses in series with the load sharing terminals of all connected units. See *chapter 2.3.5 Load Sharing* for more information.

2.5.2 Overvoltage Protection

Motor-generated overvoltage
The voltage in the intermediate circuit is increased when the motor acts as a generator. This occurs in following cases:

- The load drives the motor (at constant output frequency from the frequency converter), for example, the load generates energy.
- 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.
- Incorrect slip compensation setting may cause higher DC-link voltage.
- Back EMF from PM motor operation. If coasted at high RPM, the PM motor back EMF may potentially exceed the maximum voltage tolerance of the frequency converter and cause damage. To help prevent this, the value of *4-19 Max Output Frequency* is automatically limited via 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*.

NOTICE

To avoid motor overspeeding (for example, due to excessive windmilling effects or uncontrolled water flow), equip the frequency converter with a brake resistor.

The overvoltage can handled by either using a brake function (*2-10 Brake Function*) or using overvoltage control (*2-17 Over-voltage Control*).

Overvoltage control (OVC)
OVC reduces the risk of the frequency converter tripping due to an overvoltage on the DC-link. This is managed by automatically extending the ramp-down time.

NOTICE

OVC can be activated for PM motors (PM VVC+).

Brake functions
Connect a brake resistor for dissipation of surplus brake energy. Connecting a brake resistor prevents excessively high DC-link voltage during braking.

An AC brake is an alternative to improve braking without using a brake resistor. This function controls an overmagnetisation of the motor when running as a generator creating extra energy. This function can improve the OVC. Increasing the electrical losses in the motor allows the OVC function to increase the braking torque without exceeding the overvoltage limit.

NOTICE

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

2.5.3 Missing Motor Phase Detection

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

2.5.4 Mains Phase Imbalance Detection

Operation under severe mains imbalance conditions reduces the lifetime of the motor. Conditions are considered severe if the motor is operated continuously near nominal load. The default setting trips the frequency converter in case of mains imbalance (*14-12 Function at Mains Imbalance*).

2.5.5 Switching on the Output

Adding a switch to the output between the motor and the frequency converter is permitted. Fault messages may appear. Enable flying start to catch a spinning motor.

2.5.6 Overload Protection

Torque limit
The torque limit feature protects the motor against overload, independent of the speed. Torque limit is controlled in *4-16 Torque Limit Motor Mode* or *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*.

Speed limit
Define lower and upper limits for the operating speed range using the following parameters:

- *4-11 Motor Speed Low Limit [RPM]* or
- *4-12 Motor Speed Low Limit [Hz]* and *4-13 Motor Speed High Limit [RPM]*, or
- *4-14 Motor Speed High Limit [Hz]*

For example, the operating speed range can be defined as between 30 and 50/60Hz.
4-19 Max Output Frequency limits the maximum output speed the frequency converter can provide.

ETR
ETR is an electronic feature that simulates a bimetal relay based on internal measurements. The characteristic is shown in *Illustration 2.18*.

Voltage limit
The frequency converter turns off to protect the transistors and the intermediate circuit capacitors when a certain hard-coded voltage level is reached.

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

2.5.7 Automatic Derating

The frequency converter constantly checks for critical levels:

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

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

NOTICE

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

2.5.8 Automatic Energy Optimisation

Automatic energy optimisation (AEO) directs the frequency converter to continuously monitor the load on the motor and adjust the output voltage to maximise efficiency. Under light load, the voltage is reduced and the motor current is minimised. The motor benefits from increased efficiency, reduced heating, and quieter operation. There is no need to select a V/Hz curve because the frequency converter automatically adjusts motor voltage.

2

2.5.9 Automatic Switching Frequency Modulation

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

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

2.5.10 Automatic Derating for High Switching Frequency

The frequency converter is designed for continuous, full load operation at switching frequencies between 3.0 and 4.5 kHz (note that this frequency range is dependent on power size). A switching frequency which exceeds the maximum permissible range generates increased heat in the frequency converter and requires the output current to be derated.

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

2.5.11 Automatic Derating for Overtemperature

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

2.5.12 Auto Ramping

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

2.5.13 Current Limit Circuit

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

2.5.14 Power Fluctuation Performance

The frequency converter withstands mains fluctuations such as transients, momentary drop-outs, short voltage drops and surges. The frequency converter automatically compensates for input voltages ±10% from the nominal to provide full rated motor voltage and torque. With auto restart selected, the frequency converter automatically powers up after a voltage trip. With flying start, the frequency converter synchronises to motor rotation before start.

2.5.15 Motor Soft Start

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

2.5.16 Resonance Damping

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

2.5.17 Temperature-controlled Fans

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

2.5.18 EMC Compliance

Electromagnetic interference (EMI) or radio frequency interference (RFI, in case of radio frequency) is disturbance that can affect an electrical circuit due to electromagnetic induction or radiation from an external source. The frequency converter is designed to comply with the EMC product standard for drives IEC 61800-3 as well as the European standard EN 55011. To comply with the emission levels in EN 55011, the motor cable must be shielded and properly terminated. For more information regarding EMC performance, see *chapter 3.2.2 EMC Test Results*.

2.5.19 Current Measurement on All Three Motor Phases

Output current to the motor is continuously measured on all 3 phases to protect both the frequency converter and motor against short-circuits, ground faults, and phase loss. Output ground faults are instantly detected. If a motor phase is lost, the frequency converter stops immediately and reports which phase is missing.

2.5.20 Galvanic Isolation of Control Terminals

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

The components that make up the galvanic isolation are:

- Power supply, including signal isolation.
- Gate drive for the IGBTs, trigger transformers, and optocouplers.
- The output current Hall effect transducers.

2.6 Custom Application Functions

Custom application features are the most common features programmed in the frequency converter for enhanced system performance. They require minimum programming or set-up. Understanding that these features are available can optimise the system design and possibly avoid introducing redundant components or functionality. See the *programming guide* for instructions on activating these functions.

2.6.1 Automatic Motor Adaptation

Automatic motor adaptation (AMA) is an automated test procedure used to measure the electrical characteristics of the motor. AMA provides an accurate electronic model of the motor. It allows the frequency converter to calculate optimal performance and efficiency with the motor. Running the AMA procedure also maximises the automatic energy optimisation feature of the frequency converter. AMA is performed without the motor rotating and without uncoupling the load from the motor.

2.6.2 Motor Thermal Protection

Motor thermal protection can be provided in 3 ways:

- Via direct temperature sensing via one of the following:
  - PTC sensor in the motor windings and connected on a standard AI or DI.
  - PT100 or PT1000 in the motor windings and motor bearings, connected on VLT® Sensor Input Card MCB 114.
  - PTC thermistor input on VLT® PTC Tthermistor Card MCB 112 (ATEX approved).
- Mechanical thermal switch (Klixon type) on a DI.
- Via the built-in electronic thermal relay (ETR) for asynchronous motors.

ETR calculates motor temperature by measuring current, frequency, and operating time. The frequency converter displays the thermal load on the motor in percentage and can issue a warning at a programmable overload setpoint. Programmable options at the overload allow the frequency converter to stop the motor, reduce output, or ignore the condition. Even at low speeds, the frequency converter meets I2t Class 20 electronic motor overload standards.

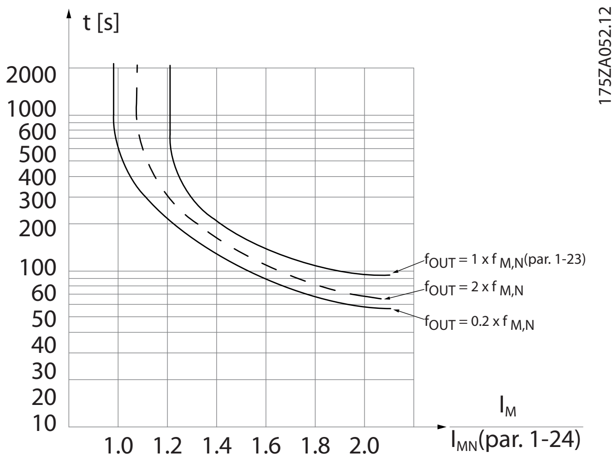


Illustration 2.18 ETR Characteristics

The X-axis in *Illustration 2.18* shows the ratio between I_{motor} and I_{motor} nominal. The Y-axis shows the time in seconds before the ETR cuts off and trips the frequency converter. The curves show the characteristic nominal speed, at twice the nominal speed and at 0.2 x the nominal speed.
At lower speed, the ETR cuts off at lower heat due to less cooling of the motor. In that way, the motor is protected from being overheated even at low speed. The ETR feature calculates the motor temperature based on actual current and speed. The calculated temperature is visible as a readout parameter in *16-18 Motor Thermal*.

2

2.6.3 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 lowest rated supply voltage. The mains voltage before the drop-out and the motor load determines how long it takes for the frequency converter to coast.

The frequency converter can be configured (*14-10 Mains Failure*) to different types of behaviour during mains drop-out,

- Trip Lock once the DC link is exhausted.
- Coast with flying start whenever mains return (*1-73 Flying Start*).
- Kinetic back-up.
- Controlled ramp-down.

Flying start
This selection makes it possible to catch a motor that is spinning freely due to a mains drop-out. This option is relevant for centrifuges and fans.

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

Configure the behaviour of the frequency converter at mains drop-out, in *14-10 Mains Failure* and *1-73 Flying Start*.

2.6.4 Built-in PID Controllers

The 4 built-in proportional, integral, derivative (PID) controllers eliminate the need for auxiliary control devices.

One of the PID controllers maintains constant control of closed-loop systems where regulated pressure, flow, temperature, or other system requirements must be maintained. The frequency converter can provide self-reliant control of the motor speed in response to feedback signals from remote sensors. The frequency converter accommodates 2 feedback signals from 2 different devices. This feature allows regulating a system with different feedback requirements. The frequency converter makes control decisions by comparing the 2 signals to optimise system performance.

Use the 3 additional and independent controllers for controlling other process equipment, such as chemical feed pumps, valve control or for aeration with different levels.

2.6.5 Automatic Restart

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

2.6.6 Flying Start

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

2.6.7 Full Torque at Reduced Speed

The frequency converter follows a variable V/Hz curve to provide full motor torque even at reduced speeds. Full output torque can coincide with the maximum designed operating speed of the motor. This is unlike variable torque converters that provide reduced motor torque at low speed, or constant torque converters that provide excess voltage, heat, and motor noise at less than full speed.

2.6.8 Frequency Bypass

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

2.6.9 Motor Preheat

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

2.6.10 Four Programmable Set-ups

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

Setup data can be copied from frequency converter to frequency converter by downloading the information from the removable LCP.

2.6.11 Dynamic Braking

Dynamic Brake is 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 overheats the motor (*2-10 Brake Function* = [2]).

2.6.12 DC Braking

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

2.6.13 Sleep Mode

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

2.6.14 Run Permissive

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

2.6.15 Smart Logic Control (SLC)

Smart logic control (SLC) is a sequence of user-defined actions (see *13-52 SL Controller Action* [x]) executed by the SLC when the associated user defined *event* (see *13-51 SL Controller Event* [x]) is evaluated as TRUE by the SLC.
The condition for an event can be a particular status or that the output from a logic rule or a comparator operand becomes TRUE. That leads to an associated action as shown in *Illustration 2.19*.

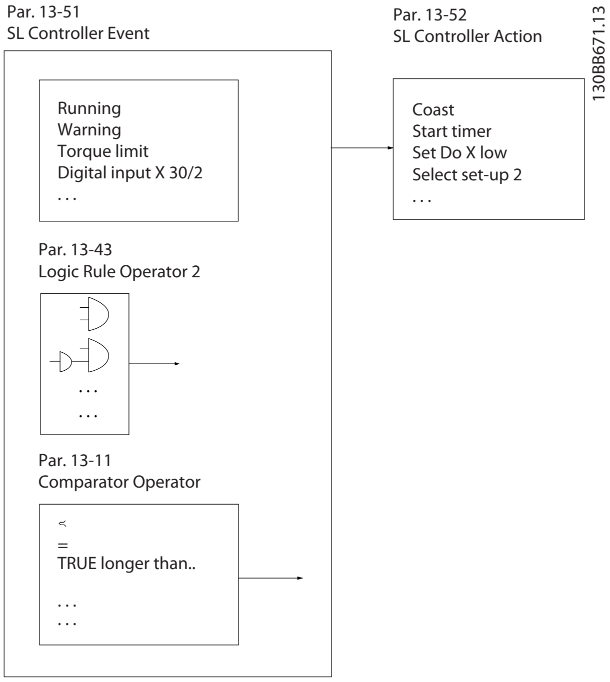


Illustration 2.19 SCL Event and Action

Events and actions are each numbered and linked in pairs (states). This means that when *event* [0] is fulfilled (attains the value TRUE), *action* [0] is executed. After this, the conditions of *event* [1] is evaluated and if evaluated TRUE, *action* [1] is executed and so on. Only one *event* is evaluated at any time. If an *event* is evaluated as FALSE, nothing happens (in the SLC) during the current scan interval and no other *events* are evaluated. This means that when the SLC starts, it evaluates *event* [0] (and only *event* [0]) each scan interval. Only when *event* [0] is evaluated TRUE, the SLC executes *action* [0] and starts evaluating *event* [1]. 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 *event* [0]/*action* [0].
Illustration 2.20 shows an example with 4 event/actions:

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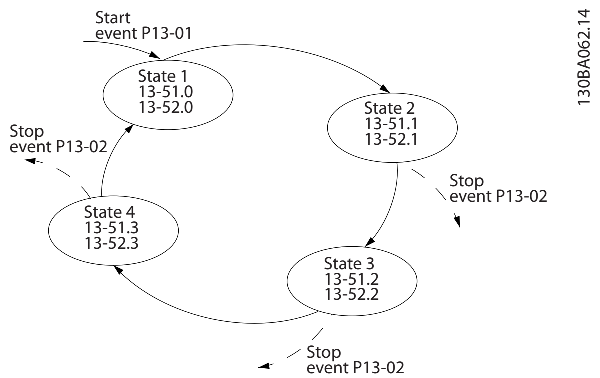


Illustration 2.20 Order of Execution when 4 Events/Actions are Programmed

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

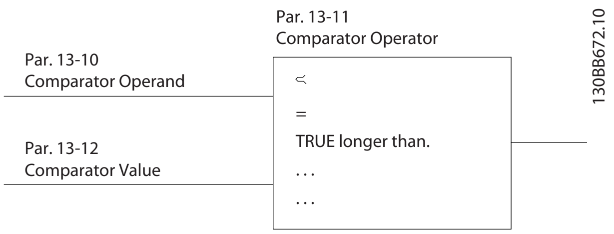


Illustration 2.21 Comparators

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

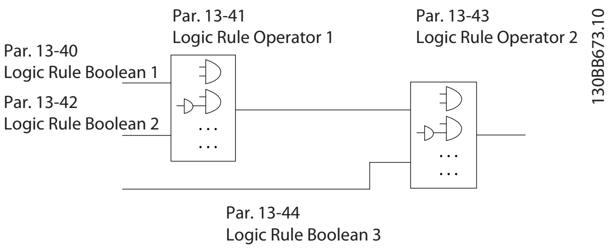


Illustration 2.22 Logic Rules

The logic rules, timers, and comparators are also available for use outside of the SLC sequence.

For an example of SLC, refer to *chapter 4.3 Application Set-up Examples*.3

2.6.16 STO Function

The frequency converter is available with STO functionality via control terminal 37. STO disables the control voltage of the power semiconductors of the frequency converter output stage. This in turn prevents generating the voltage required to rotate the motor. When the STO (terminal 37) is activated, the frequency converter issues an alarm, trips the unit, and coasts the motor to a stop. Manual restart is required. The STO function can be used as an emergency stop for the frequency converter. In the normal operating mode when STO is not required, use the regular stop function. When using automatic restart, ensure the requirements of ISO 12100-2 paragraph 5.3.2.5 are fulfilled.

Liability conditions
It is the responsibility of the user to ensure personnel installing and operating the STO function:

- Read and understand the safety regulations concerning health, safety, and accident prevention.
- Have a good knowledge of the generic and safety standards applicable to the specific application.

A user is defined as:

- Integrator
- Operator
- Service technician
- Maintenance technician

Standards
Use of STO on terminal 37 requires that the user satisfies all provisions for safety including relevant laws, regulations and guidelines. The optional STO 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 – STO function
- IEC 62061: 2005 SIL CL2
- ISO 13849-1: 2006 Category 3 PL d
- ISO 14118: 2000 (EN 1037) – prevention of unexpected startup

The information and instructions here are not sufficient for a proper and safe use of the STO functionality. For full information about STO, refer to the *VLT® Safe Torque Off Operating Instructions*.

Protective measures

- Qualified and skilled personnel are required for installation and commissioning of safety engineering systems.
- The unit must be installed in an IP54 cabinet or in an equivalent environment. In special applications, a higher IP degree is required.
- The cable between terminal 37 and the external safety device must be short-circuit protected according to ISO 13849-2 table D.4.
- When external forces influence the motor axis (for example, suspended loads), to eliminate potential hazards, additional measures are required (for example, a safety holding brake).

2.7 Fault, Warning and Alarm Functions

The frequency converter monitors many aspects of system operation including mains conditions, motor load and performance, as well as converter status. An alarm or warning does not necessarily indicate a problem with the frequency converter itself. It may be a condition outside of the converter that is being monitored for performance limits. The converter has various pre-programmed fault, warning and alarm responses. Select additional alarm and warning features to enhance or modify system performance.

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

2.7.1 Operation at Overtemperature

By default, the frequency converter issues an alarm and trip at overtemperature. If *Autoderate and Warning* is selected, the frequency converter will warn of the condition but continue to run and attempt to cool itself by first reducing its switching frequency. Then, if necessary, it reduces the output frequency.

Autoderating does not replace the user settings for derating for ambient temperature (see *chapter 5.3 Derating for Ambient Temperature*).

2.7.2 High and Low Reference Warning

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

2.7.3 High and Low Feedback Warning

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

2.7.4 Phase Imbalance or Phase Loss

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

2.7.5 High Frequency Warning

Useful in staging on additional equipment such as pumps or cooling fans, the converter can warm when the motor speed is high. A specific high frequency setting can be entered into the converter. If the output exceeds the set warning frequency, the unit displays a high frequency warning. A digital output from the converter can signal external devices to stage on.

2.7.6 Low Frequency Warning

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

2.7.7 High Current Warning

This function is similar to high frequency warning, except a high current setting is used to issue a warning and stage on additional equipment. The function is not active when stopped or at start up until the set operating current has been reached.

2.7.8 Low Current Warning

This function is similar to low frequency warning (see *chapter 2.7.6 Low Frequency Warning*), except a low current setting is used to issue a warning and stage off equipment. The function is not active when stopped or at start up until the set operating current has been reached.

2.7.9 No Load/Broken Belt Warning

This feature can be used for monitoring a no-load condition, for example a V-belt. After a low current limit has been stored in the converter, if loss of the load is detected, the converter can be programmed to issue an alarm and trip or to continue operation and issue a warning.

2.7.10 Lost Serial Interface

The frequency converter can detect loss of serial communication. A time delay of up to 99 s is selectable to avoid a response due to interruptions on the serial communications bus. When the delay is exceeded, options available include for the unit to:

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

2.8 User Interfaces and Programming

The frequency converter uses parameters for programming its application functions. Parameters provide a description of a function and a menu of options to either select from or for entering numeric values. A sample programming menu is shown in *Illustration 2.23*.

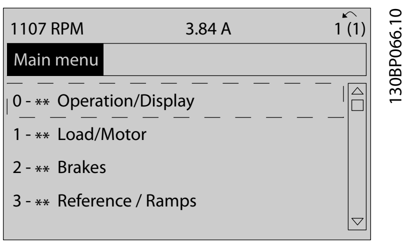


Illustration 2.23 Sample Programming Menu

Local user interface
For local programming, parameters are accessible by pressing either [Quick Menu] or [Main Menu] on the LCP.

The Quick Menu is intended for initial start up and motor characteristics. The Main Menu accesses all parameters and allows for advanced applications programming.

Remote user interface
For remote programming, Danfoss offers a software program for developing, storing, and transferring programming information. MCT 10 Set-up Software allows the user to connect a PC to the frequency converter and perform live programming rather than using the LCP keypad. Or programming can be done off-line and simply downloaded to the unit. The entire converter profile can be loaded onto the PC for back-up storage or analysis. A USB connector and RS485 terminal are available for connecting to the frequency converter.

MCT 10 Set-up Software is available for free download at Site. A CD is also available by requesting part number 130B1000. A user's manual provides detailed operation instructions. See also *chapter 2.8.2 PC Software*.

Programming control terminals

- Each control terminal has specified functions it is capable of performing.
- Parameters associated with the terminal enable the function selections.
- For proper converter functioning using control terminals, the terminals must be:
  - Wired properly.
  - Programmed for the intended function.

2.8.1 Local Control Panel

The local control panel (LCP) is a graphic display on the front of the unit, which provides the user interface through push-button controls and displays status messages, warnings and alarms, programming parameters, and more. A numeric display is also available with limited display options. *Illustration 2.24* shows the LCP.

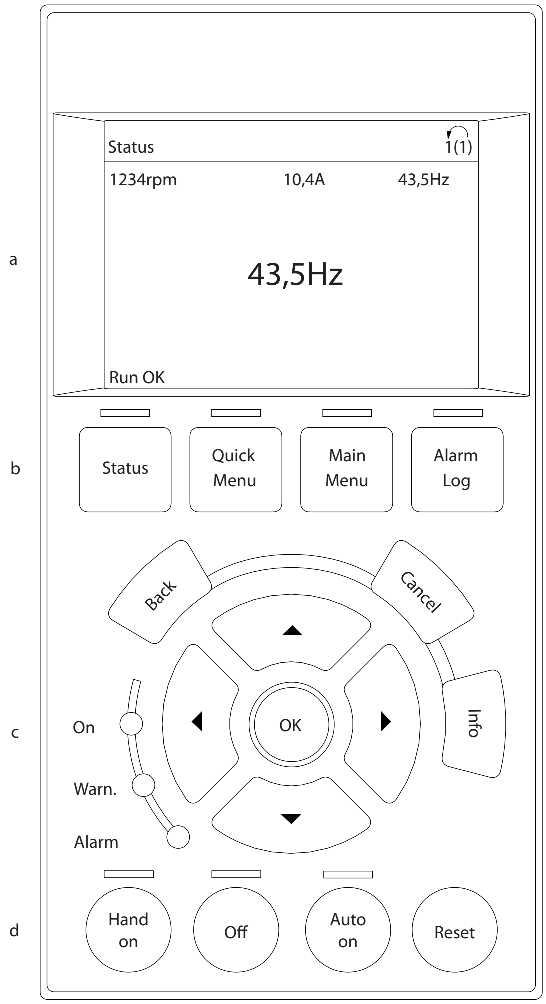


Illustration 2.24 Local Control Panel

2.8.2 PC Software

The PC is connected via a standard (host/device) USB cable, or via the RS485 interface.

USB is a serial bus utilising 4 shielded wires with ground pin 4 connected to the shield in the PC USB port. By 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 ground potential difference caused by not following the recommendations described in the *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 ground potential differences, when connecting the PC to a frequency converter through a USB cable.
Do 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 ground potential difference, but does not eliminate all potential differences due to the ground and shield connected in the PC USB port.

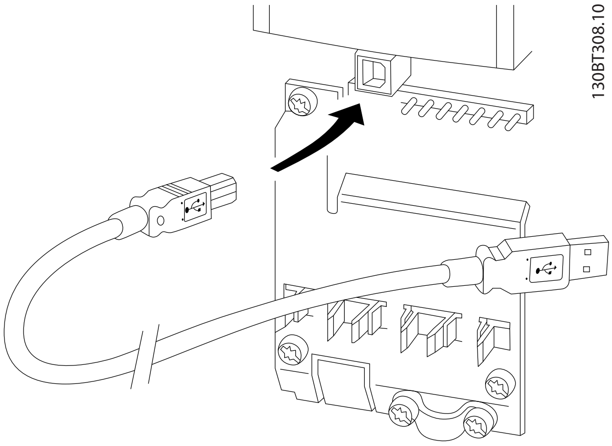


Illustration 2.25 USB Connection

2.8.2.1 MCT 10 Set-up Software

The MCT 10 Set-up Software is designed for commissioning and servicing the frequency converter including guided programming of cascade controller, real-time clock, smart logic controller, and preventive maintenance.
This software provides easy control of details as well as a general overview of systems, large or small. The tool handles all frequency converter series, VLT® advanced active filters and VLT® soft starter related data.

Example 1: Data storage in PC via MCT 10 Set-up Software

1. Connect a PC to the unit via USB or via the RS485 interface.
2. Open MCT 10 Set-up Software.
3. Select the USB port or the RS485 interface.
4. Select *copy*.
5. Select the *project* section.
6. Select *paste*.
7. Select *save as*.

All parameters are now stored.

Example 2: Data transfer from PC to frequency converter via MCT 10 Set-up Software

1. Connect a PC to the unit via USB port or via the RS485 interface.
2. Open MCT 10 Set-up Software.
3. Select *Open* – stored files are shown.
4. Open the appropriate file.
5. Select *Write to drive*.

All parameters are now transferred to the frequency converter.

2.8.2.2 VLT® Harmonics Calculation Software MCT 31

The MCT 31 harmonic calculation PC tool enables easy estimation of the harmonic distortion in a given application. Both the harmonic distortion of Danfoss frequency converters as well as non-Danfoss frequency converters with additional harmonic reduction devices, such as Danfoss AHF filters and 12-18-pulse rectifiers, can be calculated.

2.8.2.3 Harmonic Calculation Software (HCS)

HCS is an advanced version of the harmonic calculation tool. The calculated results are compared to relevant norms and can be printed afterwards.

2.9 Maintenance

Danfoss frequency converter models up to 90 kW are maintenance-free. High power frequency converters (rated at 110 kW or higher) have built-in filter mats, which require periodic cleaning by the operator, depending on the exposure to dust and contaminants. Maintenance intervals for the cooling fans (approximately 3 years) and capacitors (approximately 5 years) are recommended in most environments.

2.9.1 Storage

Like all electronic equipment, frequency converters must be stored in a dry location. Periodic forming (capacitor charging) is not necessary during storage.

It is recommended to keep the equipment sealed in its packaging until installation.

3 System Integration

This chapter describes the considerations necessary to integrate the frequency converter into a system design. The chapter is divided into these sections:

- *Chapter 3.1 Ambient Operating Conditions*
  Ambient operating conditions for the frequency converter including environment, enclosures, temperature, derating, and other considerations.
- *Chapter 3.3 Mains Integration*
  Input into the frequency converter from the mains side including power, harmonics, monitoring, cabling, fusing, and other considerations.
- *Chapter 3.2 EMC, Harmonics and Earth Leakage Protection*
  Input (regeneration) from the frequency converter to the power grid including power, harmonics, monitoring, and other considerations.
- *Chapter 3.4 Motor Integration*
  Output from the frequency converter to the motor including motor types, load, monitoring, cabling, and other considerations.
- *Chapter 3.5 Additional Inputs and Outputs*, *Chapter 3.6 Mechanical Planning*
  Integration of the frequency converter input and output for optimal system design including frequency converter/motor matching, system characteristics, and other considerations.

A comprehensive system design anticipates potential problem areas while implementing the most effective combination of converter features. The information that follows provides guidelines for planning and specifying a motor-control system incorporating frequency converters.

Operational features provide a range of design concepts, from simple motor speed control to a fully integrated automation system with feedback handling, operational status reporting, automated fault responses, remote programming, and more.

A complete design concept includes detailed specification of needs and use.

- Frequency converter types
- Motors
- Mains requirements
- Control structure and programming
- Serial communication
- Equipment size, shape, weight
- Power and control cabling requirements; type and length
- Fuses
- Auxiliary equipment
- Transportation and storage

See *chapter 3.9 System Design Checklist* for a practical guide for selection and design.

Understanding features and strategy options can optimise a system design and possibly avoid introducing redundant components or functionality.

3.1 Ambient Operating Conditions

3.1.1 Humidity

Although the frequency converter can operate properly at high humidity (up to 95% relative humidity), avoid condensation. There is a specific risk of condensation when the frequency converter is colder than moist ambient air. Moisture in the air can also condense on the electronic components and cause short-circuits. Condensation occurs in units without power. It is advisable to install a cabinet heater when condensation is possible due to ambient conditions. Avoid installation in areas subject to frost.

Alternatively, operating the frequency converter in standby mode (with the unit connected to the mains) reduces the risk of condensation. Ensure the power dissipation is sufficient to keep the frequency converter circuitry free of moisture.

3.1.2 Temperature

Minimum and maximum ambient temperature limits are specified for all frequency converters. Avoiding extreme ambient temperatures prolongs the life of the equipment and maximises overall system reliability. Follow the recommendations listed for maximum performance and equipment longevity.

- Although the frequency converter can operate at temperatures down to -10 °C, proper operation at rated load is only guaranteed at 0 °C or higher.
- Do not exceed the maximum temperature limit.
- The lifetime of electronic components decreases by 50% for every 10 °C when operated above the design temperature.
- Even devices with IP54, IP55, or IP66 protection ratings must adhere to the specified ambient temperature ranges.

3

- Additional air conditioning of the cabinet or installation site may be required.

3.1.3 Cooling

Frequency converters dissipate power in the form of heat. The following recommendations are necessary for effective cooling of the units.

- Maximum air temperature to enter enclosure must never exceed 40 °C (104 °F).
- Day/night average temperature must not exceed 35 °C (95 °F).
- Mount the unit to allow for free cooling airflow through the cooling fins. See *chapter 3.6.1 Clearance* for correct mounting clearances.
- Provide minimum front and rear clearance requirements for cooling airflow. See the *operating instructions* for proper installation requirements.

3.1.3.1 Fans

The frequency converter has built-in fans to ensure optimum cooling. The main fan forces the air flow along the cooling fins on the heat sink, ensuring a cooling of the internal air. Some power sizes have a small secondary fan close to the control card, ensuring that the internal air is circulated to avoid hot spots.

The main fan is controlled by the internal temperature in the frequency converter and the speed gradually increases along with temperature, reducing noise and energy consumption when the need is low, and ensuring maximum cooling when the need is there. The fan control can be adapted via *14-52 Fan Control* to accommodate any application, also to protect against negative effects of cooling in cold climates. In case of overtemperature inside the frequency converter, it derates the switching frequency and pattern. See *chapter 5.1 Derating* for more info.

3.1.3.2 Calculation of Airflow Required for Cooling the Frequency Converter

The airflow required to cool a frequency converter, or multiple frequency converters in one enclosure, can be calculated as follows:

1. Determine the power loss at maximum output for all frequency converters from data tables in *chapter 7 Specifications*.
2. Add power loss values of all frequency converters that can operate at same time. The resultant sum is the heat Q to be transferred. Multiply the result with the factor f, read from *Table 3.1*. For example, f = 3.1 m^3 x K/Wh at sea level.
3. Determine the highest temperature of the air entering the enclosure. Subtract this temperature from the required temperature inside the enclosure, for example 45 °C (113 °F).
4. Divide the total from step 2 by the total from step 3.

The calculation is expressed by the formula:

$$V = \frac{f \times Q}{T_i - T_A}$$

where
V = airflow in m^3/h
f = factor in m^3 x K/Wh
Q = heat to be transferred in W
T_i = temperature inside the enclosure in °C
T_A = ambient temperature in °C
f = cp x ρ (specific heat of air x density of air)

NOTICE

Specific heat of air (cp) and density of air (ρ) are not constants, but depend on temperature, humidity, and atmospheric pressure. Therefore, they depend on the altitude above sea level.

Table 3.1 shows typical values of the factor f, calculated for different altitudes.

Altitude	Specific heat of air cp	Density of air ρ	Factor f
[m]	[kJ/kgK]	[kg/m³]	[m³·K/Wh]
0	0.9480	1.225	3.1
500	0.9348	1.167	3.3
1000	0.9250	1.112	3.5
1500	0.8954	1.058	3.8
2000	0.8728	1.006	4.1
2500	0.8551	0.9568	4.4
3000	0.8302	0.9091	4.8
3500	0.8065	0.8633	5.2

Table 3.1 Factor f, Calculated for Different Altitudes

Example
What is the airflow required to cool 2 frequency converters (heat losses 295 W and 1430 W) running simultaneously, mounted in an enclosure with an ambient temperature peak of 37 °C?

1. The sum of the heat losses of both frequency converters is 1725 W.
2. Multiplying 1725 W by 3.3 m^3 x K/Wh gives 5693 m x K/h.
3. Subtracting 37 °C from 45 °C gives 8 °C (=8 K).
4. Dividing 5693 m x K/h by 8 K gives: 711.6 m^3h.

If the airflow is required in CFM, use the conversion 1 m^3/h = 0.589 CFM.

For the example above, 711.6 m^3/h = 418.85 CFM.

3.1.4 Motor-generated Overvoltage

The DC voltage in the intermediate circuit (DC bus) increases when the motor acts as a generator. This can occur in 2 ways:

- The load drives the motor when the frequency converter is operated at a constant output frequency. This is generally referred to as an overhauling load.
- During deceleration, if the inertia of the load is high and the deceleration time of the converter is set to a short value.

The frequency converter cannot regenerate energy back to the input. Therefore, it limits the energy accepted from the motor when set to enable autoramping. The frequency converter attempts to do this by automatically lengthening the ramp-down time, if the overvoltage occurs during deceleration. If this is unsuccessful, or if the load drives the motor when operating at a constant frequency, the converter shuts down and displays a fault when a critical DC bus voltage level is reached.

3.1.5 Acoustic Noise

Acoustic noise from the frequency converter comes from 3 sources:

- DC-link (intermediate circuit) coils
- RFI filter choke
- Internal fans

See *Table 7.60* for acoustic noise ratings.

3.1.6 Vibration and Shock

The frequency converter is tested according to a procedure based on the IEC 68-2-6/34/35 and 36. These tests subject the unit to 0.7 g forces, over the range of 18 to 1000 Hz randomly, in 3 directions, for 2 hours. All Danfoss frequency converters comply with requirements that correspond to these conditions when the unit is wall- or floor-mounted, as well as when mounted within panels, or bolted to walls or floors.

3.1.7 Aggressive Atmospheres

3.1.7.1 Gases

Aggressive gases, such as hydrogen sulphide, chlorine, or ammonia can damage frequency converter electrical and mechanical components. Contamination of the cooling air can also cause the gradual decomposition of PCB tracks and door seals. Aggressive contaminants are often present in sewage treatment plants or swimming pools. A clear sign of an aggressive atmosphere is corroded copper.

In aggressive atmospheres, restricted IP enclosures are recommended along with conformal-coated circuit boards. See *Table 3.2* for conformal-coating values.

NOTICE

The frequency converter comes standard with class 3C2 coating of circuit boards. On request, class 3C3 coating is available.

Gas type	Unit	Class				
		3C1	3C2		3C3	
			Average value	Max. value 1)	Average value	Max. value 1)
Sea salt	n/a	None	Salt mist		Salt mist	
Sulphur oxides	mg/m^3	0.1	0.3	1.0	5.0	10
Hydrogen sulphide	mg/m^3	0.01	0.1	0.5	3.0	10
Chlorine	mg/m^3	0.01	0.1	0.03	0.3	1.0
Hydrogen chloride	mg/m^3	0.01	0.1	0.5	1.0	5.0
Hydrogen fluoride	mg/m^3	0.003	0.01	0.03	0.1	3.0
Ammonia	mg/m^3	0.3	1.0	3.0	10	35
Ozone	mg/m^3	0.01	0.05	0.1	0.1	0.3
Nitrogen	mg/m^3	0.1	0.5	1.0	3.0	9.0

Table 3.2 Conformal-coating Class Ratings

1) Maximum values are transient peak values not to exceed 30 minutes per day.

3.1.7.2 Dust Exposure

Installation of frequency converters in environments with high dust exposure is often unavoidable. Dust affects wall- or frame-mounted units with IP55 or IP66 protection ratings, and also cabinet-mounted devices with IP21 or IP20 protection ratings. Consider the 3 aspects described in this section when frequency converters are installed in such environments.

3

Reduced cooling
Dust forms deposits on the surface of the device and inside on circuit boards and the electronic components. These deposits act as insulation layers and hamper heat transfer to the ambient air, reducing the cooling capacity. The components become warmer. This causes accelerated aging of the electronic components, and the service life of the unit decreases. Dust deposits on the heat sink in the back of the unit also decrease the service life of the unit.

Cooling fans
The airflow for cooling the unit is produced by cooling fans, usually located on the back of the device. The fan rotors have small bearings into which dust can penetrate and act as an abrasive. This leads to bearing damage and fan failure.

Filters
High-power frequency converters are equipped with cooling fans that expel hot air from the interior of the device. Above a certain size, these fans are fitted with filter mats. These filters can become quickly clogged when used in dusty environments. Preventive measures are necessary under these conditions.

Periodic maintenance
Under the conditions described above, it is advisable to clean the frequency converter during periodic maintenance. Remove dust off the heat sink and fans and clean the filter mats.

3.1.7.3 Potentially Explosive Atmospheres

Systems operated in potentially explosive atmospheres must fulfill special conditions. EU Directive 94/9/EC describes the operation of electronic devices in potentially explosive atmospheres.

Motors controlled by frequency converters in potentially explosive atmospheres must be monitored for temperature using a PTC temperature sensor. Motors with ignition protection class d or e are approved for this environment.

- d classification consists of ensuring that if a spark occurs, it is contained in a protected area. While not requiring approval, special wiring and containment are required.
- d/e combination is the most often used in potentially explosive atmospheres. The motor itself has an e ignition protection class, while the motor cabling and connection environment is in compliance with the e classification. The restriction on the e connection space consists of the maximum voltage allowed in this space. The output voltage of a frequency converter is usually limited to the mains voltage. The modulation of the output voltage may generate unallowable high peak voltage for e classification. In practice, using a sine-wave filter at the frequency converter output has proven to be an effective means to attenuate the high peak voltage.

NOTICE

Do not install a frequency converter in a potentially explosive atmosphere. Install the frequency converter in a cabinet outside of this area. Using a sine-wave filter at the output of the frequency converter is also recommended to attenuate the dU/dt voltage rise and peak voltage. Keep the motor cables as short as possible.

NOTICE

Frequency converters with the MCB 112 option have PTB-certified motor thermistor sensor monitoring capability for potentially explosive atmospheres. Shielded motor cables are not necessary when frequency converters are operated with sine-wave output filters.

3.1.8 IP Rating Definitions

		Against penetration by solid foreign objects	Against access to hazardous parts by
First digit	0	(not protected)	(not protected)
	1	≥50 mm diameter	Back of hand
	2	12.5 mm diameter	Finger
	3	2.5 mm diameter	Tool
	4	≥1.0 mm diameter	Wire
	5	Dust protected	Wire
	6	Dust-tight	Wire
		Against water penetration with harmful effect	
Second digit	0	(not protected)	
	1	Drops falling vertically	
	2	Drops at 15° angle	
	3	Spraying water	
	4	Splashing water	
	5	Water jets	
	6	Powerful water jets	
	7	Temporary immersion	
	8	Long-term immersion	
		Additional information specifically for	
First letter	A		Back of hand
	B		Finger
	C		Tool
	D		Wire
		Additional information specifically for	
Additional letter	H	High-voltage device	
	M	Device moving during water test	
	S	Device stationary during water test	
	W	Weather conditions	

Table 3.3 IEC 60529 Definitions for IP Ratings

3.1.8.1 Cabinet Options and Ratings

Danfoss frequency converters are available with 3 different protection ratings:

- IP00 or IP20 for cabinet installation.
- IP54 or IP55 for local mounting.
- IP66 for critical ambient conditions, such as extremely high (air) humidity or high concentrations of dust or aggressive gases.

3.1.9 Radio Frequency Interference

The main objective in practice is to obtain systems that operate stably without radio frequency interference between components. To achieve a high level of immunity, it is recommended to use frequency converters with high-quality RFI filters.

Use Category C1 filters specified in the EN 61800-3 which conform to the Class B limits of the general standard EN 55011.

Place warning notices on the frequency converter if RFI filters do not correspond to Category C1 (Category C2 or lower). The responsibility for proper labelling rests with the operator.

In practice, there are 2 approaches to RFI filters:

- Built in to the equipment
  - Built-in filters take up space in the cabinet but eliminate additional costs for fitting, wiring, and material. However, the most important advantage is the perfect EMC conformance and cabling of integrated filters.
- External options
  - Optional external RFI filters that are installed on the input of the frequency converter cause a voltage drop. In practice, this means that the full mains voltage is not present at the frequency converter input and a higher-rated converter may be necessary. The maximum length of the motor cable for compliance with EMC limits ranges from 1–50 m. Costs are incurred for material, cabling, and assembly. EMC conformance is not tested.

NOTICE

To ensure interference-free operation of the frequency converter/motor system, always use a category C1 RFI filter.

NOTICE

VLT® AQUA Drive units are supplied as standard with built-in RFI filters conforming to category C1 (EN 61800-3) for use with 400 V mains systems and power ratings up to 90 kW or category C2 for power ratings of 110 to 630 kW. VLT® AQUA Drive units conform to C1 with shielded motor cables up to 50 m or C2 with shielded motor cables up to 150 m. Refer to *Table 3.4* for details.

3

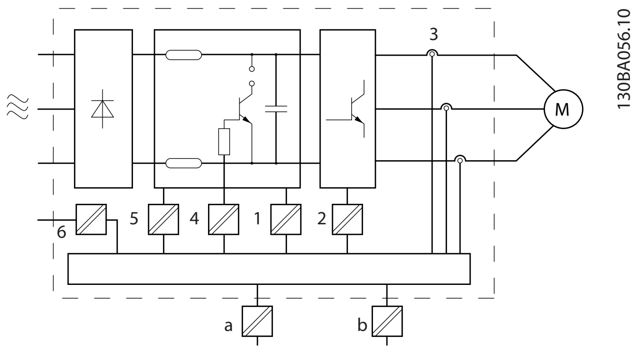
3.1.10 PELV and Galvanic Isolation Compliance

Ensure the protection against electric shock, when the electrical supply is of the protective extra-low voltage (PELV) type and the installation complies with local and national PELV regulations.

To maintain PELV at the control terminals, all connections must be PELV, such as thermistors being reinforced/double insulated. All Danfoss frequency converter control and relay terminals comply with PELV (excluding grounded Delta leg above 400 V).

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

Electrical isolation is provided as shown in *Illustration 3.1*. The components described comply with both PELV and the galvanic isolation requirements.



1	Power supply (SMPS) including signal isolation of V DC, indicating the intermediate current voltage
2	Gate drive for the IGBTs
3	Current transducers
4	Opto-coupler, brake module
5	Internal inrush, RFI, and temperature measurement circuits
6	Custom relays
a	Galvanic isolation for the 24 V back-up option
b	Galvanic isolation for the RS485 standard bus interface

Illustration 3.1 Galvanic Isolation

Installation at high altitude
Installations exceeding high altitude limits may not comply with PELV requirements. The isolation between components and critical parts could be insufficient. There is a risk for overvoltage. Reduce the risk for over-voltage using external protective devices or galvanic isolation.

For installations at high altitude, contact Danfoss regarding PELV compliance.

- 380–500 V (enclosure A, B and C): above 2000 m (6500 ft)
- 380–500 V (enclosure D, E, and F): above 3000 m (9800 ft)
- 525–690 V: above 2000 m (6500 ft)

3.1.11 Storage

Like all electronic equipment, frequency converters must be stored in a dry location. Periodic forming (capacitor charging) is not necessary during storage.

It is recommended to keep the equipment sealed in its packaging until installation.

3.2 EMC, Harmonics and Earth Leakage Protection

3.2.1 General Aspects of EMC Emissions

Frequency converters (and other electrical devices) generate electronic or magnetic fields that may interfere with their environment. The electromagnetic compatibility (EMC) of these effects depends on the power and the harmonic characteristics of the devices.

Uncontrolled interaction between electrical devices in a system can degrade compatibility and impair reliable operation. Interference may take the form of mains harmonics distortion, electrostatic discharges, rapid voltage fluctuations, or high-frequency interference. Electrical devices generate interference along with being affected by interference from other generated sources.

Electrical interference usually arises at frequencies in the range 150 kHz to 30 MHz. Airborne interference from the frequency converter system in the range 30 MHz to 1 GHz is generated from the inverter, motor cable, and the motor.
Capacitive currents in the motor cable coupled with a high dU/dt from the motor voltage generate leakage currents, as shown in *Illustration 3.2*.
The use of a screened motor cable increases the leakage current (see *Illustration 3.2*) because screened cables have higher capacitance to ground than unscreened cables. If the leakage current is not filtered, it causes greater interference on the mains in the radio frequency range below approximately 5 MHz. Since the leakage current (I_1) is carried back to the unit through the screen (I_3), there is, in principle, only a small electro-magnetic field (I_4) from the screened motor cable according to *Illustration 3.2*.

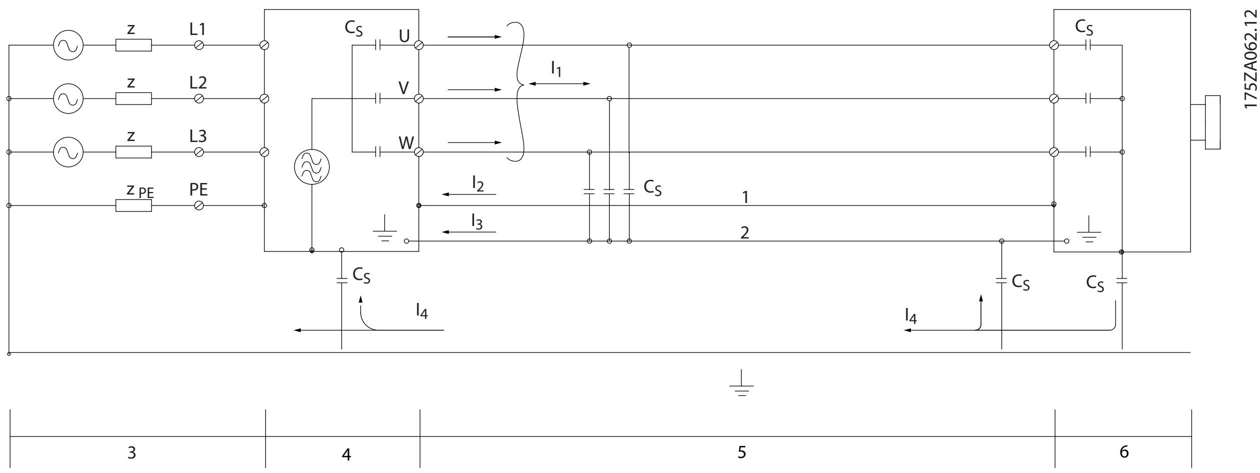
The screen reduces the radiated interference, but increases the low-frequency interference on the mains. Connect the motor cable screen to the frequency converter enclosure

as well as on the motor enclosure. This is best done by using integrated screen clamps so as to avoid twisted screen ends (pigtails). Pigtails 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 relay, control cable, signal interface and brake, mount the screen on the enclosure at both ends. In some situations, however, it is necessary to break the screen to avoid current loops.

If the screen is to be placed on a mounting plate for the frequency converter, the mounting plate must be made of metal, to convey the screen currents back to the unit. Moreover, ensure good electrical contact from the mounting plate through the mounting screws to the frequency converter chassis.

When using unscreened cables, some emission requirements are not complied with, although most immunity requirements are observed.

To reduce the interference level from the entire system (unit+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 especially generated by the control electronics.



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

Illustration 3.2 Generation of Leakage Currents

3.2.2 EMC Test Results

The following test results have been obtained using a system with a frequency converter, a screened control cable, a control box with potentiometer, as well as a single motor and screened motor cable (Ölflex Classic 100 CY) at nominal switching frequency. *Table 3.4* states the maximum motor cable lengths for compliance.

3

NOTICE

Conditions may change significantly for other set-ups.

NOTICE

Consult *Table 3.17* for parallel motor cables.

RFI filter type			Conducted emission			Radiated emission		
			Cable length [m]			Cable length [m]		
Standards and requirements	EN 55011		Class B	Class A Group 1	Class A Group 2	Class B	Class A Group 1	Class A Group 2
			Housing, trades and light industries	Industrial environment	Industrial environment	Housing, trades and light industries	Industrial environment	Industrial environment
	EN/IEC 61800-3		Category C1	Category C2	Category C3	Category C1	Category C2	Category C3
			First environment Home and office	First environment Home and office	Second environment Industrial	First environment Home and office	First environment Home and office	Second environment Industrial
H1								
FC 202	0.25-45 kW 200-240 V	T2	50	150	150	No	Yes	Yes
	1.1-7.5 kW 200-240 V	S2	50	100/150[5]	100/150[5]	No	Yes	Yes
	0.37-90 kW 380-480 V	T4	50	150	150	No	Yes	Yes
	7.5 kW 380-480 V	S4	50	100/150[5]	100/150[5]	No	Yes	Yes
H2								
FC 202	0.25-3.7 kW 200-240 V	T2	No	No	5	No	No	No
	5.5-45 kW 200-240 V	T2	No	No	25	No	No	No
	1.1-7.5 kW 200-240 V	S2	No	No	25	No	No	No
	0.37-7.5 kW 380-480 V	T4	No	No	5	No	No	No
	11-90 kW 380-380 V[4]	T4	No	No	25	No	No	No
	7.5 kW 380-480 V	S4	No	No	25	No	No	No
	11-30 kW 525-690 V[1, 4]	T7	No	No	25	No	No	No
	37-90 kW 525-690 V[2, 4]	T7	No	No	25	No	No	No
H3								
FC 202	0.25-45 kW 200-240 V	T2	10	50	50	No	Yes	Yes
	0.37-90 kW 380-480 V	T4	10	50	50	No	Yes	Yes
H4								
FC 202	1.1-30 kW 525-690 V[1]	T7	No	100	100	No	Yes	Yes
	37-90 kW 525-690 V[2]	T7	No	150	150	No	Yes	Yes
Hx[1]								
FC 202	1.1-90 kW 525-600 V	T6	No	No	No	No	No	No
	15-22 kW 200-240 V	S2	No	No	No	No	No	No
	11-37 kW 380-480 V	S4	No	No	No	No	No	No

Table 3.4 EMC Test Results (Emission) Maximum Motor Cable Length

1) Enclosure size B2.

2) Enclosure size C2.

3) Hx versions can be used according to EN/IEC 61800-3 category C4.

4) T7, 37–90 kW complies with class A group 1 with 25 m motor cable. Some restrictions for the installation apply (contact Danfoss for details).

5) 100 m for phase-neutral, 150 m for phase-phase (but not from TT or TT). Single-phase frequency converters are not intended for 2-phase supply from a TT or TN network.

Hx, H1, H2, H3, H4 or H5 is defined in the type code pos. 16–17 for EMC filters.
Hx – No EMC filters built in the frequency converter.
H1 – Integrated EMC filter. Fulfill EN 55011 Class A1/B and EN/IEC 61800-3 Category 1/2.
H2 – A limited RFI filter only containing capacitors and without a common-mode coil. Fulfill EN 55011 Class A2 and EN/IEC 61800-3 Category 3.
H3 – Integrated EMC filter. Fulfill EN 55011 class A1/B and EN/IEC 61800-3 Category 1/2.
H4 – Integrated EMC filter. Fulfill EN 55011 class A1 and EN/IEC 61800-3 Category 2.
H5 – Marine versions. Ruggedised version, fulfills same emissions levels as H2 versions.

3.2.3 Emission Requirements

The EMC product standard for frequency converters defines 4 categories (C1, C2, C3 and C4) with specified requirements for emission and immunity. *Table 3.5* states the definition of the 4 categories and the equivalent classification from EN 55011.

Category	Definition	Equivalent emission class 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, which are neither plug-in nor movable and are intended to be installed and commissioned by a professional.	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 3.5 Correlation between IEC 61800-3 and EN 55011

When the generic (conducted) emission standards are used, the frequency converters are required to comply with the limits in *Table 3.6*.

Environment	Generic emission standard	Equivalent emission class 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 3.6 Correlation between Generic Emission Standards and EN 55011

3.2.4 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 in accordance with 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 for example by lightning that strikes near installations.
- **EN 61000-4-6 (IEC 61000-4-6):** RF Common mode: Simulation of the effect from radio-transmission equipment joined by connection cables.

See *Table 3.7*.

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Basic standard	Burst[2] IEC 61000-4-42)	Surge[2] IEC 61000-4-5	ESD[2] 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
Voltage range: 200-240 V, 380-500 V, 525-600 V, 525-690 V					
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 3.7 EMC Immunity Form

1) Injection on cable shield

2) Values typically obtained by testing

3.2.5 Motor Insulation

Modern motors for use with frequency converters have a high degree of insulation to account for new generation high-efficiency IGBTs with high dU/dt. For retrofit in old motors, confirm the motor insulation or mitigate with dU/dt filter or, if necessary, a sine-wave filter.

For motor cable lengths ≤ the maximum cable length listed in *chapter 7.5 Cable Specifications*, the motor insulation ratings listed in *Table 3.8* are recommended. If a motor has lower insulation rating, it is recommended to use a dU/dt or sine-wave filter.

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

Table 3.8 Motor Insulation

3.2.6 Motor Bearing Currents

To minimise bearing and shaft currents, ground the following to the driven machine:

- Frequency converter
- Motor
- Driven machine

Standard mitigation strategies

1. Use an insulated bearing.
2. Apply rigorous installation procedures:
   - 2a Ensure that the motor and load motor are aligned.
   - 2b Strictly follow the EMC Installation guideline.
   - 2c Reinforce the PE so the high frequency impedance is lower in the PE than the input power leads.
   - 2d 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.
   - 2e Make sure that the impedance from frequency converter to building ground

is lower that the grounding impedance of the machine. This can be difficult for pumps.

2f Make a direct ground 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 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 sine-wave filter.

3.2.7 Harmonics

Electrical devices with diode rectifiers, such as fluorescent lights, computers, copiers, fax machines, various laboratory equipment and telecommunications systems, can add harmonic distortion to a mains power supply. Frequency converters use a diode bridge input, which can also contribute to harmonic distortion.

The frequency converter does not draw current uniformly from the power line. This non-sinusoidal current has components that are multiples of the fundamental current frequency. These components are referred to as harmonics. It is important to control the total harmonic distortion on the mains supply. Although the harmonic currents do not directly affect electrical energy consumption, they generate heat in wiring and transformers and can affect other devices on the same power line.

3.2.7.1 Harmonic Analysis

Various characteristics of a building's electrical system determine the exact harmonic contribution of the converter to the THD of a facility and its ability to meet IEEE standards. Generalisations about the harmonic contribution of frequency converters on a specific facility is difficult. When necessary, perform an analysis of the system harmonics to determine equipment effects.

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 series analysis and split up into sine-wave currents with different frequencies, i.e. different harmonic currents I_N with 50 Hz or 60 Hz as the fundamental frequency.

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

Abbreviation	Description
f_1	fundamental frequency
I_1	fundamental current
U_1	fundamental voltage
I_n	harmonic currents
U_n	harmonic voltage
n	harmonic order

Table 3.9 Harmonics-related Abbreviations

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

Table 3.10 Transformed Non-sinusoidal Current

Current	Harmonic current				
	I_{RMS}	I_1	I_5	I_7	I_{11-49}
Input current	1.0	0.9	0.4	0.2	< 0.1

Table 3.11 Harmonic Currents Compared to the RMS Input Current

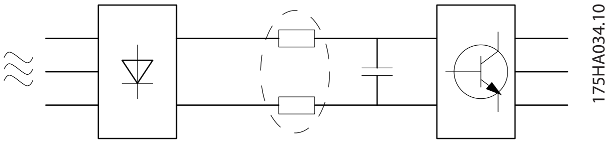

Illustration 3.3 Intermediate Circuit Coils

NOTICE

Some of the harmonic currents can disturb communication equipment connected to the same transformer or cause resonance in connection with power-factor correction capacitors.

To ensure low harmonic currents, the frequency converter is equipped with passive filters. DC-coils reduce the total harmonic distortion (THD) to 40%.

The voltage distortion on the mains supply voltage depends on the size of the harmonic currents multiplied by the mains impedance for the frequency in question. The total voltage distortion (THD) is calculated on the basis of the individual voltage harmonics using this formula:

$$THD = \frac{\sqrt{U_5^2 + U_7^2 + ... + U_N^2}}{U1}$$

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3.2.7.2 Harmonics Emission Requirements

Equipment connected to the public supply network

Option	Definition
1	IEC/EN 61000-3-2 Class A for 3-phase balanced equipment (for professional equipment only up to 1 kW total power).
2	IEC/EN 61000-3-12 Equipment 16 A-75 A and professional equipment as from 1 kW up to 16 A phase current.

Table 3.12 Harmonics Emission Standards

3.2.7.3 Harmonics Test Results (Emission)

Power sizes up to PK75 in T2 and T4 complies with IEC/EN 61000-3-2 Class A. Power sizes from P1K1 and up to P18K in T2 and up to P90K in T4 complies with IEC/EN 61000-3-12, Table 4. Power sizes P110 - P450 in T4 also complies with IEC/EN 61000-3-12 even though not required because currents are above 75 A.

Table 3.13 describes that the short-circuit power of the supply S_{sc} at the interface point between the user's supply and the public system (R_{sce}) is greater than or equal to:

$$SSC = \sqrt{3} \times RSCE \times Umains \times Iequ = \sqrt{3} \times 120 \times 400 \times Iequ$$

	Individual harmonic current I_n/I_1 (%)			
	I_5	I_7	I_{11}	I_{13}
Actual (typical)	40	20	10	8
Limit for $R_{sce} \geq 120$	40	25	15	10
	Harmonic current distortion factor (%)			
	THD		PWHD	
Actual (typical)	46		45	
Limit for $R_{sce} \geq 120$	48		46	

Table 3.13 Harmonics Test Results (Emission)

It is the responsibility of the installer or user of the equipment to ensure, by consultation with the distribution network operator if necessary, that the equipment is connected only to a supply with a short-circuit power S_{sc} greater than or equal to that specified in the equation. Consult the distribution network operator to connect other power sizes to the public supply network.

Compliance with various system level guidelines:
The harmonic current data in *Table 3.13* are provided in accordance with IEC/EN61000-3-12 with reference to the power drive systems product standard. They may be used as the basis for calculation of the influence harmonic currents have on the power supply system and for the documentation of compliance with relevant regional guidelines: IEEE 519 -1992; G5/4.

3.2.7.4 Effect of Harmonics in a Power Distribution System

In *Illustration 3.4* 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.

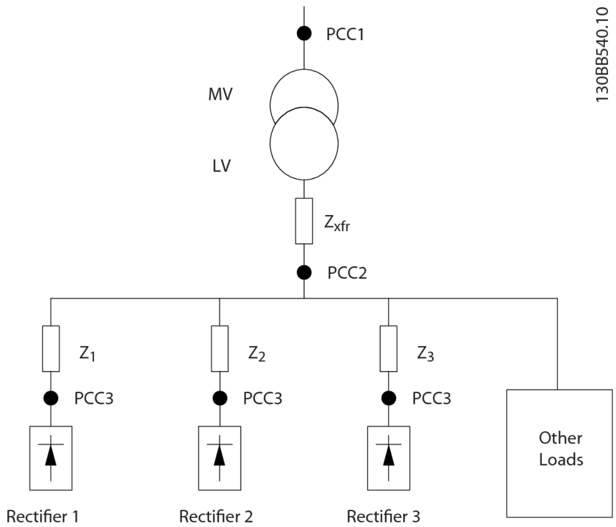

Illustration 3.4 Small Distribution System

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

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

A commonly used term for describing the impedance of a grid is the short-circuit ratio R_{sce}, 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}).

$$Rsce = \frac{Sce}{Sequ}$$

where $Ssc = \frac{U^2}{Zsupply}$ and $Sequ = U \times Iequ$

The negative effect of harmonics is 2-fold

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

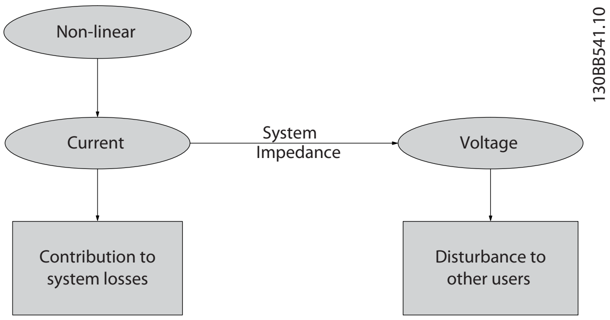

Illustration 3.5 Negative Effects of Harmonics

3.2.7.5 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 2 110 kW motors connected is sufficient, if one of the motors is connected directly online and the other is supplied through a frequency converter. However, the transformer is undersized if both motors are frequency-converter supplied. Using additional means of harmonic reduction within the installation or selecting low harmonic drive variants makes it possible for both motors to run with frequency converters.

There are various harmonic mitigation standards, regulations, and recommendations. 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 *AHF 005/010 Design Guide* for specific details on each standard.

In Europe, the maximum THVD is 8% if the plant is connected via the public grid. If the plant has its own transformer, the limit is 10% THVD. The VLT® AQUA Drive is designed to withstand 10% THVD.

3.2.7.6 Harmonic Mitigation

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

- 12-pulse drives
- AHF filters
- Low Harmonic Drives
- 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.).

Always consider harmonic mitigation if the transformer load has a non-linear contribution of 40% or more.

Danfoss offers tools for calculation of harmonics, see *chapter 2.8.2 PC Software*.

3.2.8 Earth Leakage Current

Follow national and local codes regarding protective earthing of equipment where leakage current exceeds 3.5 mA.
Frequency converter technology implies high frequency switching at high power. This generates a leakage current in the ground connection.
The earth leakage current is made up of several contributions and depends on various system configurations, including:

- RFI filtering
- Motor cable length
- Motor cable screening
- Frequency converter power

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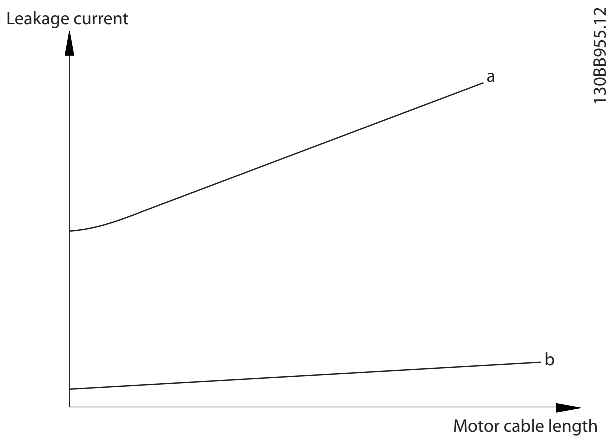

Illustration 3.6 Motor Cable Length and Power Size Influence on Leakage Current. Powersize a > Powersize b

The leakage current also depends on the line distortion.

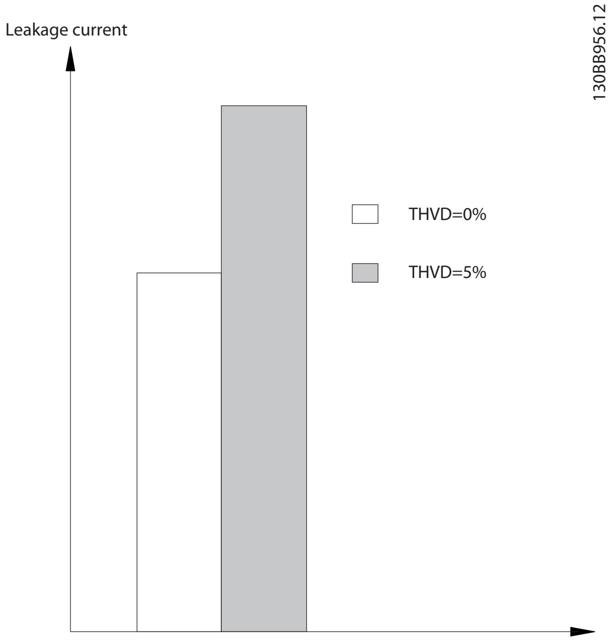

Illustration 3.7 Line Distortion Influences Leakage Current

Compliance with EN/IEC61800-5-1 (power drive system product standard) requires special care if the leakage current exceeds 3.5 mA. Reinforce grounding with the following protective earth connection requirements:

- Ground wire (terminal 95) of at least 10 mm^2 cross-section.
- 2 separate 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 as they are capable of detecting AC and DC currents.
- Use RCDs with a delay to prevent faults due to transient ground currents.
- Dimension RCDs according to the system configuration and environmental considerations.

The leakage current includes several frequencies originating from both the mains frequency and the switching frequency. Whether the switching frequency is detected depends on the type of RCD used.

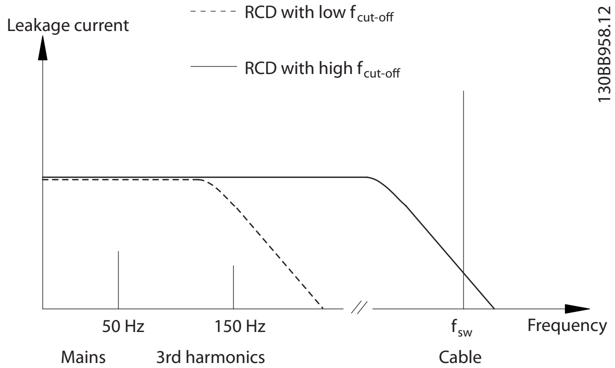

Illustration 3.8 Main Contributions to Leakage Current

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

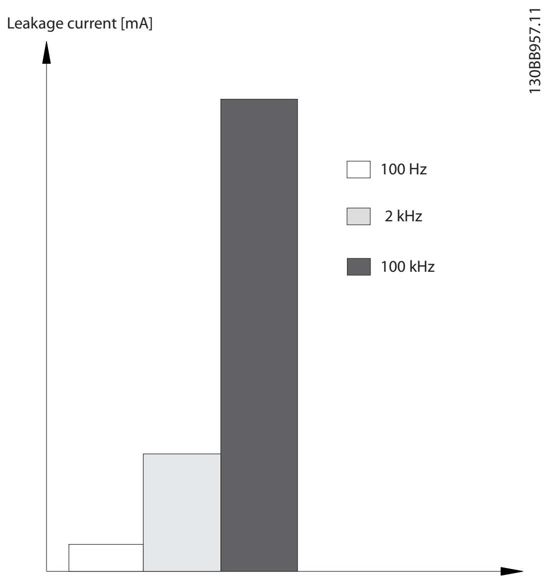

Illustration 3.9 Influence of the RCD Cut-off Frequency on Leakage Current

3.3 Mains Integration

3.3.1 Mains Configurations and EMC Effects

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

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

Table 3.14 AC Mains System Types

3.3.2 Low-frequency Mains Interference

3.3.2.1 Non-sinusoidal Mains Supply

The mains voltage is rarely a uniform sinusoidal voltage with constant amplitude and frequency. This is partly due to loads that draw non-sinusoidal currents from the mains or have non-linear characteristics, such as computers, television sets, switching power supplies, energy-efficient lamps, and frequency converters. Deviations are unavoidable and permissible within certain limits.

3.3.2.2 EMC Directives Compliance

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

Standard	Definition
EN 61000-2-2, EN 61000-2-4, EN 50160	Defines the mains voltage limits to observe in public and industrial power grids.
EN 61000-3-2, 61000-3-12	Regulates mains interference generated by connected devices.
EN 50178	Monitors electronic equipment for use in power installations.

Table 3.15 EN Design Standards for Mains Power Quality

3.3.2.3 Interference-free Frequency Converters

Every frequency converter generates mains interference. Present standards only define frequency ranges up to 2 kHz. Some converters shift the mains interference in the region above 2 kHz, which is not addressed by the standard, and label them as interference-free. Limits for this region are currently being studied. Frequency converters do not shift mains interference.

3.3.2.4 How Mains Interference Occurs

Mains interference distortion of the sinusoidal waveform caused by the pulsating input currents is referred to generally as harmonics. Derived from Fourier analysis, it is assessed up to 2.5 kHz, corresponding to the 50th harmonic of the mains frequency.

The input rectifiers of frequency converters generate this typical form of harmonic interference on the mains. When frequency converters are connected to 50 Hz mains systems, the 3rd harmonic (150 Hz), 5th harmonic (250 Hz) or 7th harmonic (350 Hz) show the strongest effects. The overall harmonic content is called the total harmonic distortion (THD).

3.3.2.5 Effects of Mains Interference

Harmonics and voltage fluctuations are 2 forms of low-frequency mains interference. They have a different appearance at their origin than at any other point in the mains system when a load is connected. Consequently, a range of influences must be determined collectively when assessing the effects of mains interference. These include the mains feed, structure, and loads.

Undervoltage warnings and higher functional losses can occur as a result of mains interference.

Undervoltage warnings

- Incorrect voltage measurements due to distortion of the sinusoidal mains voltage.
- Cause incorrect power measurements because only RMS-true measuring takes harmonic content into account.

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Higher losses

- Harmonics reduce the active power, apparent power, and reactive power.
- Distort electrical loads resulting in audible interference in other devices, or, in worst case, even destruction.
- Shorten the lifetime of devices as a result of heating.

NOTICE

Excessive harmonic content puts a load on power factor correction equipment and may even cause its destruction. For this reason, provide chokes for power factor correction equipment when excessive harmonic content is present.

3.3.3 Analysing Mains Interference

To avoid impairment of mains power quality, a variety of methods are available for analysing systems or devices that generate harmonic currents. Mains analysis programs, such as harmonic calculation software (HCS), analyse system designs for harmonics. Specific countermeasures can be tested beforehand and ensure subsequent system compatibility.

NOTICE

Danfoss has a very high level of EMC expertise and provides EMC analyses with detailed evaluation or mains calculations to customers in addition to training courses, seminars, and workshops.

3.3.4 Options for Reducing Mains Interference

Generally speaking, mains interference from converters is reduced by limiting the amplitude of pulsed currents. This improves the power factor λ (lambda).

Several methods are recommended to avoid mains harmonics:

- Input chokes or DC-link chokes in the frequency converters.
- Passive filters.
- Active filters.
- Slim DC links.
- Active front end and low harmonic drives.
- Rectifiers with 12, 18 or 24 pulses per cycle.

3.3.5 Radio Frequency Interference

Frequency converters generate radio frequency interference (RFI) due to their variable-width current pulses. Converters and motor cables radiate these components and conduct them into the mains system.

RFI filters are used to reduce this interference on the mains. They provide noise immunity to protect devices against high-frequency conducted interference. They also reduce interference emitted to the mains cable or radiation from the mains cable. The filters are intended to limit interference to a specified level. Built-in filters are often standard equipment rated for specific immunity.

NOTICE

All VLT® AQUA Drive frequency converters are equipped with integrated mains interference chokes as standard.

3.3.6 Classification of the Operating Site

Knowing the requirements for the environment the frequency converter is intended to operate in is the most important factor regarding EMC compliance.

3.3.6.1 Environment 1/Class B: Residential

Operating sites connected to the public low-voltage power grid, including light industrial areas, are classified as Environment 1/Class B. They do not have their own high-voltage or medium-voltage distribution transformers for a separate mains system. The environment classifications apply both inside and outside buildings. Some general examples are business areas, residential buildings, restaurants, car parks, and entertainment facilities.

3.3.6.2 Environment 2/Class A: Industrial

Industrial environments are not connected to the public power grid. Instead, they have their own high-voltage or medium-voltage distribution transformers. The environment classifications apply both inside and outside the buildings.

They are defined as industrial and are characterised by specific electromagnetic conditions:

- The presence of scientific, medical or industrial devices.
- Switching of large inductive and capacitive loads.
- The occurrence of strong magnetic fields (for example, due to high currents).

3.3.6.3 Special Environments

In areas with medium-voltage transformers clearly demarcated from other areas, the user decides which type of environment to classify their facility. The user is responsible for ensuring the electromagnetic compatibility necessary to enable the trouble-free operation of all devices within specified conditions. Some examples of special environments are shopping centres, supermarkets, filling stations, office buildings, and warehouses.

3.3.6.4 Warning Labels

When a frequency converter does not conform to Category C1, provide a warning notice. This is the responsibility of the user. Interference elimination are based on classes A1, A2, and B in EN 55011. The user is ultimately responsible for the appropriate classification of devices and the cost of remedying EMC problems.

3.3.7 Use with Isolated Input Source

Most utility power in the United States is referenced to earth ground. Although not in common use in the United States, the input power may be an isolated source. All Danfoss frequency converters may be used with isolated input source as well as with ground reference power lines.

3.3.8 Power Factor Correction

Power factor correction equipment serves to reduce the phase shift (φ) between the voltage and the current to move the power factor closer to unity (cos φ). This is necessary when a large number of inductive loads, such as motors or lamp ballasts, are used in an electrical distribution system. Frequency converters with an isolated DC link do not draw any reactive power from the mains system or generate any phase power-factor correction shifts. They have a cos φ of approximately 1.

For this reason, speed-controlled motors do not have to take into account when dimensioning power factor correction equipment. However, the current drawn by the phase-correction equipment rises because frequency converters generate harmonics. The load and heat factor on the capacitors increases as the number of harmonic generators increases. As a result, fit chokes in the power-factor correction equipment. The chokes also prevent resonance between load inductances and the capacitance. Converters with cos φ <1 also require chokes in the power factor correction equipment. Also consider the higher reactive power level, for cable dimensions.

3.3.9 Input Power Delay

To ensure that the input surge suppression circuitry performs correctly, observe a time delay between successive applications of input power.

Table 3.16 shows the minimum time that must be allowed between applications of input power.

Input voltage [V]	380	415	460	600
Waiting time [s]	48	65	83	133

Table 3.16 Input Power Delay

3.3.10 Mains Transients

Transients are brief voltage peaks in the range of a few thousand volts. They can occur in all types of power distribution systems, including industrial and residential environments.

Lightning strikes are a common cause of transients. However, they are also caused by switching large loads on line or off, or switching other mains transients equipment, such as power factor correction equipment. Transients can also be caused by short-circuits, tripping of circuit breakers in power distribution systems, and inductive coupling between parallel cables.

EN 61000-4-1 standard describes the forms of these transients and how much energy they contain. Their harmful effects can be limited by various methods. Gas-filled surge arresters and spark gaps provide first-level protection against high-energy transients. For second-level protection, most electronic devices, including frequency converters, use voltage-dependent resistors (varistors) to attenuate transients.

3.3.11 Operation with a Standby Generator

Use back-up power systems, when the continued operation is necessary in the event of mains failure. They are also used in parallel with the public power grid to achieve higher mains power. This is common practice for combined heat and power units, taking advantage of the high efficiency achieved with this form of energy conversion. When back-up power is provided by a generator, the mains impedance is usually higher than when power is taken from the public grid. This causes the total harmonic distortion to increase. With proper design, generators can operate in a system containing devices that induce harmonics.

System design consideration with a stand-by generator is recommended.

3

- When the system is switched from mains operation to generator, the harmonic load usually increases.
- Designers must calculate or measure the increase in the harmonic load to ensure that the power quality conforms to regulations to prevent harmonic problems and equipment failure.
- Avoid asymmetric loading of the generator must be avoided since it causes increased losses and may increase total harmonic distortion.
- A 5/6 stagger of the generator winding attenuates the 5th and 7th harmonics, but it allows the 3rd harmonic to increase. A 2/3 stagger reduces the 3rd harmonic.
- When possible, the operator should disconnect power factor correction equipment because it causes resonance in the system.
- Chokes or active absorption filters can attenuate harmonics as well as resistive loads operated in parallel.
- Capacitive loads operated in parallel create an additional load due to unpredictable resonance effects.

A more precise analysis is possible using mains analysis software, such as HCS. For analysing mains systems, go to Site

When operating with harmonic-inducing devices, the maximum loads based on trouble-free facility operation are shown in the harmonic limits table.

Harmonic limits

- B2 and B6 rectifiers⇒maximum 20% of rated generator load.
- B6 rectifier with choke⇒maximum 20–35% of rated generator load, depending on the composition.
- Controlled B6 rectifier⇒maximum 10% of rated generator load.

3.4 Motor Integration

3.4.1 Motor Selection Considerations

The frequency converter can induce electrical stress on a motor. Consider, therefore, the following effects on the motor when matching motor with frequency converter:

- Insulation stress
- Bearing stress
- Thermal stress

3.4.2 Sine-wave and dU/dt Filters

Output filters provide benefits to some motors to reduce electrical stress and allow for longer cable length. Output options include sine-wave filters (also called LC filters) and dU/dt filters. The dU/dt filters reduce the sharp rise rate of the pulse. Sine-wave filters smooth the voltage pulses to convert them into a nearly sinusoidal output voltage. With some frequency converters, sine-wave filters comply with EN 61800-3 RFI category C2 for unshielded motor cables, see *chapter 3.7.5 Sine-wave Filters*.

For more information on sine-wave and dU/dt filter options, refer to *chapter 3.7.5 Sine-wave Filters* and *chapter 3.7.6 dU/dt Filters*.

For more information on sine-wave and dU/dt filter ordering numbers, refer to and *chapter 6.2.9 dU/dt Filters*.

3.4.3 Proper Motor Grounding

Proper grounding of the motor is imperative for personal safety and to meet EMC electrical requirements for low voltage equipment. Proper grounding is necessary for the effective use of shielding and filters. Design details must be verified for proper EMC implementation.

3.4.4 Motor Cables

Motor cable recommendations and specifications are provided in *chapter 7.5 Cable Specifications*.

All types of 3-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.

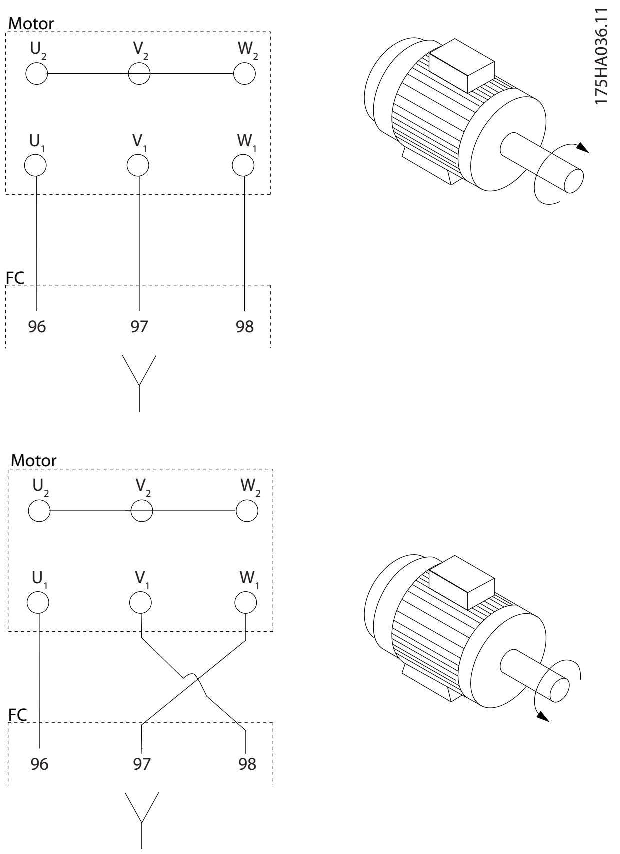

Illustration 3.10 Terminal Connection for Clockwise and Counter-clockwise Rotation

Change the direction of rotation by switching 2 phases in the motor cable or by changing the setting of *4-10 Motor Speed Direction*.

3.4.5 Motor Cable Shielding

Frequency converters generate steep-edged pulses on their outputs. These pulses contain high-frequency components (extending into the gigahertz range), which cause undesirable radiation from the motor cable. Shielded motor cables reduce this radiation.

The purposes of shielding are to:

- Reduce the magnitude of radiated interference.
- Improve the interference immunity of individual devices.

The shield captures the high-frequency components and conducts them back to the interference source, in this case the frequency converter. Shielded motor cables also provide immunity to interference from nearby external sources.

Even good shielding does not fully eliminate the radiation. System components located in radiation environments must operate without degradation.

3.4.6 Connection of Multiple Motors

NOTICE

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 frequency converter can control several parallel-connected motors. When using parallel motor connection, observe the following:

- VCC+ 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.
- Do not use common joint connection for long cable lengths, see *Illustration 3.12*.
- The total motor cable length specified in *Table 3.4*, is valid as long as the parallel cables are kept short (less than 10 m each), see *Illustration 3.14* and *Illustration 3.15*.
- Consider voltage drop across the motor cable, see *Illustration 3.15*.
- For long parallel cables, use an LC filter, see *Illustration 3.15*.
- For long cables without parallel connection, see *Illustration 3.16*.

NOTICE

When motors are connected in parallel, set *1-01 Motor Control Principle* to *[0] U/f*.

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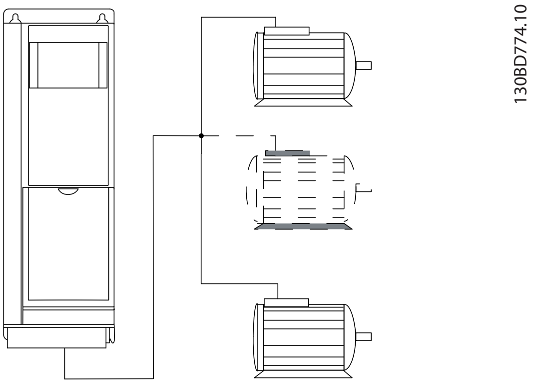

Illustration 3.11 Common Joint Connection for Short Cable Lengths

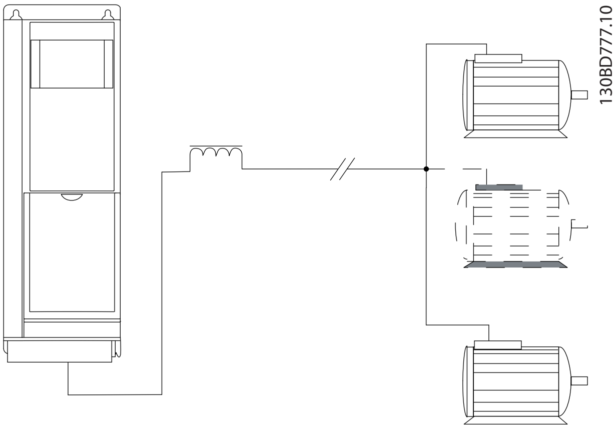

Illustration 3.14 Parallel Cables with Load

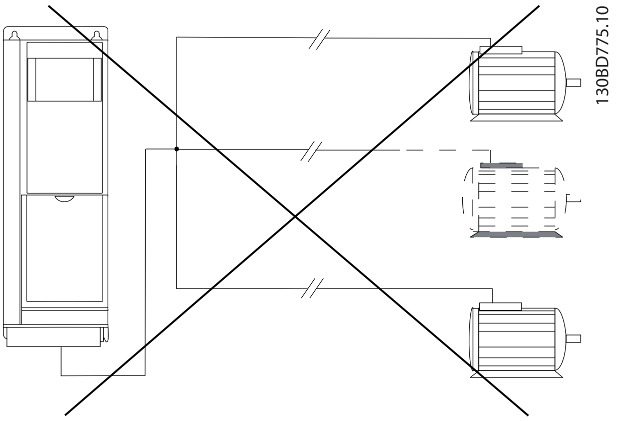

Illustration 3.12 Common Joint Connection for Long Cable Lengths

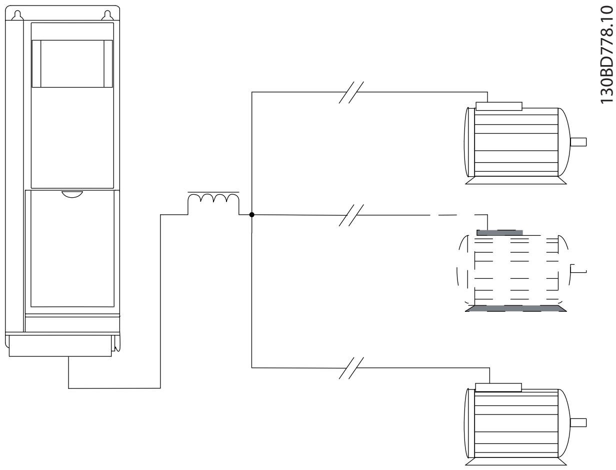

Illustration 3.15 LC Filter for Long Parallel Cables

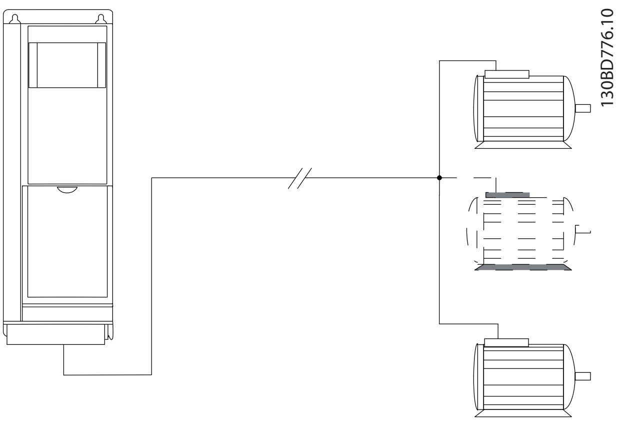

Illustration 3.13 Parallel Cables without Load

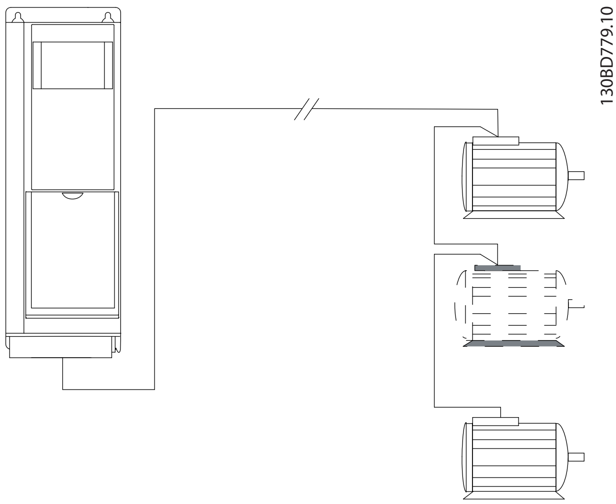

Illustration 3.16 Long Cables in Series Connection

Enclosure sizes	Power Size [kW]	Voltage [V]	1 cable [m]	2 cables [m]	3 cables [m]	4 cables [m]
A1, A2, A4, A5	0.37–0.75	400	150	45	8	6
		500	150	7	4	3
A2, A4, A5	1.1–1.5	400	150	45	20	8
		500	150	45	5	4
A2, A4, A5	2.2–4	400	150	45	20	11
		500	150	45	20	6
A3, A4, A5	5.5–7.5	400	150	45	20	11
		500	150	45	20	11
B1, B2, B3, B4, C1, C2, C3, C4	11–90	400	150	75	50	37
		500	150	75	50	37
A3	1.1–7.5	525–690	100	50	33	25
B4	11–30	525–690	150	75	50	37
C3	37–45	525–690	150	75	50	37

Table 3.17 Maximum Cable Length for Each Parallel Cable

3.4.7 Control Wire Isolation

Harmonic interference generated by motor cabling can degrade control signals in the converter control wiring and result in control faults. Motor cables and control wiring should be separate. Interference effects decrease significantly with separation.

- The distance between control wiring and motor cables should be more than 200 mm.
- Divider strips are essential with smaller separations or interference may be coupled in or transferred.
- Control cable shields must be connected at both ends in the same way as motor cable shields.
- Shielded cables with twisted conductors provide highest attenuation. The attenuation of the magnetic field increases from around 30 dB with a single shield to 60 dB with a double shield and to approximately 75 dB if the conductors are also twisted.

3.4.8 Motor Thermal Protection

The frequency converter provides motor thermal protection in several ways:

- Torque limit protects the motor from overload independent of the speed.
- Minimum speed limits the minimum operating speed range, for instance between 30 and 50/60 Hz.
- Maximum speed limits the maximum output speed.
- Input is available for an external thermistor.
- Electronic thermal relay (ETR) for asynchronous motors simulates a bi-metal relay based on internal measurements. The ETR measures actual current, speed and time to calculate motor temperature and protect the motor from being overheated by issuing a warning or cutting power to the motor. The characteristics of the ETR are shown in *Illustration 3.17*.

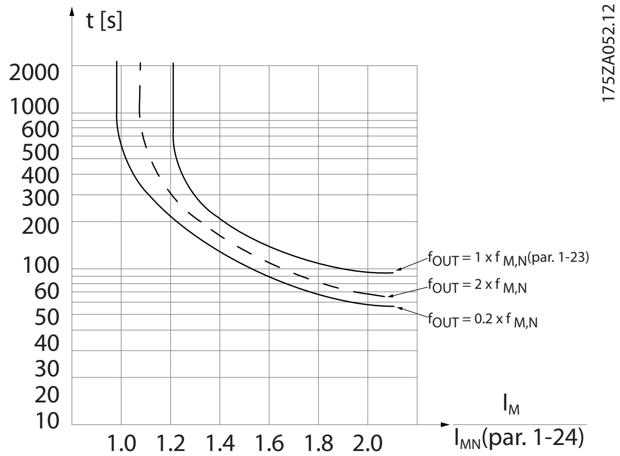

Illustration 3.17 Electronic Thermal Relay Characteristics

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 off and trip. The curves show the characteristic nominal speed, at twice the nominal speed and at 0.2 x the nominal speed.
At lower speed, the ETR cuts off at lower heat due to less cooling of the motor. In that way, the motor is protected from overheating even at low speed. The ETR feature calculates the motor temperature based on actual current and speed.

3

3.4.9 Output Contactor

Although not generally a recommended practice, operating an output contactor between the motor and the frequency converter does not cause damage to the frequency converter. Closing a previously opened output contactor may connect a running frequency converter to a stopped motor. This may cause the frequency converter to trip and display a fault.

3.4.10 Brake Functions

To brake the load on the motor shaft, use either a static (mechanical) or dynamic brake.

3.4.11 Dynamic Braking

Dynamic brake is established by the following:

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

3.4.12 Brake Resistor Calculation

A brake resistor is required to manage heat dissipation and DC-link voltage increase during electrically-generated braking. Using a brake resistor ensures that the energy is absorbed in the brake resistor and not in the frequency converter. For more information see the *Brake Resistor Design Guide*.

Duty cycle calculation
When the amount of kinetic energy transferred to the resistor in each braking period is unknown, calculate the average power on the basis of the cycle time and braking time (known as the intermittent duty cycle). The resistor intermittent duty cycle is an indication of the cycle when the resistor is active (see *Illustration 3.18*). Motor suppliers often use S5 when stating the permissible load, which is an expression of intermittent duty cycle.

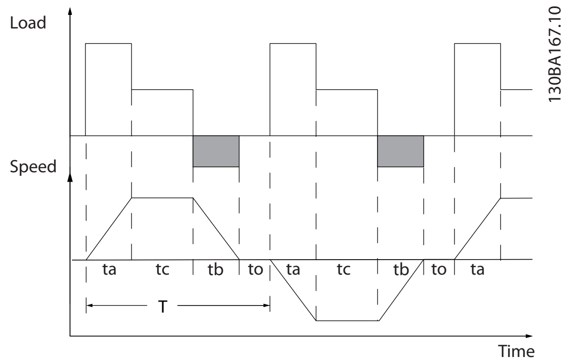

Illustration 3.18 Brake Resistor Duty Cycle

Calculate the intermittent duty cycle for the resistor as follows:

Duty cycle=t_b/T

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

Danfoss offers brake resistors with duty cycles of 5%, 10%, and 40%. When a 10% duty cycle is applied, the brake resistors absorb brake power for 10% of the cycle time. The remaining 90% of the cycle time is used to dissipate excess heat.

Ensure the brake resistor is dimensioned for the required braking time.

Brake resistance calculation
To prevent the frequency converter from cutting out for protection when the motor brakes, select resistor values on the basis of the peak braking power and the intermediate circuit voltage. Calculate resistance of the brake resistor as follows:

$$Rbr = \frac{Udc^2}{Ppeak} \ [\Omega]$$

The brake resistor performance depends on the DC-link voltage (U_{dc}).

U_{dc} is the voltage at which the brake is activated. The FC-series brake function is settled depending on the mains supply.

Mains supply input [V AC]	Brake active [V DC]	High voltage warning [V DC]	Over voltage alarm [V DC]
FC 202 3x200-240	390	405	410
FC 202 3x380-480	778	810	820
FC 202 3x525-600[1)]	943	965	975
FC 202 3x525-600[2)]	1099	1109	1130
FC 202 3x525-690	1099	1109	1130

Table 3.18 DC-link Voltage (U_{dc})

1) Enclosure sizes A, B, C

2) Enclosure sizes D, E, F

Use the brake resistance R_{rec}, to ensure that the frequency converter is able to brake at the highest braking torque ($M_{br(\%)}$) of 160%. The formula can be written as:

$$Rrec\,[\Omega] = \frac{U_{dc}^{2} \times 100}{Pmotor \times Mbr\,(\%) \times \eta VLT \times \eta motor}$$

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

When a higher brake resistor resistance is selected, 160%/150%/110% braking torque cannot be obtained, and there is a risk that the frequency converter cuts out of DC-Link overvoltage for protection.

For braking at lower torque, for example 80% torque, it is possible to install a brake resistor with lower power rating. Calculate size using the formula for calculating R_{rec}.

Frequency converter D and F enclosure sizes contain more than one brake chopper. Use a brake resistor for each chopper for those enclosure sizes.

The *VLT® Brake Resistor MCE 101 Design Guide* contains the most up-to-date selection data, and describes the calculation steps in more detail, including:

- Calculation of braking power
- Calculation of brake resistor peak power
- Calculation of brake resistor average power
- Braking of inertia

3.4.13 Brake Resistor Cabling

EMC (twisted cables/shielding)
To meet the specified EMC performance of the frequency converter, use screened cables/wires. If unscreened wires are used, it is recommended to twist the wires to reduce the electrical noise from the wires between the brake resistor and the frequency converter.

For enhanced EMC performance, use a metal screen.

3.4.14 Brake Resistor and Brake IGBT

Brake resistor power monitor
In addition, the brake power monitor function makes it possible to read out the momentary power and the mean power for a selected time period. The brake can also monitor the power energising and make sure 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)*.

NOTICE

Monitoring the brake power does not fulfil a safety function. The brake resistor circuit is not ground leakage protected.

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. Use a relay or digital output to protect the brake resistor against overloading in the event of a fault in the frequency converter.

Overvoltage control (OVC) can be selected as an alternative brake function in *2-17 Over-voltage Control*. If the DC-link voltage increases, this function is active for all units. The function ensures that a trip can be avoided. 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.

3.4.15 Energy Efficiency

Efficiency of the frequency converter
The load on the frequency converter has little effect on its efficiency.

This also means that the frequency converter efficiency does not change when other U/f characteristics are selected. However, the U/f characteristics do influence the efficiency of the motor.

The efficiency declines a little when the switching frequency is set to a value above 5 kHz. The efficiency is also slightly reduced when the motor cable is longer than 30 m.

Efficiency calculation
Calculate the efficiency of the frequency converter at different loads based on *Illustration 3.19*. Multiply the factor in this graph with the specific efficiency factor listed in *chapter 7.1 Electrical Data*.

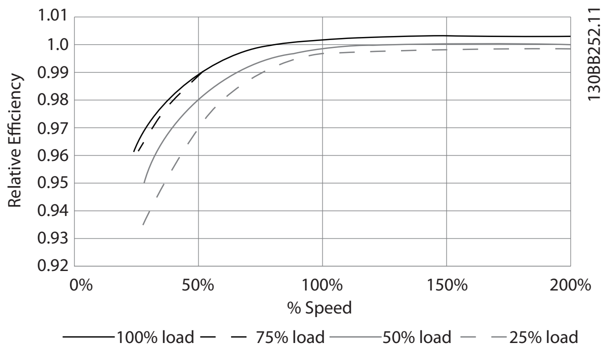

Illustration 3.19 Typical Efficiency Curves

Example: Assume a 55 kW, 380-480 V AC frequency converter with 25% load at 50% speed. The graph is showing 0.97 rated efficiency for a 55 kW frequency converter is 0.98. The actual efficiency is then: 0.97 x 0.98=0.95.

Motor efficiency
The efficiency of a motor connected to the frequency converter depends on magnetising level. 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 it is controlled by the frequency converter and when it runs directly on mains.
- The influence from the U/f characteristic on small motors is marginal. However, in motors from 11 kW and up, the efficiency advantage is significant.
- The switching frequency does not affect the efficiency of small motors. Motors from 11 kW and up have their efficiency improved 1-2%. This is because the sine-shape of the motor current is almost perfect at high switching frequency.

System efficiency
To calculate the system efficiency, multiply the efficiency of the frequency converter by the efficiency of the motor.

3

3.5 Additional Inputs and Outputs

3.5.1 Wiring Schematic

When wired and properly programmed, the control terminals provide:

- Feedback, reference, and other input signals to the frequency converter.
- Output status and fault conditions from the frequency converter.
- Relays to operate auxiliary equipment.
- A serial communication interface.
- 24 V common.

Control terminals are programmable for various functions by selecting parameter options through the local control panel (LCP) on the front of the unit or external sources. Most control wiring is customer-supplied, unless specified in the factory order.

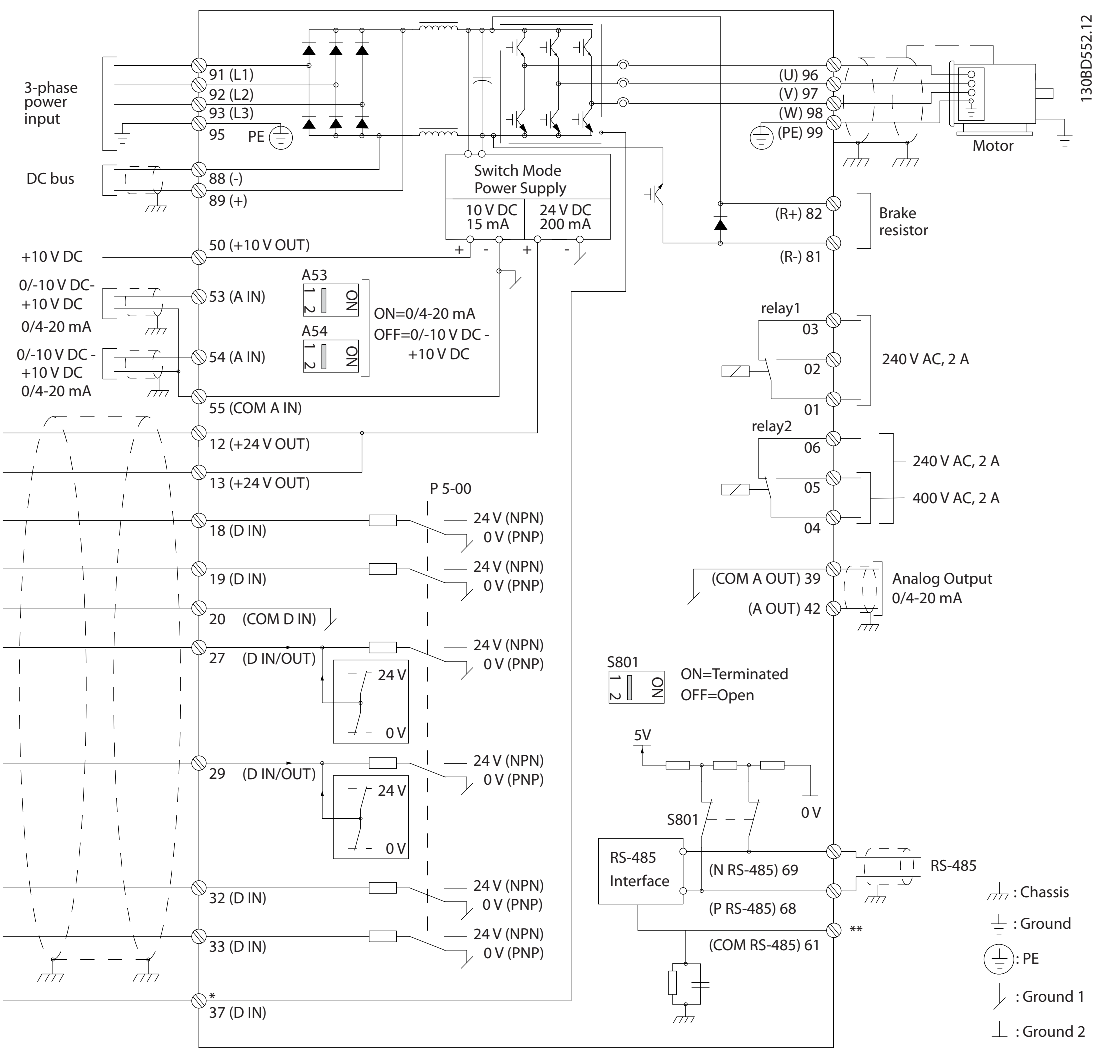

Illustration 3.20 Basic Wiring Schematic

A=Analog, D=Digital

*Terminal 37 (optional) is used for STO. For STO installation instructions, refer to the *VLT® Safe Torque Off Operating Instructions*.

**Do not connect cable screen.

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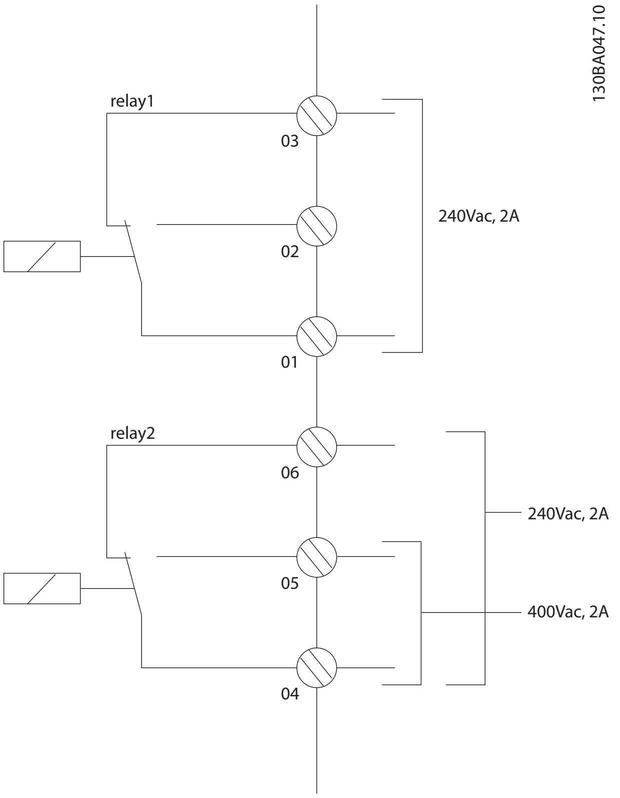
3.5.2 Relay Connections



Relay	Terminal[1)]	Description
1	1	common
	2	normally open maximum 240 V
	3	normally closed maximum 240 V
2	4	common
	5	normally closed maximum 240 V
	6	normally closed maximum 240 V
1	01-02	make (normally open)
	01-03	break (normally closed)
2	04-05	make (normally open)
	04-06	break (normally closed)

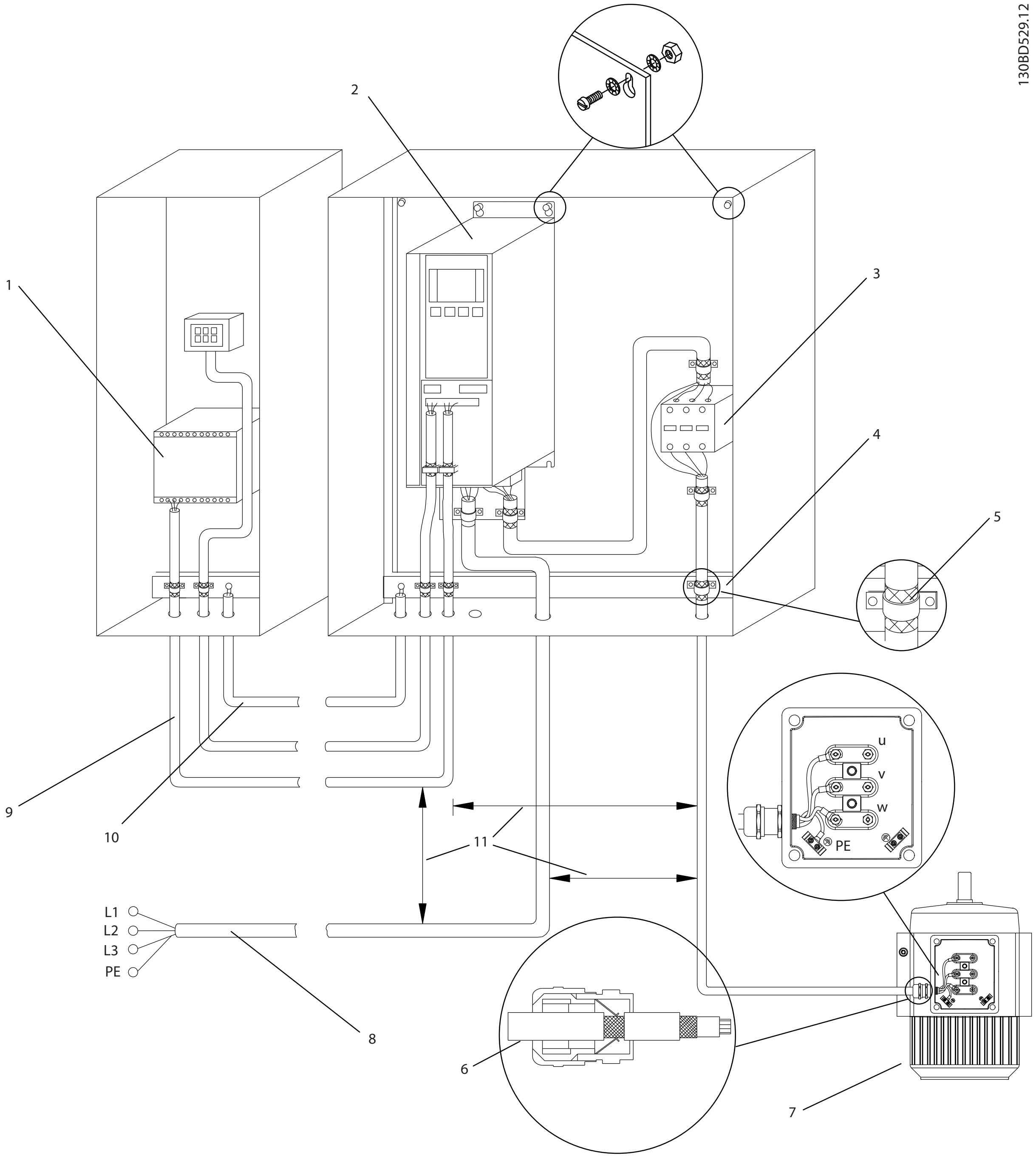
Illustration 3.21 Relay Outputs 1 and 2, Maximum Voltages

1) To add more relay outputs, install VLT® Relay Option Module MCB 105 or VLT® Relay Option Module MCB 113.

For more information about relays, refer to *chapter 7 Specifications* and *chapter 8.3 Relay Terminal Drawings*.

For more information about relay options, refer to *chapter 3.7 Options and Accessories.*

3.5.3 EMC-compliant Electrical Connection



1	PLC	7	Motor, 3-phase and PE (screened)
2	Frequency converter	8	Mains, 3-phase and reinforced PE (not screened)
3	Output contactor	9	Control wiring (screened)
4	Cable clamp	10	Potential equalisation min. 16 mm² (0.025 in)
5	Cable insulation (stripped)	11	Clearance between control cable, motor cable and mains cable: Minimum 200 mm
6	Cable gland		

Illustration 3.22 EMC-compliant Electrical Connection

For more information about EMC, see *chapter 2.5.18 EMC Compliance* and *chapter 3.2 EMC, Harmonics and Earth Leakage Protection*.

NOTICE

EMC INTERFERENCE

Use screened cables for motor and control wiring, and separate cables for input power, motor wiring and control wiring. Failure to isolate power, motor, and control cables can result in unintended behaviour or reduced performance. Minimum 200 mm (7.9 in.) clearance between power, motor, and control cables is required.

3.6 Mechanical Planning

3.6.1 Clearance

Side-by-side installation is suitable for all enclosure sizes, except when an IP21/IP4X/TYPE 1 enclosure kit is used (see *chapter 3.7 Options and Accessories*).

Horizontal clearance, IP20

IP20 A and B enclosure sizes can be arranged side-by-side with no clearance. However the correct mounting order is important. *Illustration 3.23* shows how to mount correctly.

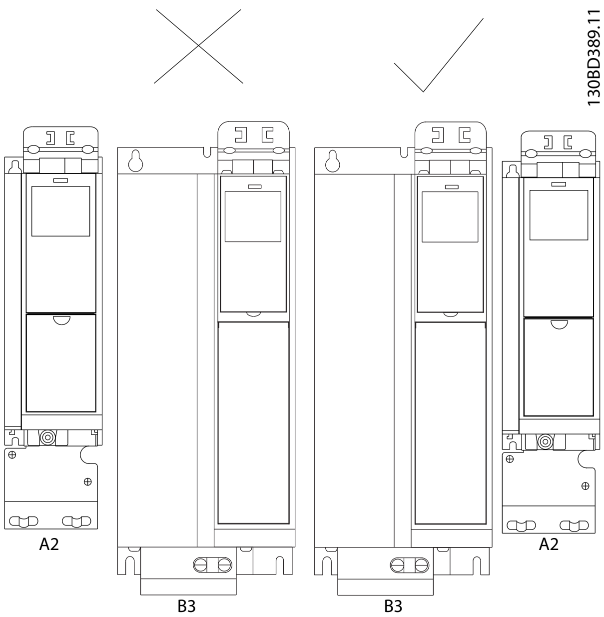


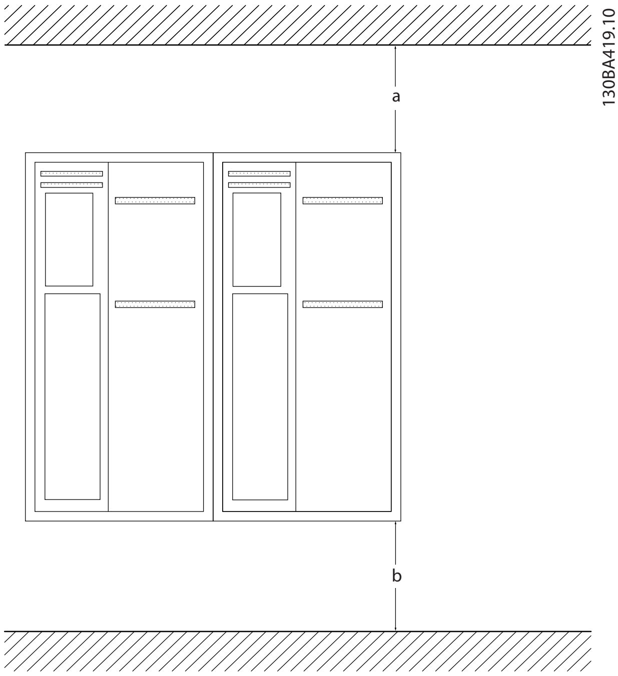
Illustration 3.23 Correct Side-by-side Mounting with no Clearance

Horizontal clearance, IP21 enclosure kit

When the IP21 enclosure kit is used on enclosure sizes A1, A2 or A3, ensure a clearance between the frequency converters of minimum 50 mm.

Vertical clearance

For optimal cooling conditions, ensure vertical clearance for free air passage above and below the frequency converter. See *Illustration 3.24*.



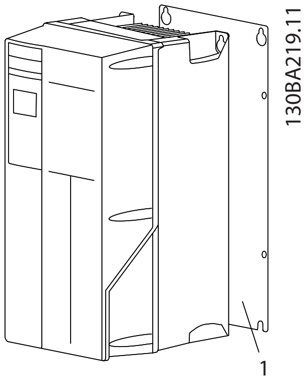
Enclosure size	A1*/A2/A3/A4/A5/B1	B2/B3/B4/C1/C3	C2/C4
a [mm]	100	200	225
b [mm]	100	200	225

Illustration 3.24 Vertical Clearance

3.6.2 Wall Mounting

When mounting on a flat wall, no back plate is required.

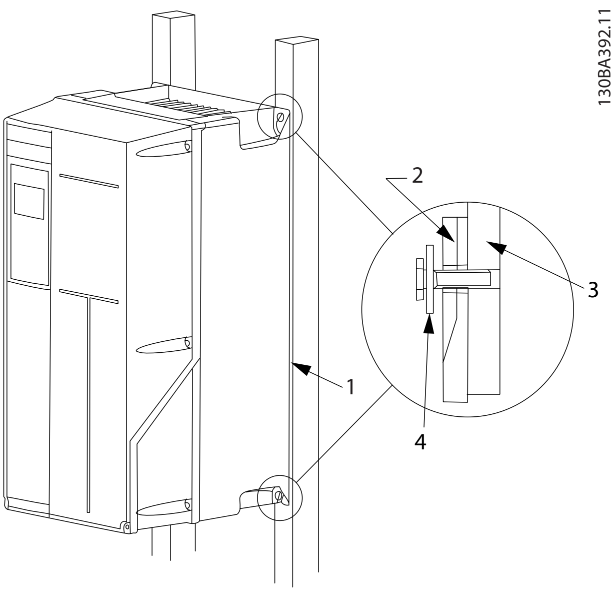
When mounting on an uneven wall, use a back plate to ensure sufficient cooling air over the heat sink. Use the back plate with enclosures A4, A5, B1, B2, C1 and C2 only.



1	Back plate

Illustration 3.25 Mounting with Back Plate

For frequency converters with protection rating IP66, use a fibre or nylon washer to protect the epoxy coating.



1	Back plate
2	Frequency converter with IP66 enclosure
3	Back plate
4	Fibre washer

Illustration 3.26 Mounting with Back Plate for Protection Rating IP66

3.6.3 Access

To plan accessibility for cabling before mounting, refer to the drawings in *chapter 8.1 Mains Connection Drawings (3-phases)* and *chapter 8.2 Motor Connection Drawings*.

3.7 Options and Accessories

Options

For ordering numbers, see *chapter 6 Typecode and Selection*

Mains shielding

- Lexan® shielding mounted in front of incoming power terminals and input plate to protect from accidental contact when the enclosure door is open.
- Space heaters and thermostat: Mounted on the cabinet interior of F frames, space heaters controlled via automatic thermostat prevents condensation inside the enclosure. The thermostat default settings turn on the heaters at 10 °C (50 °F) and turn them off at 15.6 °C (60 °F).

RFI filters

- Frequency converter feature integrated Class A2 RFI filters as standard. If additional levels of RFI/EMC protection are required, they can be obtained using optional Class A1 RFI filters, which provide suppression of radio frequency interference and electromagnetic radiation in accordance with EN 55011.

Residual current device (RCD)

Uses the core balance method to monitor ground fault currents in grounded and high-resistance grounded systems (TN and TT systems in IEC terminology). There is a pre-warning (50% of main alarm set-point) and a main alarm set-point. Associated with each setpoint is an SPDT alarm relay for external use, which requires an external *window-type* current transformer (supplied and installed by the customer).

- Integrated into the frequency converter's safe torque off circuit
- IEC 60755 Type B device monitors, pulsed DC, and pure DC ground fault currents
- LED bar graph indicator of the ground fault current level from 10-100% of the setpoint
- Fault memory
- TEST/RESET key

3

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 setpoint for the insulation level. Associated with each setpoint 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 frequency converter's safe-stop circuit
- LCD display of insulation resistance
- Fault memory
- INFO, TEST, and RESET keys

Brake chopper (IGBTs)

- Brake terminals with an IGBT brake chopper circuit allow for the connection of external brake resistors. For more information on brake resistors, refer to *chapter 3.4.12 Brake Resistor Calculation* and .

Regeneration terminals

- These terminals allow connection of regeneration units to the DC bus on the capacitor bank side of the DC-link reactors for regenerative braking. The F-frame regeneration terminals are sized for approximately ½ the power rating of the frequency converter. Consult the factory for regeneration power limits based on the specific frequency converter size and voltage

Load sharing terminals

- These terminals connect to the DC bus on the rectifier side of the DC link reactor and allow for the sharing of DC bus power among multiple drives. The F-frame load sharing terminals are sized for approximately 1/3 the power rating of the frequency converter. Consult the factory for load sharing limits based on the specific frequency converter size and voltage.

Fuses

- Fuses are recommended for fast-acting current overload protection of the frequency converter. Fuse protection limits frequency converter damage and minimises service time in the event of a failure. Fuses are required to meet marine certification.

Disconnect

- A door-mounted handle allows for the manual operation of a power disconnect switch to enable and disable power to the frequency converter, increasing safety during servicing. The disconnect is interlocked with the enclosure doors to prevent them from being opened while power is still applied.

Circuit breakers

- A circuit breaker can be remotely tripped but must be manually reset. Circuit breakers are interlocked with the enclosure doors to prevent them from being opened while power is still applied. When a circuit breaker is ordered as an option, fuses are also included for fast-acting current overload protection of the frequency converter.

Contactors

- An electrically controlled contactor switch allows for the remote enabling and disabling of power to the frequency converter. If the IEC emergency stop option is ordered, the Pilz Safety monitors an auxiliary contact on the contactor.

Manual motor starters

Provide 3-phase power for electric cooling 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 and from the input side of the Class 1 RFI filter (optional). 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-amp, fuse-protected circuit is ordered). Integrated into the frequency converter's safe torque off circuit.

Unit features include:

- Operation switch (on/off).
- Short-circuit and overload protection with test function.
- Manual reset function.

30 Amp, fuse-protected terminals

- 3-phase power matching incoming mains voltage for powering auxiliary customer equipment.
- Not available if 2 manual motor starters are selected.
- Terminals are off when the incoming power to the frequency converter is off.
- Power for the fused-protected terminals is provided from the load side of any supplied contactor, circuit breaker, or disconnect switch and from the input side of the Class 1 RFI filter (optional).

24 V DC power supply

- 5 Amp, 120 W, 24 V DC.
- Protected against output overcurrent, overload, short-circuits, and overtemperature.
- 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 8 universal input modules plus 2 dedicated thermistor input modules. All 10 modules are integrated into the frequency converter's safe torque off circuit and can be monitored via a fieldbus network (requires the purchase of a separate module/bus coupler). Order a safe torque off brake option to select external temperature monitoring.

Serial communications

PROFIBUS DP V1 MCA 101

- PROFIBUS DP V1 gives wide compatibility, a high level of availability, support for all major PLC vendors, and compatibility with future versions.
- Fast, efficient communication, transparent installation, advanced diagnosis and parameterisation and auto-configuration of process data via GSD-file.
- A-cyclic parameterisation using PROFIBUS DP V1, PROFIdrive or Danfoss FC profile state machines, PROFIBUS DP V1, Master Class 1 and 2 Ordering number 130B1100 uncoated – 130B1200 coated (Class G3/ISA S71.04-1985).

DeviceNet MCA 104

- This modern communications model offers key capabilities that allow operators effectively determine what information is needed and when.
- It benefits from ODVA's strong conformance testing policies, which ensure that products are interoperable. Ordering number 130B1102 uncoated 130B1202 coated (Class G3/ISA S71.04-1985).

PROFINET RT MCA 120

The PROFINET option offers connectivity to PROFINET-based networks via the PROFINET protocol. The option is able to handle a single connection with an actual packet interval down to 1 ms in both directions.

- Built-in web server for remote diagnosis and reading out of basic frequency converter parameters.
- An e-mail notification can be configured for sending an e-mail message to one or several receivers, if certain warnings or alarms occur, or have cleared again.
- TCP/IP for easy access to frequency converter configuration data from MCT 10 Set-up Software.
- FTP (File Transfer Protocol) file uploaed and download.
- Support of DCP (discovery and configuration protocol).

EtherNet IP MCA 121

EtherNet becomes the future standard for communication on the factory floor. The EtherNet option is based on the newest technology available for the Industrial use and handles even the most demanding requirements. EtherNet/IP extends commercial off the-shelf EtherNet to the common industrial protocol (CIP™) the same upper-layer protocol and object model found in DeviceNet. The MCA 121 offers advanced features as:

- Built-in high performance switch enabling line-topology, and eliminating the need for external switches.
- Advanced switch and diagnosis functions.
- A built-in web server.
- An e-mail client for service notification.

Modbus TCP MCA 122

The Modbus option offers connectivity to Modbus TCP-based networks, such as Groupe Schneider PLC system via the Modbus TCP Protocol. The option is able to handle a single connection with an actual packet interval down to 5 ms in both directions.

- Built-in web-server for remote diagnosis and reading out basic frequency converter parameters.
- An e-mail notification can be configured for sending an e-mail message to one or several receivers, if certain warnings or alarms occur, or have cleared again.
- 2 ethernet ports with built-in switch.
- FTP (file transfer protocol) file uploded and download.
- Protocol automatic IP address configuration.

More Options

General purpose I/O MCB 101

The I/O option offers an extended number of control inputs and outputs.

- 3 digital inputs 0–24 V: Logic 0<5 V; Logic 1>10 V
- 2 analog inputs 0–10 V: Resolution 10 bit plus sign
- 2 digital outputs NPN/PNP push pull
- 1 analog output 0/4–20 mA
- Spring-loaded connection
- Separate parameter settings Ordering number 130B1125 uncoated – 130B1212 coated (Class G3/ISA S71.04-1985)

Relay option MCB 105

Enables to extend relay functions with 3 additional relay outputs.

- Maximum terminal load: AC-1 resistive load: 240 V AC 2 A AC-15
- Inductive load @cos ϕ 0.4: 240 V AC 0.2 A DC-1
- Resistive load: 24 V DC 1 A DC-13
- Inductive load: @cos ϕ 0.4: 24 V DC 0.1 A
- Minimum terminal load: DC 5 V: 10 mA
- Maximum switch rate at rated load/min. load: 6 min-1/20 s-1
- Ordering number 130B1110 uncoated–130B1210 coated (Class G3/ISA S71.04-1985)

Analog I/O option MCB 109
This analog input/output option is easily fitted in the frequency converter for upgrading to advanced performance and control using the additional inputs/outputs. This option also upgrades the frequency converter with a battery backup supply for the clock built into the frequency converter. This provides stable use of all frequency converter clock functions as timed actions.

- 3 analog inputs, each configurable as both voltage and temperature input.
- Connection of 0–10 V analog signals as well as PT1000 and NI1000 temperature inputs.
- 3 analog outputs each configurable as 0–10 V outputs.
- Included back-up supply for the standard clock function in the frequency converter The back-up battery typically lasts for 10 years, depending on environment. Ordering number 130B1143 uncoated – 130B1243 coated (Class G3/ISA S71.04-1985).

PTC thermistor card MCB 112
With the MCB 112 PTC thermistor card, all Danfoss frequency converters with STO can be used to supervise motors in potentially explosive atmospheres. MCB 112 offers superior performance compared to the bult-in ETR function and thermistor terminal.

- Protects the motor from overheating.
- ATEX-approved for use with EX d and EX e motors.
- Uses the safe torque off function of Danfoss frequency converters to stop the motor in case of over temperature.
- Certified for use to protect motors in zones 1, 2, 21, and 22.
- Certified up to SIL2.

Sensor input card MCB 114
The option protects the motor from being overheated by monitoring the bearings and windings temperature in the motor. The limits, as well as the action, are adjustable and the individual sensor temperature is visible as a read out in the display or by field bus.

- Protects the motor from overheating.
- 3 self-detecting sensor inputs for 2 or 3 wire PT100/PT1000 sensors.
- One additional analog input 4–20 mA.

Extended cascade controller MCO 101
Easily fitted and upgrades the built-in cascade controller to operate more pumps and more advanced pump control in master/slave mode.

- Up to 6 pumps in standard cascade set-up
- Up to 6 pumps in master/slave set-up
- Technical specification: See MCB 105 relay option

Extended relay card MCB 113
The extended relay card MCB 113 adds inputs/outputs to VLT® AQUA Drive for increased flexibility.

- 7 digital inputs: 0–24 V
- 2 analog outputs: 0/4–20 mA
- 4 SPDT relays
- Rating of load relays: 240 V AC/2 A (Ohm)
- Meets NAMUR recommendations
- Galvanic isolation capability Ordering number 130B1164 uncoated – 130B1264 coated (Class G3/ISA S71.04-1985)

MCO 102 advanced cascade controller
Extends the capabilities of the standard cascade controller built into frequency converters.

- Provides 8 additional relays for staging of additional motors.
- Provides accurate flow, pressure, and level control for optimising the efficiency of systems that use multiple pumps or blowers.
- Master/slave mode runs all blowers/pumps at the same speed, potentially reducing the energy consumption to less than half that of valve throttling or traditional, across-the-line on/off cycling.
- Lead-pump alternation assures that multiple pumps or blowers are used equally.

24 V DC supply option MCB 107
The option is used to connect an external DC supply to keep the control section and any installed option active when mains power is down.

- Input voltage range: 24 V DC +/- 15% (max. 37 V in 10 s).
- Maximum input current: 2.2 A.
- Maximum cable length: 75 m.

- Input capitance load: <10 uF.
- Power-up delay: <0.6 s.
- Easy to install in frequency converters in existing machines.
- Keeps the control board and options active during power cuts.
- Keeps fieldbuses active during power cuts Ordering number 130B1108 uncoated – 130B1208 coated (Class G3/ISA S71.04-1985).

3.7.1 Communication Options

- VLT® PROFIBUS DP V1 MCA 101
- VLT® DeviceNet MCA 104
- VLT® PROFINET MCA 120
- VLT® EtherNet/IP MCA 121
- VLT® Modbus TCP MCA 122

For further information, refer to *chapter 7 Specifications*.

3.7.2 Input/Output, Feedback and Safety Options

- VLT® General Purpose I/O Module MCB 101
- VLT® Relay Card MCB 105
- VLT® PTC Thermistor Card MCB 112
- VLT® Extended Relay Card MCB 113
- VLT® Sensor Input Option MCB 114

For further information, refer to *chapter 7 Specifications*.

3.7.3 Cascade Control Options

The cascade controller options extend the number of available relays. Once one of the options is installed, the parameters needed to support the cascade controller functions will be available through the control panel.

MCO 101 and 102 are add-on options extending the supported number of pumps and the functionalities of the built-in cascade controller in the VLT® AQUA Drive.

The following options for cascade control are available for the VLT® AQUA Drive:

- Built-in basic cascade controller (standard cascade controller)
- MCO 101 (extended cascade controller)
- MCO 102 (advanced cascade controller)

For further information, see *chapter 7 Specifications*.

The extended cascade controller can be used in 2 different modes:

- With the extended features controlled by parameter group *27-** Cascade CTL Option*.
- To extend the number of available relays for the basic cascade controlled by parameter group *25-**. Cascade Controller*.

MCO 101 allows using a total of 5 relays for cascade control. MCO 102 allows controlling a total of 8 pumps. The options are able to alternate the lead pump with 2 relays per pump.

NOTICE

If MCO 102 is installed, the relay option MCB 105 can extend the number of relays to 13.

Application
Cascade control is a common control system used to control parallel pumps or fans in an energy-efficient way.

The cascade controller option enables control of multiple pumps configured in parallel by:

- Automatically turning individual pumps on/off.
- Controlling the speed of the pumps.

When using cascade controllers, the individual pumps are automatically turned on (staged) and turned off (de-staged) as needed in order to satisfy the required system output for flow or pressure. The speed of pumps connected to the VLT® AQUA Drive is also controlled to provide a continuous range of system output.

Designated use
The cascade controller options are designed for pump applications, however, it is also possible to use cascade controllers in any application requiring multiple motors configured in parallel.

Operating principle
The cascade controller software runs from a single frequency converter with the cascade controller option. It controls a set of pumps, each controlled by a frequency converter or connected to a contactor or a soft starter.

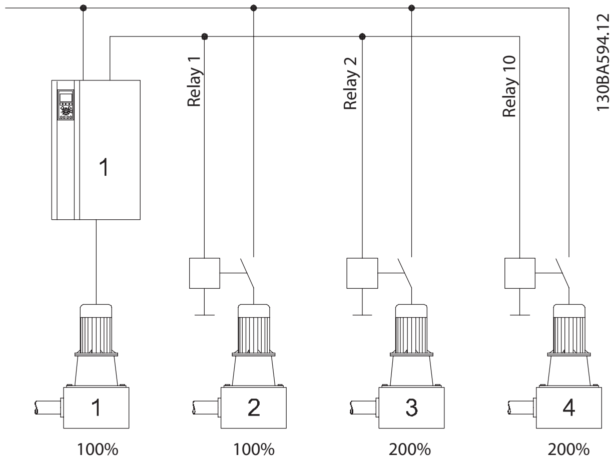
Additional frequency converters in the system (slave frequency converters) do not need any cascade controller option card. They are operated in open-loop mode and receive their speed reference from the master frequency converter. Pumps connected to slave frequency converters are referred to as variable speed pumps.

Pumps connected to mains through a contactor or soft starter are referred to as fixed speed pumps.

Each pump, variable speed or fixed speed, is controlled by a relay in the master frequency converter.

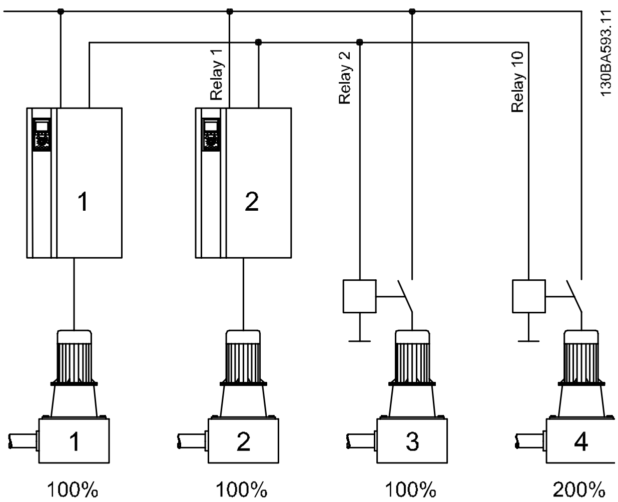
3

The cascade controller options can control a mix of variable speed and fixed speed pumps.



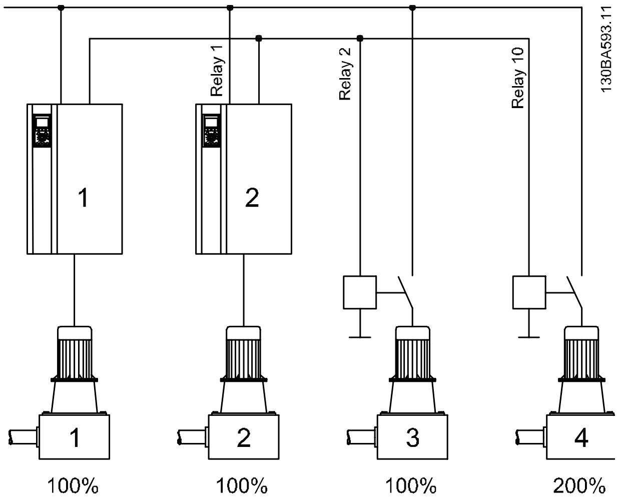
Built-in	1 VSP + 2 FSP parameter group 25-** *Cascade Controller*
MCO 101	1 VSP + 5 FSP parameter group 25-** *Cascade Controller*
MCO 102	1 VSP + 8 FSP parameter group 25-** *Cascade Controller*

Illustration 3.27 Application Overview



Built-in	-
MCO 101	1 to 6 VSP + 1 to 5 FSP (maximum 6 pumps) parameter group 27-** *Cascade CTL Option*
MCO 102	1 to 8 VSP + 1 to 7 FSP (maximum 8 pumps) parameter group 27-** *Cascade CTL Option*

Illustration 3.28 Application Overview



Built-in	-
MCO 101	6 VSP parameter group 27-** *Cascade CTL Option*
MCO 102	8 VSP parameter group 27-** *Cascade CTL Option*

Illustration 3.29 Application Overview

VSP = Variable speed pump (directly connected to the frequency converter)
FSP = Fixed speed pump (the motor could be connected via contactor, soft starter or star/delta starter)

3.7.4 Brake Resistors

In applications where the motor is used as a brake, energy is generated in the motor and sent back into the frequency converter. If the energy cannot be transported back to the motor, it increases the voltage in the frequency converter DC line. In applications with frequent braking and/or high inertia loads, this increase may lead to an overvoltage trip in the frequency converter and, finally, a shut down. Brake resistors are used to dissipate the excess energy resulting from the regenerative braking. The resistor is selected based on its ohmic value, its power dissipation rate and its physical size. Danfoss offers a wide variety of different resistors that are specially designed to Danfoss frequency converters. See *chapter 3.4.12 Brake Resistor Calculation* for dimensioning of brake resistors. For ordering numbers refer to *chapter 6.2 Options, Accessories, and Spare Parts*.

3.7.5 Sine-wave Filters

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

Danfoss supplies 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 also causes some noise. Solve the problem by integrating the filter in a cabinet or similar.

3.7.6 dU/dt Filters

Danfoss supplies dU/dt filters which are differential-mode, low-pass filters that reduce motor terminal phase-to-phase peak voltages and reduce the rise time to a level that lowers the stress on the insulation at the motor windings. This is especially an issue with short motor cables.

Compared to sine-wave filters (see *chapter 3.7.5 Sine-wave Filters*), the dU/dt filters have a cut off frequency above the switching frequency.

3.7.7 Common-mode Filters

High-frequency common-mode cores (HF-CM cores) reduce electromagnetic interference and eliminate bearing damage by electrical discharge. They are special nanocrystalline magnetic cores, which have superior filtering performance compared to regular ferrite cores. The HF-CM core acts like a common-mode inductor between phases and ground.

Installed around the 3 motor phases (U, V, W), the common mode filters reduce high-frequency common-mode currents. As a result, high-frequency electromagnetic interference from the motor cable is reduced.

The number of cores required is depedent on motor cable length and frequency converter voltage. Each kit consists of 2 cores. Refer to *Table 3.19* to determine the number of cores required.

Cable length[1]	Enclosure size				
[m]	A and B		C		D
	T2/T4	T7	T2/T4	T7	T7
50	2	4	2	2	4
100	4	4	2	4	4
150	4	6	4	4	4
300	4	6	4	4	6

Table 3.19 Number of Cores

1) Where longer cables are required, stack additional HF-CM cores.

Install the HF-CM cores by passing the 3 motor phase cables (U, V, W) through each core, as shown in *Illustration 3.30*.

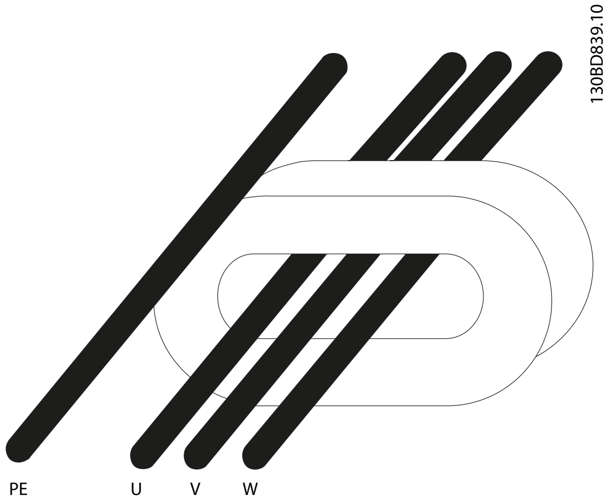


Illustration 3.30 HF-CM Core with Motor Phases

3.7.8 Harmonic Filters

The Danfoss AHF 005 and AHF 010 are advanced harmonic filters, not to be compared with traditional harmonic trap filters. The Danfoss harmonic filters have been specially designed to match the Danfoss frequency converters.

By connecting the Danfoss harmonic filters AHF 005 or AHF 010 in front of a Danfoss frequency converter, the total harmonic current distortion generated back to the mains is reduced to 5% and 10%.

3

3.7.9 IP21/NEMA Type 1 Enclosure Kit

IP20/IP4X top/NEMA TYPE 1 is an optional enclosure element available for IP20 compact units.
If the enclosure kit is used, an IP20 unit is upgraded to comply with enclosure IP21/4X top/TYPE 1.

The IP4X top can be applied to all standard IP20 FC 202 variants.

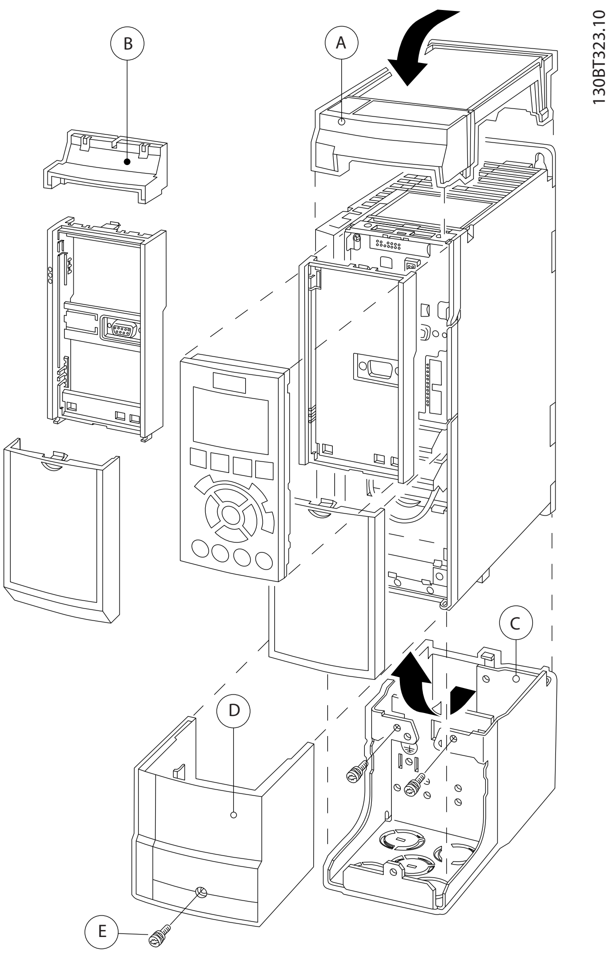
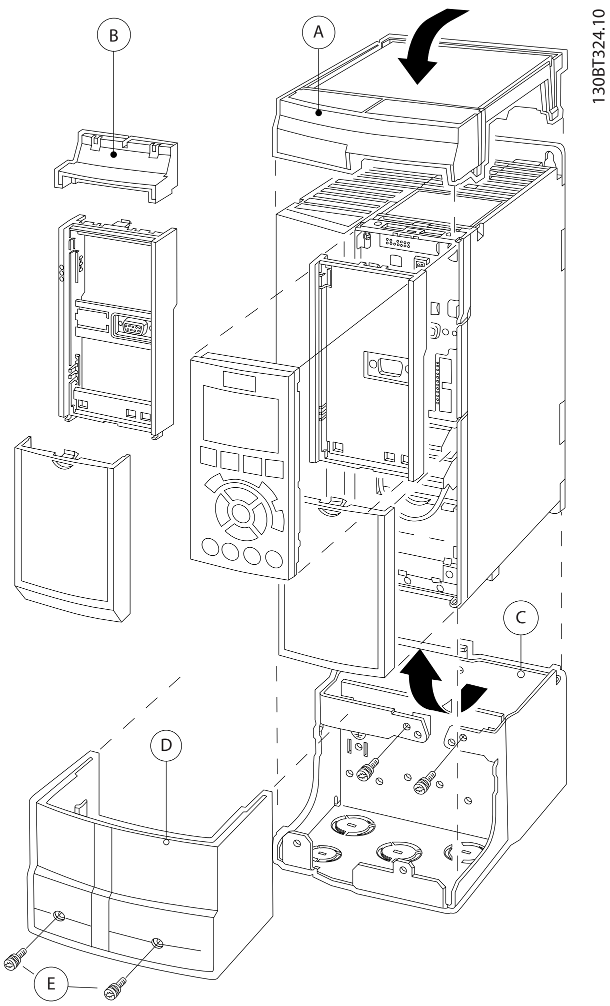


Illustration 3.31 Enclosure Size A2



A	Top cover
B	Brim
C	Base part
D	Base cover
E	Screw(s)

Illustration 3.32 Enclosure Size A3

Place the top cover as shown. If an A or B option is used, the brim must be fitted to cover the top inlet. Place the base part C at the bottom of the frequency converter and use the clamps from the accessory bag to fasten the cables correctly.

Holes for cable glands:

- Size A2: 2x M25 and 3xM32
- Size A3: 3xM25 and 3xM32

Enclosure type	Height A [mm]	Width B [mm]	Depth C[1)] [mm]
A2	372	90	205
A3	372	130	205
B3	475	165	249
B4	670	255	246
C3	755	329	337
C4	950	391	337

Table 3.20 Dimensions

1) If option A/B is used, the depth increases (see chapter 7.8 Power Ratings, Weight and Dimensions for details)

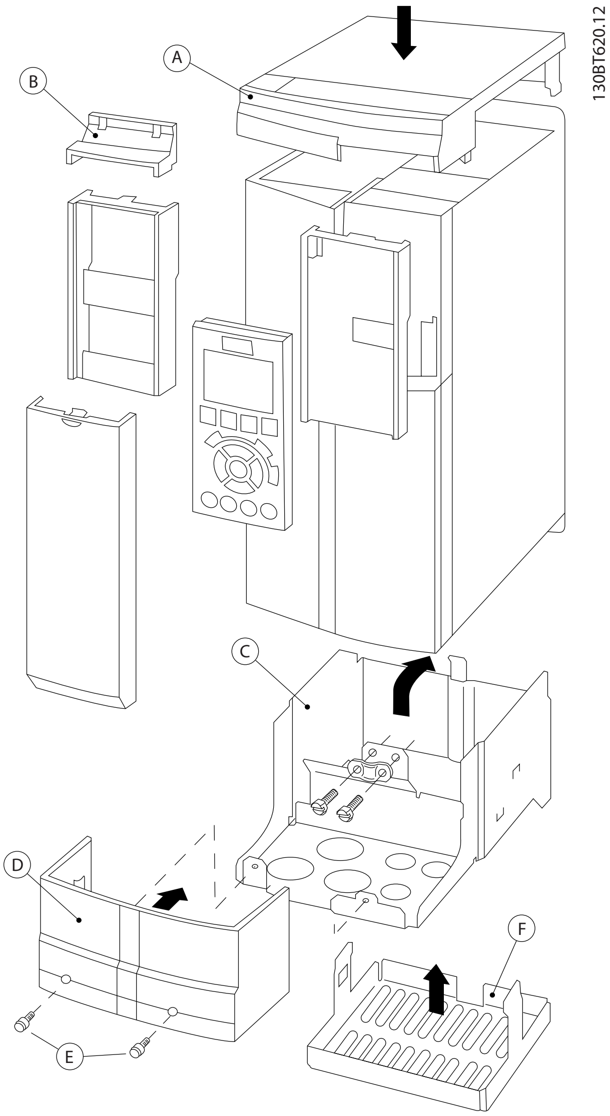


Illustration 3.33 Enclosure Size B3

Illustration 3.34 Enclosure Sizes B4, C3, and C4

A	Top cover
B	Brim
C	Base part
D	Base cover
E	Screw(s)
F	Fan cover
G	Top clip

Table 3.21 Legend to *Illustration 3.33* and *Illustration 3.34*

When option module A and/or option module B is/are used, fit the brim (B) to the top cover (A).

NOTICE

Side-by-side installation is not possible when using the *IP21/IP4X/TYPE 1 Enclosure Kit*

3.7.10 Remote Mounting Kit for LCP

The LCP can be moved to the front of an enclosure by using the remote built-in kit. The fastening screws must be tightened with a torque of maximum 1 Nm.

The LCP enclosure is rated IP66.

Enclosure	IP66 front
Maximum cable length between LCP and unit	3 m
Communication standard	RS485

Table 3.22 Technical Data

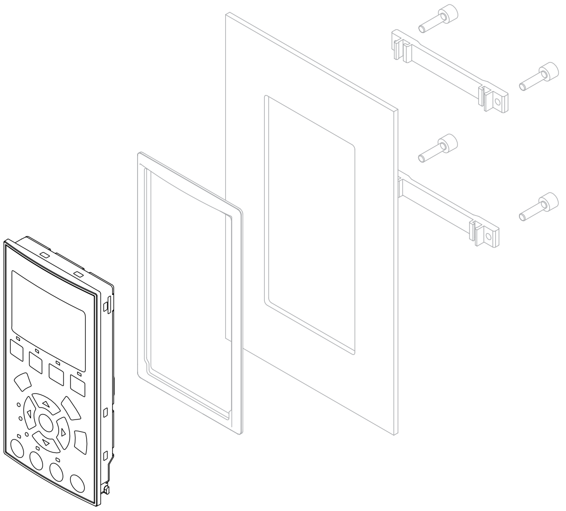


Illustration 3.35 LCP Kit with Graphical LCP, Fasteners, 3 m Cable and Gasket
Ordering Number 130B1113

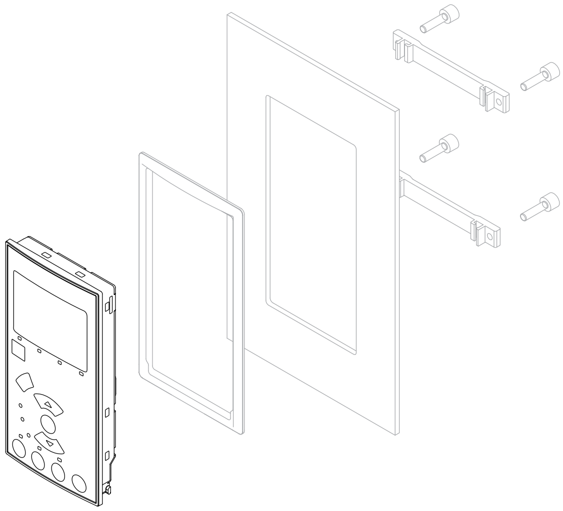


Illustration 3.36 LCP Kit with Numerical LCP, Fasteners and Gasket
Ordering Number 130B1114

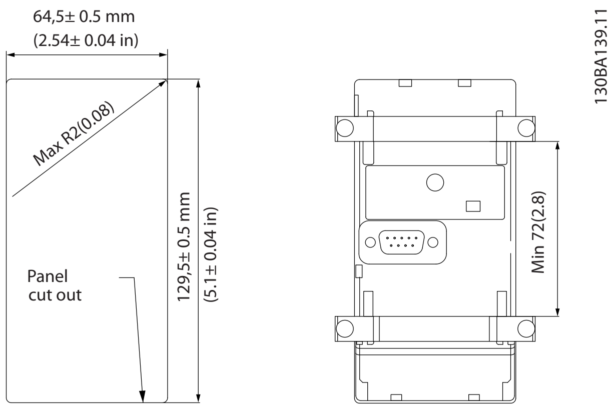


Illustration 3.37 Dimensions of LCP Kit

www.famcocorp.com
E-mail: info@famcocorp.com
@famco_group
Tel:۰۲۱-۴۸۰۰۰۰۴۹
Fax:۰۲۱ - ۴۴۹۹۴۶۴۲
تهران، کیلومتر۲۱ بزرگراه لشگری (جاده مخصوص کرج)
روبروی پالایشگاه نفت پارس، پلاک ۱۲

3.7.11 Mounting Bracket for Enclosure Sizes A5, B1, B2, C1 and C2

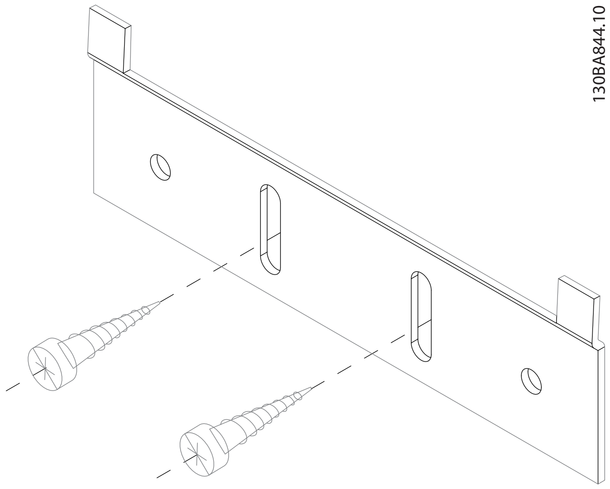


Illustration 3.38 Lower Bracket

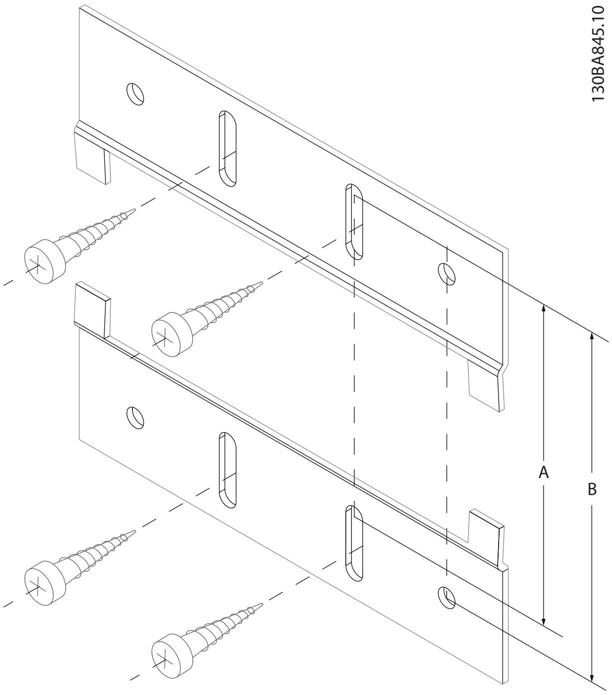


Illustration 3.39 Upper Bracket

See dimensions in *Table 3.23*.

Enclosure Size	IP	A [mm]	B [mm]	Ordering number
A5	55/66	480	495	130B1080
B1	21/55/66	535	550	130B1081
B2	21/55/66	705	720	130B1082
B3	21/55/66	730	745	130B1083
B4	21/55/66	820	835	130B1084

Table 3.23 Details of Mounting Brackets

3

3.8 Serial Interface RS485

3.8.1 Overview

RS485 is a 2-wire bus interface compatible with multi-drop network topology, that is, nodes can be connected as a bus, or via drop cables from a common trunk line. A total of 32 nodes can be connected to 1 network segment. Repeaters divide network segments, see *Illustration 3.40*.

NOTICE

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

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

Low-impedance ground connection of the screen at every node is important, including at high frequencies. Thus, connect a large surface of the screen to ground, for example, with a cable clamp or a conductive cable gland. It may be necessary to apply potential-equalising 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 [Ω]	120
Cable length [m]	Maximum 1200 (including drop lines) Maximum 500 station-to-station

Table 3.24 Cable Specifications

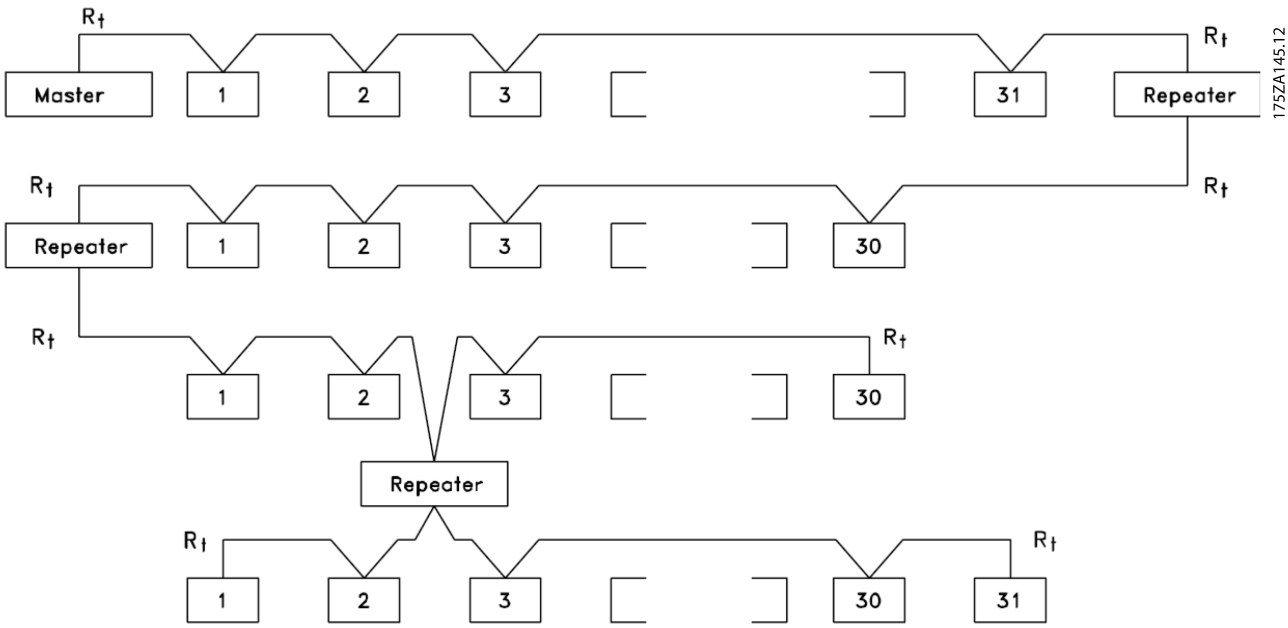


Illustration 3.40 RS485 Bus Interface

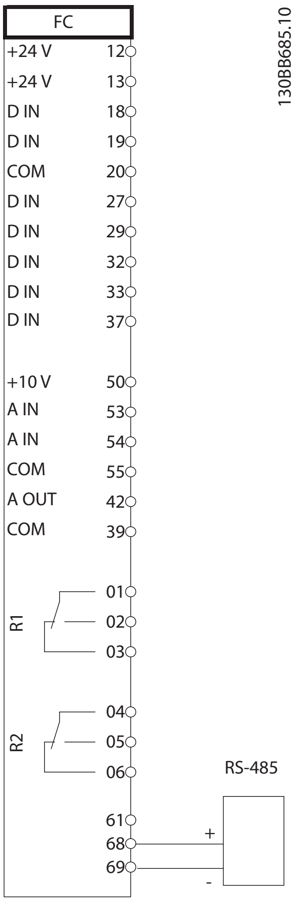
	Parameters	
	Function	**Setting**
	8-30 Protocol	FC*
	8-31 Address	1*
	8-32 Baud Rate	9600*
	* = Default value	
	Notes/comments: Select protocol, address and baud rate in the above mentioned parameters. D IN 37 is an option.	

Table 3.25 RS485 Network Connection

3.8.2 Network Connection

One or more frequency converters can be connected to a control (or master) using the RS485 standardised 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 *chapter 3.5.1 Wiring Schematic*.

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

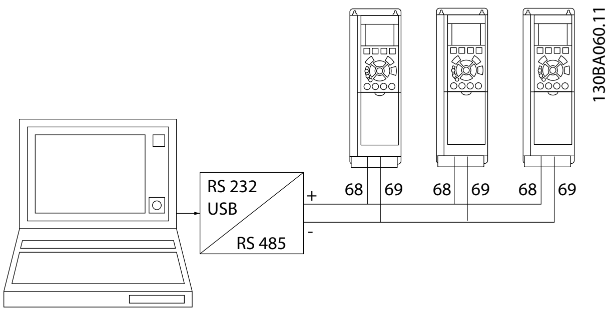


Illustration 3.41 Parallel Connections

To avoid potential equalising currents in the screen, wire according to *Illustration 3.20*.

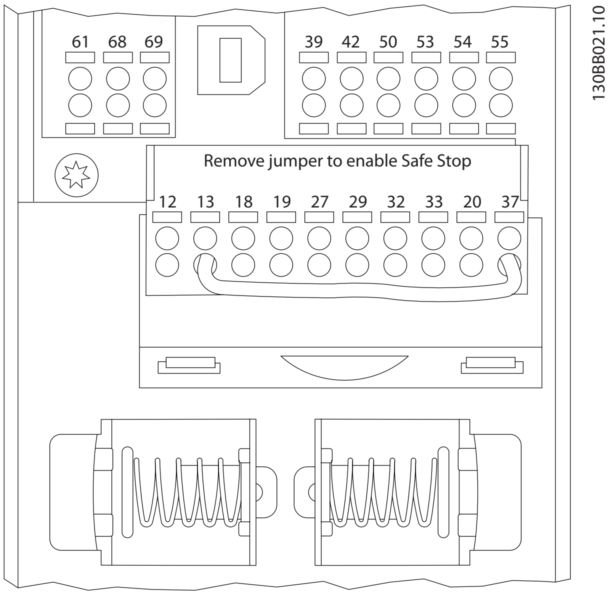


Illustration 3.42 Control Card Terminals

3.8.3 RS485 Bus Termination

Terminate RS485 bus with a resistor network at both ends. For this purpose, set switch S801 on the control card to ON.

Set the communication protocol to *8-30 Protocol*.

3.8.4 EMC Precautions

The following EMC precautions are recommended to achieve interference-free operation of the RS485 network.

Observe relevant national and local regulations, for example, regarding protective earth connection. Keep the RS485 communication cable 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 inches) 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 RS485 cable must cross motor and brake resistor cables at an angle of 90°.

3

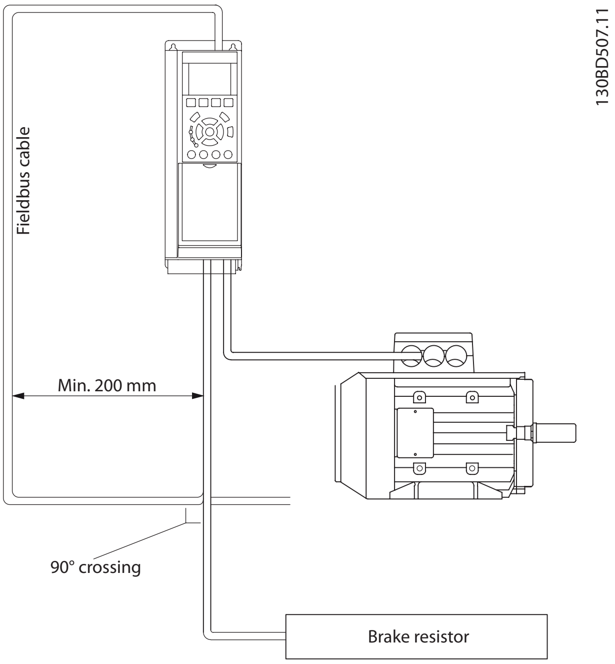


Illustration 3.43 Cable Routing

3.8.5 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.
1 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 RS485, thus utilising the RS485 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.

3.8.6 Network Configuration

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 Baud Rate	2400–115200
8-33 Parity / Stop Bits	Even parity, 1 stop bit (default)

Table 3.26 FC Protocol Parameters

3.8.7 FC Protocol Message Framing Structure

3.8.7.1 Content of a Character (byte)

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

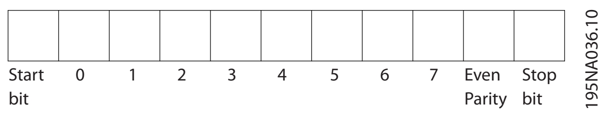


Illustration 3.44 Content of a Character

3.8.7.2 Telegram Structure

Each telegram has the following structure:

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

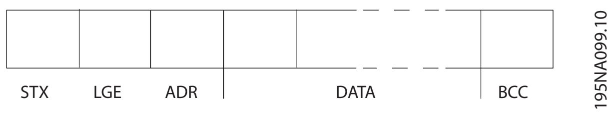


Illustration 3.45 Telegram Structure

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3.8.7.3 Telegram Length (LGE)

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

4 data bytes	LGE=4+1+1=6 bytes
12 data bytes	LGE=12+1+1=14 bytes
Telegrams containing texts	10[1)]+n bytes

Table 3.27 Length of Telegrams

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

3.8.7.4 Frequency Converter Address (ADR)

2 different address formats are used.
The address range of the frequency converter is either 1-31 or 1-126.

- Address format 1-31
  - Bit 7=0 (address format 1-31 active).
  - Bit 6 is not used.
  - Bit 5=1: Broadcast, address bits (0-4) are not used.
  - Bit 5=0: No Broadcast.
  - Bit 0-4=frequency converter address 1-31.
- 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.

3.8.7.5 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.

3

3.8.7.6 The Data Field

The structure of data blocks depends on the type of telegram. There are 3 telegram types, and the type applies for both control telegrams (master⇒slave) and response telegrams (slave⇒master).

The 3 types of telegram are:

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

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

Illustration 3.46 Process Block

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.

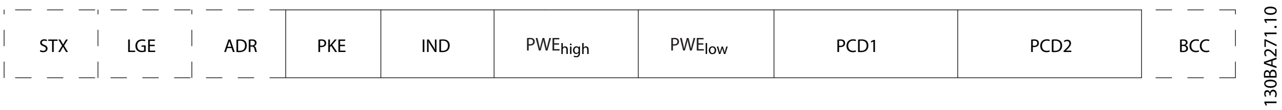

Illustration 3.47 Parameter Block

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

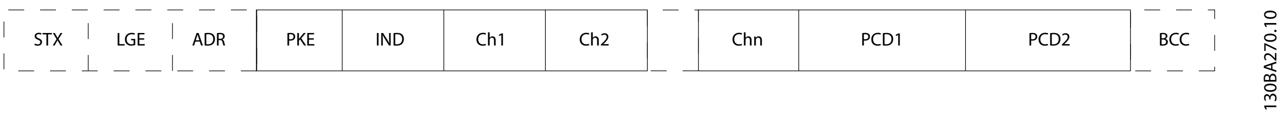

Illustration 3.48 Text Block

3.8.7.7 The PKE Field

The PKE field contains 2 sub-fields:

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

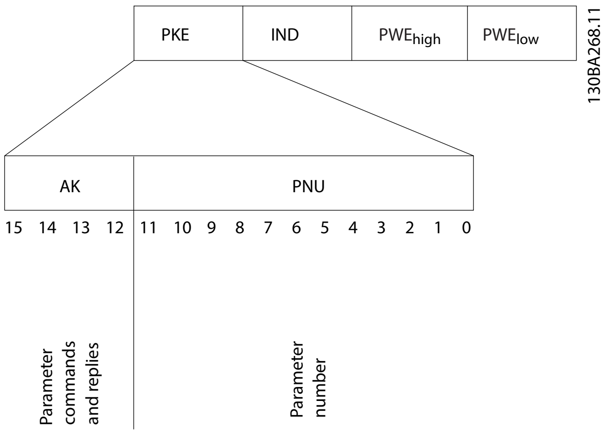

Illustration 3.49 PKE Field

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

Bit number				Parameter command
15	14	13	12	
0	0	0	0	No command
0	0	0	1	Read parameter value
0	0	1	0	Write parameter value in RAM (word)
0	0	1	1	Write parameter value in RAM (double word)
1	1	0	1	Write parameter value in RAM and EEprom (double word)
1	1	1	0	Write parameter value in RAM and EEprom (word)
1	1	1	1	Read/write text

Table 3.28 Parameter Commands Master⇒Slave

Bit number				Response
15	14	13	12	
0	0	0	0	No response
0	0	0	1	Parameter value transferred (word)
0	0	1	0	Parameter value transferred (double word)
0	1	1	1	Command cannot be performed
1	1	1	1	text transferred

Table 3.29 Response Slave⇒Master

If the command cannot be performed, the slave sends this response:
0111 Command cannot be performed
- and issues a fault report (see *Table 3.30*) in the parameter value (PWE):

PWE low (hex)	Fault report
0	The parameter number used does not exit.
1	There is no write access to the defined parameter.
2	Data value exceeds the parameter's limits.
3	The sub index used does not exit.
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 frequency converter's present mode. Certain parameters can only be changed when the motor is turned off.
82	There is no bus access to the defined parameter.
83	Data change is not possible because factory set-up is selected

Table 3.30 Parameter Value Fault Report

3.8.7.8 Parameter Number (PNU)

Bits number 0-11 transfer parameter numbers. The function of the relevant parameter is defined in the parameter description in the *Programming Guide*.

3.8.7.9 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.

3.8.7.10 Parameter Value (PWE)

The parameter value block consists of 2 words (4 bytes), and the value depends on the defined command (AK). The master prompts for a parameter value when the PWE block contains no value. To change a parameter value (write), write the new value in the PWE block and send from the master to the 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 does not contain a numerical value, but several data options, e.g. *0-01 Language* where [0] is English, and [4] is Danish, select the data value by entering the value in the PWE block. Serial communication is only capable of reading parameters containing data type 9 (text string).

15-40 FC Type to *15-53 Power Card Serial Number* contain data type 9.
For example, read the unit size and mains voltage range in *15-40 FC Type*. When a text string is transferred (read), the length of the telegram is variable, and the texts are of different lengths. The telegram length is defined in the

3

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 to 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.

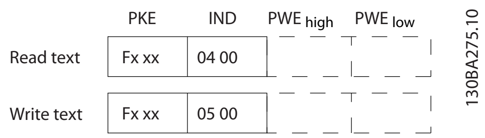

Illustration 3.50 Text via PWE Block

3.8.7.11 Supported Data Types

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 3.31 Supported Data Types

3.8.7.12 Conversion

The various attributes of each parameter are displayed in factory setting. 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 therefore read as 10.0.

Examples:
0 s⇒conversion index 0
0.00 s⇒conversion index -2
0 ms⇒conversion index -3
0.00 ms⇒conversion index -5

3.8.7.13 Process Words (PCD)

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

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

Table 3.32 Process Words (PCD)

3.8.8 FC Protocol Examples

3.8.8.1 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
PWEHIGH=0000 hex
PWELOW=03E8 hex - Data value 1000, corresponding to 100 Hz, see *chapter 3.8.7.12 Conversion*.

The telegram looks like this:

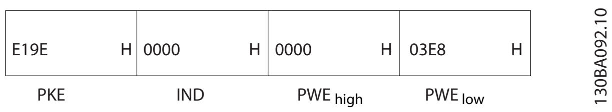

Illustration 3.51 Write Data in EEPROM

NOTICE

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

The response from the slave to the master is:

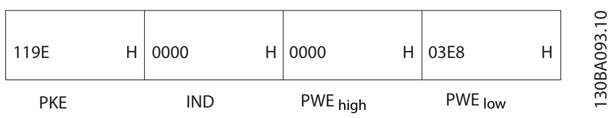

Illustration 3.52 Response from Slave

3.8.8.2 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
PWEHIGH=0000 hex
PWELOW=0000 hex

1155 H	0000 H	0000 H	0000 H
PKE	IND	PWE high	PWE low

130BA094.10

Illustration 3.53 Parameter Value

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 3.54 Response from Slave

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*.

3.8.9 Modbus RTU Protocol

3.8.9.1 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.

The built-in 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.

3.8.9.2 Modbus RTU Overview

Regardless of the type of physical communication networks, the Modbus RTU overview describes the process a controller uses to request access to another device. This process includes how the Modbus RTU responds to requests from another device, and how errors are detected and reported. It also establishes a common format for the layout and contents of message fields.
During communications over a Modbus RTU network, the protocol:

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

If a reply is required, the controller constructs the reply message and sends it.
Controllers communicate using a master-slave technique in which only the master can initiate transactions (called queries). 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 initiate a broadcast message to all slaves. Slaves return a response to queries that are addressed to them individually. No responses are returned to broadcast queries from the master. The Modbus RTU protocol establishes the format for the master's query by providing:

- The device (or broadcast) address.
- A function code defining the requested action.
- Any data to be sent.
- 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 be returned, 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.

3.8.9.3 Frequency Converter with Modbus RTU

The frequency converter communicates in Modbus RTU format over the built-in RS485 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 a variety of preset speeds
- Run in reverse
- Change the active set-up
- Control the frequency converter's built-in relay

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.

3

3.8.9.4 Network Configuration

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 3.33 Modbus RTU Parameters

3.8.10 Modbus RTU Message Framing Structure

3.8.10.1 Frequency Converter with Modbus RTU

The controllers are set up to communicate on the Modbus network using RTU mode, with each byte in a message containing 2 4-bit hexadecimal characters. The format for each byte is shown in *Table 3.34*.

Start bit	Data byte								Stop/ parity	Stop

Table 3.34 Format for Each Byte

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

3.8.10.2 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 3.35*.

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 3.35 Typical Modbus RTU Message Structure

3.8.10.3 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 field to be transmitted is the device address. Following the last transmitted character, a similar period of at least 3.5 character intervals marks the end of the message. A new message can begin after this period. The entire message frame must be transmitted as a continuous stream. If a silent period of more than 1.5 character intervals occurs before completion of the frame, the receiving device flushes the incomplete message and assumes that the next byte is the address field of a new message. Similarly, if a new message begins before 3.5 character intervals after a previous message, the receiving device considers it a continuation of the previous message. 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.

3.8.10.4 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 recognise.) 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.

3.8.10.5 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 kind of 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 some kind of error 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 tells the master what kind of error occurred, or the reason for the exception. Also refer to *chapter 3.8.10.10 Function Codes Supported by Modbus RTU* and *chapter 3.8.10.11 Modbus Exception Codes*.

3.8.10.6 Data Field

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

3.8.10.7 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 2 values are unequal, a bus time-out results. The error-checking field contains a 16-bit binary value implemented as 2 8-bit bytes. When this is done, 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.

3.8.10.8 Coil Register Addressing

In Modbus, all data is organised in coils and holding registers. Coils hold a single bit, whereas holding registers hold a 2-byte word (16 bits). All data addresses in Modbus messages are referenced to zero. The first occurrence of a data item is addressed as item number 0. For example: The coil known as *coil 1* in a programmable controller is addressed as 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).

<table>
<tr><th>Coil number</th><th colspan="2">Description</th><th>Signal direction</th></tr>
<tr><td>1–16</td><td colspan="2">Frequency converter control word.</td><td>Master to slave</td></tr>
<tr><td>17–32</td><td colspan="2">Frequency converter speed or setpoint reference range 0x0–0xFFFF (-200% ... ~200%).</td><td>Master to slave</td></tr>
<tr><td>33–48</td><td colspan="2">Frequency converter status word (see Table 3.38)</td><td>Slave to master</td></tr>
<tr><td>49–64</td><td colspan="2">Open-loop mode: Frequency converter output frequency.
Closed-loop mode: Frequency converter feedback signal.</td><td>Slave to master</td></tr>
<tr><td rowspan="3">65</td><td colspan="2">Parameter write control (master to slave)</td><td rowspan="3">Master to slave</td></tr>
<tr><td>0 =</td><td>Parameter changes are written to the RAM of the frequency converter.</td></tr>
<tr><td>1 =</td><td>Parameter changes are written to the RAM and EEPROM of the frequency converter.</td></tr>
<tr><td>66-65536</td><td colspan="2">Reserved</td><td></td></tr>
</table>

Table 3.36 Coil Descriptions

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 3.37 Frequency Converter Control Word (FC Profile)

www.famcocorp.com
E-mail: info@famcocorp.com
@famco_group
Tel:۰۲۱-۴۸۰۰۰۰۴۹
Fax:۰۲۱ - ۴۴۹۹۴۶۴۲
تهران، کیلومتر ۲۱ بزرگراه لشگری (جاده مخصوص کرج)
روبروی پالایشگاه نفت پارس، پلاک ۱۲

3

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 frequency range	In frequency range
44	Stopped	Running
45	Not used	Not used
46	No voltage warning	Voltage warning
47	Not in current limit	Current limit
48	No thermal warning	Thermal warning

Table 3.38 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 index1)
00010-00990	000 parameter group (parameters 0-01 through 0-99)
01000-01990	100 parameter group (parameters 1-00 through 1-99)
02000-02990	200 parameter group (parameters 2-00 through 2-99)
03000-03990	300 parameter group (parameters 3-00 through 3-99)
04000-04990	400 parameter group (parameters 4-00 through 4-99)
...	...
49000-49990	4900 parameter group (parameters 49-00 through 49-99)
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 3.39 Holding Registers

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

3.8.10.9 How to Control the Frequency Converter

Codes available for use in the function and data fields of a Modbus RTU message are listed in *chapter 3.8.10.10 Function Codes Supported by Modbus RTU* and *chapter 3.8.10.11 Modbus Exception Codes*.

3.8.10.10 Function Codes Supported by Modbus RTU

Modbus RTU supports use of the function codes (see *Table 3.40*) in the function field of a message.

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

Table 3.40 Function Codes

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

Table 3.41 Function Codes and Sub-function Codes

3.8.10.11 Modbus Exception Codes

For a full explanation of the structure of an exception code response, refer to *chapter 3.8.10.5 Function Field*.

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 generates exception 02.
3	Illegal data value	A value contained in the query data field is not an allowable value for server (or slave). This 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 3.42 Modbus Exception Codes

3.8.11 Access to Parameters

3.8.11.1 Parameter Handling

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

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

For information on the parameters, size and converting index, consult the *programming guide*.

3.8.11.2 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).

3.8.11.3 IND (Index)

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

3.8.11.4 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.

3.8.11.5 Conversion Factor

Since a parameter value can only be transferred as a whole number, a conversion factor must be used to transfer decimals.

3.8.11.6 Parameter Values

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

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

3

3.8.12 FC Drive Control Profile

3.8.12.1 Control Word According to FC Profile (*8-10 Control Profile*=FC profile)

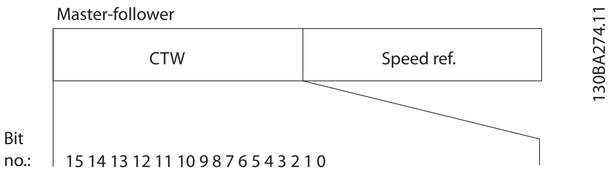

Illustration 3.55 Control Word

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 3.43 Control Word Bits

Explanation of the Control Bits

Bits 00/01
Bits 00 and 01 are used to select between the 4 reference values, which are pre-programmed in *3-10 Preset Reference* according to *Table 3.44*.

Programmed ref. value	Parameter	Bit 01	Bit 00
1	*3-10 Preset Reference* [0]	0	0
2	*3-10 Preset Reference* [1]	0	1
3	*3-10 Preset Reference* [2]	1	0
4	*3-10 Preset Reference* [3]	1	1

Table 3.44 Reference Values

NOTICE

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

Bit 02, DC brake
Bit 02=0 leads to DC braking and stop. Set braking current and duration in *2-01 DC Brake Current* and *2-02 DC Braking Time*.
Bit 02=1 leads to ramping.

Bit 03, Coasting
Bit 03=0: The frequency converter immediately releases the motor, (the output transistors are shut off) and it coasts to a standstill.
Bit 03=1: The frequency converter starts the motor, if the other starting conditions are met.

Make a selection in *8-50 Coasting Select* to define how bit 03 gates with the corresponding function on a digital input.

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

Bit 05, Hold output frequency
Bit 05=0: The present output frequency (in Hz) freezes. Change the frozen output frequency only with the digital inputs (*5-10 Terminal 18 Digital Input* to *5-15 Terminal 33 Digital Input*) programmed to *Speed up* and *Slow down*.

NOTICE

If freeze output is active, the frequency converter can only be stopped by the following:

- **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 signal's leading edge, for example, 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
Tells 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. Turn off the control word, if it should not be used when updating or reading parameters.

Bit 11, Relay 01
Bit 11=0: Relay not activated.
Bit 11=1: Relay 01 activated provided that *Control word bit 11* is selected in *5-40 Function Relay*.

Bit 12, Relay 04
Bit 12=0: Relay 04 is not activated.
Bit 12=1: Relay 04 is activated provided that *Control word bit 12* is selected in *5-40 Function Relay*.

Bit 13/14, Selection of set-up
Use bits 13 and 14 to select from the 4 menu set-ups according to *Table 3.45*.

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

Table 3.45 Specification of Menu Set-ups

The function is only possible when *[9] 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* or *Logic and* is selected.

3.8.12.2 Status Word According to FC Profile (STW) (*8-10 Control Profile*=FC profile)

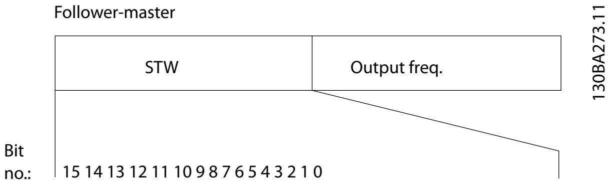

Illustration 3.56 Status Word

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 3.46 Status Word Bits

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.

3

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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 might, for example, be the case when the speed ramps up/down during start/stop.
Bit 08=1: The motor speed matches the preset speed reference.

Bit 09, Local operation/bus control
Bit 09=0: [Stop/Reset] is activated on the control unit or *Local control* in *3-13 Reference Site* is selected. Control via serial communication is not possible.
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 overtemperature on the inverter.
Bit 12=1: The inverter stops because of overtemperature, but the unit does not trip and resumes operation once the overtemperature stops.

Bit 13, Voltage OK/limit exceeded
Bit 13=0: There are no voltage warnings.
Bit 13=1: The DC-voltage in the frequency converter's 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.

3.8.12.3 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 by means of 2's complement. The actual output frequency (MAV) is scaled in the same way as the bus reference.

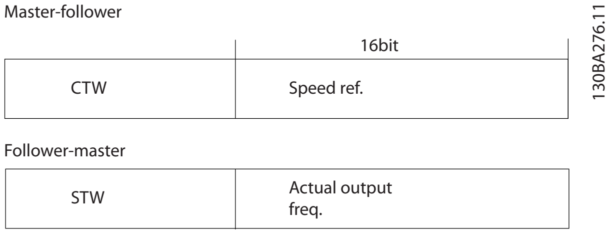

Illustration 3.57 Actual Output Frequency (MAV)

The reference and MAV are scaled as follows:

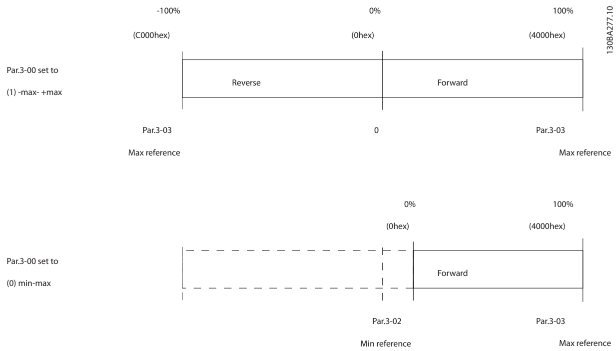

Illustration 3.58 Reference and MAV

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3.8.12.4 Control Word according to PROFIdrive Profile (CTW)

The control word is used to send commands from a master (for example, 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 3.47 Control Word Bits

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 0=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*.

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

Bit 03, Coasting/No coasting
Coasting stop bit 03=0 leads to a stop.
When bit 03=1, the frequency converter can start if the other start conditions are satisfied.

NOTICE

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

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

NOTICE

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

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

Bit 06, Ramp stop/Start
Normal ramp stop using the ramp times of the actual ramp as selected. In addition, activation of the output relay 01 or 04 if the output frequency is 0 Hz and 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 fulfilled.

NOTICE

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

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

Bit 08, Jog 1 Off/On
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. It is possible to turn off the control word, if it should not be used for 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*.
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, that is, the speed reference value is reduced.

Bits 13/14, Set-up selection
Bits 13 and 14 are used to select between the 4 parameter set-ups according to *Table 3.48*.

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

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

Table 3.48 Set-up Selection

Bit 15, No function/Reverse
Bit 15=0 causes no reversing.
Bit 15=1 causes reversing.

NOTICE

In the factory settings reversing is set to *digital* in *8-54 Reversing Select*.

NOTICE

Bit 15 causes reversing only when *Ser. communication, Logic or* or *Logic and* is selected.

3.8.12.5 Status Word according to PROFIdrive Profile (STW)

The status word is used to notify a master (for example, 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 3.49 Status Word Bits

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, Drive not ready/ready
Same significance as bit 00, however, there is a supply of the power unit. The frequency converter is ready when it receives the necessary start signals.

Bit 02, Coasting/Enable
When bit 02=0, bit 00, 01 or 02 of the control word is 0 (Off 1, Off 2 or Off 3 or coasting) – or the frequency converter is switched off (trip).
When bit 02=1, bit 00, 01 or 02 of the control word is 1; the frequency converter has not tripped.

Bit 03, No error/Trip
When bit 03=0, no error condition of the frequency converter exists.
When bit 03=1, the frequency converter has tripped and requires a reset signal before it can start.

Bit 04, On 2/Off 2
When bit 01 of the control word is 0, then bit 04=0.
When bit 01 of the control word is 1, then bit 04=1.

Bit 05, On 3/Off 3
When bit 02 of the control word is 0, then bit 05=0.
When bit 02 of the control word is 1, then bit 05=1.

Bit 06, Start possible/Start not possible
If *[1] PROFIdrive* has been selected in *8-10 Control Profile*, bit 06 is 1 after a switch-off acknowledgment, after activation of Off2 or Off3, and after switching on the mains voltage, *Start not possible* is reset, with bit 00 of the control word is set to 0 and bits 01, 02 and 10 are set to 1.

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

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

Bit 09, Local operation/Bus control
Bit 09=0 indicates that the frequency converter has been stopped with [Stop] 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 starts 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%.

3

3.9 System Design Checklist

Table 3.50 provides a checklist for integrating a frequency converter into a motor control system. The list is intended as a reminder of the general categories and options necessary for specifying the system requirements.

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

Category	Details	Notes	☑
	Contacts		
	Filters		
Motor			
	Type		
	Rating		
	Voltage		
	Options		
Special tools and equipment			
	Moving and storage		
	Mounting		
	Electrical connection		

Table 3.50 System Design Checklist

4

4 Application Examples

4.1 Application Feature Overview

The VLT® AQUA Drive FC 202 is designed for water and wastewater applications. The wide range of standard and optional features includes optimised SmartStart and quick menu with a focus on water and wastewater applications:

- **Cascade control**
  Basic cascade control is built-in as standard, with a capacity of up to 3 pumps. Cascade control provides speed control of a single pump in a multi pump system. This is a cost attractive solution, for example for booster sets. Systems with multiple variable speed pumps require the extended cascade controller (MCO 101) or the advanced cascade controller (MCO 102).
- **Motor alternation**
  The motor alternation functionality is suitable for applications with 2 motors or 2 pumps sharing 1 frequency converter.
- **Flow compensation**
  Flow compensation adapts the setpoint according to the flow, and enables mounting of the pressure sensor close to the pump.
- **Dry-run detection**
  The feature prevents damage of the pump by avoiding dry-running and pump overheat
- **End-of-curve detection**
  The feature detects when the pump is running at maximum speed and the setpoint cannot be reached for a user defined time period.
- **Deragging**
  This preventive or reactive cleaning feature is designed for pumps in wastewater applications. See *chapter 4.2.3 29-1* Deragging Function* for details.
- **Initial/final ramps**
  Programming of short ramp times to/from minimum speed protects bearings, and ensures sufficient cooling in applications with submersible pumps.
- **Check valve protection**
  A slow ramp-down rate protects check valves and prevents water hammering
- **STO**
  STO enables safe stop (coast) when a critical situation arises.
- **Low-flow detection**
  This feature detects no-flow or low-flow conditions of the system.
- **Sleep mode**
  The sleep mode feature saves energy by stopping the pump when there is no demand.
- **Pipe fill mode**
  Pipe fill mode comprises functionalities to fill pipes smothly and avoid water hammering. This feature provides different modes for horizontal and vertical pipes.
- Real-time clock
- **Smart logic control (SLC)**
  SLC comprises programming of a sequence consisting of events and actions. SLC offers a wide range of PLC functions using comparators, logic rules and timers.
- **Pre/post Lube**
  See *chapter 4.2.4 Pre/post Lube* for details.
- **Flow confirmation**
  See *chapter 4.2.5 29-5* Flow Confirmation* for details.
- **Advanced minimum speed monitoring for submersible pumps**
  See *chapter 4.2.6 Advanced Minimum Speed Monitoring for Submersible Pumps* for details.
- **Preventive maintenance**
  The preventive maintenance feature enables programming of scheduled service intervals into the frequency converter.

4.2 Selected Application Features

4.2.1 SmartStart

With the SmartStart wizard, it is now easier and more cost-efficient to commission the frequency converter. SmartStart is activated at the first power up or after a factory reset and guides users through a series of easy steps to ensure the correct and most efficient motor control. The SmartStart can also be started directly via the quick menu. Select settings on the 28-language graphical control panel.

- Single pump/motor in open or closed loop
- Motor alternation: When 2 motors share 1 frequency converter.
- Basic cascade control: Speed control of a single pump in a multi-pump system. This is a cost-attractive solution in, for example, booster sets.
- Master-follower: Control up to 8 frequency converters and pumps to ensure smooth operation of the overall pump system.

4.2.2 Quick Menu Water and Pumps

The quick menu entry water and pumps provides quick access to the most common water and pump features of the VLT® AQUA Drive:

- Special ramps (initial/final ramp, check valve ramp)
- Sleep mode
- Deragging
- Dry-run detection
- End of curve detection
- Flow compensation
- Pipe fill mode for horizontal, vertical and mixed pipe systems
- Control performance
- Minimum speed monitor

4.2.3 29-1* Deragging Function

The purpose of the deragging feature is to free the pump blade of debris in waste water applications so that the pump operates normally.
A deragging event is defined as the time when the frequency converter starts to derag to when the deragging finishes. When a derag is started, the frequency converter ramps first to a stop and then an off delay expires before the first cycle begins.

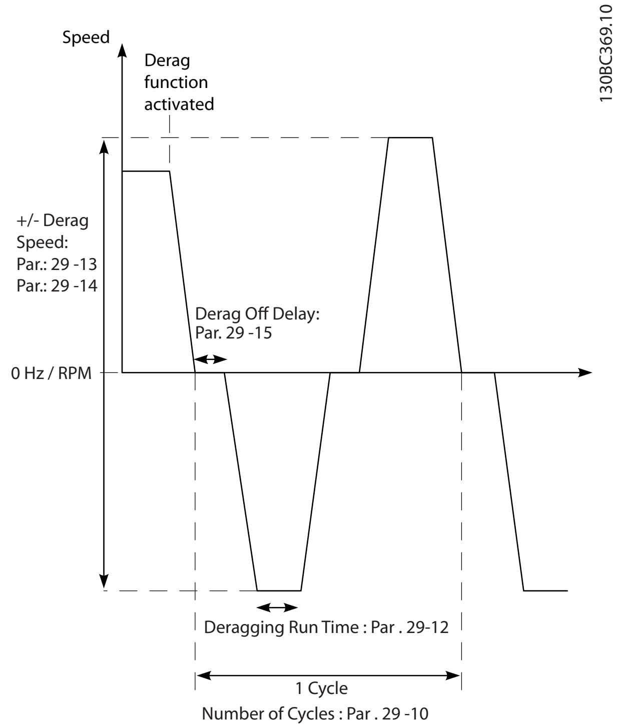


Illustration 4.1 Derag Function

If a derag is triggered from a frequency converter-stopped state, the first off delay is skipped. The deragging event may consist of several cycles. One cycle consisting of one pulse in the reverse direction followed by one pulse in the forward direction. Deragging is considered finished after the specified number of cycles has completed. More specifically, on the last pulse (it will always be forward) of the last cycle, the derag is considered finished after the deragging run time expires (the frequency converter is running at derag speed). In between pulses, the frequency converter output coasts for a specified off delay time to let debris in the pump settle.

NOTICE

Do not enable deragging if the pump cannot operate in reverse direction.

There are 3 different notifications for an ongoing deragging event:

- Status in the LCP: *Auto Remote Derag*.
- A bit in the extended status word (Bit 23, 80 0000 hex).
- A digital output can be configured to reflect the active deragging status.

Depending on the application and the purpose of using it, this feature can be used as a preventive or reactive measure and can be triggered/started in the following ways:

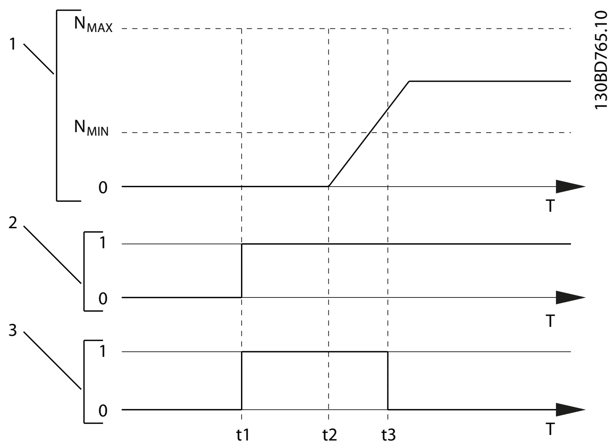
- On each start command (*29-11 Derag at Start/ Stop*)
- On each stop command (*29-11 Derag at Start/ Stop*)
- On each start/stop command (*29-11 Derag at Start/Stop*)
- On digital input (parameter group *5-1* Digital Inputs*)
- On drive action with the smart logic controller (*13-52 SL Controller Action*)
- As timed action (parameter group *23-** Time-based Functions*)
- On high power (parameter group *29-2* Derag Power Tuning*)

4.2.4 Pre/post Lube

Certain motors require lubrication of their mechanical parts before and during running to prevent damage/wear. This is especially the case when the motor has not been running for extended periods of time. Pre-lube also supports applications that may require certain exhaust fans to be running. The Pre-lube feature signals an external device to start performing a specific action for a user-defined period of time beginning at the rising edge of a run command (for example, start request). Furthermore, a start delay (*1-71 Start Delay*) can be entered such that the pre-lube only occurs while the frequency converter is stopped and the pre-lube completes just before the frequency converter starts to ramp up. Pre-lube can also be configured such that the external device remains signalled at all times when the frequency converter is in a running state or such that the signal stays on after the motor has stopped (*29-42 Post Lube Time*). Application examples include a device to lubricate the mechanical parts of a motor/pump or some type of exhaust fan unit.

An example use case for a lubrication device would be to start lubrication at the rising edge of a start request. Delay the start for a period of time and stop lubrication when the delay expires and the frequency converter starts.

Illustration 4.2 shows a different usage of the feature. In this case, the delay expires while the frequency converter is already ramping up. See the related parameters in *Table 4.1*.



1	Speed curve
2	Start command (for example, terminal 18)
3	Pre lube output signal
t_1	Start command issued (for example, terminal 18 is set active). The start delay timer (*1-71 Start Delay*) and the pre lube timer (*29-41 Pre Lube Time*).
t_2	The start delay timer expires. The frequency converter starts to ramp up.
t_3	The pre lube timer (*29-41 Pre Lube Time*) expires.

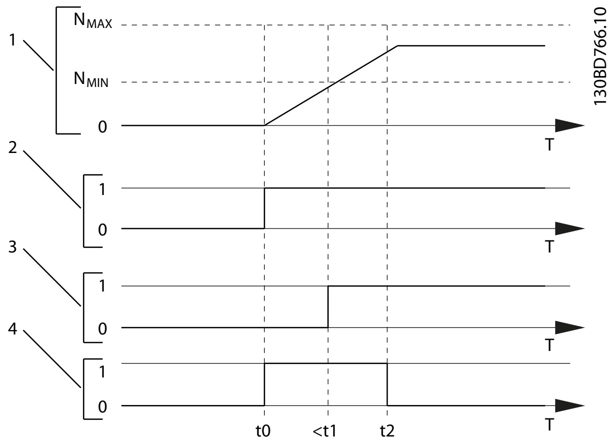
Illustration 4.2 Pre/post Lube Function Example

Parameter and Name	Description	Settings	Unit
29-40 Pre/Post Lube Function	Select the pre/post lube function. Use *1-71 Start Delay* to set the delay before the motor will start ramping.	[0]*Disabled [1] Pre lube only [2] Pre & running [3] Pre & running & post	-
29-41 Pre Lube Time	Enter the duration of the signal after the start signal. Used only when *[1] Pre lube Only* is selected in *29-40 Pre/Post Lube Function*.	0-600 (*10)	s
29-42 Post Lube Time	Select the duration of the signal after the motor has stopped. Used only when *[3] Pre & running & post* is selected in *29-40 Pre/Post Lube Function*.	0-600 (*10)	s

Table 4.1 Pre/Post Lube Parameters

4.2.5 29-5* Flow Confirmation

The flow confirmation feature is designed for applications where there is a need for the motor/pump to run while waiting for an external event. The flow confirmation monitor expects to get a digital input from a sensor on a gate valve, flow switch, or a similar external device indicating that the device is in the open position and flow is possible. In *29-50 Validation Time*, a user defines how long the VLT® AQUA Drive FC 202 waits for the digital input signal from the external device to confirm the flow. After the flow is confirmed, the frequency converter checks the signal again after the flow verification time and then runs normally. The LCP status reads "Verifying flow" while the flow monitor is active.
The frequency converter trips with the alarm *Flow Not Confirmed*, if the expected digital input signal becomes inactive before either the flow validation time or the flow verification time expires.



1	Speed curve
2	Start command (for example, terminal 18)
3	Digital signal from an external device that confirms that the flow is possible.
4	Flow verification
t_0	Start command issued (for example, terminal 18 is set active)
t_1	Digital signal from an external device becomes active before *29-50 Validation Time* expires.
t_2	When *29-51 Verification Time* passes, the frequency converter checks the signal from the external device again and then runs normally.

Illustration 4.3 Flow Confirmation

Parameter and Name	Description	Settings	Unit
29-50 Validation Time	The digital input must be active during the validation time.	0.1–999.0 (*size dependent)	s
29-51 Verification Time	Flow will be confirmed if, at the end of the verification time, the digital input is still active.	0.1–255.0 (*15)	s

Table 4.2 Flow Confirmation Parameters

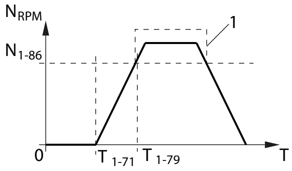
NOTICE

The parameters are only visible on the LCP when a digital input is configured as flow confirmation.

4.2.6 Advanced Minimum Speed Monitoring for Submersible Pumps

Some pumps are very sensitive to operating at low speed. Typical reasons for this are insufficient cooling or lubrication at low speed.
Under overload conditions, the frequency converter protects itself using its integral protection features, which include lowering the speed. For example, the current limit controller can lower the speed. This means that, in some cases, the speed may go lower than the speed specified in *4-11 Motor Speed Low Limit [RPM]* and *4-12 Motor Speed Low Limit [Hz]*.
The advanced minimum-speed monitoring feature trips the frequency converter if the speed drops below a certain value. If the pump motor of the pump does not reach the speed specified in *1-86 Trip Speed Low [RPM]* within the time specified in *1-79 Pump Start Max Time to Trip* (ramping up takes too long), the frequency converter trips. Timers for *1-71 Start Delay* and *1-79 Pump Start Max Time to Trip* start at the same time when the start command is issued. For instance, this means that if the value in *1-71 Start Delay* is more than or equal to the value in *1-79 Pump Start Max Time to Trip*, the frequency converter never starts.

4



T_{1-71}	*1-71 Start Delay*.
T_{1-79}	*1-79 Pump Start Max Time to Trip*. This time includes the time in T_{1-71}.
N_{1-86}	*1-86 Trip Speed Low [RPM]*. If the speed drops below this value during normal operation, the frequency converter trips.
1	Normal operation.

Illustration 4.4 Advanced Minimum Speed Monitoring

4.3 Application Set-up Examples

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

SLC Application Example

One sequence 1:

1. Start.
2. Ramp up.
3. Run at reference speed 2 s.
4. Ramp down.
5. Hold shaft until stop.

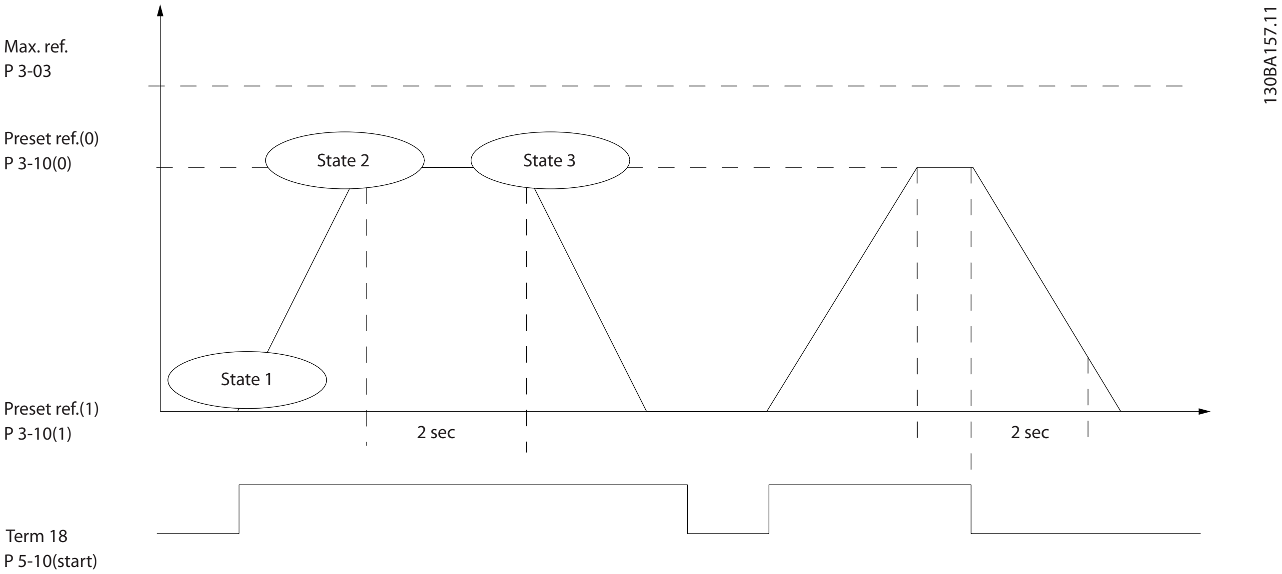


Illustration 4.5 Ramp Up/Ramp Down

- 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.
- Required switch settings for analog terminals A53 or A54 are also shown.

NOTICE

When the optional STO feature is used, a jumper wire may be required between terminal 12 (or 13) and terminal 37 for the frequency converter to operate when using factory default programming values.

Set the ramping times in *3-41 Ramp 1 Ramp Up Time* and *3-42 Ramp 1 Ramp Down Time* to the desired times

$$tramp = \frac{tacc \times nnorm\,(par.\ 1-25)}{ref\,[RPM]}$$

Set terminal 27 to *[0] No Operation* (*5-12 Terminal 27 Digital Input*)

Set preset reference 0 to first preset speed (*3-10 Preset Reference* [0]) in percentage of maximum reference speed (*3-03 Maximum Reference*). Example: 60%
Set preset reference 1 to second preset speed (*3-10 Preset Reference* [1] Example: 0% (zero).
Set the timer 0 for constant running speed in *13-20 SL Controller Timer* [0]. Example: 2 s

Set Event 1 in *13-51 SL Controller Event* [1] to *[1] True*.
Set Event 2 in *13-51 SL Controller Event* [2] to *[4] On Reference*.
Set Event 3 in *13-51 SL Controller Event* [3] to *[30] Time Out 0*.
Set Event 4 in *13-51 SL Controller Event* [4] to *[0] False*.

Set Action 1 in *13-52 SL Controller Action* [1] to *[10] Select preset 0*.
Set Action 2 in *13-52 SL Controller Action* [2] to *[29] Start Timer 0*.
Set Action 3 in *13-52 SL Controller Action* [3] to *[11] Select preset 1*.
Set Action 4 in *13-52 SL Controller Action* [4] to *[1] No Action*.

Set the in *13-00 SL Controller Mode* to ON.

Start/stop command is applied on terminal 18. If the stop signal is applied, the frequency converter ramps down and goes into free mode.

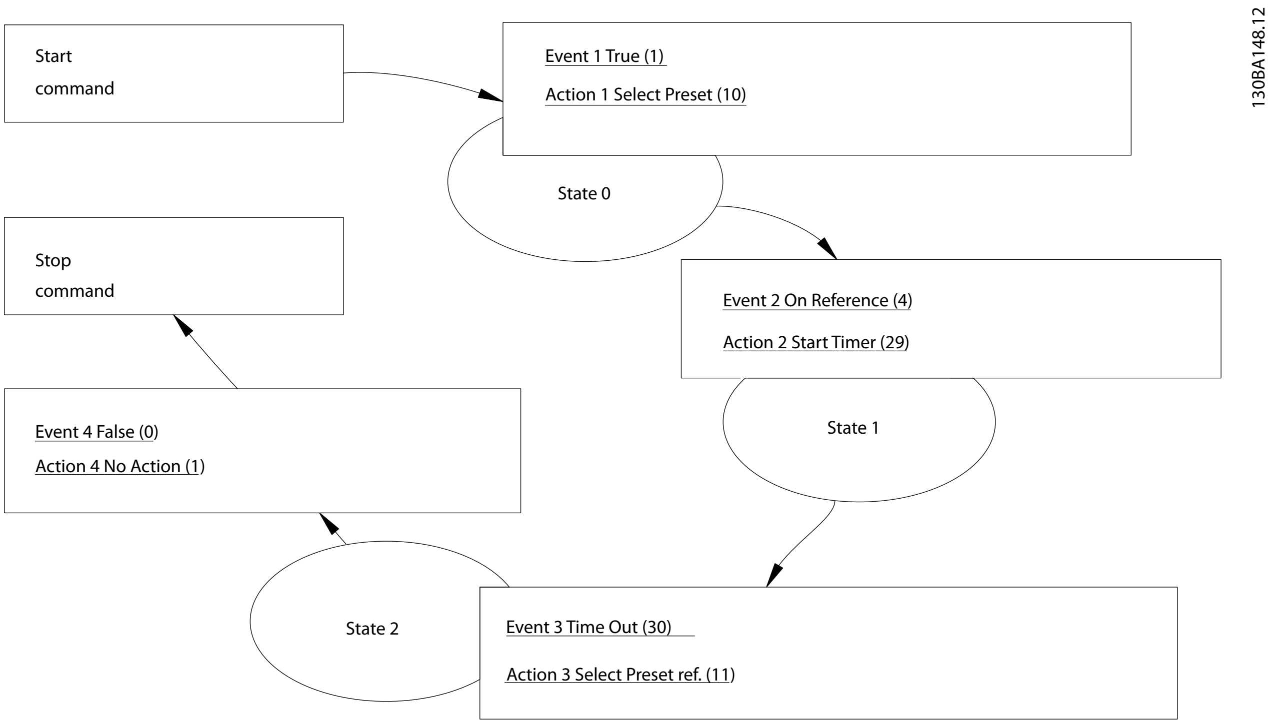


Illustration 4.6 SLC Application Example

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@famco_group
Tel:021-48000049
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تهران، کیلومتر ۲۱ بزرگراه لشگری (جاده مخصوص کرج)
روبروی پالایشگاه نفت پارس، پلاک ۱۲

4.3.1 Submersible Pump Application

The system consists of a submersible pump controlled by a Danfoss VLT® AQUA Drive and a pressure transmitter. The transmitter gives a 4-20 mA feedback signal to the frequency converter, which keeps a constant pressure by controlling the speed of the pump. To design a frequency converter for a submersible pump application, there are a few important issues to consider. Select the frequency converter according to motor current.

1. The motor is a so-called *CAN motor* with a stainless steel can between the rotor and stator. There is a larger and a more magnetic resistant air-gap than on a normal motor, hence a weaker field, which results in the motors being designed with a higher rated current than a normal motor with similar rated power.
2. The pump contains thrust bearings that are damaged when running below minimum speed, which is normally 30 Hz.
3. The motor reactance is nonlinear in submersible pump motors and, therefore, automatic motor adaption (AMA) may not be possible. Normally, submersible pumps are operated with long motor cables that might eliminate the nonlinear motor reactance and enable the frequency converter to perform AMA. If AMA fails, the motor data can be set from parameter group *1-3* Adv. Motor Data* (see the motor datasheet). Be aware that, if AMA has succeeded, the frequency converter will compensate for the voltage drop in the long motor cables, so if the advanced motor data are set manually, the length of the motor cable must be considered to optimise system performance.
4. It is important that the system be operated with a minimum of wear and tear on the pump and motor. A Danfoss sine-wave filter can lower the motor insulation stress and increase lifetime (check actual motor insulation and the frequency converter dU/dt specification). Note that most manufacturers of submersible pumps require the use of output filters.
5. EMC performance can be difficult to achieve due to the fact that the special pump cable, which is able to withstand the wet conditions in the well is normally unscreened. A solution could be to use a screened cable above the well and fix the screen to the well pipe if it is made of steel. A sine-wave filter also reduces the EMI from unscreened motor cables.

The special CAN motor is used due to the wet installation conditions. The frequency converter needs to be designed for the system according to output current to be able to run the motor at nominal power.

To prevent damage to the thrust bearings of the pump, and to ensure sufficient motor cooling as quickly as possible, it is important to ramp the pump from stop to minimum speed as quick as possible. Well-known manufacturers of submersible pumps recommend that the pump is ramped to min. speed (30 Hz) in max. 2–3 s. The VLT® AQUA Drive FC 202 is designed with initial and final ramp for these applications. The initial and final ramps are 2 individual ramps, where initial ramp, if enabled, ramps the motor from stop to minimum speed and automatically switches to normal ramp, when minimum speed is reached. Final ramp will do the opposite from minimum speed to stop in a stop situation. Consider also enabling advanced minimum speed monitoring as described in *chapter 4.2 Selected Application Features*.

To achieve additional pump protection, use the dry-run detection function. Refer to the *programming guide* for further information.

Pipe-fill mode can be enabled to prevent water hammering. The Danfoss frequency converter is capable of filling vertical pipes using the PID controller to ramp up the pressure slowly with a user specified rate (units/second). If enabled, the frequency converter enters pipe-fill mode when it reaches minimum speed after start-up. The pressure is slowly ramped up until it reaches a user-specified filled set point, where the frequency converter automatically disables pipe fill mode and continues in normal closed-loop operation.

Electrical Wiring

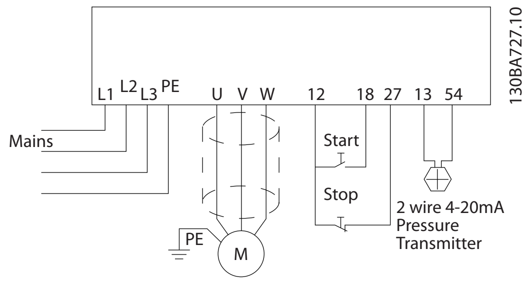


Illustration 4.7 Wiring for Submersible Pump Application

NOTICE

Set the analog input 2, (terminal 54) format to mA. (switch 202).

Parameter Settings

Parameter
1-20 Motor Power [kW]/1-21 Motor Power [HP]
1-22 Motor Voltage
1-24 Motor Current
1-28 Motor Rotation Check
Enable reduced automatic motor adaptation in *1-29 Automatic Motor Adaptation (AMA)*

Table 4.3 Relevant Parameters for Submersible Pump Application

Parameter	Setting
3-02 Minimum Reference	The minimum reference unit matches the unit in *20-12 Reference/Feedback Unit*
3-03 Maximum Reference	The maximum reference unit matches the unit in *20-12 Reference/Feedback Unit*
3-84 Initial Ramp Time	(2 s)
3-88 Final Ramp Time	(2 s)
3-41 Ramp 1 Ramp Up Time	(8 s depending on size)
3-42 Ramp 1 Ramp Down Time	(8 s depending on size)
4-11 Motor Speed Low Limit [RPM]	(30 Hz)
4-13 Motor Speed High Limit [RPM]	(50/60 Hz)
Use the *Closed-loop wizard* under *Quick Menu_Function_Set-up*, to easily set up the feedback settings in the PID controller.	

Table 4.4 Example of Settings for Submersible Pump Application

Parameter	Setting
29-00 Pipe Fill Enable	
29-04 Pipe Fill Rate	(Feedback units/s)
29-05 Filled Setpoint	(Feedback units)

Table 4.5 Example of Settings for Pipe-Fill Mode

Performance

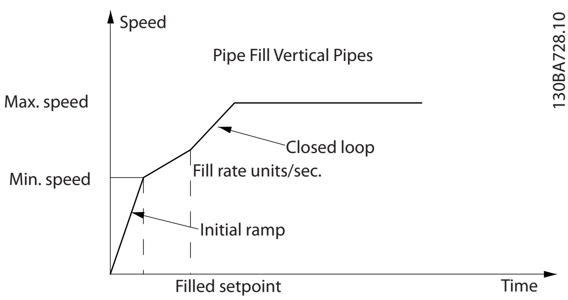


Illustration 4.8 Pipe Fill-Mode, Performance Curve

4.3.2 BASIC Cascade Controller

The BASIC cascade controller is used for pump applications where a certain pressure (head) or level must be maintained over a wide dynamic range. Running a large pump at variable speed over a wide range is not an ideal solution because of low pump efficiency at lower speed. In a practical way, the limit is 25% of the rated full-load speed for the pump.

In the BASIC cascade controller, the frequency converter controls a variable speed (lead) motor as the variable speed pump and can stage up to 2 additional constant speed pumps on and off. Connect the additional constant speed pumps directly to mains or via soft starters. By varying the speed of the initial pump, variable speed control of the entire system is provided. The variable speed maintains constant pressure, which results in reduced system stress, and quieter operation in pumping systems.

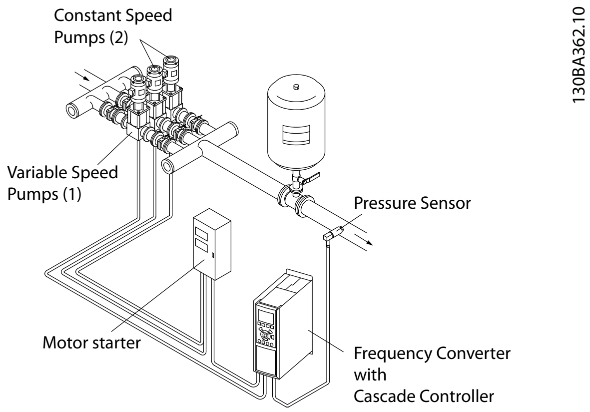


Illustration 4.9 BASIC Cascade Controller

Fixed lead pump
The motors must be of equal size. The BASIC cascade controller allows the frequency converter to control up to 3 equal pumps using the frequency converter's 2 built-in relays. When the variable pump (lead) is connected directly to the frequency converter, the 2 built-in relays control the other two pumps. When lead pump alternations are enabled, pumps are connected to the built-in relays and the frequency converter can operate 2 pumps.

Lead pump alternation
The motors must be of equal size. This function makes it possible to cycle the frequency converter between the pumps in the system (maximum of 2 pumps). In this operation, the run time between pumps is equalised, reducing the required pump maintenance and increasing reliability and lifetime of the system. The alternation of the lead pump can take place at a command signal or at staging (adding another pump).

The command can be a manual alternation or an alternation event signal. If the alternation event is selected, the lead pump alternation takes place every time the event occurs. Selections include:

- Whenever an alternation timer expires;
- at a predefined time of day;
- or when the lead pump goes into sleep mode.

The actual system load determines staging.

A separate parameter limits alternation only to take place if total capacity required is >50%. Total pump capacity is determined as lead pump plus fixed speed pumps capacities.

Bandwidth management
In cascade control systems, to avoid frequent switching of fixed speed pumps, the desired system pressure is kept within a bandwidth rather than at a constant level. The staging bandwidth provides the required bandwidth for operation. When a large and quick change in system pressure occurs, the override bandwidth overrides the staging bandwidth to prevent immediate response to a short duration pressure change. An override bandwidth timer can be programmed to prevent staging until the system pressure has stabilised and normal control is established.

When the cascade controller is enabled and the frequency converter issues a trip alarm, the system head is maintained by staging and destaging fixed speed pumps. To prevent frequent staging and destaging and minimise pressure fluctuations, a wider fixed speed bandwidth is used instead of the staging bandwidth.

4.3.3 Pump Staging with Lead Pump Alternation

With lead pump alternation enabled, a maximum of 2 pumps are controlled. At an alternation command, the PID stops, the lead pump ramps to minimum frequency (f_{min}) and, after a delay, it ramps to maximum frequency (f_{max}). When the speed of the lead pump reaches the de-staging frequency, the fixed speed pump is cut out (de-staged). The lead pump continues to ramp up and then ramps down to a stop and the 2 relays are cut out.

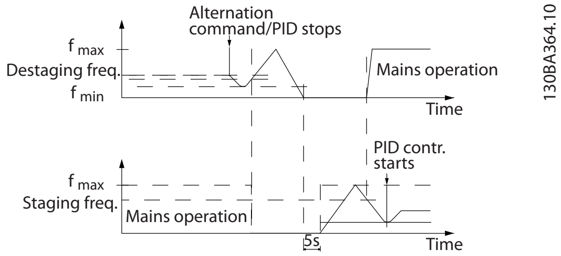


Illustration 4.10 Lead Pump Alternation

After a time delay, the relay for the fixed speed pump cuts in (staged) and this pump becomes the new lead pump. The new lead pump ramps up to maximum speed and then down to minimum speed. When ramping down and reaching the staging frequency, the old lead pump is now cut in (staged) on the mains as the new fixed-speed pump.

If the lead pump has been running at minimum frequency (f_{min}) for a programmed amount of time, with a fixed speed pump running, the lead pump contributes little to the system. When programmed value of the timer expires, the lead pump is removed, avoiding water heating problems.

4.3.4 System Status and Operation

If the lead pump goes into sleep mode, the function is displayed on the LCP. It is possible to alternate the lead pump on a sleep mode condition.

When the cascade controller is enabled, the operation status for each pump and the cascade controller is displayed on the LCP. Information displayed includes:

- Pumps status is a readout of the status for the relays assigned to each pump. The display shows pumps that are disabled, off, running on the frequency converter or running on the mains/motor starter.
- Cascade status is a readout of the status for the cascade controller. The display shows that the cascade controller is disabled, all pumps are off, and emergency has stopped all pumps, all pumps are running, fixed speed pumps are being staged/de-staged and lead pump alternation is occurring.
- De-stage at no-flow ensures that all fixed-speed pumps are stopped individually until the no-flow status disappears.

4

4.3.5 Cascade Controller Wiring Diagram

Illustration 4.11 shows an example with the built-in BASIC cascade controller with 1 variable-speed pump (lead) and 2 fixed-speed pumps, a 4–20 mA transmitter and system safety interlock.

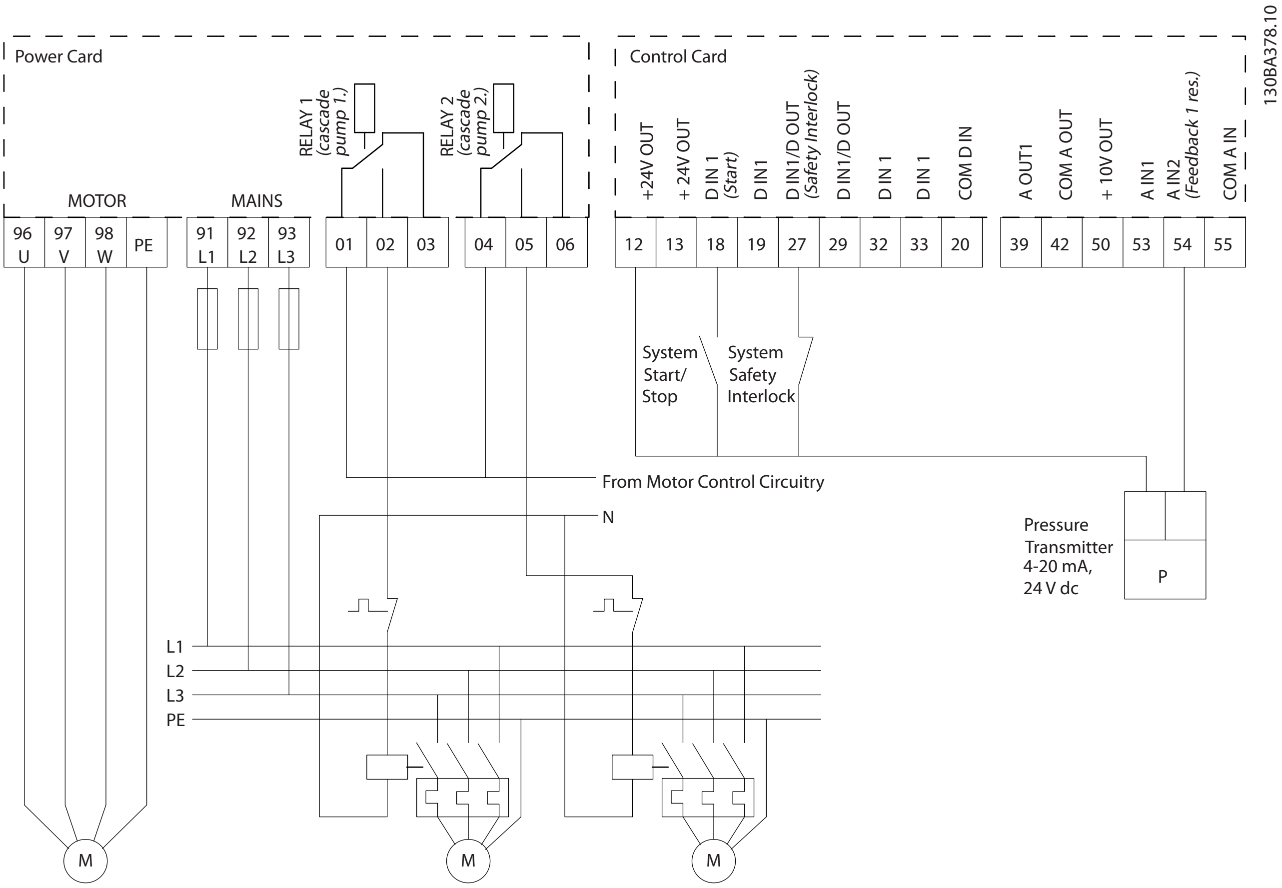


Illustration 4.11 Cascade Controller Wiring Diagram

4.3.6 Fixed Variable Speed Pump Wiring Diagram

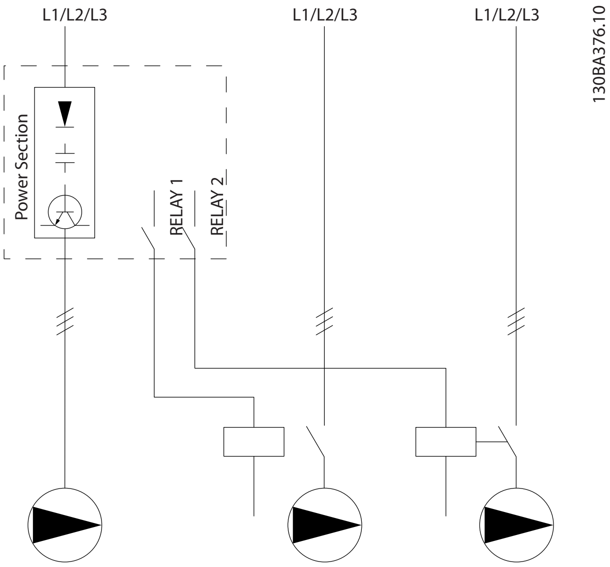


Illustration 4.12 Fixed Variable Speed Pump Wiring Diagram

4.3.7 Lead Pump Alternation Wiring Diagram

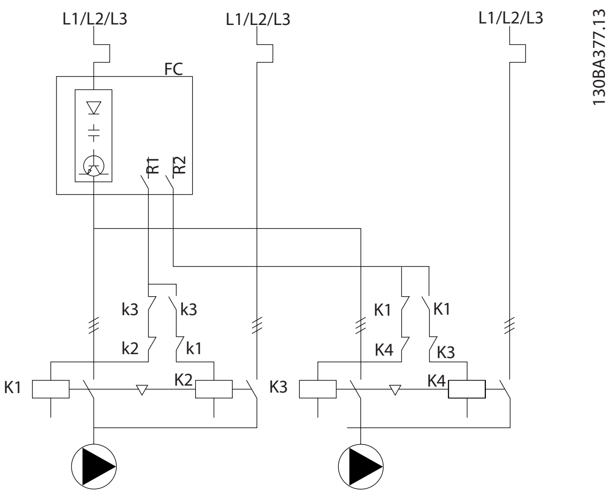


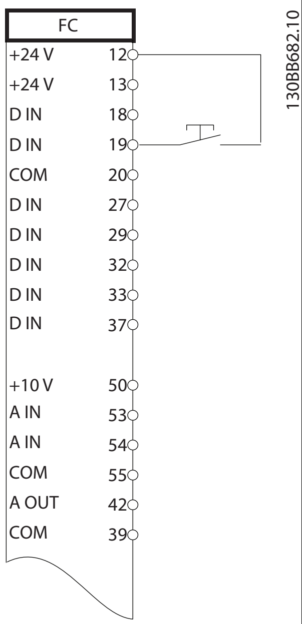
Illustration 4.13 Lead Pump Alternation Wiring Diagram

Every pump must be connected to 2 contactors (K1/K2 and K3/K4) with a mechanical interlock. Thermal relays or other motor protection devices must be applied according to local regulation and/or individual demands.

- Relay 1 (R1) and Relay 2 (R2) are the built-in relays in the frequency converter.
- When all relays are de-energised, the first built-in relay that is energised cuts in the contactor corresponding to the pump controlled by the relay. For example, Relay 1 cuts in contactor K1, which becomes the lead pump.
- K1 blocks for K2 via the mechanical interlock, preventing mains from being connected to the output of the frequency converter (via K1).
- Auxiliary break contact on K1 prevents K3 from cutting in.
- Relay 2 controls contactor K4 for on/off control of the fixed speed pump.
- At alternation, both relays de-energise and now Relay 2 is energised as the first relay.

For a detailed description of commissioning for mixed pump and master/slave applications, refer to *VLT® Cascade Controller Options MCO 101/102 Operating Instructions*.

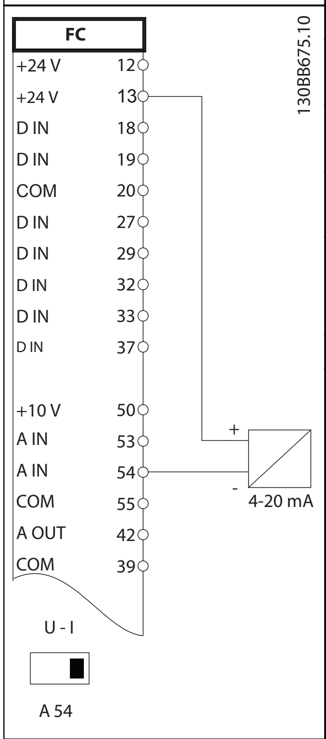
4.3.8 External Alarm Reset



Parameters	
Function	**Setting**
5-11 Terminal 19 Digital Input	[1] Reset
* = Default value	
Notes/comments: D IN 37 is an option.	

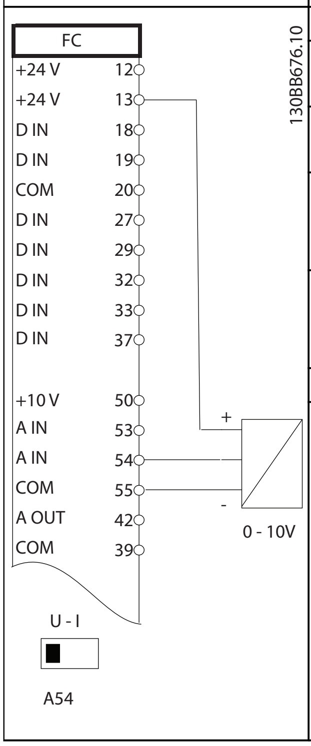
Table 4.6 External Alarm Reset

4.3.9 Feedback



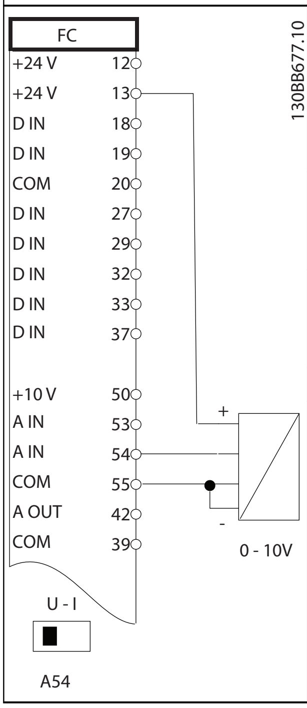
Parameters	
Function	**Setting**
6-22 Terminal 54 Low Current	4 mA*
6-23 Terminal 54 High Current	20 mA*
6-24 Terminal 54 Low Ref./Feedb. Value	0*
6-25 Terminal 54 High Ref./Feedb. Value	50*
* = Default value	
Notes/comments: D IN 37 is an option.	

Table 4.7 Analog Current Feedback Transducer



Parameters	
Function	**Setting**
6-20 Terminal 54 Low Voltage	0.07 V*
6-21 Terminal 54 High Voltage	10 V*
6-24 Terminal 54 Low Ref./Feedb. Value	0*
6-25 Terminal 54 High Ref./Feedb. Value	50*
* = Default value	
Notes/comments: D IN 37 is an option.	

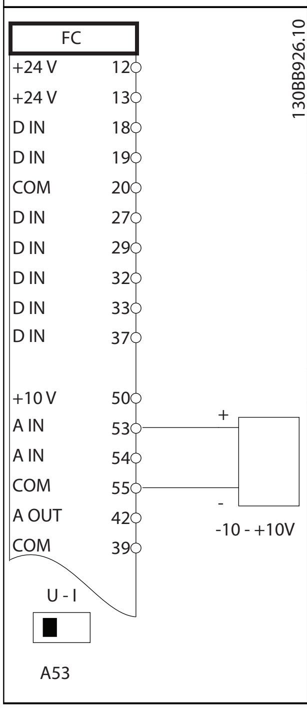
Table 4.8 Analog Voltage Feedback Transducer (3-wire)



Parameters	
Function	**Setting**
6-20 Terminal 54 Low Voltage	0.07 V*
6-21 Terminal 54 High Voltage	10 V*
6-24 Terminal 54 Low Ref./Feedb. Value	0*
6-25 Terminal 54 High Ref./Feedb. Value	50*
* = Default value	
Notes/comments: D IN 37 is an option.	

Table 4.9 Analog Voltage Feedback Transducer (4-wire)

4.3.10 Speed

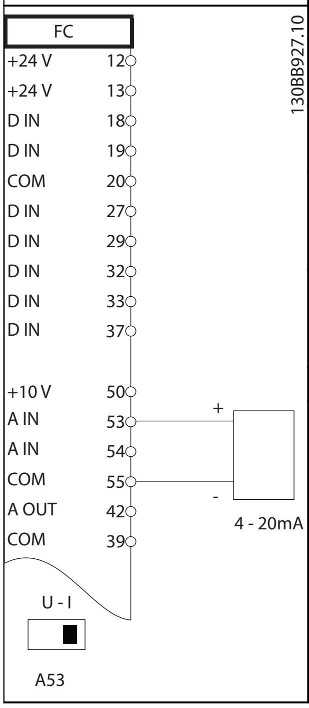


Parameters	
Function	**Setting**
6-10 Terminal 53 Low Voltage	0.07 V*
6-11 Terminal 53 High Voltage	10 V*
6-14 Terminal 53 Low Ref./Feedb. Value	0 Hz
6-15 Terminal 53 High Ref./Feedb. Value	50 Hz
* = Default value	
Notes/comments: D IN 37 is an option.	

Table 4.10 Analog Speed Reference (Voltage)

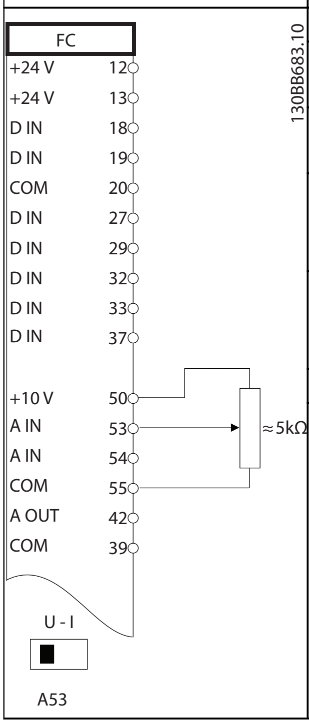
4

4



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 Hz
6-15 Terminal 53 High Ref./Feedb. Value	50 Hz
* = Default value	
Notes/comments: D IN 37 is an option.	

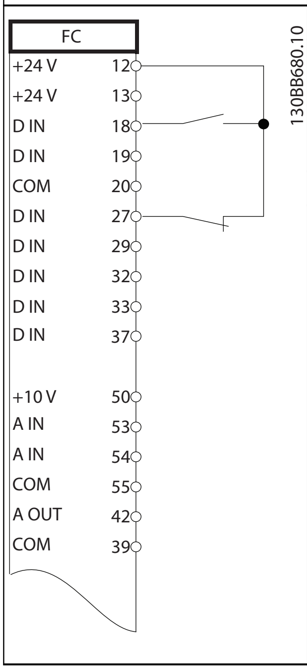
Table 4.11 Analog Speed Reference (Current)



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 Hz
6-15 Terminal 53 High Ref./Feedb. Value	1500 Hz
* = Default value	
Notes/comments: D IN 37 is an option.	

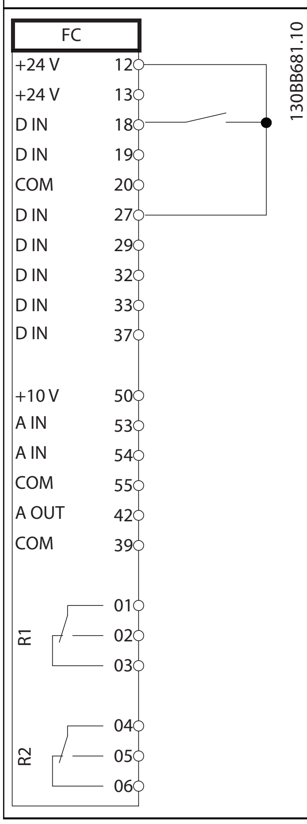
Table 4.12 Speed Reference (Using a Manual Potentiometer)

4.3.11 Run/Stop



Parameters	
Function	**Setting**
5-10 Terminal 18 Digital Input	[8] Start*
5-12 Terminal 27 Digital Input	[7] External interlock
* = Default value	
Notes/comments: D IN 37 is an option.	

Table 4.13 Run/Stop Command with External Interlock



Parameters	
Function	**Setting**
5-10 Terminal 18 Digital Input	[8] Start*
5-12 Terminal 27 Digital Input	[7] External interlock
* = Default value	
Notes/comments: If parameter *5-12 Terminal 27 Digital Input* is set to *[0] no operation*, a jumper wire to terminal 27 is not needed. D IN 37 is an option.	

Table 4.14 Run/Stop Command without External Interlock

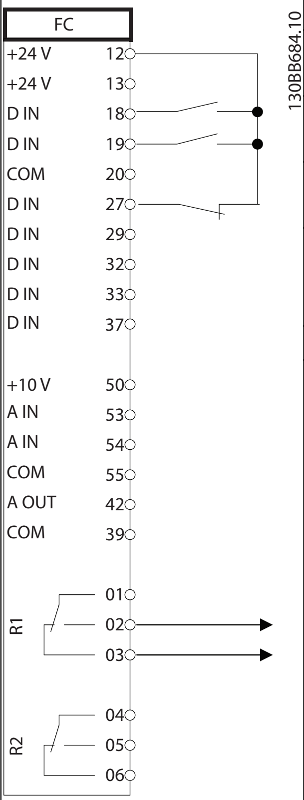
	Parameters	
	**Function**	**Setting**
	5-10 Terminal 18 Digital Input	[8] Start*
	5-11 Terminal 19 Digital Input	[52] Run Permissive
	5-12 Terminal 27 Digital Input	[7] External interlock
	5-40 Function Relay	[167] Start command act.
	* = Default value	
	Notes/comments: D IN 37 is an option.	

Table 4.15 Run Permissive

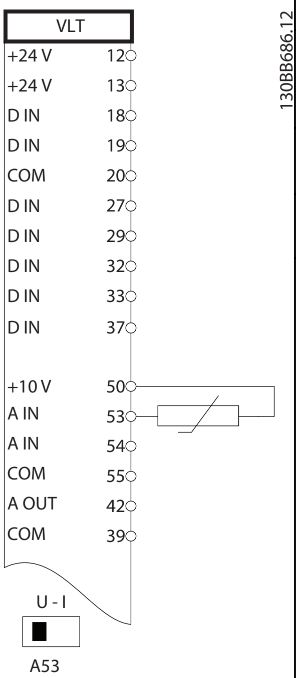
	Parameters	
	**Function**	**Setting**
	1-90 Motor Thermal Protection	[2] Thermistor trip
	1-93 Thermistor Source	[1] Analog input 53
	* = Default Value	
	Notes/comments: If only a warning is desired, parameter *1-90 Motor Thermal Protection* should be set to *[1] Thermistor warning*. D IN 37 is an option.	

Table 4.16 Motor Thermistor

4.3.12 Motor Thermistor

⚠WARNING

THERMISTOR INSULATION

Risk of personal injury or equipment damage.

- **Use only thermistors with reinforced or double insulation to meet PELV insulation requirements.**

5 Special Conditions

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

5.1 Manual Derating

5.1.1 When to Consider Derating

Consider derating when any of the following conditions are present:

- Operating above 1000 m (low air pressure)
- Low-speed operation
- Long motor cables
- Cables with a large cross-section
- High ambient temperature

For more information, refer to *chapter 5.3 Derating for Ambient Temperature*.

5.1.2 Derating for Running at Low Speed

When a motor is connected to a frequency converter, it is necessary to check that the cooling of the motor is adequate.
The level of heating depends on the load on the motor, as well as the operating speed and time.

Constant torque applications (CT mode)
A problem may occur at low RPM values in constant torque applications. In a constant torque application, a motor may overheat at low speeds due to less cooling air from the motor integral fan.
Therefore, if the motor is to be run continuously at an RPM value lower than half the rated value, the motor must be supplied with additional air cooling (or a motor designed for this type of operation may be used).

An alternative is to reduce the load level of the motor by selecting a larger motor. However, the design of the frequency converter puts a limit on the motor size.

Variable (quadratic) torque applications (VT)
In VT applications such as centrifugal pumps and fans, where the torque is proportional to the square of the speed and the power is proportional to the cube of the speed, there is no need for additional cooling or derating of the motor.

5.1.3 Derating for Low Air Pressure

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

Below 1000 m altitude, no derating is necessary. At altitudes above 1000 m, dereate the maximum output current (I_{out}) at ambient temperature (T_{AMB}) in accordance with *Illustration 5.1*. At altitudes above 2000 m, contact Danfoss regarding PELV.

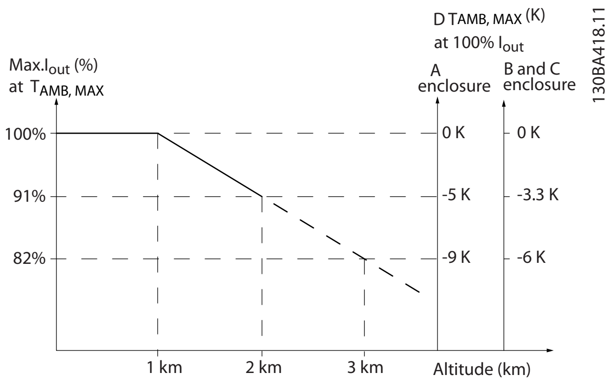


Illustration 5.1 Derating of Output Current versus Altitude at $T_{AMB, MAX}$ for Enclosure Sizes A, B and C.

An alternative is to lower the ambient temperature at high altitudes and thereby ensure 100% output current at high altitudes. As an example of how to read the graph, the situation at 2000 m is elaborated for an enclosure size B with $T_{AMB, MAX}$ = 50 °C. At a temperature of 45 °C ($T_{AMB, MAX}$ - 3.3 K), 91% of the rated output current is available. At a temperature of 41.7 °C, 100% of the rated output current is available.

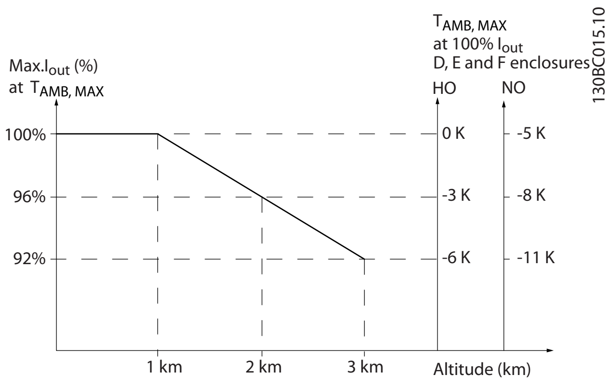


Illustration 5.2 Derating of Output Current versus Altitude at $T_{AMB, MAX}$ for Enclosure Sizes D3h.

5.2 Derating for Long Motor Cables or Cables with Larger Cross-Section

NOTICE

Applicable for frequency converters up to 90 kW only.
The maximum cable length for this frequency converter is 300 m unscreened and 150 m screened cable.
The frequency converter has been designed to work using a motor cable with a rated cross-section. If a cable with a larger cross-section is used, reduce the output current by 5% for every step the cross-section is increased.
Increased cable cross-section leads to increased capacity to earth, and thus an increased earth leakage current.

5.3 Derating for Ambient Temperature

The average temperature ($T_{AMB, AVG}$) measured over 24 hours must be at least 5 °C lower than the maximum permitted ambient temperature ($T_{AMB,MAX}$). If the frequency converter operates at high ambient temperatures, then decrease the continuous output current. Derating depends on the switching pattern, which can be set to 60° AVM or SFAVM in *14-00 Switching Pattern*.

5.3.1 Derating for Ambient Temperature, Enclosure Size A

60° AVM – Pulse Width Modulation

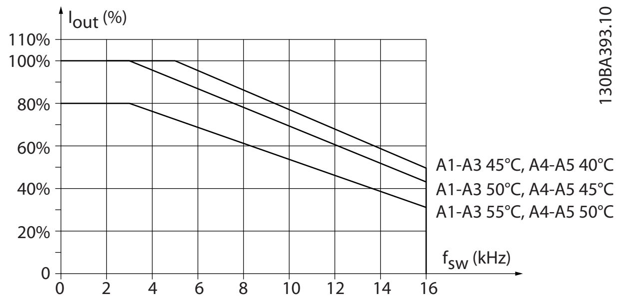


Illustration 5.3 Derating of I_{out} for Different $T_{AMB, MAX}$ for Enclosure Size A, using 60° AVM

SFAVM – Stator Frequency Asyncron Vector Modulation

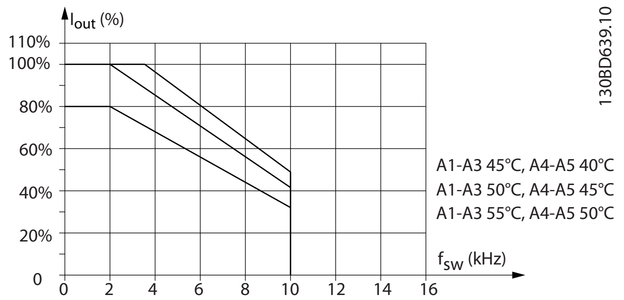


Illustration 5.4 Derating of I_{out} for Different $T_{AMB, MAX}$ for Enclosures Type A, using SFAVM

When using only 10 m motor cable or less in enclosure size A, less derating is necessary. This is due to the fact that the length of the motor cable has a relatively high impact on the recommended derating.

60° AVM

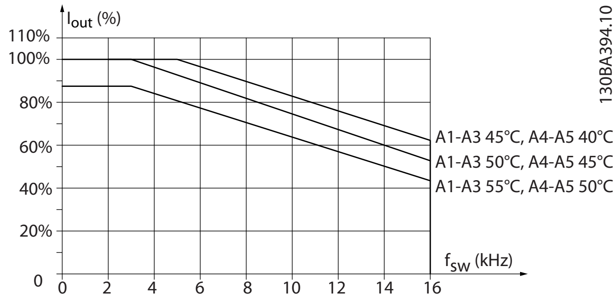


Illustration 5.5 Derating of I_{out} for Different $T_{AMB, MAX}$ for Enclosures Type A, using 60° AVM and Maximum 10 m Motor Cable

SFAVM

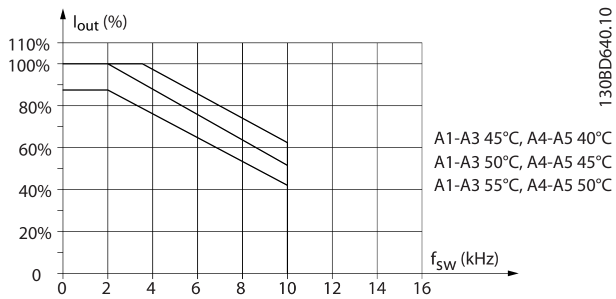


Illustration 5.6 Derating of I_{out} for Different $T_{AMB, MAX}$ for Enclosures Type A, using SFAVM and Maximum 10 m Motor Cable

5.3.2 Derating for Ambient Temperature, Enclosure Size B

Enclosure B, T2, and T4
60° AVM – Pulse Width Modulation

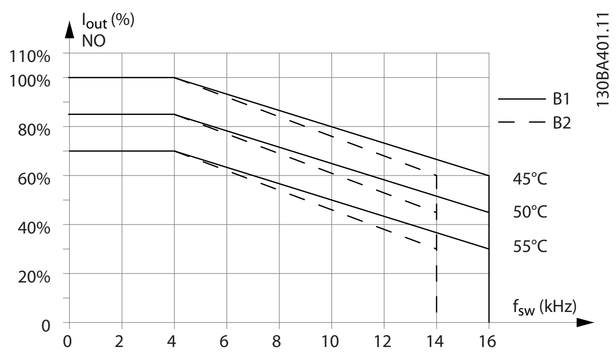


Illustration 5.7 Derating of I_{out} for different $T_{AMB, MAX}$ for Enclosure Sizes B1 and B2, using 60° AVM in Normal Overload Mode (110% Overtorque)

5

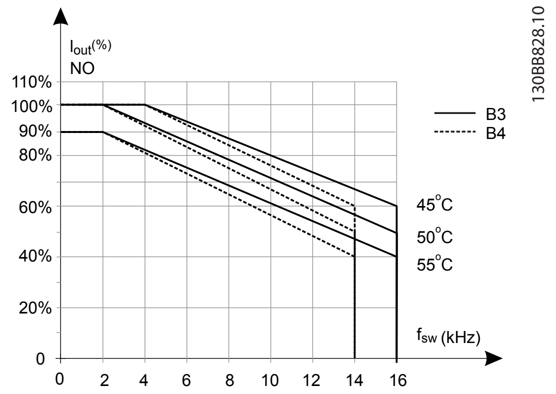


Illustration 5.8 Derating of I_{out} for Different $T_{AMB, MAX}$ for Enclosure Sizes B3 and B4, using 60° AVM in Normal Overload Mode (110% Overtorque)

SFAVM – Stator Frequency Asyncron Vector Modulation

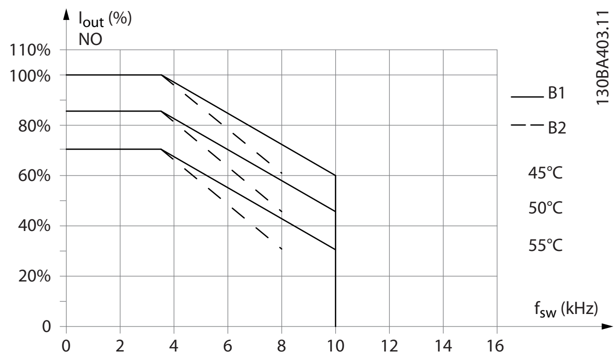


Illustration 5.9 Derating of I_{out} for different $T_{AMB, MAX}$ for Enclosure Sizes B1 and B2, using SFAVM in Normal Overload Mode (110% Overtorque)

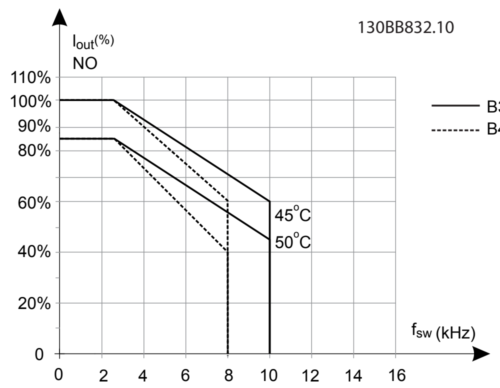


Illustration 5.10 Derating of I_{out} for different $T_{AMB, MAX}$ for Enclosure Sizes B3 and B4, using SFAVM in Normal Overload Mode (110% Overtorque)

Enclosures B, T6

60° AVM – Pulse Width Modulation

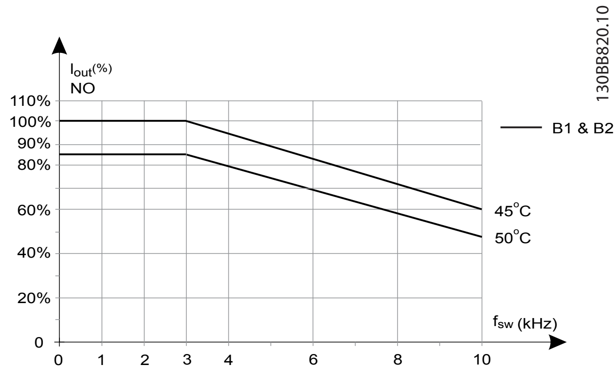


Illustration 5.11 Output Current Derating with Switching Frequency and Ambient Temperature for 600 V Frequency Converters, Enclosure Sizes B, 60 AVM, NO

SFAVM – Stator Frequency Asyncron Vector Modulation

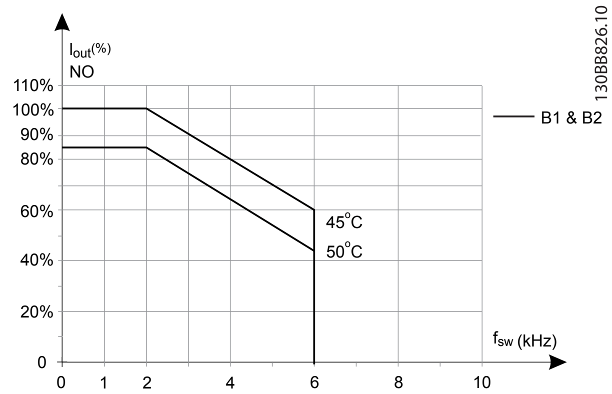


Illustration 5.12 Output Current Derating with Switching Frequency and Ambient Temperature for 600 V Frequency Converters, Enclosure Size B; SFAVM, NO

Enclosures B, T7
Enclosures B2 and B4, 525-690 V
60° AVM – Pulse Width Modulation

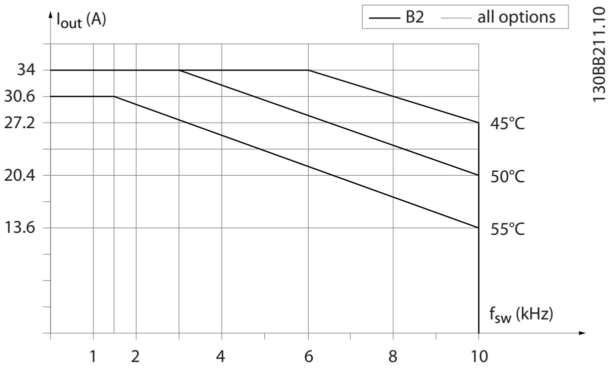


Illustration 5.13 Output Current Derating with Switching Frequency and Ambient Temperature for Enclosure Sizes B2 and B4, 60° AVM.

SFAVM – Stator Frequency Asyncron Vector Modulation

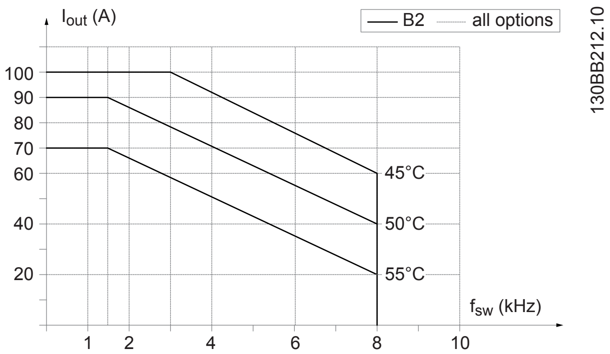


Illustration 5.14 Output Current Derating with Switching Frequency and Ambient Temperature for Enclosure Sizes B2 and B4, SFAVM.

5.3.3 Derating for Ambient Temperature, Enclosure Size C

Enclosures C, T2, and T4
60° AVM – Pulse Width Modulation

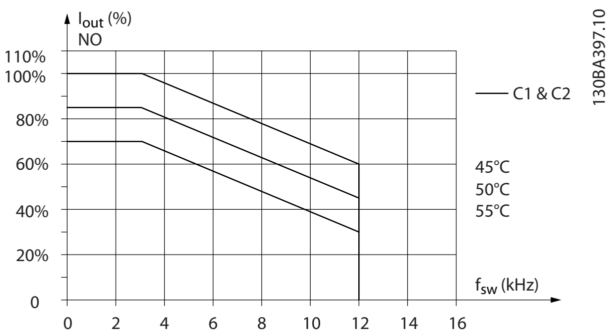


Illustration 5.15 Derating of I_{out} for Different $T_{AMB, MAX}$ for Enclosure Sizes C1 and C2, using 60° AVM in Normal Overload Mode (110% Over Torque)

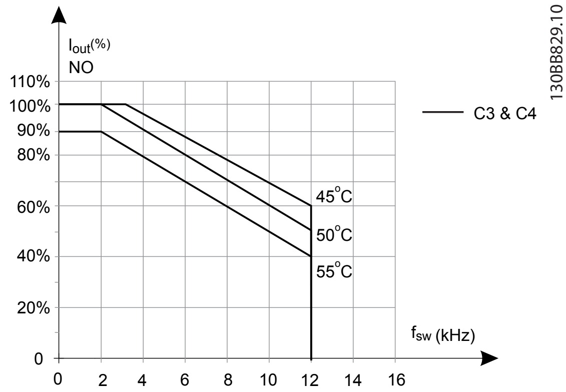


Illustration 5.16 Derating of I_{out} for Different $T_{AMB, MAX}$ for Enclosure Sizes C3 and C4, using 60° AVM in Normal Overload Mode (110% Over Torque)

SFAVM – Stator Frequency Asyncron Vector Modulation

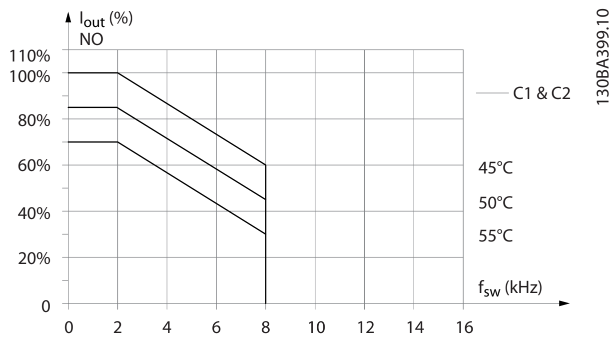


Illustration 5.17 Derating of I_{out} for Different $T_{AMB, MAX}$ for Enclosure Sizes C1 and C2, using SFAVM in Normal Overload Mode (110% Over Torque)

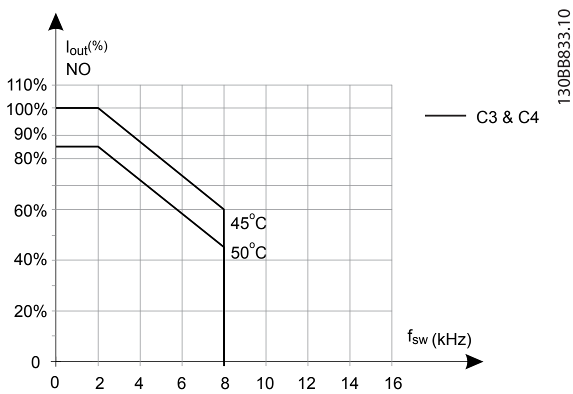


Illustration 5.18 Derating of I_{out} for Different $T_{AMB, MAX}$ for Enclosure Sizes C3 and C4, using SFAVM in Normal Overload Mode (110% Over Torque)

5

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Enclosure Sizes C, T6

60° AVM – Pulse Width Modulation

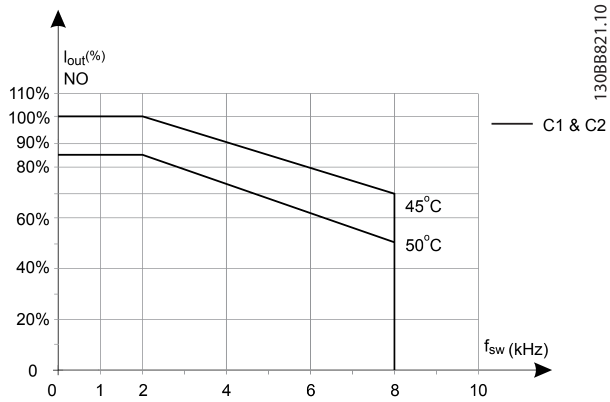

Illustration 5.19 Output Current Derating with Switching Frequency and Ambient Temperature for 600 V Frequency Converters, Enclosure Sizes C, 60 AVM, NO

SFAVM – Stator Frequency Asyncron Vector Modulation

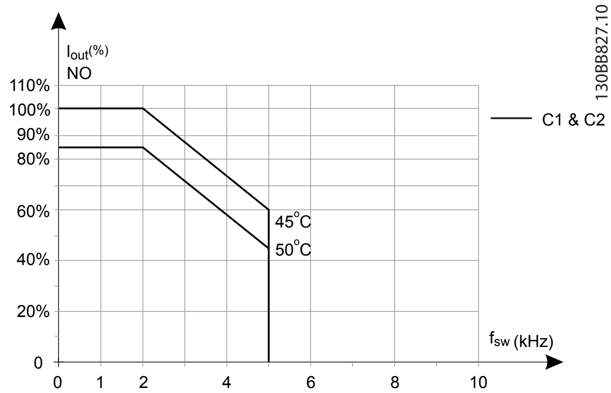

Illustration 5.20 Output Current Derating with Switching Frequency and Ambient Temperature for 600 V Frequency Converters, Enclosure Sizes C; SFAVM, NO

Enclosure Size C, T7

60° AVM – Pulse Width Modulation

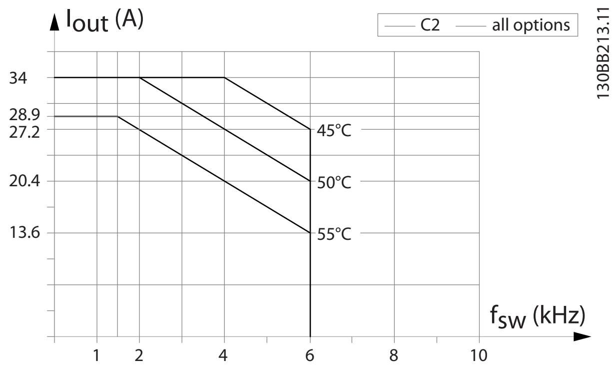

Illustration 5.21 Output Current Derating with Switching Frequency and Ambient Temperature for Enclosure Size C2, 60° AVM.

SFAVM – Stator Frequency Asyncron Vector Modulation

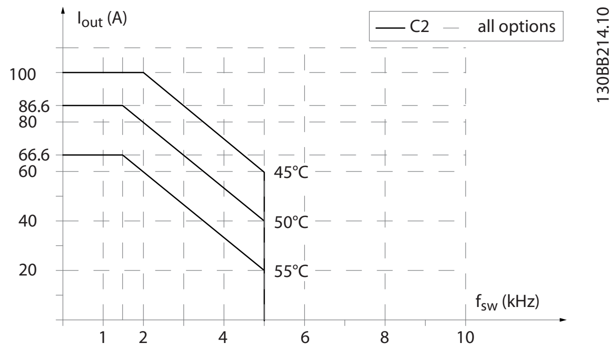

Illustration 5.22 Output Current Derating with Switching Frequency and Ambient Temperature for Enclosure Size C2, SFAVM.

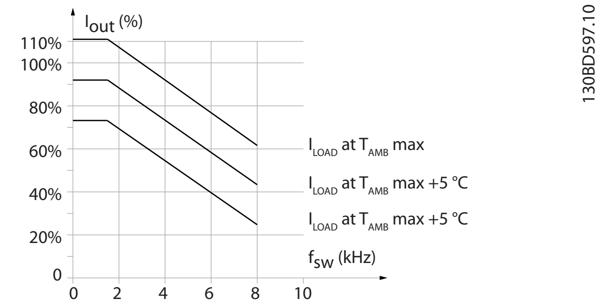

Illustration 5.23 Output Current Derating with Switching Frequency and Ambient Temperature for Enclosure Size C3

6 Typecode and Selection

6.1 Ordering

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	-				P				T											X	X	S	X	X	X	X	A		B		C					D	

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Illustration 6.1 Type Code Example

Configure the right frequency converter for the right application from the internet-based drive configurator and generate the type code string. The drive configurator automatically generates an 8-digit ordering number for delivery to the local sales office.
The Drive Configurator can also establish a project list with several products and send it to a Danfoss sales representative.

6.1.1 Type Code

An example of the type code is:

FC-202PK75T4E20H1BGCXXXSXXXXA0BXCXXXXD0

The meaning of the characters in the string can be found in *Table 6.1* and *Table 6.2*. In the example above, a PROFIBUS DP V1 and a 24 V back-up option are built-in.

Description	Position	Possible choices[1)]
Product group	1-2	FC
Drive series	4-6	202: FC 202
Power rating	8-10	0.25–90 kW
Phases	11	S: Single phase T: Three phases
Mains voltage	12	2: 200–240 V 4: 380–480 V 6: 525–600 V 7: 525–690 V
Enclosure	13-15	E20: IP20 E55: IP 55/NEMA Type 12 P20: IP20 (with back plate) P21: IP21/NEMA Type 1 (with back plate) P55: IP55/NEMA Type 12 (with back plate) Z20: IP 20[1)] E66: IP 66

Description	Position	Possible choices[1)]
RFI filter	16-17	Hx: No EMC filters built into the frequency converter H1: Integrated EMC filter. Fulfill EN 55011 Class A1/B and EN/IEC 61800-3 Category 1/2 H2: No additional EMC filter. Fulfill EN 55011 Class A2 and EN/IEC 61800-3 Category 3 H3: Integrated EMC filter. Fulfill EN 55011 class A1/B and EN/IEC 61800-3 Category 1/2 H4: Integrated EMC filter. Fulfill EN 55011 class A1 and EN/IEC 61800-3 Category 2 H5: Marine versions. Fulfill same emissions levels as H2 versions
Brake	18	B: Brake chopper included X: No brake chopper included T: Safe torque off No brake[1)] U: Safe torque off brake chopper[1)]
Display	19	G: Graphical local control panel (LCP) N: Numerical local control panel (LCP) X: No local control panel
Coating PCB	20	C: Coated PCB R: Coated PCB + Ruggedised X: No coated PCB
Mains option	21	X: No mains option 1: Mains disconnect 3: Mains disconnect and fuse 5: Mains disconnect, Fuse and load sharing 7: Fuse 8: Mains disconnect and load sharing A: Fuse and load sharing D: Load sharing
Adaptation	22	X: Standard cable entries O: European metric thread in cable entries S: Imperial cable entries
Adaptation	23	X: No adaptation

6

Description	Position	Possible choices[1)]
Software release	24-27	SXXX: Latest release – standard software
Software language	28	X: Not used

Table 6.1 Ordering Type Code

1) Some of the available choices depend on the enclosure size.

2) Only available for frequency converters ≥75 kW.

3) Only available for frequency converters ≥355 kW.

Description	Position	Possible choices
A options	29-30	AX: No A option A0: MCA 101 PROFIBUS DP V1 (standard) A4: MCA 104 DeviceNet (standard) AN: MCA 121 Ethernet IP AL: MCA 120 ProfiNet AQ: MCA 122 Modbus TCP
B options	31-32	BX: No option BY: MCO 101 extended cascade control BK: MCB 101 general purpose I/O option BP: MCB 105 relay option B0: MCB 109 I/O option with RTC back-up B2: MCB 112 PTC thermistor card B4: MCB 114 VLT sensor input
C0 options	33-34	CX: No option
C1 options	35	X: No option R: MCB 113 Ext. relay card 5: MCO 102 Advanced cascade control
C option software	36-37	XX: Standard controller
D options	38-39	DX: No option D0: Extended 24 V DC back-up

Table 6.2 Ordering Type Code, Options

NOTICE

For power sizes over 90 kW, see the *VLT® AQUA Drive FC 202 110-1400 kW Design Guide*.

6

6.1.2 Software Language

The frequency converter is automatically delivered with a software language package relevant to the region from which it is ordered. The regional language packages are listed in *Table 6.3*.

Language package 1			**Language package 2**
Brazilian Portuguese	Finnish	Russian	Bahasa Indonesian
Bulgarian	French	Spanish	Chinese
Croatian	German	Serbian	Chinese, traditional
Czech	Greek	Slovenian	German
Danish	Hungarian	Spanish	Japanese
Dutch	Italian	Swedish	Korean
English	Polish	Turkish	Russian
English, US	Romanian	-	Thai

Table 6.3 Software Language Packages

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

6.2 Options, Accessories, and Spare Parts

6.2.1 Options and Accessories

Description	**Ordering no.**	
	Uncoated	**Coated**
Miscellaneous hardware		
VLT® Panel through kit enclosure size A5	130B1028	
VLT® Panel through kit enclosure size B1	130B1046	
VLT® Panel through kit enclosure size B2	130B1047	
VLT® Panel through kit enclosure size C1	130B1048	
VLT® Panel through kit enclosure size C2	130B1049	
VLT® Mounting brackets for enclosure size A5	130B1080	
VLT® Mounting brackets for enclosure size B1	130B1081	
VLT® Mounting brackets for enclosure size B2	130B1082	
VLT® Mounting brackets for enclosure size C1	130B1083	
VLT® Mounting brackets for enclosure size C2	130B1084	
VLT® IP 21/NEMA Type 1 kit, enclosure size A1	130B1121	
VLT® IP 21/NEMA Type 1 kit, enclosure size A2	130B1122	
VLT® IP 21/NEMA Type 1 kit, enclosure size A3	130B1123	
VLT® IP 21/NEMA Type 1 Top kit, enclosure size A2	130B1132	
VLT® IP 21/NEMA Type 1 Top kit, enclosure size A3	130B1133	
VLT® Back plate IP55/NEMA Type12, enclosure size A5	130B1098	
VLT® Back plate IP21/NEMA Type 1, IP55/NEMA Type 12, enclosure size B1	130B3383	
VLT® Back plate IP21/NEMA Type 1, IP55/NEMA Type 12, enclosure size B2	130B3397	
VLT® Back plate IP20/Type 1, enclosure size B4	130B4172	
VLT® Back plate IP21/NEMA Type 1, IP55/NEMA Type 12, enclosure size C1	130B3910	
VLT® Back plate IP21/NEMA Type 1, IP55/NEMA Type 12, enclosure size C2	130B3911	
VLT® Back plate IP20/NEMA Type 1, enclosure size C3	130B4170	
VLT® Back plate IP20/NEMA Type 1, enclosure size C4	130B4171	
VLT® Back plate IP66/NEMA Type 4X, enclosure size A5	130B3242	
VLT® Back plate in stainless steel IP66/NEMA Type 4X, enclosure size B1	130B3434	
VLT® Back plate in stainless steel IP66/NEMA Type 4X, enclosure size B2	130B3465	
VLT® Back plate in stainless steel IP66/NEMA Type 4X, enclosure size C1	130B3468	

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Description	Ordering no.	
	Uncoated	Coated
VLT® Back plate in stainless steel IP66/NEMA Type 4X, enclosure size C2	130B3491	
VLT® Profibus adapter Sub-D9 connector	130B1112	
Profibus screen plate kit for IP20, enclosure sizes A1, A2 and A3	130B0524	
Terminal block for DC link connection on enclosure sizes A2/A3	130B1064	
VLT® Screw terminals	130B1116	
VLT® USB extension, 350 mm cable	130B1155	
VLT® USB extension, 650 mm cable	130B1156	
VLT® Back frame A2 for 1 brake resistor	175U0085	
VLT® Back frame A3 for 1 brake resistor	175U0088	
VLT® Back frame A2 for 2 brake resistors	175U0087	
VLT® Back A3 for 2 brake resistors	175U0086	
Local Control Panel		
VLT® LCP 101 Numeric local contral pad	130B1124	
VLT® LCP 102 Graphical local control pad	130B1107	
VLT® Cable for LCP 2, 3 m	175Z0929	
VLT® Panel mounting kit for all LCP types	130B1170	
VLT® Panel mounting kit, graphical LCP	130B1113	
VLT® Panel mounting kit, numerical LCP	130B1114	
VLT® LCP mounting kit, no LCP	130B1117	
VLT® LCP mounting kit blind cover IP55/66, 8 m	130B1129	
VLT® Control Panel LCP 102, graphical	130B1078	
VLT® Blindcover, with Danfoss logo, IP55/66	130B1077	
Options for slot A		
VLT® PROFIBUS DP V1 MCA 101	130B1100	130B1200
VLT® DeviceNet MCA 104	130B1102	130B1202
VLT® Profinet MCA 120	130B1135	130B1235
VLT® Ethernet/IP MCA 121	130B1119	130B1219
VLT® Modbus TCP MCA 122	130B1196	130B1296
Options for slot B		
VLT® General purpose I/O MCB 101	130B1125	130B1212
VLT® Relay option MCB 105	130B1110	130B1210
VLT® PTC thermistor card MCB 112		130B1137
VLT® Extended cascade controller MCO 101	130B1118	130B1218
VLT® Sensor input option MCB 114	130B1172	130B1272
VLT® Analog I/O option with RTC MCB 109	130B1143	130B1243
Mounting kits for C options		
VLT® Mounting kit for C option, 40 mm, enclosure sizes A2/A3	130B7530	
VLT® Mounting kit for C option, 60 mm, enclosure sizes A2/A3	130B7531	
VLT® Mounting kit for C option, enclosure size A5	130B7532	
VLT® Mounting kit for C option, enclosure sizes B/C/D/E/F (except B3)	130B7533	
VLT® Mounting kit for C option, 40 mm, enclosure size B3	130B1413	
VLT® Mounting kit for C option, 60 mm, enclosure size B3	130B1414	
Options for slot C		
VLT® Advanced cascade controller MCO102	130B1154	130B1254
VLT® Extended relay card MCB 113	130B1164	130B1264
Option for slot D		
VLT® 24 V DC supply MCB 107	130B1108	130B1208
Leakage current monitor kits		
VLT® Leakage current monitor kit, enclosure sizes A2/A3	130B5645	

Description	Ordering no.	
	Uncoated	Coated
VLT® Leakage current monitor kit, enclosure size B3	130B5764	
VLT® Leakage current monitor kit, enclosure size B4	130B5765	
VLT® Leakage current monitor kit, enclosure size C3	130B6226	
VLT® Leakage current monitor kit, enclosure size C4	130B5647	
PC Software		
MCT 10 Set-up Software, 1 license	130B1000	
MCT 10 Set-up Software, 5 licenses	130B1001	
MCT 10 Set-up Software, 10 licenses	130B1002	
MCT 10 Set-up Software, 25 licenses	130B1003	
MCT 10 Set-up Software, 50 licenses	130B1004	
MCT 10 Set-up Software, 100 licenses	130B1005	
MCT 10 Set-up Software, >100 licenses	130B1006	
Options can be ordered as factory built-in options, see ordering information, *chapter 6.1 Ordering*.		

Table 6.4 Ordering Numbers for Options and Accessories

6.2.2 Spare Parts

6.2.3 Accessory Bags

Type	Description	Ordering no.
Accessory bags		
Accessory bag A1	Accessory bag, enclosure size A1	130B1021
Accessory bag A2/A3	Accessory bag, enclosure size A2/A3	130B1022
Accessory bag A5	Accessory bag, enclosure size A5	130B1023
Accessory bag A1–A5	Accessory bag, enclosure size A1-A5 Brake and load sharing connector	130B0633
Accessory bag B1	Accessory bag, enclosure size B1	130B2060
Accessory bag B2	Accessory bag, enclosure size B2	130B2061
Accessory bag B3	Accessory bag, enclosure size B3	130B0980
Accessory bag B4	Accessory bag, enclosure size B4, 18.5-22 kW	130B1300
Accessory bag B4	Accessory bag, enclosure size B4, 30 kW	130B1301
Accessory bag C1	Accessory bag, enclosure size C1	130B0046
Accessory bag C2	Accessory bag, enclosure size C2	130B0047
Accessory bag C3	Accessory bag, enclosure size C3	130B0981
Accessory bag C4	Accessory bag, enclosure size C4, 55 kW	130B0982
Accessory bag C4	Accessory bag, enclosure size C4, 75 kW	130B0983

Table 6.5 Ordering Numbers for Accessory Bags

6.2.4 Brake Resistor Selection

When the speed reference of a frequency converter is reduced, the motor acts as a generator and the frequency converter brakes. When a motor acts as a generator, it supplies energy to the frequency converter which is collected in the DC link. The function of the brake resistor is to provide a load on the DC link during braking, thereby ensuring that the braking power is absorbed by the brake resistor.

If a brake resistor is not used, the DC-link voltage of the frequency converter continues to increase, until disconnecting for protection. The advantage of using a brake resistor is that it enables braking of a heavy load quickly, e.g. on a conveyor belt.

The brake resistors in this series are all external components. Therefore, the brake resistor does not form an integral part of the frequency converter.
The external brake resistor provides the following advantages:

- The resistor time cycle can be selected as required.
- The heat developed during braking can be conveyed beyond the panel cabinet to allow the energy to be used.
- The electronic components do not overheat, even when the brake resistor is overloaded.

Recommended brake resistors are listed in *chapter 6.2.5 Recommended Brake Resistors* and *chapter 6.2.6 Alternative Brake Resistors, T2 and T4*. For more information, see the *VLT® Brake Resistor MCE 101 Design Guide*.

Horizontal and Vertical Loads
The Danfoss brake resistor range consists of 2 groups:

- Brake resistors for horizontal loads (conveyors, trolleys, gantry cranes, etc.), see *Illustration 6.2*;
- Brake resistors for vertical loads (cranes, hoists, elevators), see *Illustration 6.3*.

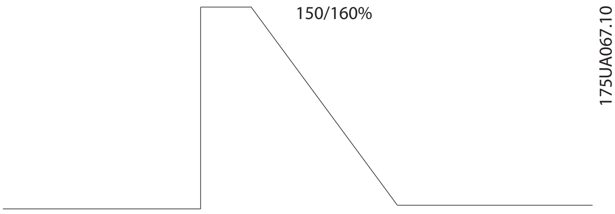

Illustration 6.2 Horizontal Loads

Illustration 6.3 Vertical Loads

The brake resistor range is intended to cover the general braking requirements for horizontal and vertical brake applications.

To cater for both the horizontal and vertical ranges, 3 types of brake resistors are available:

- Aluminium-housed flat-pack brake resistors
- Aluminium-housed compact brake resistors
- Steel grid brake resistors

See *chapter 6.2.5 Recommended Brake Resistors* and *chapter 6.2.6 Alternative Brake Resistors, T2 and T4* for ordering information.

6.2.5 Recommended Brake Resistors

Mains	Voltage class
P_m	Rated motor size for frequency converter type
R_{min}	Minimum permissible brake resistor by frequency converter
R_{rec}	Recommended brake resistor resistance of Danfoss brake resistors
Thermo relay	Brake current setting of external thermo relay
Part number	Danfoss brake resistor order numbers
Cable cross section	Recommended minimum value based upon PVC insulated copper cable. 30 °C ambient temperature with normal heat dissipation
$P_{br,cont.}$	Brake resistor average rated power. The temperature switch enables at approximate 90% of continuous rated power at brake resistors with IP54, IP21 and IP65 enclosure protection
$R_{br,nom}$	The nominal (calculated) resistor value to ensure a brake power on motor shaft of 150/160/110% for 1 minute

Table 6.6 Abbreviations used in *Table 6.7* to *Table 6.14*

10% duty cycle, horizontal braking, T2

FC 202				Horizontal braking 10% duty cycle							
Frequency converter data				Brake resistor data						Installation	
						Danfoss part number				Cable cross-section	Thermo relay
Mains type	P_m [kW]	R_{min} [Ω]	$R_{br,nom}$ [Ω]	R_{rec} [Ω]	$P_{br,cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20	[mm²]	[A]
T2	0.25	380	691.3	630	0.100	175u3002	-	-	-	1.5	0.4
T2	0.37	380	466.7	410	0.100	175u3004	-	-	-	1.5	0.5
T2	0.55	275	313.7	300	0.100	175u3006	-	-	-	1.5	0.6
T2	0.75	188	230.0	200	0.100	175u3011	-	-	-	1.5	0.7
T2	1.1	130	152.9	145	0.100	175u3016	-	-	-	1.5	0.8
T2	1.5	81.0	110.5	100	0.100	175u3021	-	-	-	1.5	0.9
T2	2.2	58.5	74.1	70	0.200	175u3026	-	-	-	1.5	1.6
T2	3	45.0	53.7	48	0.200	175u3031	-	-	-	1.5	1.9
T2	3.7	31.5	39.9	35	0.300	175u3325	-	-	-	1.5	2.7
T2	5.5	22.5	28.7	27	0.360	175u3326	175u3477	175u3478	-	1.5	3.5
T2	7.5	17.7	20.8	18	0.570	175u3327	175u3442	175u3441	-	1.5	5.3
T2	11	12.6	14.0	13	0.680	175u3328	175u3059	175u3060	-	1.5	6.8
T2	15	8.7	10.2	9.0	1.130	175u3329	175u3068	175u3069	-	2.5	10.5
T2	18.5	5.3	8.2	5.7	1.400	175u3330	175u3073	175u3074	-	4	15
T2	22	5.1	6.9	5.7	1.700	175u3331	175u3483	175u3484	-	4	16
T2	30	3.2	5.0	3.5	2.200	175u3332	175u3080	175u3081	-	6	24
T2	37	3.0	4.1	3.5	2.800	175u3333	175u3448	175u3447	-	10	27
T2	45	2.4	3.3	2.8	3.200	175u3334	175u3086	175u3087	-	16	32

Table 6.7 T2, Horizontal Braking 10% Duty Cycle, Recommended Brake Resistors

40% duty cycle, vertical braking, T2

FC 202				Vertical braking 40% duty cycle							
Frequency converter data				Brake resistor data						Installation	
						Danfoss part number				Cable cross-section	Thermo relay
Mains type	P_m [kW]	R_{min} [Ω]	$R_{br,nom}$ [Ω]	R_{rec} [Ω]	$P_{br,cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20	[mm²]	[A]
T2	0.25	380	691.3	630	0.100	175u3002	-	-	-	1.5	0.4
T2	0.37	380	466.7	410	0.100	175u3004	-	-	-	1.5	0.5
T2	0.55	275	313.7	300	0.200	175u3096	-	-	-	1.5	0.8
T2	0.75	188	230.0	200	0.200	175u3008	-	-	-	1.5	0.9
T2	1.1	130	152.9	145	0.300	175u3300	-	-	-	1.5	1.3
T2	1.5	81.0	110.5	100	0.450	175u3301	175u3402	175u3401	-	1.5	2
T2	2.2	58.5	74.1	70	0.570	175u3302	175u3404	175u3403	-	1.5	2.7
T2	3	45.0	53.7	48	0.960	175u3303	175u3406	175u3405	-	1.5	4.2
T2	3.7	31.5	39.9	35	1.130	175u3304	175u3408	175u3407	-	1.5	5.4
T2	5.5	22.5	28.7	27	1.400	175u3305	175u3410	175u3409	-	1.5	6.8
T2	7.5	17.7	20.8	18	2.200	175u3306	175u3412	175u3411	-	1.5	10.4
T2	11	12.6	14.0	13	3.200	175u3307	175u3414	175u3413	-	2.5	14.7
T2	15	8.7	10.2	9.0	5.500	-	175u3176	175u3177	-	4	23
T2	18.5	5.3	8.2	5.7	6.000	-	-	-	175u3233	10	33
T2	22	5.1	6.9	5.7	8.000	-	-	-	175u3234	10	38
T2	30	3.2	5.0	3.5	9.000	-	-	-	175u3235	16	51
T2	37	3.0	4.1	3.5	14.000	-	-	-	175u3224	25	63
T2	45	2.4	3.3	2.8	17.000	-	-	-	175u3227	35	78

Table 6.8 T2, Vertical Braking 40% Duty Cycle, Recommended Brake Resistors

10% duty cycle, horizontal braking, T4

FC 202				Horizontal braking 10% duty cycle							
Frequency converter data				Brake resistor data						Installation	
						Danfoss part number				Cable cross-section	Thermo relay
Mains type	P_m [kW]	R_{min} [Ω]	$R_{br,nom}$ [Ω]	R_{rec} [Ω]	$P_{br,cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20	[mm²]	[A]
T4	0.37	1000	1864.2	1200	0.100	175u3000	-	-	-	1.5	0.3
T4	0.55	1000	1246.3	1200	0.100	175u3000	-	-	-	1.5	0.3
T4	0.75	620	910.2	850	0.100	175u3001	-	-	-	1.5	0.4
T4	1.1	546	607.3	630	0.100	175u3002	-	-	-	1.5	0.4
T4	1.5	382	437.3	410	0.100	175u3004	-	-	-	1.5	0.5
T4	2.2	260	293.3	270	0.200	175u3007	-	-	-	1.5	0.8
T4	3	189	212.7	200	0.200	175u3008	-	-	-	1.5	0.9
T4	4	135	157.3	145	0.300	175u3300	-	-	-	1.5	1.3
T4	5.5	99.0	113.3	110	0.450	175u3335	175u3450	175u3449	-	1.5	1.9
T4	7.5	72.0	82.4	80	0.570	175u3336	175u3452	175u3451	-	1.5	2.5
T4	11	50.0	55.3	56	0.680	175u3337	175u3027	175u3028	-	1.5	3.3
T4	15	36.0	40.3	38	1.130	175u3338	175u3034	175u3035	-	1.5	5.2
T4	18.5	27.0	32.5	28	1.400	175u3339	175u3039	175u3040	-	1.5	6.7
T4	22	20.3	27.2	22	1.700	175u3340	175u3047	175u3048	-	1.5	8.3
T4	30	18.0	19.8	19	2.200	175u3357	175u3049	175u3050	-	1.5	10.1
T4	37	13.4	16.0	14	2.800	175u3341	175u3055	175u3056	-	2.5	13.3
T4	45	10.8	13.1	12	3.200	175u3359	175u3061	175u3062	-	2.5	15.3
T4	55	8.8	10.7	9.5	4.200	-	175u3065	175u3066	-	4	20
T4	75	6.5	7.8	7.0	5.500	-	175u3070	175u3071	-	6	26
T4	90	4.2	6.5	5.5	7.000	-	-	-	175u3231	10	36
T4	110	3.6	5.3	4.7	9.000	-	-	-	175u3079	16	44
T4	132	3.0	4.4	3.7	11.000	-	-	-	175u3083	25	55
T4	160	2.5	3.6	3.3	13.000	-	-	-	175u3084	35	63
T4	200	2.0	2.9	2.7	16.000	-	-	-	175u3088	50	77
T4	250	1.6	2.3	2.1	20.000	-	-	-	175u3091	70	98
T4	315	1.2	1.8	1.7	26.000	-	-	-	175u3093	2 x 35	124
T4	355	1.2	1.6	1.3	32.000	-	-	-	175u3097	2 x 35	157
T4	400	1.2	1.4	1.2	36.000	-	-	-	175u3098	2 x 50	173
T4	450	1.1	1.3	1.1	42.000	-	-	-	175u3099	2 x 50	196
T4	500	0.9	1.1	2 x 1.9	-	-	-	-	-	-	-
T4	560	0.9	1.0	2 x 1.7	-	-	-	-	-	-	-
T4	630	0.8	0.9	2 x 1.5	-	-	-	-	-	-	-
T4	710	0.7	0.8	2 x 1.3	-	-	-	-	-	-	-
T4	800	0.6	0.7	3 x 1.8	-	-	-	-	-	-	-
T4	1000	0.5	0.6	3 x 1.6	-	-	-	-	-	-	-

Table 6.9 T4, Horizontal Braking 10% Duty Cycle, Recommended Brake Resistors

40% duty cycle, vertical braking, T4

FC 202				Vertical braking 40% duty cycle							
Frequency converter data				Brake resistor data						Installation	
						Danfoss part number				Cable cross-section	Thermo relay
Mains type	P_m [kW]	R_{min} [Ω]	$R_{br,nom}$ [Ω]	R_{rec} [Ω]	$P_{br,cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20	[mm²]	[A]
T4	0.37	1000	1864.2	1200	0.200	175u3101	-	-	-	1.5	0.4
T4	0.55	1000	1246.3	1200	0.200	175u3101	-	-	-	1.5	0.4
T4	0.75	620	910.2	850	0.200	175u3308	-	-	-	1.5	0.5
T4	1.1	546	607.3	630	0.300	175u3309	-	-	-	1.5	0.7
T4	1.5	382	437.3	410	0.450	175u3310	175u3416	175u3415	-	1.5	1
T4	2.2	260	293.3	270	0.570	175u3311	175u3418	175u3417	-	1.5	1.4
T4	3	189	212.7	200	0.960	175u3312	175u3420	175u3419	-	1.5	2.1
T4	4	135	157.3	145	1.130	175u3313	175u3422	175u3421	-	1.5	2.7
T4	5.5	99.0	113.3	110	1.700	175u3314	175u3424	175u3423	-	1.5	3.7
T4	7.5	72.0	82.4	80	2.200	175u3315	175u3138	175u3139	-	1.5	5
T4	11	50.0	55.3	56	3.200	175u3316	175u3428	175u3427	-	1.5	7.1
T4	15	36.0	40.3	38	5.000	-	-	-	175u3236	1.5	11.5
T4	18.5	27.0	32.5	28	6.000	-	-	-	175u3237	2.5	14.7
T4	22	20.3	27.2	22	8.000	-	-	-	175u3238	4	19
T4	30	18.0	19.8	19	10.000	-	-	-	175u3203	4	23
T4	37	13.4	16.0	14	14.000	-	-	-	175u3206	10	32
T4	45	10.8	13.1	12	17.000	-	-	-	175u3210	10	38
T4	55	8.8	10.7	9.5	21.000	-	-	-	175u3213	16	47
T4	75	6.5	7.8	7.0	26.000	-	-	-	175u3216	25	61
T4	90	4.2	6.5	5.5	36.000	-	-	-	175u3219	35	81
T4	110	3.6	5.3	4.7	42.000	-	-	-	175u3221	50	95
T4	132	3.0	4.4	3.7	52.000	-	-	-	175u3223	70	119
T4	160	2.5	3.6	3.3	60.000	-	-	-	175u3225	2 x 35	135
T4	200	2.0	2.9	2.7	78.000	-	-	-	175u3228	2 x 50	170
T4	250	1.6	2.3	2.1	90.000	-	-	-	175u3230	2 x 70	207
T4	315	1.2	1.8	1.7	-	-	-	-	-	-	-
T4	355	1.2	1.6	1.3	-	-	-	-	-	-	-
T4	400	1.2	1.4	1.2	-	-	-	-	-	-	-
T4	450	1.1	1.3	1.1	-	-	-	-	-	-	-
T4	500	0.9	1.1	2 x 1.9	-	-	-	-	-	-	-
T4	560	0.9	1.0	2 x 1.7	-	-	-	-	-	-	-
T4	630	0.8	0.9	2 x 1.5	-	-	-	-	-	-	-
T4	710	0.7	0.8	2 x 1.3	-	-	-	-	-	-	-
T4	800	0.6	0.7	3 x 1.8	-	-	-	-	-	-	-
T4	1000	0.5	0.6	3 x 1.6	-	-	-	-	-	-	-

Table 6.10 T4, Vertical Braking 40% Duty Cycle, Recommended Brake Resistors

6

10% duty cycle, horizontal braking, T6

FC 202				Horizontal braking 10% duty cycle							
Frequency converter data				Brake resistor data						Installation	
						Danfosspart number				Cable cross-section [mm^2]	Thermo relay [A]
Mains type	P_m [kW]	R_{min} [Ω]	$R_{br,nom}$ [Ω]	R_{rec} [Ω]	$P_{br,cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20		
T6	0.75	620	1329.7	1200	0.100	175u3000	-	-	-	1.5	0.3
T6	1.1	620	889.1	850	0.100	175u3001	-	-	-	1.5	0.4
T6	1.5	550	642.7	570	0.100	175u3003	-	-	-	1.5	0.4
T6	2.2	380	431.1	415	0.200	175u3005	-	-	-	1.5	0.7
T6	3	260	312.5	270	0.200	175u3007	-	-	-	1.5	0.8
T6	4	189	231.6	200	0.300	175u3342	-	-	-	1.5	1.1
T6	5.5	135	166.6	145	0.450	175u3343	175u3012	175u3013	-	1.5	1.7
T6	7.5	99.0	121.1	100	0.570	175u3344	175u3136	175u3137	-	1.5	2.3
T6	11	69.0	81.6	72	0.680	175u3345	175u3456	175u3455	-	1.5	2.9
T6	15	48.6	59.4	52	1.130	175u3346	175u3458	175u3457	-	1.5	4.4
T6	18.5	35.1	47.9	38	1.400	175u3347	175u3460	175u3459	-	1.5	5.7
T6	22	27.0	40.1	31	1.700	175u3348	175u3037	175u3038	-	1.5	7
T6	30	22.5	29.2	27	2.200	175u3349	175u3043	175u3044	-	1.5	8.5
T6	37	17.1	23.6	19	2.800	175u3350	175u3462	175u3461	-	2.5	11.4
T6	45	13.5	19.4	14	3.200	175u3358	175u3464	175u3463	-	2.5	14.2
T6	55	11.7	15.8	13.5	4.200	-	175u3057	175u3058	-	4	17
T6	75	9.9	11.5	11	5.500	-	175u3063	175u3064	-	6	21
T6	90	8.6	9.6	7.0	7.000	-	-	-	175u3245	10	32

Table 6.11 T6, Horizontal Braking 10% Duty Cycle, Recommended Brake Resistors

40% duty cycle, vertical braking, T6

FC 202				Vertical braking 40% duty cycle							
Frequency converter data				Brake resistor data						Installation	
						Danfoss part number				Cable cross-section [mm^2]	Thermo relay [A]
Mains type	P_m [kW]	R_{min} [Ω]	$R_{br,nom}$ [Ω]	R_{rec} [Ω]	$P_{br,cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20		
T6	0.75	620	1329.7	1200	0.360	-	175u3102	175u3103	-	1.5	0.6
T6	1.1	620	889.1	850	0.280	175u3317	175u3104	175u3105	-	1.5	0.6
T6	1.5	550	642.7	570	0.450	175u3318	175u3430	175u3429	-	1.5	0.9
T6	2.2	380	431.1	415	0.570	175u3319	175u3432	175u3431	-	1.5	1.1
T6	3	260	312.5	270	0.960	175u3320	175u3434	175u3433	-	1.5	1.8
T6	4	189	231.6	200	1.130	175u3321	175u3436	175u3435	-	1.5	2.3
T6	5.5	135	166.6	145	1.700	175u3322	175u3126	175u3127	-	1.5	3.3
T6	7.5	99.0	121.1	100	2.200	175u3323	175u3438	175u3437	-	1.5	4.4
T6	11	69.0	81.6	72	3.200	175u3324	175u3440	175u3439	-	1.5	6.3
T6	15	48.6	59.4	52	5.500	-	175u3148	175u3149	-	1.5	9.7
T6	18.5	35.1	47.9	38	6.000	-	-	-	175u3239	2.5	12.6
T6	22	27.0	40.1	31	8.000	-	-	-	175u3240	4	16
T6	30	22.5	29.2	27	10.000	-	-	-	175u3200	4	19
T6	37	17.1	23.6	19	14.000	-	-	-	175u3204	10	27
T6	45	13.5	19.4	14	17.000	-	-	-	175u3207	10	35
T6	55	11.7	15.8	13.5	21.000	-	-	-	175u3208	16	40
T6	75	9.9	11.5	11	26.000	-	-	-	175u3211	25	49
T6	90	8.6	9.6	7.0	30.000	-	-	-	175u3241	35	66

Table 6.12 T6, Vertical Braking 40% Duty Cycle, Recommended Brake Resistors

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10% duty cycle, horizontal braking, T7

FC 202				Horizontal braking 10% duty cycle							
Frequency converter data				Brake resistor data						Installation	
						Danfoss part number				Cable cross-section	Thermo relay
Mains type	P_m [kW]	R_{min} [Ω]	$R_{br,nom}$ [Ω]	R_{rec} [Ω]	$P_{br,cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20	[mm^2]	[A]
T7	1.1	620	830	630	0.100	175u3002	-	-	-	1.5	0.4
T7	1.5	513	600	570	0.100	175u3003	-	-	-	1.5	0.4
T7	2.2	340	403	415	0.200	175u3005	-	-	-	1.5	0.7
T7	3	243	292	270	0.300	175u3361	-	-	-	1.5	1
T7	4	180	216	200	0.360	-	175u3009	175u3010	-	1.5	1.3
T7	5.5	130	156	145	0.450	-	175u3012	175u3013	-	1.5	1.7
T7	7.5	94	113	105	0.790	-	175u3481	175u3482	-	1.5	2.6
T7	11	94.5	110.9	105	0.790	175u3360	175u3481	175u3482	-	1.5	2.7
T7	15	69.7	80.7	72	1.130	175u3351	175u3466	175u3465	-	1.5	3.8
T7	18.5	46.8	65.1	52	1.400	175u3352	175u3468	175u3467	-	1.5	4.9
T7	22	36.0	54.5	42	1.700	175u3353	175u3032	175u3033	-	1.5	6
T7	30	29.0	39.7	31	2.200	175u3354	175u3470	175u3469	-	1.5	7.9
T7	37	22.5	32.1	27	2.800	175u3355	175u3472	175u3471	-	2.5	9.6
T7	45	18.0	26.3	22	3.200	175u3356	175u3479	175u3480	-	2.5	11.3
T7	55	13.5	21.4	15.5	4.200	-	175u3474	175u3473	-	4	15
T7	75	13.5	15.6	13.5	5.500	-	175u3476	175u3475	-	6	19
T7	90	8.8	13.0	11	7.000	-	-	-	175u3232	10	25
T7	110	8.8	10.6	9.1	9.000	-	-	-	175u3067	16	32
T7	132	6.6	8.8	7.4	11.000	-	-	-	175u3072	16	39
T7	160	4.2	7.2	6.1	13.000	-	-	-	175u3075	16	46
T7	200	4.2	5.8	5.0	16.000	-	-	-	175u3078	25	57
T7	250	3.4	4.6	4.0	20.000	-	-	-	175u3082	35	71
T7	315	2.3	3.7	3.2	26.000	-	-	-	175u3085	50	90
T7	400	2.3	2.9	2.5	32.000	-	-	-	175u3089	70	113
T7	450	2.0	2.6	2.3	36.000	-	-	-	175u3090	2 x 35	125
T7	500	1.9	2.3	2.0	42.000	-	-	-	175u3092	2 x 35	145
T7	560	1.5	2.1	1.6	52.000	-	-	-	175u3094	2 x 50	180
T7	630	1.4	1.8	1.4	60.000	-	-	-	175u3095	2 x 50	207
T7	710	1.2	1.6	2 x 2.6	-	-	-	-	-	-	-
T7	800	1.1	1.4	2 x 2.2	-	-	-	-	-	-	-
T7	900	1.0	1.3	2 x 2.0	-	-	-	-	-	-	-
T7	1000	0.9	1.1	3 x 2.6	-	-	-	-	-	-	-
T7	1200	0.8	1.0	3 x 2.4	-	-	-	-	-	-	-
T7	1400	0.6	0.8	3 x 2.0	-	-	-	-	-	-	-

Table 6.13 T7, Horizontal Braking 10% Duty Cycle, Recommended Brake Resistors

40% duty cycle, vertical braking, T7

FC 202				Vertical braking 40% duty cycle							
Frequency converter data				Brake resistor data						Installation	
						Danfoss part number				Cable cross-section	Thermo relay
Mains type	P_m [kW]	R_{min} [Ω]	$R_{br,nom}$ [Ω]	R_{rec} [Ω]	$P_{br,cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20	[mm²]	[A]
T7	1.1	620	830	630	0.360	-	175u3108	175u3109	-	1.5	0.8
T7	1.5	513	600	570	0.570	-	175u3110	175u3111	-	1.5	1
T7	2.2	340	403	415	0.790	-	175u3112	175u3113	-	1.5	1.3
T7	3	243	292	270	1.130	-	175u3118	175u3119	-	1.5	2
T7	4	180	216	200	1.700	-	175u3122	175u3123	-	1.5	2.8
T7	5.5	130	156	145	2.200	-	175u3106	175u3107	-	1.5	3.7
T7	7.5	94	113	105	3.200	-	175u3132	175u3133	-	1.5	5.2
T7	11	94.5	110.9	105	4.200	-	175u3134	175u3135	-	1.5	6
T7	15	69.7	80.7	72	4.200	-	175u3142	175u3143	-	1.5	7.2
T7	18.5	46.8	65.1	52	6.000	-	-	-	175u3242	2.5	10.8
T7	22	36.0	54.5	42	8.000	-	-	-	175u3243	2.5	13.9
T7	30	29.0	39.7	31	10.000	-	-	-	175u3244	4	18
T7	37	22.5	32.1	27	14.000	-	-	-	175u3201	10	23
T7	45	18.0	26.3	22	17.000	-	-	-	175u3202	10	28
T7	55	13.5	21.4	15.5	21.000	-	-	-	175u3205	16	37
T7	75	13.5	15.6	13.5	26.000	-	-	-	175u3209	16	44
T7	90	8.8	13.0	11	36.000	-	-	-	175u3212	25	57
T7	110	8.8	10.6	9.1	42.000	-	-	-	175u3214	35	68
T7	132	6.6	8.8	7.4	52.000	-	-	-	175u3215	50	84
T7	160	4.2	7.2	6.1	60.000	-	-	-	175u3218	70	99
T7	200	4.2	5.8	5.0	78.000	-	-	-	175u3220	2 x 35	125
T7	250	3.4	4.6	4.0	90.000	-	-	-	175u3222	2 x 35	150
T7	315	2.3	3.7	3.2	-	-	-	-	-	-	-
T7	400	2.3	2.9	2.5	-	-	-	-	-	-	-
T7	450	2.0	2.6	2.3	-	-	-	-	-	-	-
T7	500	1.9	2.3	2.0	-	-	-	-	-	-	-
T7	560	1.5	2.1	1.6	-	-	-	-	-	-	-
T7	630	1.4	1.8	1.4	-	-	-	-	-	-	-
T7	710	1.2	1.6	2 x 2.6	-	-	-	-	-	-	-
T7	800	1.1	1.4	2 x 2.2	-	-	-	-	-	-	-
T7	900	1.0	1.3	2 x 2.0	-	-	-	-	-	-	-
T7	1000	0.9	1.1	3 x 2.6	-	-	-	-	-	-	-
T7	1200	0.8	1.0	3 x 2.4	-	-	-	-	-	-	-
T7	1400	0.6	0.8	3 x 2.0	-	-	-	-	-	-	-

Table 6.14 T7, Vertical Braking 40% Duty Cycle, Recommended Brake Resistors

6.2.6 Alternative Brake Resistors, T2 and T4

Mains	Voltage class
P_m	Rated motor size for frequency converter type
R_{min}	Minimum permissible brake resistor - by frequency converter
R_{rec}	Recommended brake resistor resistance of Danfoss brake resistors
Duty cycle	$P_{br,cont.}$x100/Pm
Part number	Danfoss brake resistor order numbers
$P_{br,cont.}$	Brake resistor average rated power.
$R_{br,nom}$	The nominal (calculated) resistor value to ensure a brake power on motor shaft of 150/160/110% for 1 minute

Table 6.15 Abbreviations used in *Table 6.16* to *Table 6.17*

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Mains: 200-240 V, T2

FC 202	P_m	R_{min}	$R_{br,nom}$	Flat-pack IP65		
				R_{rec} per item/$P_{br,cont.}$	Duty cycle	Danfoss part number
T2	[kW]	[Ω]	[Ω]	[Ω/W]	%	175Uxxxx
PK25	0.25	380	691.3	430/100	40	1002
PK37	0.37	380	466.7	430/100	27	1002
PK55	0.55	275	313.7	330/100	18	1003
PK55	0.55	275	313.7	310/200	36	0984
PK75	0.75	188	230.0	220/100	13	1004
PK75	0.75	188	230.0	210/200	26	0987
P1K1	1.1	130	152.9	150/100	9	1005
P1K1	1.1	130	152.9	150/200	18	0989
P1K5	1.5	81.0	110.5	100/100	7	1006
P1K5	1.5	81.0	110.5	100/200	14	0991
P2K2	2.2	58.5	74.1	72/200	9	0992
P3K0	3	45.0	53.7	50/200	7	0993
P3K7	3.7	31.5	39.9	35/200	6	0994
P3K7	3.7	31.5	39.9	72/200	11	2 x 0992
P5K5	5.5	22.5	28.7	40/200	7	2 x 0996

Table 6.16 Mains: 200-240 V (T2), Alternative Brake Resistors

Mains: 380-480 V, T4

FC 202	P_m	R_{min}	$R_{br,nom}$	Flat-pack IP65		
				R_{rec} per item/$P_{br,cont.}$	Duty cycle	Danfoss part number
T4	[kW]	[Ω]	[Ω]	[Ω/W]	%	175Uxxxx
PK75	0.75	620	910.2	830/100	13	1000
P1K1	1.1	546	607.3	620/100	9	1001
P1K1	1.1	546	607.3	620/200	18	0982
P1K5	1.5	382	437.3	430/100	7	1002
P1K5	1.5	382	437.3	430/200	14	0983
P2K2	2.2	260	293.3	310/200	9	0984
P3K0	3	189	212.7	210/200	7	0987
P4K0	4	135	157.3	150/200	5	0989
P4K0	4	135	157.3	300/200	10	2 x 0985
P5K5	5.5	99.0	113.3	130/200	7	2 x 0990
P7K5	7.5	72.0	82.4	80/240	6	2 x 0090

Table 6.17 Mains: 380-480 V (T4), Alternative Brake Resistors

6.2.7 Harmonic Filters

Harmonic filters are used to reduce mains harmonics.

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

Cooling and ventilation
IP20: Cooled by natural convection or with built-in fans.
IP00: Additional forced cooling is required. Secure sufficient airflow through the filter during installation to prevent overheating of the filter. Airflow of minimum 2 m/s is required through the filter.

Power and current ratings1)		Typical motor	Filter current rating 50 Hz	Ordering number AHF 005		Ordering number AHF 010	
[kW]	[A]	[kW]	[A]	IP00	IP20	IP00	IP20
0.37-4.0	1.2-9	3	10	130B1392	130B1229	130B1262	130B1027
5.5-7.5	14.4	7.5	14	130B1393	130B1231	130B1263	130B1058
11.0	22	11	22	130B1394	130B1232	130B1268	130B1059
15.0	29	15	29	130B1395	130B1233	130B1270	130B1089
18.0	34	18.5	34	130B1396	130B1238	130B1273	130B1094
22.0	40	22	40	130B1397	130B1239	130B1274	130B1111
30.0	55	30	55	130B1398	130B1240	130B1275	130B1176
37.0	66	37	66	130B1399	130B1241	130B1281	130B1180
45.0	82	45	82	130B1442	130B1247	130B1291	130B1201
55.0	96	55	96	130B1443	130B1248	130B1292	130B1204
75.0	133	75	133	130B1444	130B1249	130B1293	130B1207
90.0	171	90	171	130B1445	130B1250	130B1294	130B1213

Table 6.18 Harmonic Filters for 380-415 V, 50 Hz

Power and current ratings1)		Typical motor	Filter current rating 60 Hz	Ordering number AHF 005		Ordering number AHF 010	
[kW]	[A]	[kW]	[A]	IP00	IP20	IP00	IP20
0.37-4.0	1.2-9	3	10	130B3095	130B2857	130B2874	130B2262
5.5-7.5	14.4	7.5	14	130B3096	130B2858	130B2875	130B2265
11.0	22	11	22	130B3097	130B2859	130B2876	130B2268
15.0	29	15	29	130B3098	130B2860	130B2877	130B2294
18.0	34	18.5	34	130B3099	130B2861	130B3000	130B2297
22.0	40	22	40	130B3124	130B2862	130B3083	130B2303
30.0	55	30	55	130B3125	130B2863	130B3084	130B2445
37.0	66	37	66	130B3026	130B2864	130B3085	130B2459
45.0	82	45	82	130B3127	130B2865	130B3086	130B2488
55.0	96	55	96	130B3128	130B2866	130B3087	130B2489
75.0	133	75	133	130B3129	130B2867	130B3088	130B2498
90.0	171	90	171	130B3130	130B2868	130B3089	130B2499

Table 6.19 Harmonic Filters for 380-415 V, 60 Hz

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Power and current ratings[1)]		Typical motor	Filter current rating 60 Hz	Ordering number AHF 005		Ordering number AHF 010	
[kW]	[A]	[kW]	[A]	IP00	IP20	IP00	IP20
0.37–4.0	1–7.4	3	10	130B1787	130B1752	130B1770	130B1482
5.5–7.5	9.9–13	7.5	14	130B1788	130B1753	130B1771	130B1483
11.0	19	11	19	130B1789	130B1754	130B1772	130B1484
15.0	25	15	25	130B1790	130B1755	130B1773	130B1485
18.0	31	18.5	31	130B1791	130B1756	130B1774	130B1486
22.0	36	22	36	130B1792	130B1757	130B1775	130B1487
30.0	47	30	48	130B1793	130B1758	130B1776	130B1488
37.0	59	37	60	130B1794	130B1759	130B1777	130B1491
45.0	73	45	73	130B1795	130B1760	130B1778	130B1492
55.0	95	55	95	130B1796	130B1761	130B1779	130B1493
75.0	118	75	118	130B1797	130B1762	130B1780	130B1494
90	154	90	154	130B1798	130B1763	130B1781	130B1495

Table 6.20 Harmonic Filters for 440-480 V, 60 Hz

1) Frequency converter power and current ratings according to actual operating conditions

Power and current ratings[1)]		Typical motor	Filter current rating 60 Hz	Ordering number AHF 005		Ordering number AHF 010	
[kW]	[A]	[kW]	[A]	IP00	IP20	IP00	IP20
11.0	15	10	15	130B5261	130B5246	130B5229	130B5212
15.0	19	16.4	20	130B5262	130B5247	130B5230	130B5213
18.0	24	20	24	130B5263	130B5248	130B5231	130B5214
22.0	29	24	29	130B5263	130B5248	130B5231	130B5214
30.0	36	33	36	130B5265	130B5250	130B5233	130B5216
37.0	49	40	50	130B5266	130B5251	130B5234	130B5217
45.0	58	50	58	130B5267	130B5252	130B5235	130B5218
55.0	74	60	77	130B5268	130B5253	130B5236	130B5219
75.0	85	75	87	130B5269	130B5254	130B5237	130B5220
90	106	90	109	130B5270	130B5255	130B5238	130B5221

Table 6.21 Harmonic Filters for 600 V, 60 Hz

Power and current ratings[1)] 500-550 V		Typical motor	Power and Current Ratings 551-690 V		Typical motor	Filter current rating 50 Hz	Ordering number AHF 005		Ordering number AHF 010	
[kW]	[A]	[kW]	[kW]	[A]	[kW]	[A]	IP00	IP20	IP00	IP20
11.0	15	7.5	P15K	16	15	15	130B5000	130B5088	130B5297	130B5280
15.0	19.5	11	P18K	20	18.5	20	130B5017	130B5089	130B5298	130B5281
18.0	24	15	P22K	25	22	24	130B5018	130B5090	130B5299	130B5282
22.0	29	18.5	P30K	31	30	29	130B5019	130B5092	130B5302	130B5283
30.0	36	22	P37K	38	37	36	130B5021	130B5125	130B5404	130B5284
37.0	49	30	P45K	48	45	50	130B5022	130B5144	130B5310	130B5285
45.0	59	37	P55K	57	55	58	130B5023	130B5168	130B5324	130B5286
55.0	71	45	P75K	76	75	77	130B5024	130B5169	130B5325	130B5287
75.0	89	55				87	130B5025	130B5170	130B5326	130B5288
90.0	110	90				109	130B5026	130B5172	130B5327	130B5289

Table 6.22 Harmonic Filters for 500-690 V, 50 Hz

1) Frequency converter power and current ratings according to actual operating conditions

6.2.8 Sine-Wave Filters

Frequency converter power and current ratings						Filter current rating			Switching frequency	Ordering number	
200-240 V		380-440 V		441-500 V		50 Hz	60 Hz	100 Hz		IP00	IP20/23[1)]
[kW]	[A]	[kW]	[A]	[kW]	[A]	[A]	[A]	[A]	[kHz]		
-	-	0.37	1.3	0.37	1.1	2.5	2.5	2	5	130B2404	130B2439
0.25	1.8	0.55	1.8	0.55	1.6						
0.37	2.4	0.75	2.4	0.75	2.1						
		1.1	3	1.1	3	4.5	4	3.5	5	130B2406	130B2441
0.55	3.5	1.5	4.1	1.5	3.4						
0.75	4.6	2.2	5.6	2.2	4.8	8	7.5	5.5	5	130B2408	130B2443
1.1	6.6	3	7.2	3	6.3						
1.5	7.5	-	-	-	-						
-	-	4	10	4	8.2	10	9.5	7.5	5	130B2409	130B2444
2.2	10.6	5.5	13	5.5	11	17	16	13	5	130B2411	130B2446
3	12.5	7.5	16	7.5	14.5						
3.7	16.7	-	-	-	-						
5.5	24.2	11	24	11	21	24	23	18	4	130B2412	130B2447
7.5	30.8	15	32	15	27	38	36	28.5	4	130B2413	130B2448
		18.5	37.5	18.5	34						
11	46.2	22	44	22	40	48	45.5	36	4	130B2281	130B2307
15	59.4	30	61	30	52	62	59	46.5	3	130B2282	130B2308
18.5	74.8	37	73	37	65	75	71	56	3	130B2283	130B2309
22	88	45	90	55	80	115	109	86	3	130B3179	130B3181*
30	115	55	106	75	105						
37	143	75	147	90	130	180	170	135	3	130B3182	130B3183*
45	170	90	177								

Table 6.23 Sine-wave Filters for Frequency Converters with 380-500 V

*1) Ordering numbers marked with * are IP23.*

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Frequency converter power and current ratings						Filter current rating @690 V			Switching frequency	Ordering number	
525–600 V		551–690 V		525–550 V		50 Hz	60 Hz	100 Hz		IP00	IP20/23[1)]
[kW]	[A]	[kW]	[A]	[kW]	[A]	[A]	[A]	[A]	kHz		
0.75	1.7	1.1	1.6	1.1	2.1	4.5	4	3	4	130B7335	130B7356
1.1	2.4	1.5	2.2	1.5	2.7						
1.5	2.7	2.2	3.2	2.2	3.9						
2.2	3.9	3.0	4.5	3.0	4.9						
3	4.9	4.0	5.5	4.0	6.1	10	9	7	4	130B7289	130B7324
4	6.1	5.5	7.5	5.5	9.0						
5.5	9	7.5	10	7.5	11						
7.5	11	11	13	7.5	14	13	12	9	3	130B3195	130B3196
11	18	15	18	11	19	28	26	21	3	130B4112	130B4113
15	22	18.5	22	15	23						
18.5	27	22	27	18	28						
22	34	30	34	22	36	45	42	33	3	130B4114	130B4115
30	41	37	41	30	48						
37	52	45	52	37	54	76	72	57	3	130B4116	130B4117*
45	62	55	62	45	65						
55	83	75	83	55	87	115	109	86	3	130B4118	130B4119*
75	100	90	100	75	105						
90	131	-	-	90	137	165	156	124	2	130B4121	130B4124*

Table 6.24 Sine-wave Filters for Frequency Converters with 525–600 V and 525–690 V

*1) Ordering numbers marked with * are IP23.*

Parameter	Setting
14-00 Switching Pattern	[1] SFAVM
14-01 Switching Frequency	Set according the individual filter. Listed at filter product label and in output filter manual. Sine-wave filters do not allow lower switching frequency than specified by the individual filter.
14-55 Output Filter	[2] Sine-wave filter fixed

Table 6.25 Parameter Settings for Sine-wave Filter Operation

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6.2.9 dU/dt Filters

Frequency converter ratings [V]										Filter current rating [V]				Ordering number		
200-240		380-440		441-500		525-550		551-690		380 @60 Hz 200-400/ 440@50 Hz	460/480 @60 Hz 500/525 @50 Hz	575/600 @60 Hz	690 @50 Hz	IP00	IP20	IP54
[kW]	[A]	[kW]	[A]	[kW]	[A]	[kW]	[A]	[kW]	[A]	[A]	[A]	[A]	[A]			
3	12.5	5.5	13	5.5	11	5.5	9.5	1.1	1.6	17	15	13	10	N/A	130B7367 1)	N/A
3.7	16	7.5	16	7.5	14.5	7.5	11.5	1.5	2.2							
-	-	-	-	-	-	-	-	2.2	3.2							
								3	4.5							
								4	5.5							
								5.5	7.5							
								7.5	10							
5.5	24.2	11	24	11	21	7,5	14	11	13	44	40	32	27	130B2835	130B2836*	130B2837
7.5	30.8	15	32	15	27	11	19	15	18							
-	-	18.5	37.5	18.5	34	15	23	18.5	22							
-	-	22	44	22	40	18,5	28	22	27							
11	46.2	30	61	30	52	30	43	30	34	90	80	58	54	130B2838	130B2839*	130B2840
15	59.4	37	73	37	65	37	54	37	41							
18.5	74.8	45	90	55	80	45	65	45	52							
22	88	-	-	-	-	-	-	-	-							
-	-	55	106	75	105	55	87	55	62	106	105	94	86	130B2841	130B2842*	130B2843
-	-							75	83							
30	115	75	147	90	130	75	113	90	108	177	160	131	108	130B2844	130B2845*	130B2846
37	143	90	177	-	-	90	137	-	-							
45	170	-	-	-	-	-	-	-	-							

Table 6.26 dU/dt Filters for 200-690 V

1) Dedicated A3 enclosure sizes supporting foot print mounting and book style mounting. Fixed screened cable connection to frequency converter.

Parameter	Setting
14-01 Switching Frequency	Higher operating switching frequency than specified by the individual filter is not recommended.
14-55 Output Filter	[0] No filter
14-56 Capacitance Output Filter	Not used
14-57 Inductance Output Filter	Not used

Table 6.27 Parameter Settings for dU/dt Filter Operation

6.2.10 Common Mode Filters

Enclosure size	Order number	Core dimension					Weight
		W	w	H	h	d	[kg]
A and B	130B3257	60	43	40	25	22.3	0.25
C1	130B7679	82.8	57.5	45.5	20.6	33	
C2, C3, C4	130B3258	102	69	61	28	37	1.6
D	130B3259	189	143	126	80	37	2.45

Table 6.28 Common Mode Filters, Ordering Numbers

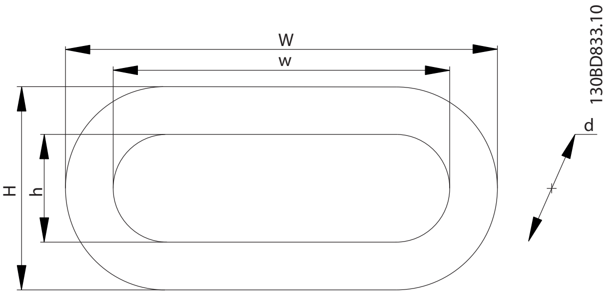

Illustration 6.4 HF-CM Core

7 Specifications

7.1 Electrical Data

7.1.1 Mains Supply 1x200–240 V AC

Type designation	**P1K1**	**P1K5**	**P2K2**	**P3K0**	**P3K7**	**P5K5**	**P7K5**	**P15K**	**P22K**
Typical shaft output [kW]	1.1	1.5	2.2	3.0	3.7	5.5	7.5	15	22
Typical shaft output at 240 V [hp]	1.5	2.0	2.9	4.0	4.9	7.5	10	20	30
Protection rating IP20/Chassis	A3	-	-	-	-	-	-	-	-
Protection rating IP21/Type 1	-	B1	B1	B1	B1	B1	B2	C1	C2
Protection rating IP55/Type 12	A5	B1	B1	B1	B1	B1	B2	C1	C2
Protection rating IP66/NEMA 4X	A5	B1	B1	B1	B1	B1	B2	C1	C2
Output current									
Continuous (3x200–240 V) [A]	6.6	7.5	10.6	12.5	16.7	24.2	30.8	59.4	88
Intermittent (3x200–240 V) [A]	7.3	8.3	11.7	13.8	18.4	26.6	33.4	65.3	96.8
Continuous kVA at 208 V [kVA]	2.4	2.7	3.8	4.5	6.0	8.7	11.1	21.4	31.7
Maximum input current									
Continuous (1x200–240 V) [A]	12.5	15	20.5	24	32	46	59	111	172
Intermittent (1x200–240 V) [A]	13.8	16.5	22.6	26.4	35.2	50.6	64.9	122.1	189.2
Maximum pre-fuses [A]	20	30	40	40	60	80	100	150	200
Additional specifications									
Maximum cable cross-section (mains, motor, brake) [mm^2] ([AWG])	0.2-4 (4-10)					10 (7)	35 (2)	50 (1/0)	95 (4/0)
Maximum cable cross-section[2)] for mains with disconnect switch [mm2] ([AWG])	16 (6)	16 (6)	16 (6)	16 (6)	16 (6)	16 (6)	25 (3)	50 (1/0)	2 x 50 (2 x 1/0) [9)] [10)]
Maximum cable cross-section[2)] for mains without disconnect switch [mm2] ([AWG])	16 (6)	16 (6)	16 (6)	16 (6)	16 (6)	16 (6)	25 (3)	50 (1/0)	95 (4/0)
Cable insulation temperature rating [°C]	75	75	75	75	75	75	75	75	75
Estimated power loss[3)] at rated maximum load [W][4)]	44	30	44	60	74	110	150	300	440
Efficiency[5)]	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98

Table 7.1 Mains Supply 1x200–240 V AC, Normal Overload 110% for 1 Minute, P1K1–P22K

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7.1.2 Mains Supply 3x200–240 V AC

Type designation	PK25		PK37		PK55		PK75	
High/normal overload[1)]	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output [kW]	0.25		0.37		0.55		0.75	
Typical shaft output at 208 V [hp]	0.34		0.5		0.75		1	
Protection rating IP20/Chassis[6)] Protection rating IP21/Type 1	A2		A2		A2		A2	
Protection rating IP55/Type 12 Protection rating IP66/NEMA 4X	A4/A5		A4/A5		A4/A5		A4/A5	
Output current								
Continuous (3x200–240 V) [A]	1.8		2.4		3.5		4.6	
Intermittent (3x200–240 V) [A]	2.7	2.0	3.6	2.6	5.3	3.9	6.9	5.1
Continuous kVA at 208 V [kVA]	0.65		0.86		1.26		1.66	
Maximum input current								
Continuous (3x200–240 V) [A]	1.6		2.2		3.2		4.1	
Intermittent (3x200–240 V) [A]	2.4	1.8	3.3	2.4	4.8	3.5	6.2	4.5
Maximum pre-fuses [A]	10		10		10		10	
Additional specifications								
Maximum cable cross-section[2)] for mains, motor, brake, and load sharing [mm²] ([AWG])	4, 4, 4 (12, 12, 12) (minimum 0.2 (24))							
Maximum cable cross-section[2)] for mains disconnect [mm²] ([AWG])	6, 4, 4 (10, 12, 12)							
Estimated power loss[3)] at rated maximum load [W][4)]	21		29		42		54	
Efficiency[5)]	0.94		0.94		0.95		0.95	

Table 7.2 Mains Supply 3x200–240 V AC, PK25–PK75

Type designation	P1K1		P1K5		P2K2		P3K0		P3K7	
High/normal overload[1)]	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output [kW]	1.1		1.5		2.2		3.0		3.7	
Typical shaft output at 208 V [hp]	1.5		2		3		4		5	
Protection rating IP20/Chassis[6)] Protection rating IP21/Type 1	A2		A2		A2		A3		A3	
Protection rating IP55/Type 12 Protection rating IP66/NEMA 4X	A4/A5		A4/A5		A4/A5		A5		A5	
Output current										
Continuous (3x200–240 V) [A]	6.6		7.5		10.6		12.5		16.7	
Intermittent (3x200–240 V) [A]	9.9	7.3	11.3	8.3	15.9	11.7	18.8	13.8	25	18.4
Continuous kVA at 208 V [kVA]	2.38		2.70		3.82		4.50		6.00	
Maximum input current										
Continuous (3x200–240 V) [A]	5.9		6.8		9.5		11.3		15.0	
Intermittent (3x200–240 V) [A]	8.9	6.5	10.2	7.5	14.3	10.5	17.0	12.4	22.5	16.5
Maximum pre-fuses [A]	20		20		20		32		32	
Additional specifications										
Maximum cable cross-section[2)] for mains, motor, brake, and load sharing [mm²] ([AWG])	4, 4, 4 (12, 12, 12) (minimum 0.2 (24))									
Maximum cable cross-section[2)] for mains disconnect [mm²] [(AWG)]	6, 4, 4 (10, 12, 12)									
Estimated power loss[3)] at rated maximum load [W][4)]	63		82		116		155		185	
Efficiency[5)]	0.96		0.96		0.96		0.96		0.96	

Table 7.3 Mains Supply 3x200–240 V AC, P1K1–P3K7

Type designation	P5K5		P7K5		P11K		P15K	
High/normal overload[1)]	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output [kW]	3.7	5.5	5.5	7.5	7.5	11	11	15
Typical shaft output at 208 V [hp]	5.0	7.5	7.5	10	10	15	15	20
IP20/Chassis[7)]	B3		B3		B3		B4	
Protection rating IP21/Type 1 Protection rating IP55/Type 12 Protection rating IP66/NEMA 4X	B1		B1		B1		B2	
Output current								
Continuous (3x200–240 V) [A]	16.7	24.2	24.2	30.8	30.8	46.2	46.2	59.4
Intermittent (3x200–240 V) [A]	26.7	26.6	38.7	33.9	49.3	50.8	73.9	65.3
Continuous kVA at 208 V [kVA]	6.0	8.7	8.7	11.1	11.1	16.6	16.6	21.4
Maximum input current								
Continuous (3x200–240 V) [A]	15.0	22.0	22.0	28.0	28.0	42.0	42.0	54.0
Intermittent (3x200–240 V) [A]	24.0	24.2	35.2	30.8	44.8	46.2	67.2	59.4
Maximum pre-fuses [A]	63		63		63		80	
Additional specifications								
IP20 maximum cable cross-section[2)] for mains, brake, motor, and load sharing [mm²] ([AWG])	10, 10, - (8, 8, -)		10, 10, - (8, 8, -)		10, 10, - (8, 8, -)		35, -, - (2, -, -)	
Protection rating IP21 maximum cable cross-section[2)] for mains, brake, and load sharing [mm²] ([AWG])	16, 10, 16 (6, 8, 6)		16, 10, 16 (6, 8, 6)		16, 10, 16 (6, 8, 6)		35, -, - (2, -, -)	
Protection rating IP21 maximum cable cross-section[2)] for motor [mm²] ([AWG])	10, 10, - (8, 8, -)		10, 10, - (8, 8, -)		10, 10, - (8, 8, -)		35, 25, 25 (2, 4, 4)	
Maximum cable cross-section[2)] for mains disconnect [mm²] ([AWG])	16, 10, 10 (6, 8, 8)						35 (2)	
Estimated power loss[3)] at rated maximum load [W][4)]	239	310	239	310	371	514	463	602
Efficiency[5)]	0.96		0.96		0.96		0.96	

Table 7.4 Mains Supply 3x200–240 V AC, P5K5–P15K

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Type designation	P18K		P22K		P30K		P37K		P45K	
High/normal overload[1)]	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output [kW]	15	18.5	18.5	22	22	30	30	37	37	45
Typical shaft output at 208 V [hp]	20	25	25	30	30	40	40	50	50	60
Protection rating IP20/Chassis[7)]	B4		C3		C3		C4		C4	
Protection rating IP21/Type 1 Protection rating IP55/Type 12 Protection rating IP66/NEMA 4X	C1		C1		C1		C2		C2	
Output current										
Continuous (3x200–240 V) [A]	59.4	74.8	74.8	88.0	88.0	115	115	143	143	170
Intermittent (3x200–240 V) [A]	89.1	82.3	112	96.8	132	127	173	157	215	187
Continuous kVA at 208 V [kVA]	21.4	26.9	26.9	31.7	31.7	41.4	41.4	51.5	51.5	61.2
Maximum input current										
Continuous (3x200–240 V) [A]	54.0	68.0	68.0	80.0	80.0	104	104	130	130	154.0
Intermittent (3x200–240 V) [A]	81.0	74.8	102	88.0	120	114	156	143	195	169.0
Maximum pre-fuses [A]	125		125		160		200		250	
Additional specifications										
Protection rating IP20 maximum cable cross-section for mains, brake, motor, and load sharing [mm²] ([AWG])	35 (2)		50 (1)		50 (1)		150 (300 MCM)		150 (300 MCM)	
Protection ratings IP21, IP55, IP66 maximum cable cross-section for mains and motor [mm²] ([AWG])	50 (1)		50 (1)		50 (1)		150 (300 MCM)		150 (300 MCM)	
Protection ratings IP21, IP55, IP66 maximum cable cross-section for brake, and load sharing [mm²] ([AWG])	50 (1)		50 (1)		50 (1)		95 (3/0)		95 (3/0)	
Maximum cable cross-section[2)] for disconnect [mm²] ([AWG])	50, 35, 35 (1, 2, 2)						95, 70, 70 (3/0, 2/0, 2/0)		185, 150, 120 (350 MCM, 300 MCM, 4/0)	
Estimated power loss[3)] at rated maximum load [W][4)]	624	737	740	845	874	1140	1143	1353	1400	1636
Efficiency[5)]	0.96		0.97		0.97		0.97		0.97	

Table 7.5 Mains Supply 3x200–240 V AC, P18K–P45K

7.1.3 Mains Supply 1x380–480 V AC

Type designation	P7K5	P11K	P18K	P37K
Typical shaft output [kW]	7.5	11	18.5	37
Typical shaft output at 240 V [hp]	10	15	25	50
Protection rating IP21/Type 1	B1	B2	C1	C2
Protection rating IP55/Type 12	B1	B2	C1	C2
Protection rating IP66/NEMA 4X	B1	B2	C1	C2
Output current				
Continuous (3x380–440 V) [A]	16	24	37.5	73
Intermittent (3x380–440 V) [A]	17.6	26.4	41.2	80.3
Continuous (3x441–480 V) [A]	14.5	21	34	65
Intermittent (3x441–480 V) [A]	15.4	23.1	37.4	71.5
Continuous kVA at 400 V [kVA]	11.0	16.6	26	50.6
Continuous kVA at 460 V [kVA]	11.6	16.7	27.1	51.8
Maximum input current				
Continuous (1x380–440 V) [A]	33	48	78	151
Intermittent (1x380–440 V) [A]	36	53	85.5	166

Continuous (1x441–480 V) [A]	30	41	72	135
Intermittent (1x441–480 V) [A]	33	46	79.2	148
Maximum pre-fuses [A]	63	80	160	250
Additional specifications				
Maximum cable cross-section for mains, motor, and brake [mm²]] ([AWG])	10 (7)	35 (2)	50 (1/0)	120 (4/0)
Estimated power loss3) at rated maximum load [W]4	300	440	740	1480
Efficiency5)	0.96	0.96	0.96	0.96

Table 7.6 Mains Supply 1x380–480 V AC, Normal Overload 110% for 1 Minute, P7K5–P37K

7.1.4 Mains Supply 3x380–480 V AC

Type designation	PK37		PK55		PK75		P1K1		P1K5	
High/normal overload1)	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output [kW]	0.37		0.55		0.75		1.1		1.5	
Typical shaft output at 460 V [hp]	0.5		0.75		1.0		1.5		2.0	
Protection rating IP20/Chassis6)	A2		A2		A2		A2		A2	
Protection rating IP55/Type 12 Protection rating IP66/NEMA 4X	A4/A5		A4/A5		A4/A5		A4/A5		A4/A5	
Output current										
Continuous (3x380–440 V) [A]	1.3		1.8		2.4		3.0		4.1	
Intermittent (3x380–440 V) [A]	2.0	1.4	2.7	2.0	3.6	2.6	4.5	3.3	6.2	4.5
Continuous (3x441–480 V) [A]	1.2		1.6		2.1		2.7		3.4	
Intermittent (3x441–480 V) [A]	1.8	1.3	2.4	1.8	3.2	2.3	4.1	3.0	5.1	3.7
Continuous kVA at 400 V [kVA]	0.9		1.3		1.7		2.1		2.8	
Continuous kVA at 460 V [kVA]	0.9		1.3		1.7		2.4		2.7	
Maximum input current										
Continuous (3x380–440 V) [A]	1.2		1.6		2.2		2.7		3.7	
Intermittent (3x380–440 V) [A]	1.8	1.3	2.4	1.8	3.3	2.4	4.1	3.0	5.6	4.1
Continuous (3x441–480 V) [A]	1.0		1.4		1.9		2.7		3.1	
Intermittent (3x441–480 V) [A]	1.5	1.1	2.1	1.5	2.9	2.1	4.1	3.0	4.7	3.4
Maximum pre-fuses [A]	10		10		10		10		10	
Additional specifications										
Protection ratings IP20, IP21 maximum cable cross-section2) for mains, motor, brake, and load sharing [mm²] ([AWG])	4, 4, 4 (12, 12, 12) (minimum 0.2 (24))									
Protection ratings IP55, IP66 maximum cable cross-section2) for mains, motor, brake, and load sharing [mm²] ([AWG])	4, 4, 4 (12, 12, 12)									
Maximum cable cross-section2) for disconnect [mm²] ([AWG])	6, 4, 4 (10, 12, 12)									
Estimated power loss3) at rated maximum load [W]4	35		42		46		58		62	
Efficiency5)	0.93		0.95		0.96		0.96		0.97	

Table 7.7 Mains Supply 3x380–480 V AC, PK37–P1K5

7

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Type designation	P2K2		P3K0		P4K0		P5K5		P7K5	
High/normal overload[1]	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output [kW]	2.2		3.0		4.0		5.5		7.5	
Typical shaft output at 460 V [hp]	2.9		4.0		5.3		7.5		10	
Protection rating IP20/Chassis[6]	A2		A2		A2		A3		A3	
Protection rating IP55/Type 12 Protection rating IP66/NEMA 4X	A4/A5		A4/A5		A4/A5		A5		A5	
Output current										
Continuous (3x380–440 V) [A]	5.6		7.2		10		13		16	
Intermittent (3x380–440 V) [A]	8.4	6.2	10.8	7.9	15.0	11.0	19.5	14.3	24.0	17.6
Continuous (3x441–480 V) [A]	4.8		6.3		8.2		11		14.5	
Intermittent (3x441–480 V) [A]	7.2	5.3	9.5	6.9	12.3	9.0	16.5	12.1	21.8	16.0
Continuous kVA at 400 V [kVA]	3.9		5.0		6.9		9.0		11.0	
Continuous kVA at 460 V [kVA]	3.8		5.0		6.5		8.8		11.6	
Maximum input current										
Continuous (3x380–440 V) [A]	5.0		6.5		9.0		11.7		14.4	
Intermittent (3x380–440 V) [A]	7.5	5.5	9.8	7.2	13.5	9.9	17.6	12.9	21.6	15.8
Continuous(3x441–480 V) [A]	4.3		5.7		7.4		9.9		13.0	
Intermittent (3x441–480 V) [A]	6.5	4.7	8.6	6.3	11.1	8.1	14.9	10.9	19.5	14.3
Maximum pre-fuses [A]	20		20		20		30		30	
Additional specifications										
Protection ratings IP20, IP21 maximum cable cross-section[2] for mains, motor, brake, and load sharing [mm^2] ([AWG])	4, 4, 4 (12, 12, 12) (minimum 0.2 (24))									
Protection ratings IP55, IP66 maximum cable cross-section[2] for mains, motor, brake, and load sharing [mm^2] ([AWG])	4, 4, 4 (12, 12, 12)									
Maximum cable cross-section[2] for disconnect [mm^2] ([AWG])	6, 4, 4 (10, 12, 12)									
Estimated power loss[3] at rated maximum load [W][4]	88		116		124		187		225	
Efficiency[5]	0.97		0.97		0.97		0.97		0.97	

Table 7.8 Mains Supply 3x380–480 V AC, P2K2–P7K5

Type designation	P11K		P15K		P18K		P22K		P30K	
High/normal overload[1]	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output [kW]	7.5	11	11	15	15	18.5	22.0	22.0	22.0	30
Typical shaft output at 460 V [hp]	10	15	15	20	20	25	30	30	30	40
Protection rating IP20/Chassis[7]	B3		B3		B3		B4			B4
Protection rating IP21/Type 1	B1		B1		B1		B2		B2	
Protection rating IP55/Type 12 Protection rating IP66/NEMA 4X	B1		B1		B1		B2		B2	
Output current										
Continuous (3x380–440 V) [A]	-	24	24	32	32	37.5	37.5	44	44	61
Intermittent (60 s overload) (3x380–440 V) [A]	-	26.4	38.4	35.2	51.2	41.3	60	48.4	70.4	67.1
Continuous (3x441–480 V) [A]	-	21	21	27	27	34	34	40	40	52
Intermittent (60 s overload) (3x441–480 V) [A]	-	23.1	33.6	29.7	43.2	37.4	54.4	44	64	61.6
Continuous kVA at 400 V [kVA]	-	16.6	16.6	22.2	22.2	26	26	30.5	30.5	42.3
Continuous kVA at 460 V [kVA]	-	16.7	16.7	21.5	21.5	27.1	27.1	31.9	31.9	41.4
Maximum input current										
Continuous (3x380–440 V) [A]	-	22	22	29	29	34	34	40	40	55
Intermittent (60 s overload) (3x380–440 V) [A]	-	24.2	35.2	31.9	46.4	37.4	54.4	44	64	60.5
Continuous (3x441–480 V) [A]	-	19	19	25	25	31	31	36	36	47
Intermittent (60 s overload) (3x441–480 V) [A]	-	20.9	30.4	27.5	40	34.1	49.6	39.6	57.6	51.7
Maximum pre-fuses [A]	-	63		63		63		63		80
Additional specifications										
Protection ratings IP21, IP55, IP66 maximum cable cross-section[2] for mains, brake, and load sharing [mm^2] ([AWG])	16, 10, 16 (6, 8, 6)						35, -, - (2, -, -)			
Protection ratings IP21, IP55, IP66 maximum cable cross-section[2] for motor [mm^2] ([AWG])	10, 10,- (8, 8,-)						35, 25, 25 (2, 4, 4)			
Protection rating IP20 maximum cable cross-section[2] for mains, brake, motor, and load sharing [mm^2] ([AWG])	10, 10,- (8, 8,-)						35, -, - (2, -, -)			
Maximum cable cross-section[2] for disconnect [mm^2] ([AWG])	16, 10, 10 (6, 8, 8)									
Estimated power loss[3] at rated maximum load [W][4]	291	392	291	392	379	465	444	525	547	739
Efficiency[5]	0.98		0.98		0.98		0.98		0.98	

Table 7.9 Mains Supply 3x380–480 V AC, P11K–P30K

7

Type designation	P37K		P45K		P55K		P75K		P90K	
High/normal overload[1)]	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output [kW]	30	37	37	45	45	55	55	75	75	90
Typical shaft output at 460 V [hp]	40	50	50	60	60	75	75	100	100	125
Protection rating IP20/Chassis[6)]	B4		C3		C3		C4		C4	
Protection rating IP21/Type 1	C1		C1		C1		C2		C2	
Protection rating IP55/Type 12 Protection rating IP66/NEMA 4X	C1		C1		C1		C2		C2	
Output current										
Continuous (3x380–440 V) [A]	61	73	73	90	90	106	106	147	147	177
Intermittent (60 s overload) (3x380–440 V) [A]	91.5	80.3	110	99	135	117	159	162	221	195
Continuous (3x441–480 V) [A]	52	65	65	80	80	105	105	130	130	160
Intermittent (60 s overload) (3x441–480 V) [A]	78	71.5	97.5	88	120	116	158	143	195	176
Continuous kVA at 400 V [kVA]	42.3	50.6	50.6	62.4	62.4	73.4	73.4	102	102	123
Continuous kVA at 460 V [kVA]	41.4	51.8	51.8	63.7	63.7	83.7	83.7	104	103.6	128
Maximum input current										
Continuous (3x380–440 V) [A]	55	66	66	82	82	96	96	133	133	161
Intermittent (60 s overload) (3x380–440 V) [A]	82.5	72.6	99	90.2	123	106	144	146	200	177
Continuous (3x441–480 V) [A]	47	59	59	73	73	95	95	118	118	145
Intermittent (60 s overload) (3x441–480 V) [A]	70.5	64.9	88.5	80.3	110	105	143	130	177	160
Maximum pre-fuses [A]	100		125		160		250		250	
Additional specifications										
Protection rating IP20 maximum cable cross-section for mains and motor [mm²] ([AWG])	35 (2)		50 (1)		50 (1)		150 (300 MCM)		150 (300 MCM)	
Protection rating IP20 maximum cable cross-section for brake and load sharing [mm²] ([AWG])	35 (2)		50 (1)		50 (1)		95 (4/0)		95 (4/0)	
Protection ratings IP21, IP55, IP66 maximum cable cross-section for mains and motor [mm²] ([AWG])	50 (1)		50 (1)		50 (1)		150 (300 MCM)		150 (300 MCM)	
Protection ratings IP21, IP55, IP66 maximum cable cross-section for brake and load sharing [mm²] ([AWG])	50 (1)		50 (1)		50 (1)		95 (3/0)		95 (3/0)	
Maximum cable cross-section[2)] for mains disconnect [mm²] ([AWG])	50, 35, 35 (1, 2, 2)						95, 70, 70 (3/0, 2/0, 2/0)		185, 150, 120 (350 MCM, 300 MCM, 4/0)	
Estimated power loss[3)] at rated maximum load [W][4)]	570	698	697	843	891	1083	1022	1384	1232	1474
Efficiency[5)]	0.98		0.98		0.98		0.98		0.99	

Table 7.10 Mains Supply 3x380–480 V AC, P37K–P90K

7.1.5 Mains Supply 3x525–600 V AC

Type designation	PK75		P1K1		P1K5		P2K2	
High/normal overload[1]	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output [kW]	0.75		1.1		1.5		2.2	
Typical shaft output [hp]	1		1.5		2		3	
Protection rating IP20/Chassis Protection rating IP21/Type 1	A3		A3		A3		A3	
Protection rating IP55/Type 12	A5		A5		A5		A5	
Output current								
Continuous (3x525–550 V) [A]	1.8		2.6		2.9		4.1	
Intermittent (3x525–550 V) [A]	2.7	2.0	3.9	2.9	4.4	3.2	6.2	4.5
Continuous (3x551–600 V) [A]	1.7		2.4		2.7		3.9	
Intermittent (3x551–600 V) [A]	2.6	1.9	3.6	2.6	4.1	3.0	5.9	4.3
Continuous kVA at 550 V [kVA]	1.7		2.5		2.8		3.9	
Continuous kVA at 550 V [kVA]	1.7		2.4		2.7		3.9	
Maximum input current								
Continuous (3x525–600 V) [A]	1.7		2.4		2.7		4.1	
Intermittent (3x525–600 V) [A]	2.6	1.9	3.6	2.6	4.1	3.0	6.2	4.5
Maximum pre-fuses [A]	10		10		10		20	
Additional specifications								
Maximum cable cross-section[2] for mains, motor, brake, and load sharing [mm^2] ([AWG])	4,4,4 (12,12,12) (minimum 0.2 (24))							
Maximum cable cross-section[2] for mains disconnect [mm^2] ([AWG])	6,4,4 (10,12,12)							
Estimated power loss[3] at rated maximum load [W][4]	35		50		65		92	
Efficiency[5]	0.97		0.97		0.97		0.97	

Table 7.11 Mains Supply 3x525–600 V AC, PK75–P2K2

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Type designation	P3K0		P4K0		P5K5		P7K5	
High/normal overload[1]	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output [kW]	3.0		4.0		5.5		7.5	
Typical shaft output [hp]	4		5		7.5		10	
Protection rating IP20/Chassis Protection rating IP21/Type 1	A2		A2		A3		A3	
IP55/Type 12	A5		A5		A5		A5	
Output current								
Continuous (3x525–550 V) [A]	5.2		6.4		9.5		11.5	
Intermittent (3x525–550 V) [A]	7.8	5.7	9.6	7.0	14.3	10.5	17.3	12.7
Continuous (3x551–600 V) [A]	4.9		6.1		9.0		11.0	
Intermittent (3x551–600 V) [A]	7.4	5.4	9.2	6.7	13.5	9.9	16.5	12.1
Continuous kVA at 550 V [kVA]	5.0		6.1		9.0		11.0	
Continuous kVA at 550 V [kVA]	4.9		6.1		9.0		11.0	
Maximum input current								
Continuous (3x525–600 V) [A]	5.2		5.8		8.6		10.4	
Intermittent (3x525–600 V) [A]	7.8	5.7	8.7	6.4	12.9	9.5	15.6	11.4
Maximum pre-fuses [A]	20		20		32		32	
Additional specifications								
Maximum cable cross-section[2] for mains, motor, brake, and load sharing [mm^2] ([AWG])	4,4,4 (12,12,12) (minimum 0.2 (24))							
Maximum cable cross-section[2] for mains disconnect [mm^2] ([AWG])	6,4,4 (10,12,12)							
Estimated power loss[3] at rated maximum load [W][4]	122		145		195		261	
Efficiency[5]	0.97		0.97		0.97		0.97	

Table 7.12 Mains Supply 3x525–600 V AC, P3K0–P7K5

Type designation	P11K		P15K		P18K		P22K		P30K		P37K	
High/normal overload[1]	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output [kW]	7.5	11	11	15	15	18.5	18.5	22	22	30	30	37
Typical shaft output [hp]	10	15	15	20	20	25	25	30	30	40	40	50
Protection rating IP20/ Chassis	B3		B3		B3		B4		B4		B4	
Protection rating IP21/ Type 1 Protection rating IP55/ Type 12 Protection rating IP66/ NEMA 4X	B1		B1		B1		B2		B2		C1	
Output current												
Continuous (3x525–550 V) [A]	11.5	19	19	23	23	28	28	36	36	43	43	54
Intermittent (3x525–550 V) [A]	18.4	21	30	25	37	31	45	40	58	47	65	59
Continuous (3x551–600 V) [A]	11	18	18	22	22	27	27	34	34	41	41	52
Intermittent (3x551–600 V) [A]	17.6	20	29	24	35	30	43	37	54	45	62	57
Continuous kVA at 550 V [kVA]	11	18.1	18.1	21.9	21.9	26.7	26.7	34.3	34.3	41.0	41.0	51.4
Continuous kVA at 575 V [kVA]	11	17.9	17.9	21.9	21.9	26.9	26.9	33.9	33.9	40.8	40.8	51.8
Maximum input current												
Continuous at 550 V [A]	10.4	17.2	17.2	20.9	20.9	25.4	25.4	32.7	32.7	39	39	49
Intermittent at 550 V [A]	16.6	19	28	23	33	28	41	36	52	43	59	54
Continuous at 575 V [A]	9.8	16	16	20	20	24	24	31	31	37	37	47
Intermittent at 575 V [A]	15.5	17.6	26	22	32	27	39	34	50	41	56	52
Maximum pre-fuses [A]	40		40		50		60		80		100	
Additional specifications												
Protection rating IP20, maximum cable cross-section[2] for mains, brake, motor, and load sharing [mm²] ([AWG])	10, 10,- (8, 8,-)						35,-,- (2,-,-)					
Protection ratings IP21, IP55, IP66 maximum cable cross-section[2] for mains, brake, and load sharing [mm²] ([AWG])	16, 10, 10 (6, 8, 8)						35,-,- (2,-,-)					
Protection ratings IP21, IP55, IP66 maximum cable cross-section[2] for motor [mm²] ([AWG])	10, 10,- (8, 8,-)						35, 25, 25 (2, 4, 4)					
Maximum cable cross-section[2] for mains disconnect [mm²] ([AWG])	16, 10, 10 (6, 8, 8)										50, 35, 35 (1, 2, 2)	
Estimated power loss[3] at rated maximum load [W][4]	220	300	220	300	300	370	370	440	440	600	600	740
Efficiency[5]	0.98		0.98		0.98		0.98		0.98		0.98	

Table 7.13 Mains supply 3x525-600 V AC, P11K-P37K

Type designation	P45K		P55K		P75K		P90K	
High/normal overload[1]	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output [kW]	37	45	45	55	55	75	75	90
Typical shaft output [hp]	50	60	60	75	75	100	100	125
Protection rating IP20/Chassis	C3		C3		C4		C4	
Protection rating IP21/Type 1 Protection rating IP55/Type 12 Protection rating IP66/NEMA 4X	C1		C1		C2		C2	
Output current								
Continuous (3x525–550 V) [A]	54	65	65	87	87	105	105	137
Intermittent (3x525–550 V) [A]	81	72	98	96	131	116	158	151
Continuous (3x525–600 V) [A]	52	62	62	83	83	100	100	131
Intermittent (3x525–600 V) [A]	78	68	93	91	125	110	150	144
Continuous kVA at 525 V [kVA]	51.4	61.9	61.9	82.9	82.9	100	100.0	130.5
Continuous kVA at 575 V [kVA]	51.8	61.7	61.7	82.7	82.7	99.6	99.6	130.5
Maximum input current								
Continuous at 550 V [A]	49	59	59	78.9	78.9	95.3	95.3	124.3
Intermittent at 550 V [A]	74	65	89	87	118	105	143	137
Continuous at 575 V [A]	47	56	56	75	75	91	91	119
Intermittent at 575 V [A]	70	62	85	83	113	100	137	131
Maximum pre-fuses [A]	150		160		225		250	
Additional specifications								
Protection rating IP20 maximum cable cross-section for mains and motor [mm²] ([AWG])	50 (1)				150 (300 MCM)			
Protection rating IP20 maximum cable cross-section for brake and load sharing [mm²] ([AWG])	50 (1)				95 (4/0)			
Protection ratings IP21, IP55, IP66 maximum cable cross-section for mains and motor [mm²] ([AWG])	50 (1)				150 (300 MCM)			
Protection ratings IP21, IP55, IP66 maximum cable cross-section for brake and load sharing [mm²] ([AWG])	50 (1)				95 (4/0)			
Maximum cable cross-section[2] for mains disconnect [mm²] ([AWG])	50, 35, 35 (1, 2, 2)				95, 70, 70 (3/0, 2/0, 2/0)		185, 150, 120 (350 MCM, 300 MCM, 4/0)	
Estimated power loss[3] at rated maximum load [W][4]	740	900	900	1100	1100	1500	1500	1800
Efficiency[5]	0.98		0.98		0.98		0.98	

Table 7.14 Mains supply 3x525–600 V AC, P45K–P90K

7.1.6 Mains Supply 3x525–690 V AC

Type designation	P1K1		P1K5		P2K2		P3K0		P4K0		P5K5		P7K5	
High/normal overload[1)]	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output [kW]	1.1		1.5		2.2		3.0		4.0		5.5		7.5	
Typical shaft output [hp]	1.5		2		3		4		5		7.5		10	
Protection rating IP20/Chassis	A3		A3		A3		A3		A3		A3		A3	
Output current														
Continuous (3x525–550 V) [A]	2.1		2.7		3.9		4.9		6.1		9.0		11.0	
Intermittent (3x525–550 V) [A]	3.2	2.3	4.1	3.0	5.9	4.3	7.4	5.4	9.2	6.7	13.5	9.9	16.5	12.1
Continuous (3x551–690 V) [A]	1.6		2.2		3.2		4.5		5.5		7.5		10.0	
Intermittent (3x551–690 V) [A]	2.4	1.8	3.3	2.4	4.8	3.5	6.8	5.0	8.3	6.1	11.3	8.3	15.0	11.0
Continuous kVA at 525 V [kVA]	1.9		2.5		3.5		4.5		5.5		8.2		10.0	
Continuous kVA at 690 V [kVA]	1.9		2.6		3.8		5.4		6.6		9.0		12.0	
Maximum input current														
Continuous (3x525–550 V) [A]	1.9		2.4		3.5		4.4		5.5		8.1		9.9	
Intermittent (3x525–550 V) [A]	2.9	2.1	3.6	2.6	5.3	3.9	6.6	4.8	8.3	6.1	12.2	8.9	14.9	10.9
Continuous (3x551–690 V) [A]	1.4		2.0		2.9		4.0		4.9		6.7		9.0	
Intermittent (3x551–690 V) [A]	2.1	1.5	3.0	2.2	4.4	3.2	6.0	4.4	7.4	5.4	10.1	7.4	13.5	9.9
Additional specifications														
Maximum cable cross-section[2)] for mains, motor, brake, and load sharing [mm²] ([AWG])	4, 4, 4 (12, 12, 12) (minimum 0.2 (24)													
Maximum cable cross-section[2)] for mains disconnect [mm²] ([AWG])	6, 4, 4 (10, 12, 12)													
Estimated power loss[3)] at rated maximum load [W][4)]	44		60		88		120		160		220		300	
Efficiency[5)]	0.96		0.96		0.96		0.96		0.96		0.96		0.96	

Table 7.15 A3 Enclosure, Mains Supply 3x525–690 V AC IP20/Protected Chassis, P1K1–P7K5

7

Type designation	P11K		P15K		P18K		P22K		P30K	
High/normal overload[1]	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output at 550 V [kW]	5.9	7.5	7.5	11	11	15	15	18.5	18.5	22
Typical shaft output at 550 V [hp]	7.5	10	10	15	15	20	20	25	25	30
Typical shaft output at 690 V [kW]	7.5	11	11	15	15	18.5	18.5	22	22	30
Typical shaft output at 690 V [hp]	10	15	15	20	20	25	25	30	30	40
Protection rating IP20/Chassis	B4		B4		B4		B4		B4	
Protection rating IP21/Type 1 Protection rating IP55/Type 12	B2		B2		B2		B2		B2	
Output current										
Continuous (3x525–550 V) [A]	11	14	14.0	19.0	19.0	23.0	23.0	28.0	28.0	36.0
Intermittent (60 s overload) (3x525–550 V) [A]	17.6	15.4	22.4	20.9	30.4	25.3	36.8	30.8	44.8	39.6
Continuous (3x551–690 V) [A]	10	13	13.0	18.0	18.0	22.0	22.0	27.0	27.0	34.0
Intermittent (60 s overload) (3x551–690 V) [A]	16	14.3	20.8	19.8	28.8	24.2	35.2	29.7	43.2	37.4
Continuous kVA at 550 V [kVA]	10	13.3	13.3	18.1	18.1	21.9	21.9	26.7	26.7	34.3
Continuous kVA at 690 V kVA]	12	15.5	15.5	21.5	21.5	26.3	26.3	32.3	32.3	40.6
Maximum input current										
Continuous at 550 V [A]	9.9	15	15.0	19.5	19.5	24.0	24.0	29.0	29.0	36.0
Intermittent (60 s overload) at 550 V [A]	15.8	16.5	23.2	21.5	31.2	26.4	38.4	31.9	46.4	39.6
Continuous (at 690 V) [A]	9	14.5	14.5	19.5	19.5	24.0	24.0	29.0	29.0	36.0
Intermittent (60 s overload) at 690 V [A]	14.4	16	23.2	21.5	31.2	26.4	38.4	31.9	46.4	39.6
Additional specifications										
Maximum cable cross-section[2] for mains, motor, brake, and load sharing [mm^2] ([AWG])	35, 25, 25 (2, 4, 4)									
Maximum cable cross-section[2)] for mains disconnect [mm^2] ([AWG])	16,10,10 (6, 8, 8)									
Estimated power loss[3)] at rated maximum load [W][4)]	150	220	150	220	220	300	300	370	370	440
Efficiency[5)]	0.98		0.98		0.98		0.98		0.98	

Table 7.16 B2/B4 Enclosure, Mains Supply 3x525–690 V AC IP20/IP21/IP55, Chassis/NEMA 1/NEMA 12, P11K–P22K

Type Designation	P37K		P45K		P55K		P75K/N75K[8)]		P90K/N90K[8)]	
High/normal overload[1)]	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output at 550 V [kW]	22	30	30	37	37	45	45	55	55	75
Typical shaft output at 550 V [hp]	30	40	40	50	50	60	60	75	75	100
Typical shaft output at 690 V [kW]	30	37	37	45	45	55	55	75	75	90
Typical shaft output at 690 V [hp]	40	50	50	60	60	75	75	100	199	125
Protection rating IP20/Chassis	B4		C3		C3		D3h		D3h	
Protection rating IP21/Type 1 Protection rating IP55/Type 12	C2		C2		C2		C2		C2	
Output current										
Continuous (3x525–550 V) [A]	36.0	43.0	43.0	54.0	54.0	65.0	65.0	87.0	87.0	105
Intermittent (60 s overload) (3x525–550 V) [A]	54.0	47.3	64.5	59.4	81.0	71.5	97.5	95.7	130.5	115.5
Continuous (3x551–690 V) [A]	34.0	41.0	41.0	52.0	52.0	62.0	62.0	83.0	83.0	100
Intermittent (60 s overload) (3x551–690 V) [A]	51.0	45.1	61.5	57.2	78.0	68.2	93.0	91.3	124.5	110
Continuous kVA at 550 V [kVA]	34.3	41.0	41.0	51.4	51.4	61.9	61.9	82.9	82.9	100
Continuous kVA at 690 V [kVA]	40.6	49.0	49.0	62.1	62.1	74.1	74.1	99.2	99.2	119.5
Maximum input current										
Continuous at 550 V [A]	36.0	49.0	49.0	59.0	59.0	71.0	71.0	87.0	87.0	99.0
Intermittent (60 s overload) at 550 V [A]	54.0	53.9	72.0	64.9	87.0	78.1	105.0	95.7	129	108.9
Continuous at 690 V [A]	36.0	48.0	48.0	58.0	58.0	70.0	70.0	86.0	-	-
Intermittent (60 s overload) at 690 V [A]	54.0	52.8	72.0	63.8	87.0	77.0	105	94.6	-	-
Additional specifications										
Maximum cable cross-section for mains and motor [mm^2] ([AWG])	150 (300 MCM)									
Maximum cable cross-section for brake and load sharing [mm^2] ([AWG])	95 (3/0)									
Maximum cable cross-section[2)] for mains disconnect [mm^2] ([AWG])	95 (3/0)						185, 150, 120 (350 MCM, 300 MCM, 4/0)		-	
Estimated power loss[3)] at rated maximum load [W][4)]	600	740	740	900	900	1100	1100	1500	1500	1800
Efficiency[5)]	0.98		0.98		0.98		0.98		0.98	

Table 7.17 B4, C2, C3 Enclosure, Mains Supply 3x525–690 V AC IP20/IP21/IP55, Chassis/NEMA1/NEMA 12, P30K–P75K

For fuse ratings, see chapter 7.7 Fuses and Circuit Breakers.

1) High overload=150% or 160% torque for a duration of 60 s. Normal overload=110% torque for a duration of 60 s.

2) The 3 values for the maximum cable cross-section are for single core, flexible wire and flexible wire with sleeve, respectively.

3) Applies for dimensioning of frequency converter cooling. If the switching frequency is higher than the default setting, the power losses may increase. LCP and typical control card power consumptions are included.

4) Efficiency measured at nominal current. For energy efficiency class see chapter 7.4 Ambient Conditions.

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

6) Enclosure sizes A2+A3 can be converted to IP21 using a conversion kit. See also chapter 3.6 Mechanical Planning.

7) Enclosure sizes B3+B4 and C3+C4 can be converted to IP21 using a conversion kit. See also chapter 3.6 Mechanical Planning.

8) Enclosure sizes for N75K, N90K are D3h for IP20/Chassis, and D5h for IP54/Type 12.

9) 2 wires are required.

10) Variant not available in IP21.

7.2 Mains Supply

Mains supply (L1, L2, L3)

Supply voltage	200–240 V ±10%
Supply voltage	380–480 V ±10%
Supply voltage	525–600 V ±10%

Supply voltage	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. Typically this corresponds to 15% below the lowest rated supply voltage of the frequency converter. Power-up and full torque cannot be expected at mains voltage <10% below the lowest rated supply voltage of the frequency converter.

Supply frequency	50/60 Hz +4/-6%

The frequency converter power supply is tested in accordance with IEC61000-4-28, 50 Hz +4/-6%.

Maximum imbalance temporary between mains phases	3.0% of rated supply voltage
True power factor (λ)	≥0.9 nominal at rated load
Displacement power factor (cosφ) near unity	(>0.98)
Switching on input supply L1, L2, L3 (power-ups) ≤7.5 kW	maximum 2 times/min.
Switching on input supply L1, L2, L3 (power-ups) 11–90 kW	maximum 1 time/min.
Environment according to EN 60664-1	overvoltage category III/pollution degree 2

The unit is suitable for use on a circuit capable of delivering not more than 100000 RMS symmetrical Amperes, 240/480/600/690 V maximum.

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7.3 Motor Output and Motor Data

Motor output (U, V, W)	
Output voltage	0–100% of supply voltage
Output frequency	0–590 Hz[1)]
Switching on output	Unlimited
Ramp times	1–3600 s

1) Dependent on power size.

Torque characteristics, normal overload	
Starting torque (constant torque)	maximum 110% for 1 minute, once in 10 minutes[2)]
Overload torque (constant torque)	maximum 110% for 1 minute, once in 10 minutes[2)]

Torque characteristics, high overload	
Starting torque (constant torque)	maximum 150/160% for 1 minute, once in 10 minutes[2)]
Overload torque (constant torque)	maximum 150/160% for 1 minute, once in 10 minutes[2)]

2) Percentage relates to the nominal torque of the frequency converter, dependent on power size.

7.4 Ambient Conditions

Environment	
Enclosure size A, protection ratings	IP20/Chassis, IP21/Type 1, IP55/Type 12, IP66/Type 4X
Enclosure size B1/B2, protection ratings	IP21/Type 1, IP55/Type 12, IP66/Type 4X
Enclosure size B3/B4, protection ratings	IP20/Chassis
Enclosure size C1/C2, protection ratings	IP21/Type 1, IP55/Type 12, IP66/Type 4X
Enclosure size C3/C4, protection ratings	IP20/Chassis
Enclosure kit available ≤ enclosure size A	IP21/TYPE 1/IP4X top
Vibration test enclosure A/B/C	1.0 g
Maximum relative humidity	5–95% (IEC 721-3-3; Class 3K3 (non-condensing) during operation
Aggressive environment (IEC 721-3-3), uncoated	class 3C2
Aggressive environment (IEC 721-3-3), coated	class 3C3
Test method according to IEC 60068-2-43 H2S (10 days)	
Ambient temperature	Maximum 50 °C

Derating for high ambient temperature, see chapter 5 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 without derating	1000 m
Maximum altitude above sea level with derating	3000 m

Derating for high altitude, see chapter 5 Special Conditions.

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

1) Determined according to EN50598-2 at:

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

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7.5 Cable Specifications

Maximum motor cable length, screened/armoured	150 m
Maximum motor cable length, unscreened/unarmoured	300 m
Maximum cross section to motor, mains, load sharing and brake[1)]	
Maximum cross section to control terminals, rigid wire	1.5 mm^2/16 AWG (2 x 0.75 mm^2)
Maximum cross section to control terminals, flexible cable	1 mm^2/18 AWG
Maximum cross section to control terminals, cable with enclosed core	0.5 mm^2/20 AWG
Minimum cross section to control terminals	0.25 mm^2

1) See electrical data tables in chapter 7.1 Electrical Data for more information.

It is mandatory to ground the mains connection properly using T95 (PE) of the frequency converter. The ground connection cable cross section must be at least 10 mm^2 or 2 rated mains wires terminated separately according to EN 50178. See also *chapter 3.2.8 Earth Leakage Current*. Use unscreened cable.

7.5.1 Cable Lengths for Multiple Parallel Motor Connections

Enclosure sizes	Power Size [kW]	Voltage [V]	1 cable [m]	2 cables [m]	3 cables [m]	4 cables [m]
A1, A2, A4, A5	0.37–0.75	400	150	45	8	6
		500	150	7	4	3
A2, A4, A5	1.1–1.5	400	150	45	20	8
		500	150	45	5	4
A2, A4, A5	2.2–4	400	150	45	20	11
		500	150	45	20	6
A3, A4, A5	5.5-–7.5	400	150	45	20	11
		500	150	45	20	11
B1, B2, B3, B4, C1, C2, C3, C4	11–75	400	150	75	50	37
		500	150	75	50	37
A3	1.1–7.5	525–690	100	50	33	25
B4	11–30	525–690	150	75	50	37
C3	37–45	525–690	150	75	50	37

Table 7.18 Maximum Cable Length for Each Parallel Cable[1)]

1) For more information, refer to chapter 3.4.6 Connection of Multiple Motors.

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7.6 Control Input/Output and Control Data

Control card, RS485 serial communication

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

The RS485 serial communication circuit is functionally separated from other central circuits and galvanically isolated from the supply voltage (PELV).

Analog inputs

Number of analog inputs	2
Terminal number	53, 54
Modes	voltage or current
Mode select	switches S201 and S202
Voltage mode	switch S201/S202 = OFF (U)
Voltage level	0-10 V (scaleable)
Input resistance, R_i	approx. 10 kΩ
Maximum voltage	±20 V
Current mode	switch S201/S202=On (I)
Current level	0/4-20 mA (scaleable)
Input resistance, R_i	approx. 200 Ω
Maximum current	30 mA
Resolution for analog inputs	10 bit (+ sign)
Accuracy of analog inputs	maximum error 0.5% of full scale
Bandwidth	200 Hz

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

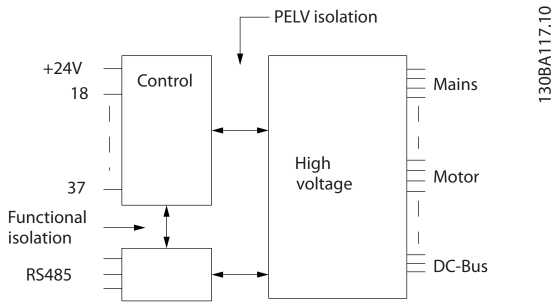

Illustration 7.1 PELV Isolation of Analog Inputs

Analog output

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

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

Digital inputs

Programmable digital inputs	4 (6)
Terminal number	18, 19, 27[1)], 29[1)], 32, 33,
Logic	PNP or NPN
Voltage level	0–24 V DC
Voltage level, logic 0 PNP	<5 V DC
Voltage level, logic 1 PNP	>10 V DC
Voltage level, logic 0 NPN	>19 V DC
Voltage level, logic '1' NPN	<14 V DC
Maximum voltage on input	28 V DC
Input resistance, R_i	approx. 4 kΩ

All digital inputs are galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.
1) Terminals 27 and 29 can also be programmed as output.

Digital output

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

1) 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.

Pulse inputs

Programmable pulse inputs	2
Terminal number pulse	29, 33
Maximum frequency at terminal 29, 33	110 kHz (push-pull driven)
Maximum frequency at terminal 29, 33	5 kHz (open collector)
Minimum frequency at terminal 29, 33	4 Hz

Voltage level	see *Digital inputs*
Maximum voltage on input	28 V DC
Input resistance, R_i	approx. 4 kΩ
Pulse input accuracy (0.1–1 kHz)	maximum error 0.1% of full scale

Control card, 24 V DC output	
Terminal number	12, 13
Maximum load	200 mA

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

Relay outputs	
Programmable relay outputs	2
Relay 01 terminal number	1-3 (break), 1-2 (make)
Maximum terminal load (AC-1)[1)] on 1-3 (NC), 1-2 (NO) (resistive load)	240 V AC, 2 A
Maximum terminal load (AC-15)[1)] (inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1)[1)] on 1-2 (NO), 1-3 (NC) (resistive load)	60 V DC, 1 A
Maximum terminal load (DC-13)[1)] (inductive load)	24 V DC, 0.1 A
Relay 02 terminal number	4-6 (break), 4-5 (make)
Maximum terminal load (AC-1)[1)] on 4-5 (NO) (resistive load)[2) 3)]	400 V AC, 2 A
Maximum terminal load (AC-15)[1)] on 4-5 (NO) (inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1)[1)] on 4-5 (NO) (resistive load)	80 V DC, 2 A
Maximum terminal load (DC-13)[1)] on 4-5 (NO) (inductive load)	24 V DC, 0.1 A
Maximum terminal load (AC-1)[1)] on 4-6 (NC) (resistive load)	240 V AC, 2 A
Maximum terminal load (AC-15)[1)] on 4-6 (NC) (inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1)[1)] on 4-6 (NC) (resistive load)	50 V DC, 2 A
Maximum terminal load (DC-13)[1)] on 4-6 (NC) (inductive load)	24 V DC, 0.1 A
Minimum terminal load on 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 parts 4 and 5.
The relay contacts are galvanically isolated from the rest of the circuit by reinforced isolation (PELV).
2) Overvoltage category II.
3) UL applications 300 V AC 2 A.

Control card, 10 V DC output	
Terminal number	50
Output voltage	10.5 V ±0.5 V
Maximum load	25 mA

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

Control characteristics	
Resolution of output frequency at 0–590 Hz	±0.003 Hz
System response time (terminals 18, 19, 27, 29, 32, 33)	≤2 ms
Speed control range (open loop)	1:100 of synchronous speed
Speed accuracy (open loop)	30–4000 RPM: maximum error of ±8 RPM

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

Control card performance	
Scan interval	5 ms

Control card, USB serial communication	
USB standard	1.1 (full speed)
USB plug	USB type B "device" plug

CAUTION

Connection to a PC is carried out via a standard host/device USB cable.
The USB connection is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.
The USB connection is not galvanically isolated from protective earth. Use only an isolated laptop/PC as a connection to the USB connector on the frequency converter, or an isolated USB cable/converter.

7.7 Fuses and Circuit Breakers

Use recommended fuses and/or circuit breakers on the supply side as protection in case of component break-down inside the frequency converter (first fault).

NOTICE

Use of fuses on the supply side is mandatory for IEC 60364 (CE) and NEC 2009 (UL) compliant installations.

Recommendations:

- gG type fuses.
- Moeller type circuit breakers. For other circuit breaker types, ensure that the energy into the frequency converter is equal to or lower than the energy provided by Moeller types.

Use of recommended fuses and circuit breakers ensures that possible damage to the frequency converter is limited to damages inside the unit. For further information, see *Application Note Fuses and Circuit Breakers*.

The fuses below are suitable for use on a circuit capable of delivering 100000 A_{rms} (symmetrical), depending on the frequency converter voltage rating. With the proper fusing, the frequency converter short-circuit current rating (SCCR) is 100000 A_{rms}.

7.7.1 CE Compliance

200–240 V, Enclosure sizes A, B, and C

Enclosure	Power [kW]	Recommended fuse size	Recommended maximum fuse	Recommended circuit breaker Moeller	Maximum trip level [A]
A2	0.25–2.2	gG-10 (0.25–1.5) gG-16 (2.2)	gG-25	PKZM0-25	25
A3	3.0–3.7	gG-16 (3) gG-20 (3.7)	gG-32	PKZM0-25	25
A4	0.25–2.2	gG-10 (0.25–1.5) gG-16 (2.2)	gG-32	PKZM0-25	25
A5	0.25–3.7	gG-10 (0.25–1.5) gG-16 (2.2–3) gG-20 (3.7)	gG-32	PKZM0-25	25
B1	5.5–11	gG-25 (5.5) gG-32 (7.5)	gG-80	PKZM4-63	63
B2	15	gG-50	gG-100	NZMB1-A100	100
B3	5.5–11	gG-25	gG-63	PKZM4-50	50
B4	15–18	gG-32 (7.5) gG-50 (11) gG-63 (15)	gG-125	NZMB1-A100	100
C1	18.5–30	gG-63 (15) gG-80 (18.5) gG-100 (22)	gG-160 (15–18.5) aR-160 (22)	NZMB2-A200	160
C2	37–45	aR-160 (30) aR-200 (37)	aR-200 (30) aR-250 (37)	NZMB2-A250	250
C3	22–30	gG-80 (18.5) aR-125 (22)	gG-150 (18.5) aR-160 (22)	NZMB2-A200	150
C4	37–45	aR-160 (30) aR-200 (37)	aR-200 (30) aR-250 (37)	NZMB2-A250	250

Table 7.19 200–240 V, Enclosure Sizes A, B, and C

38–480 V, Enclosure Sizes A, B, and C

Enclosure	Power [kW]	Recommended fuse size	Recommended maximum fuse	Recommended circuit breaker Moeller	Maximum trip level [A]
A2	1.1–4.0	gG-10 (0.37-3) gG-16 (4)	gG-25	PKZM0-25	25
A3	5.5–7.5	gG-16	gG-32	PKZM0-25	25
A4	1.1–4.0	gG-10 (0.37-3) gG-16 (4)	gG-32	PKZM0-25	25
A5	1.1–7.5	gG-10 (0.37-3) gG-16 (4-7.5)	gG-32	PKZM0-25	25
B1	11–18.5	gG-40	gG-80	PKZM4-63	63
B2	22–30	gG-50 (18.5) gG-63 (22)	gG-100	NZMB1-A100	100
B3	11–18	gG-40	gG-63	PKZM4-50	50
B4	22–37	gG-50 (18.5) gG-63 (22) gG-80 (30)	gG-125	NZMB1-A100	100
C1	37–55	gG-80 (30) gG-100 (37) gG-160 (45)	gG-160	NZMB2-A200	160
C2	75–90	aR-200 (55) aR-250 (75)	aR-250	NZMB2-A250	250
C3	45–55	gG-100 (37) gG-160 (45)	gG-150 (37) gG-160 (45)	NZMB2-A200	150
C4	75–90	aR-200 (55) aR-250 (75)	aR-250	NZMB2-A250	250

Table 7.20 380–480 V, Enclosure Sizes A, B, and C

525–600 V, Enclosure Sizes A, B, and C

Enclosure	Power [kW]	Recommended fuse size	Recommended maximum fuse	Recommended circuit breaker Moeller	Maximum trip level [A]
A2	1.1–4.0	gG-10	gG-25	PKZM0-25	25
A3	5.5–7.5	gG-10 (5.5) gG-16 (7.5)	gG-32	PKZM0-25	25
A5	1.1–7.5	gG-10 (0.75-5.5) gG-16 (7.5)	gG-32	PKZM0-25	25
B1	11–18	gG-25 (11) gG-32 (15) gG-40 (18.5)	gG-80	PKZM4-63	63
B2	22–30	gG-50 (22) gG-63 (30)	gG-100	NZMB1-A100	100
B3	11–18.5	gG-25 (11) gG-32 (15)	gG-63	PKZM4-50	50
B4	22–37	gG-40 (18.5) gG-50 (22) gG-63 (30)	gG-125	NZMB1-A100	100
C1	37–55	gG-63 (37) gG-100 (45) aR-160 (55)	gG-160 (37-45) aR-250 (55)	NZMB2-A200	160
C2	75–90	aR-200 (75)	aR-250	NZMB2-A250	250
C3	45–55	gG-63 (37) gG-100 (45)	gG-150	NZMB2-A200	150
C4	75–90	aR-160 (55) aR-200 (75)	aR-250	NZMB2-A250	250

Table 7.21 52–-600 V, Enclosure Sizes A, B, and C

525-690 V, Enclosure Sizes A, B, and C

Enclosure	Power [kW]	Recommended fuse size	Recommended maximum fuse	Recommended circuit breaker Danfoss	Maximum trip level [A]
A3	1.1	gG-6	gG-25	CTI25M 10-16	16
	1.5	gG-6	gG-25	CTI25M 10-16	16
	2.2	gG-6	gG-25	CTI25M 10-16	16
	3	gG-10	gG-25	CTI25M 10-16	16
	4	gG-10	gG-25	CTI25M 10-16	16
	5.5	gG-16	gG-25	CTI25M 10-16	16
	7.5	gG-16	gG-25	CTI25M 10-16	16
B2	11	gG-25	gG-63		
	15	gG-25	gG-63		
	18	gG-32			
	22	gG-32			
C2	30	gG-40			
	37	gG-63	gG-80		
	45	gG-63	gG-100		
	55	gG-80	gG-125		
	75	gG-100	gG-160		
C3	37	gG-100	gG-125		
	45	gG-125	gG-160		

Table 7.22 525–690 V, Enclosure Sizes A, B, and C

7.7.2 UL Compliance

1x200–240 V, Enclosure Sizes A, B, and C

Recommended maximum fuse													
Power [kW]	Max. prefuse size [A]	Buss-mann JFHR2	Buss-mann RK1	Buss-mann J	Buss-mann T	Buss-mann CC	Buss-mann CC	Buss-mann CC	SIBA RK1	Littel fuse RK1	Ferraz-Shawmut CC	Ferraz-Shawmut RK1	Ferraz-Shawmut J
1.1	15	FWX-15	KTN-R15	JKS-15	JJN-15	FNQ-R-15	KTK-R-15	LP-CC-15	5017906-016	KLN-R15	ATM-R15	A2K-15R	HSJ15
1.5	20	FWX-20	KTN-R20	JKS-20	JJN-20	FNQ-R-20	KTK-R-20	LP-CC-20	5017906-020	KLN-R20	ATM-R20	A2K-20R	HSJ20
2.2	30 1)	FWX-30	KTN-R30	JKS-30	JJN-30	FNQ-R-30	KTK-R-30	LP-CC-30	5012406-032	KLN-R30	ATM-R30	A2K-30R	HSJ30
3.0	35	FWX-35	KTN-R35	JKS-35	JJN-35	---	---	---	---	KLN-R35	---	A2K-35R	HSJ35
3.7	50	FWX-50	KTN-R50	JKS-50	JJN-50	---	---	---	5014006-050	KLN-R50	---	A2K-50R	HSJ50
5.5	60 2)	FWX-60	KTN-R60	JKS-60	JJN-60	---	---	---	5014006-063	KLN-R60	---	A2K-60R	HSJ60
7.5	80	FWX-80	KTN-R80	JKS-80	JJN-80	---	---	---	5014006-080	KLN-R80	---	A2K-80R	HSJ80
15	150	FWX-150	KTN-R150	JKS-150	JJN-150	---	---	---	2028220-150	KLN-R150	---	A2K-150R	HSJ150
22	200	FWX-200	KTN-R200	JKS-200	JJN-200	---	---	---	2028220-200	KLN-R200	---	A2K-200R	HSJ200

Table 7.23 1x200–240 V, Enclosure Sizes A, B, and C

1) Siba allowed up to 32 A.

2) Siba allowed up to 63 A.

1x380–500 V, Enclosure Sizes B and C

Recommended maximum fuse													
Power [kW]	Max. pre-fuse size [A]	Buss-mann JFHR2	Buss-mann RK1	Buss-mann J	Buss-mann T	Buss-mann CC	Buss-mann CC	Buss-mann CC	SIBA RK1	Littel fuse RK1	Ferraz-Shawmut CC	Ferraz-Shawmut RK1	Ferraz-Shawmut J
7.5	60	FWH-60	KTS-R60	JKS-60	JJS-60				5014006-063	KLS-R60	-	A6K-60R	HSJ60
11	80	FWH-80	KTS-R80	JKS-80	JJS-80				2028220-100	KLS-R80	-	A6K-80R	HSJ80
22	150	FWH-150	KTS-R150	JKS-150	JJS-150				2028220-160	KLS-R150	-	A6K-150R	HSJ150
37	200	FWH-200	KTS-R200	JKS-200	JJS-200				2028220-200	KLS-200		A6K-200R	HSJ200

Table 7.24 1x380–500 V, Enclosure Sizes B and C

- *KTS-fuses from Bussmann may substitute KTN for 240 V frequency converters.*
- *FWH-fuses from Bussmann may substitute FWX for 240 V frequency converters.*
- *JJS-fuses from Bussmann may substitute JJN for 240 V frequency converters.*
- *KLSR fuses from Littel fuse may substitute KLNR fuses for 240 V frequency converters.*
- *A6KR fuses from Ferraz-Shawmut may substitute A2KR for 240 V frequency converters.*

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3x200–240 V, Enclosure Sizes A, B, and C

	Recommended maximum fuse					
Power [kW]	Bussmann Type RK1 1)	Bussmann Type J	Bussmann Type T	Bussmann Type CC	Bussmann	Bussmann Type CC
0.25–0.37	KTN-R-05	JKS-05	JJN-05	FNQ-R-5	KTK-R-5	LP-CC-5
0.55–1.1	KTN-R-10	JKS-10	JJN-10	FNQ-R-10	KTK-R-10	LP-CC-10
1.5	KTN-R-15	JKS-15	JJN-15	FNQ-R-15	KTK-R-15	LP-CC-15
2.2	KTN-R-20	JKS-20	JJN-20	FNQ-R-20	KTK-R-20	LP-CC-20
3.0	KTN-R-25	JKS-25	JJN-25	FNQ-R-25	KTK-R-25	LP-CC-25
3.7	KTN-R-30	JKS-30	JJN-30	FNQ-R-30	KTK-R-30	LP-CC-30
5.5–7.5	KTN-R-50	JKS-50	JJN-50	-	-	-
11	KTN-R-60	JKS-60	JJN-60	-	-	-
15	KTN-R-80	JKS-80	JJN-80	-	-	-
18.5–22	KTN-R-125	JKS-125	JJN-125	-	-	-
30	KTN-R-150	JKS-150	JJN-150	-	-	-
37	KTN-R-200	JKS-200	JJN-200	-	-	-
45	KTN-R-250	JKS-250	JJN-250	-	-	-

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Table 7.25 3x200–240 V, Enclosure Sizes A, B, and C

	Recommended maximum fuse							
Power [kW]	SIBA Type RK1	Littel fuse Type RK1	Ferraz-Shawmut Type CC	Ferraz-Shawmut Type RK1 2)	Bussmann Type JFHR2 3)	Littel fuse JFHR2	Ferraz-Shawmut JFHR2 4)	Ferraz-Shawmut J
0.25–0.37	5017906-005	KLN-R-05	ATM-R-05	A2K-05-R	FWX-5	-	-	HSJ-6
0.55–1.1	5017906-010	KLN-R-10	ATM-R-10	A2K-10-R	FWX-10	-	-	HSJ-10
1.5	5017906-016	KLN-R-15	ATM-R-15	A2K-15-R	FWX-15	-	-	HSJ-15
2.2	5017906-020	KLN-R-20	ATM-R-20	A2K-20-R	FWX-20	-	-	HSJ-20
3.0	5017906-025	KLN-R-25	ATM-R-25	A2K-25-R	FWX-25	-	-	HSJ-25
3.7	5012406-032	KLN-R-30	ATM-R-30	A2K-30-R	FWX-30	-	-	HSJ-30
5.5–7.5	5014006-050	KLN-R-50	-	A2K-50-R	FWX-50	-	-	HSJ-50
11	5014006-063	KLN-R-60	-	A2K-60-R	FWX-60	-	-	HSJ-60
15	5014006-080	KLN-R-80	-	A2K-80-R	FWX-80	-	-	HSJ-80
18.5–22	2028220-125	KLN-R-125	-	A2K-125-R	FWX-125	-	-	HSJ-125
30	2028220-150	KLN-R-150	-	A2K-150-R	FWX-150	L25S-150	A25X-150	HSJ-150
37	2028220-200	KLN-R-200	-	A2K-200-R	FWX-200	L25S-200	A25X-200	HSJ-200
45	2028220-250	KLN-R-250	-	A2K-250-R	FWX-250	L25S-250	A25X-250	HSJ-250

Table 7.26 3x200–240 V, Enclosure Sizes A, B, and C

1) KTS-fuses from Bussmann may substitute KTN for 240 V frequency converters.
2) A6KR fuses from Ferraz-Shawmut may substitute A2KR for 240 V frequency converters.
3) FWH-fuses from Bussmann may substitute FWX for 240 V frequency converters.
4) A50X fuses from Ferraz-Shawmut may substitute A25X for 240 V frequency converters.

3x380–480 V, Enclosure Sizes A, B, and C

	Recommended maximum fuse					
Power [kW]	Bussmann Type RK1	Bussmann Type J	Bussmann Type T	Bussmann Type CC	Bussmann Type CC	Bussmann Type CC
-	KTS-R-6	JKS-6	JJS-6	FNQ-R-6	KTK-R-6	LP-CC-6
1.1–2.2	KTS-R-10	JKS-10	JJS-10	FNQ-R-10	KTK-R-10	LP-CC-10
3	KTS-R-15	JKS-15	JJS-15	FNQ-R-15	KTK-R-15	LP-CC-15
4	KTS-R-20	JKS-20	JJS-20	FNQ-R-20	KTK-R-20	LP-CC-20
5.5	KTS-R-25	JKS-25	JJS-25	FNQ-R-25	KTK-R-25	LP-CC-25
7.5	KTS-R-30	JKS-30	JJS-30	FNQ-R-30	KTK-R-30	LP-CC-30
11	KTS-R-40	JKS-40	JJS-40	-	-	-
15	KTS-R-50	JKS-50	JJS-50	-	-	-
22	KTS-R-60	JKS-60	JJS-60	-	-	-
30	KTS-R-80	JKS-80	JJS-80	-	-	-
37	KTS-R-100	JKS-100	JJS-100	-	-	-
45	KTS-R-125	JKS-125	JJS-125	-	-	-
55	KTS-R-150	JKS-150	JJS-150	-	-	-
75	KTS-R-200	JKS-200	JJS-200	-	-	-
90	KTS-R-250	JKS-250	JJS-250	-	-	-

Table 7.27 3x380–480 V, Enclosure Sizes A, B, and C

	Recommended maximum fuse							
Power [kW]	SIBA Type RK1	Littel fuse Type RK1	Ferraz-Shawmut Type CC	Ferraz-Shawmut Type RK1	Bussmann JFHR2	Ferraz-Shawmut J	Ferraz-Shawmut JFHR2[1)]	Littel fuse JFHR2
-	5017906-006	KLS-R-6	ATM-R-6	A6K-6-R	FWH-6	HSJ-6	-	-
1.1–2.2	5017906-010	KLS-R-10	ATM-R-10	A6K-10-R	FWH-10	HSJ-10	-	-
3	5017906-016	KLS-R-15	ATM-R-15	A6K-15-R	FWH-15	HSJ-15	-	-
4	5017906-020	KLS-R-20	ATM-R-20	A6K-20-R	FWH-20	HSJ-20	-	-
5.5	5017906-025	KLS-R-25	ATM-R-25	A6K-25-R	FWH-25	HSJ-25	-	-
7.5	5012406-032	KLS-R-30	ATM-R-30	A6K-30-R	FWH-30	HSJ-30	-	-
11	5014006-040	KLS-R-40	-	A6K-40-R	FWH-40	HSJ-40	-	-
15	5014006-050	KLS-R-50	-	A6K-50-R	FWH-50	HSJ-50	-	-
22	5014006-063	KLS-R-60	-	A6K-60-R	FWH-60	HSJ-60	-	-
30	2028220-100	KLS-R-80	-	A6K-80-R	FWH-80	HSJ-80	-	-
37	2028220-125	KLS-R-100	-	A6K-100-R	FWH-100	HSJ-100	-	-
45	2028220-125	KLS-R-125	-	A6K-125-R	FWH-125	HSJ-125	-	-
55	2028220-160	KLS-R-150	-	A6K-150-R	FWH-150	HSJ-150	-	-
75	2028220-200	KLS-R-200	-	A6K-200-R	FWH-200	HSJ-200	A50-P-225	L50-S-225
90	2028220-250	KLS-R-250	-	A6K-250-R	FWH-250	HSJ-250	A50-P-250	L50-S-250

Table 7.28 3x380–480 V, Enclosure Sizes A, B, and C

1) Ferraz-Shawmut A50QS fuses may substitute A50P fuses.

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3x525–600 V, Enclosure Sizes A, B, and C

	Recommended maximum fuse								
Power [kW]	Bussmann Type RK1	Bussman n Type J	Bussmann Type T	Bussmann Type CC	Bussman n Type CC	Bussman n Type CC	SIBA Type RK1	Littel fuse Type RK1	Ferraz-Shawmut Type RK1	Ferraz-Shawmut J
0.75–1.1	KTS-R-5	JKS-5	JJS-6	FNQ-R-5	KTK-R-5	LP-CC-5	5017906-005	KLS-R-005	A6K-5-R	HSJ-6
1.5–2.2	KTS-R-10	JKS-10	JJS-10	FNQ-R-10	KTK-R-10	LP-CC-10	5017906-010	KLS-R-010	A6K-10-R	HSJ-10
3	KTS-R15	JKS-15	JJS-15	FNQ-R-15	KTK-R-15	LP-CC-15	5017906-016	KLS-R-015	A6K-15-R	HSJ-15
4	KTS-R20	JKS-20	JJS-20	FNQ-R-20	KTK-R-20	LP-CC-20	5017906-020	KLS-R-020	A6K-20-R	HSJ-20
5.5	KTS-R-25	JKS-25	JJS-25	FNQ-R-25	KTK-R-25	LP-CC-25	5017906-025	KLS-R-025	A6K-25-R	HSJ-25
7.5	KTS-R-30	JKS-30	JJS-30	FNQ-R-30	KTK-R-30	LP-CC-30	5017906-030	KLS-R-030	A6K-30-R	HSJ-30
11–15	KTS-R-35	JKS-35	JJS-35	-	-	-	5014006-040	KLS-R-035	A6K-35-R	HSJ-35
18	KTS-R-45	JKS-45	JJS-45	-	-	-	5014006-050	KLS-R-045	A6K-45-R	HSJ-45
22	KTS-R-50	JKS-50	JJS-50	-	-	-	5014006-050	KLS-R-050	A6K-50-R	HSJ-50
30	KTS-R-60	JKS-60	JJS-60	-	-	-	5014006-063	KLS-R-060	A6K-60-R	HSJ-60
37	KTS-R-80	JKS-80	JJS-80	-	-	-	5014006-080	KLS-R-075	A6K-80-R	HSJ-80
45	KTS-R-100	JKS-100	JJS-100	-	-	-	5014006-100	KLS-R-100	A6K-100-R	HSJ-100
55	KTS-R-125	JKS-125	JJS-125	-	-	-	2028220-125	KLS-R-125	A6K-125-R	HSJ-125
75	KTS-R-150	JKS-150	JJS-150	-	-	-	2028220-150	KLS-R-150	A6K-150-R	HSJ-150
90	KTS-R-175	JKS-175	JJS-175	-	-	-	2028220-200	KLS-R-175	A6K-175-R	HSJ-175

Table 7.29 3x525–600 V, Enclosure Sizes A, B, and C

3x525–690 V, Enclosure Sizes B and C

	Recommended maximum fuse							
Power [kW]	Maximum pre-fuse [A]	Bussmann E52273 RK1/JDDZ	Bussmann E4273 J/JDDZ	Bussmann E4273 T/JDDZ	SIBA E180276 RK1/JDDZ	LittelFuse E81895 RK1/JDDZ	Ferraz-Shawmut E163267/E2137 RK1/JDDZ	Ferraz-Shawmut E2137 J/HSJ
11–15	30	KTS-R-30	JKS-30	JJS-30	5017906-030	KLS-R-030	A6K-30-R	HST-30
22	45	KTS-R-45	JKS-45	JJS-45	5014006-050	KLS-R-045	A6K-45-R	HST-45
30	60	KTS-R-60	JKS-60	JJS-60	5014006-063	KLS-R-060	A6K-60-R	HST-60
37	80	KTS-R-80	JKS-80	JJS-80	5014006-080	KLS-R-075	A6K-80-R	HST-80
45	90	KTS-R-90	JKS-90	JJS-90	5014006-100	KLS-R-090	A6K-90-R	HST-90
55	100	KTS-R-100	JKS-100	JJS-100	5014006-100	KLS-R-100	A6K-100-R	HST-100
75	125	KTS-R-125	JKS-125	JJS-125	2028220-125	KLS-150	A6K-125-R	HST-125
90	150	KTS-R-150	JKS-150	JJS-150	2028220-150	KLS-175	A6K-150-R	HST-150

Table 7.30 3x525–690 V, Enclosure Sizes B and C

7.8 Power Ratings, Weight and Dimensions

Enclosure size [kW]		A2		A3		A4	A5	B1	B2	B3	B4	C1	C2	C3	C4
1x200-240 V	S2	–		1.1		1.1–2.2	1.1	1.5–3.7	7.5	–	–	15	22	–	–
3x200-240 V	T2	0.25–3.0		3.7		0.25–2.2	0.25–3.7	5.5–11	15	5.5–11	15–18.5	18.5–30	37–45	22–30	37–45
1x380-480 V	S4	–		–		1.1–4.0	–	7.5	11	–	–	18	37	–	–
3x380-480 V	T4	0.37–4.0		5.5–7.5		0.37–4.0	0.37–7.5	11–18.5	22–30	11–18.5	22–37	37–55	75–90	45–55	75–90
3x525-600 V	T6	–		0.75–7.5		–	0.75–7.5	11–18.5	22–30	11–18.5	22–37	37–55	75–90	45–55	75–90
3x525-690 V	T7	–		–		–	–	–	11–30	–	–	–	37–90	–	–
IP NEMA		20 Chassis	21 Type 1	20 Chassis	21 Type 1	55/66 Type 12/4X	55/66 Type 12/4X	21/55/66 Type 1/12/4X	21/55/66 Type 1/12/4X	20 Chassis	20 Chassis	21/55/66 Type 1/12/4X	21/55/66 Type 1/12/4X	20 Chassis	20 Chassis
Height [mm]															
Height of back plate	A	268	375	268	375	390	420	480	650	399	520	680	770	550	660
Height with de-coupling plate for fieldbus cables	A	374	–	374	–	–	–	–	–	419	595	–	–	630	800
Distance between mounting holes	a	257	350	257	350	401	402	454	624	380	495	648	739	521	631
Width [mm]															
Width of back plate	B	90	90	130	130	200	242	242	242	165	231	308	370	308	370
Width of back plate with 1 C option	B	130	130	170	170	-	242	242	242	205	231	308	370	308	370
Width of back plate with 2 C options	B	90	90	130	130	-	242	242	242	165	231	308	370	308	370
Distance between mounting holes	b	70	70	110	110	171	215	210	210	140	200	272	334	270	330
Depth[1] [mm]															
Without option A/B	C	205	205	205	205	175	200	260	260	248	242	310	335	333	333
With option A/B	C	220	220	220	220	175	200	260	260	262	242	310	335	333	333
Screw holes [mm]															
	c	8.0	8.0	8.0	8.0	8.25	8.2	12	12	8	-	12	12	-	-
	d	ø11	ø11	ø11	ø11	ø12	ø12	ø19	ø19	12	-	ø19	ø19	-	-
	e	ø5.5	ø5.5	ø5.5	ø5.5	ø6.5	ø6.5	ø9	ø9	6.8	8.5	ø9.0	ø9.0	8.5	8.5
	f	9	9	9	9	6	9	9	9	7.9	15	9.8	9.8	17	17
Maximum weight [kg]		4.9	5.3	6.6	7.0	9.7	14	23	27	12	23.5	45	65	35	50
1) Depth of enclosure will vary with different options installed.															

Table 7.31 Power Ratings, Weight, and Dimensions

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7.9 dU/dt Testing

To avoid damage to motors without phase insulation paper or other insulation reinforcement designed for operation of the frequency converter, installation of a dU/dt filter or LC filter on the output of the frequency converter is recommended.

When a transistor in the inverter bridge switches, the voltage across the motor increases by a dU/dt ratio depending on:

- Motor inductance
- Motor cable (type, cross-section, length, screened, or unscreened)

The natural induction causes an overshoot voltage peak in the motor voltage before it stabilises. The level depends on the voltage in the DC-link.

Peak voltage on the motor terminals is caused by the switching of the IGBTs. The rise time and the peak voltage affects the service life of the motor. If the peak voltage is too high, motors without phase coil insulation can be adversely affected over time.

With short motor cables (a few metres), the rise time and peak voltage are lower. The rise time and peak voltage increase with cable length.

The frequency converter complies with IEC 60034-25 and IEC 60034-17 for motor design.

7.9.1 Peak Voltage on Motor

To obtain approximate values for cable lengths and voltages not mentioned below, use the following “Rules of Thumb”:

1. Rise time increases/decreases proportionally with cable length.
2. U_{PEAK} = DC link voltage x 1.9
(DC link voltage = Mains voltage x 1.35).
3. $dU/dt = \frac{0.8 \times UPEAK}{Risetime}$

Data is measured according to IEC 60034-17.
Cable lengths are in metres.

200–240 V (T2)

Cable length [m]	Mains voltage [V]	Rise time [µsec]	U_{PEAK} [kV]	dU/dt [kV/µsec]
36	240	0.226	0.616	2.142
50	240	0.262	0.626	1.908
100	240	0.650	0.614	0.757
150	240	0.745	0.612	0.655

Table 7.32 Frequency Converter, P5K5, T2

Cable length [m]	Mains voltage [V]	Rise time [µsec]	U_{PEAK} [kV]	dU/dt [kV/µsec]
5	230	0.13	0.510	3.090
50	230	0.23	0.590	2.034
100	230	0.54	0.580	0.865
150	230	0.66	0.560	0.674

Table 7.33 Frequency Converter, P7K5, T2

Cable length [m]		Rise time [µsec]	U_{PEAK} [kV]	dU/dt [kV/µsec]
36	240	0.264	0.624	1.894
136	240	0.536	0.596	0.896
150	240	0.568	0.568	0.806

Table 7.34 Frequency Converter, P11K, T2

Cable length [m]	Mains voltage [V]	Rise time [µsec]	U_{PEAK} [kV]	dU/dt [kV/µsec]
30	240	0.556	0.650	0.935
100	240	0.592	0.594	0.807
150	240	0.708	0.575	0.669

Table 7.35 Frequency Converter, P15K, T2

Cable length [m]	Mains voltage [V]	Rise time [µsec]	U_{PEAK} [kV]	dU/dt [kV/µsec]
36	240	0.244	0.608	1.993
136	240	0.568	0.580	0.832
150	240	0.720	0.574	0.661

Table 7.36 Frequency Converter, P18K, T2

Cable length [m]	Mains voltage [V]	Rise time [µsec]	U_{PEAK} [kV]	dU/dt [kV/µsec]
36	240	0.244	0.608	1.993
136	240	0.560	0.580	0.832
150	240	0.720	0.574	0.661

Table 7.37 Frequency Converter, P22K, T2

Cable length [m]	Mains voltage [V]	Rise time [µsec]	U_{PEAK} [kV]	dU/dt [kV/µsec]
15	240	0.194	0.626	2.581
50	240	0.252	0.574	1.929
150	240	0.444	0.538	0.977

Table 7.38 Frequency Converter, P30K, T2

Cable length [m]	Mains voltage [V]	Rise time [µsec]	U_{PEAK} [kV]	dU/dt [kV/µsec]
30	240	0.300	0.598	1.593
100	240	0.536	0.566	0.843
150	240	0.776	0.546	0.559

Table 7.39 Frequency Converter, P37K, T2

Cable length [m]	Mains voltage [V]	Rise time [µsec]	U_{PEAK} [kV]	dU/dt [kV/µsec]
30	240	0.300	0.598	1.593
100	240	0.536	0.566	0.843
150	240	0.776	0.546	0.559

Table 7.40 Frequency Converter, P45K, T2

380–480 V (T4)

Cable length [m]	Mains voltage [V]	Rise time [µsec]	U_{PEAK} [kV]	dU/dt [kV/µsec]
5	400	0.640	0.690	0.862
50	400	0.470	0.985	0.985
150	400	0.760	1.045	0.947

Table 7.41 Frequency Converter, P1K5, T4

Cable length [m]	Mains voltage [V]	Rise time [µsec]	U_{PEAK} [kV]	dU/dt [kV/µsec]
5	400	0.172	0.890	4.156
50	400	0.310		2.564
150	400	0.370	1.190	1.770

Table 7.42 Frequency Converter, P4K0, T4

Cable length [m]	Mains voltage [V]	Rise time [µsec]	U_{PEAK} [kV]	dU/dt [kV/µsec]
5	400	0.04755	0.739	8.035
50	400	0.207	1.040	4.548
150	400	0.6742	1.030	2.828

Table 7.43 Frequency Converter, P7K5, T4

Cable length [m]	Mains voltage [V]	Rise time [µsec]	U_{PEAK} [kV]	dU/dt [kV/µsec]
15	400	0.408	0.718	1.402
100	400	0.364	1.050	2.376
150	400	0.400	0.980	2.000

Table 7.44 Frequency Converter, P11K, T4

Cable length [m]	Mains voltage [V]	Rise time [µsec]	U_{PEAK} [kV]	dU/dt [kV/µsec]
36	400	0.422	1.060	2.014
100	400	0.464	0.900	1.616
150	400	0.896	1.000	0.915

Table 7.45 Frequency Converter, P15K, T4

Cable length [m]	Mains voltage [V]	Rise time [µsec]	U_{PEAK} [kV]	dU/dt [kV/µsec]
36	400	0.344	1.040	2.442
100	400	1.000	1.190	0.950
150	400	1.400	1.040	0.596

Table 7.46 Frequency Converter, P18K, T4

Cable length [m]	Mains voltage [V]	Rise time [µsec]	U_{PEAK} [kV]	dU/dt [kV/µsec]
36	400	0.232	0.950	3.534
100	400	0.410	0.980	1.927
150	400	0.430	0.970	1.860

Table 7.47 Frequency Converter, P22K, T4

Cable length [m]	Mains voltage [V]	Rise time [µsec]	U_{PEAK} [kV]	dU/dt [kV/µsec]
15	400	0.271	1.000	3.100
100	400	0.440	1.000	1.818
150	400	0.520	0.990	1.510

Table 7.48 Frequency Converter, P30K, T4

Cable length [m]	Mains voltage [V]	Rise time [µsec]	U_{PEAK} [kV]	dU/dt [kV/µsec]
5	480	0.270	1.276	3.781
50	480	0.435	1.184	2.177
100	480	0.840	1.188	1.131
150	480	0.940	1.212	1.031

Table 7.49 Frequency Converter, P37K, T4

Cable length [m]	Mains voltage [V]	Rise time [µsec]	U_{PEAK} [kV]	dU/dt [kV/µsec]
36	400	0.254	1.056	3.326
50	400	0.465	1.048	1.803
100	400	0.815	1.032	1.013
150	400	0.890	1.016	0.913

Table 7.50 Frequency Converter, P45K, T4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	U_{PEAK} [kV]	dU/dt [kV/μsec]
10	400	0.350	0.932	2.130

Table 7.51 Frequency Converter, P55K, T4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	U_{PEAK} [kV]	dU/dt [kV/μsec]
5	480	0.371	1.170	2.466

Table 7.52 Frequency Converter, P75K, T4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	U_{PEAK} [kV]	dU/dt [kV/μsec]
5	400	0.364	1.030	2.264

Table 7.53 Frequency Converter, P90K, T4

7

525–600V (T6)

Cable length [m]	Mains voltage [V]	Rise time [μsec]	U_{PEAK} [kV]	dU/dt [kV/μsec]
36	600	0.304	1.560	4.105
50	600	0.300	1.550	4.133
100	600	0.536	1.640	2.448
150	600	0.576	1.640	2.278

Table 7.54 Frequency Converter, P11K, T6

Cable length [m]	Mains voltage [V]	Rise time [μsec]	U_{PEAK} [kV]	dU/dt [kV/μsec]
36	600	0.084	1.560	7.962
50	600	0.120	1.540	5.467
100	600	0.165	1.472	3.976
150	600	0.190	1.530	3.432

Table 7.55 Frequency Converter, P22K, T6

Cable length [m]	Mains voltage [V]	Rise time [μsec]	U_{PEAK} [kV]	dU/dt [kV/μsec]
15	600	0.276	1.184	4.290

Table 7.56 Frequency Converter, P55K, T6

525–690V (T7)

Cable length [m]	Mains voltage [V]	Rise time [μsec]	U_{PEAK} [kV]	dU/dt [kV/μsec]
80	690	0.580	1.728	2.369
130	690	0.930	1.824	1.569
180	690	0.925	1.818	1.570

Table 7.57 Frequency Converter, P7K5, T7

Cable length [m]	Mains voltage [V]	Rise time [μsec]	U_{PEAK} [kV]	dU/dt [kV/μsec]
5	690	0.250	1.440	4.608
105	690	0.570	1.800	2.526
180	690	0.982	1.840	1.499

Table 7.58 Frequency Converter, P45K, T7

Cable length [m]	Mains voltage [V]	Rise time [μsec]	U_{PEAK} [kV]	dU/dt [kV/μsec]
6	690	0.238	1.416	4.739
50	690	0.358	1.764	3.922
150	690	0.465	1.872	3.252

Table 7.59 Frequency Converter, P55K, T7

7.10 Acoustic Noise Ratings

Enclosure size	50% fan speed [dBA]	Full fan speed [dBA]
A1	51	60
A2	51	60
A3	51	60
A4	51	60
A5	54	63
B1	61	67
B2	58	70
B4	52	62
C1	52	62
C2	55	65
C4	56	71
D3h	58	71

Table 7.60 Acoustic Noise Ratings

Values are measured 1 m from the unit.

7.11 Selected Options

7.11.1 VLT® General Purpose I/O Module MCB 101

MCB 101 is used for extension of digital and analog inputs and outputs.

Fit MCB 101 into slot B of the frequency converter.

Contents:

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

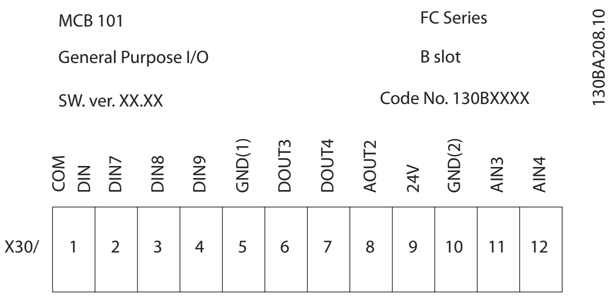


Illustration 7.2 MCB 101 Option

7.11.2 VLT® Relay Card MCB 105

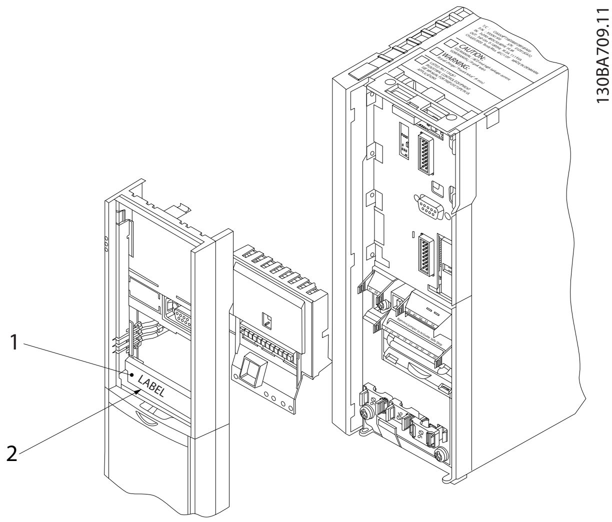
The relay option MCB 105 includes 3 pieces of SPDT contacts and must be fitted into option slot B.

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

1) IEC 947 part 4 and 5

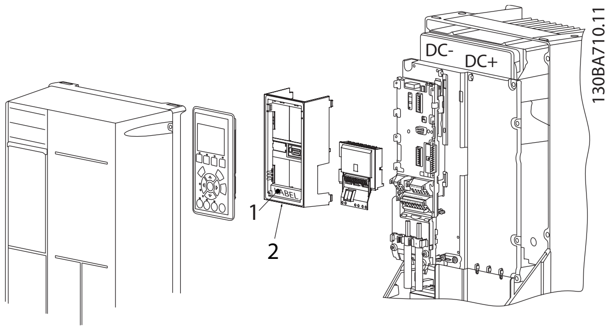
When the relay option kit is ordered separately, the kit includes

- Relay module MCB 105
- Enlarged LCP fixture and enlarged terminal cover
- Label for covering access to switches S201, S202 and S801
- Cable strips for fastening cables to relay module



1	**WARNING !** The label MUST be placed on the LCP frame as shown (UL approved).
2	Relay card

Illustration 7.3 Enclosure Sizes A2-A3-B3



1	**WARNING!** The label MUST be placed on the LCP frame as shown (UL approved).
2	Relay card

Illustration 7.4 Enclosure Sizes A5-B1-B2-B4-C1-C2-C3-C4

Illustration 7.5 Warning Label Placed on Option

How to add the Relay card MCB 105 option:

1. Disconnect power to the frequency converter.
2. Disconnect power to the live part connections on relay terminals.
3. Remove the LCP, the terminal cover, and the LCP fixture from the frequency converter.
4. Fit the MCB 105 option in slot B.
5. Connect the control cables and fasten the cables with the enclosed cable strips.
6. Make sure the length of the stripped wire is correct (see *Illustration 7.7*).
7. Do not mix live parts (high voltage) with control signals (PELV).
8. Fit the enlarged LCP fixture and enlarged terminal cover.
9. Replace the LCP.
10. Connect power to the frequency converter.
11. Select the relay functions in *5-40 Function Relay* [6-8], *5-41 On Delay, Relay* [6-8] and *5-42 Off Delay, Relay* [6-8].

NOTICE

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

NOTICE

To access RS485 termination, switch S801 or current/voltage switches S201/S202, dismount the relay card (see *Illustration 7.3* and *Illustration 7.4*, position 2).

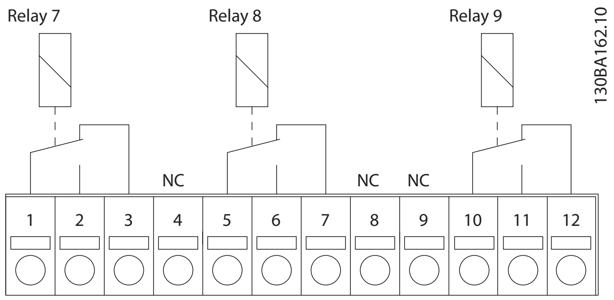


Illustration 7.6 Relays

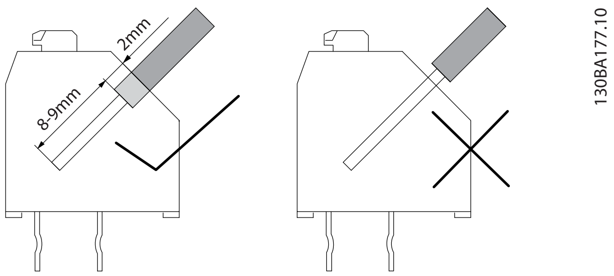
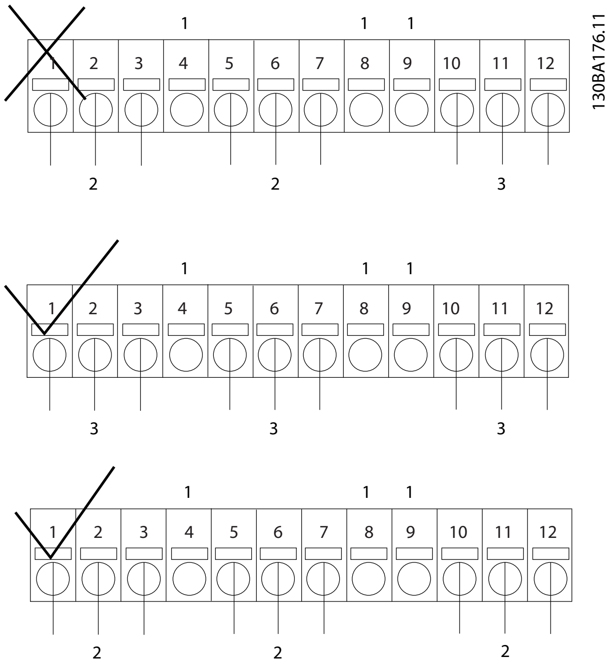


Illustration 7.7 Correct Wire Inserting



1	NC
2	Live part
3	PELV

Illustration 7.8 Correct Relay Wiring

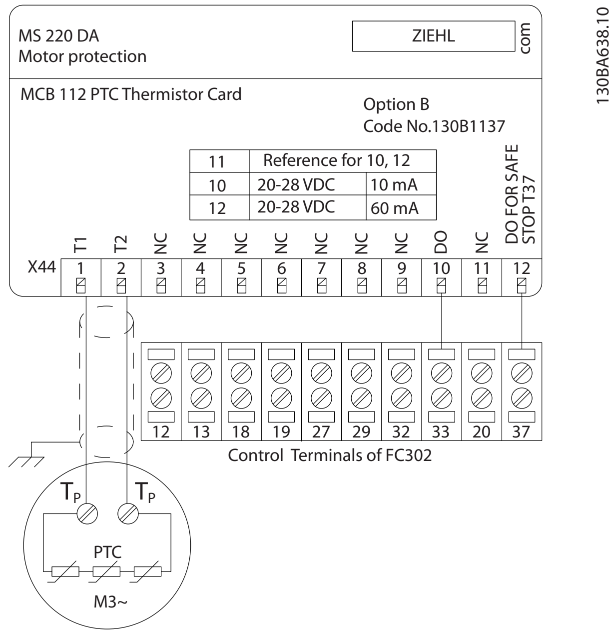


Illustration 7.9 Installation of MCB 112

NOTICE

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

7.11.3 VLT® PTC Thermistor Card MCB 112

The MCB 112 option makes it possible to monitor the temperature of an electrical motor through a galvanically isolated PTC thermistor input. It is a B option for frequency converters with STO.

For different application possibilities, see *chapter 4 Application Examples*.

X44/1 and X44/2 are the thermistor inputs. X44/12 enables STO of the frequency converter (T37), if the thermistor values make it necessary, and X44/10 informs the frequency converter that a request for STO came from the MCB 112 to ensure suitable alarm handling. One of the digital input parameters (or a digital input of a mounted option) must be set to *[80] PTC Card 1* to use the information from X44/10. Configure *5-19 Terminal 37 Digital Input* to the desired STO functionality (default is safe stop alarm).

ATEX Certification with FC 102, FC 103, FC 202, and FC 302

The MCB 112 has been certified for ATEX, which means that the frequency converter with the MCB 112 can be used with motors in potentially explosive atmospheres. See the *VLT® PTC Thermistor Card MCB 112 Operating Instructions* for more information.

Illustration 7.10 ATmosphère EXplosive (ATEX)

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
Rated ambient temperature range	-20 °C to +60 °C
	EN 60068-2-1 dry heat
Moisture	5-95%, no condensation permissible
Vibration resistance	10 to 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)	$4.10x10^{-3}$
SFF	78%
$\lambda_S + \lambda_{DD}$	8494 FIT
λ_{DU}	934 FIT
Ordering number 130B1137	

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روبروی پالایشگاه نفت پارس، پلاک ۱۲

7.11.4 VLT® Extended Relay Card MCB 113

The MCB 113 extends the I/O of the frequency converter by 7 digital inputs, 2 analog outputs, and 4 SPDT relays. The extended I/O increases flexibility and enables compliance with the German NAMUR NE37 recommendations.
The MCB 113 is a standard C1 option and is automatically detected after mounting.

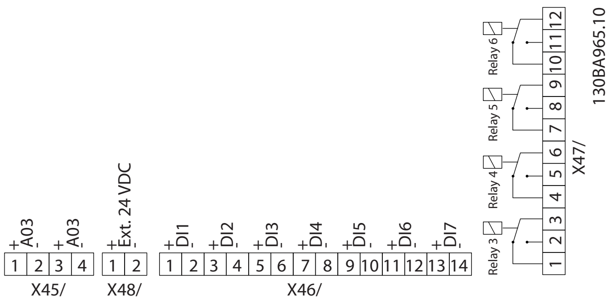


Illustration 7.11 Electrical Connections of MCB 113

To ensure galvanic isolation between the frequency converter and the option card, connect MCB 113 to an external 24 V on X48. When galvanic isolation is not required, the option card can be supplied through internal 24 V from the frequency converter.

NOTICE

To connect both 24 V signals and high-voltage signals in the relays, ensure that there is one unused relay between the 24 V signal and the high-voltage signal.

To set up MCB 113, use parameter groups:

- *5-1* Digital input*
- *6-7* Analog utput 3*
- *6-8* Analog output 4*
- *14-8* Options*
- *5-4* Relays*
- *16-6* Inputs and outputs*

NOTICE

In parameter group *5-4* Relay*,

- **Array [2] is relay 3.**
- **Array [3] is relay 4.**
- **Array [4] is relay 5.**
- **Array [5] is relay 6.**

Electrical Data

Relays	
Numbers	4 SPDT
Load at 250 V AC/30 V DC	8 A
Load at 250 V AC/30 V DC with cosφ = 0.4	3.5 A
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 between
Maximum throughput 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 throughput delay	10 ms

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

7.11.5 VLT® Sensor Input Option MCB 114

The sensor input option card MCB 114 can be used in the following cases:

- Sensor input for temperature transmitters PT100 and PT1000 for monitoring bearing temperatures.
- As general extension of analog inputs with one additional input for multi-zone control or differential pressure measurements.
- Support extended PID controllers with I/Os for set point, transmitter/sensor inputs.

Typical motors, designed with temperature sensors to protect bearings from being overloaded, are fitted with 3 PT100/1000 temperature sensors; 1 in front, 1 in the back-end bearing, and 1 in the motor windings. The VLT® Sensor Input Option MCB 114 supports 2- or 3-wire sensors with individual temperature limits for under-/overtemperature. An auto-detection of sensor type PT100 or PT1000 takes place at power-up.

7

If the measured temperature is either below the specified low limit, or above the specified high limit, the option generates an alarm. The individual measured temperature on each sensor input can be read out in the display or by readout parameters. If an alarm occurs, the relays or digital outputs can be programmed to be active high by selecting *[21] Thermal Warning* in parameter group *5-** Digital In/Out*.

A fault condition has a common warning/alarm number associated with it, which is *Alarm/Warning 20, Temp. input error*. Any present output can be programmed to be active in case the warning or alarm appears.

7.11.5.1 Electrical and Mechanical Specifications

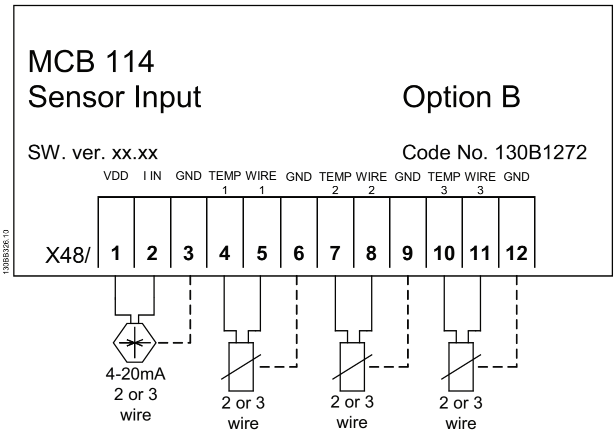
Analog Input	
Number of analog inputs	1
Format	0–20 mA or 4–20 mA
Wires	2
Input impedance	<200 Ω
Sample rate	1 kHz
3rd order filter	100 Hz at 3 dB
The option is able to supply the analog sensor with 24 V DC (terminal 1).	

Temperature Sensor Input	
Number of analog inputs supporting PT100/1000	3
Signal type	PT100/1000
Connection	PT 100 2 or 3 wire/PT1000 2 or 3 wire
Frequency PT100 and PT1000 input	1 Hz for each channel
Resolution	10 bit
Temperature range	-50–204 °C -58–399 °F

Galvanic Isolation	
The sensors to be connected are expected to be galvanically isolated from the mains voltage level	IEC 61800-5-1 and UL508C

Cabling	
Maximum signal cable length	500 m

7.11.5.2 Electrical Wiring



Terminal	Name	Function
1	VDD	24 V DC to supply 4–20 mA sensor
2	I in	4–20 mA input
3	GND	Analog input GND
4, 7, 10	Temp 1, 2, 3	Temperature input
5, 8, 11	Wire 1, 2, 3	3rd wire input if 3 wire sensors are used
6, 9, 12	GND	Temperature input GND

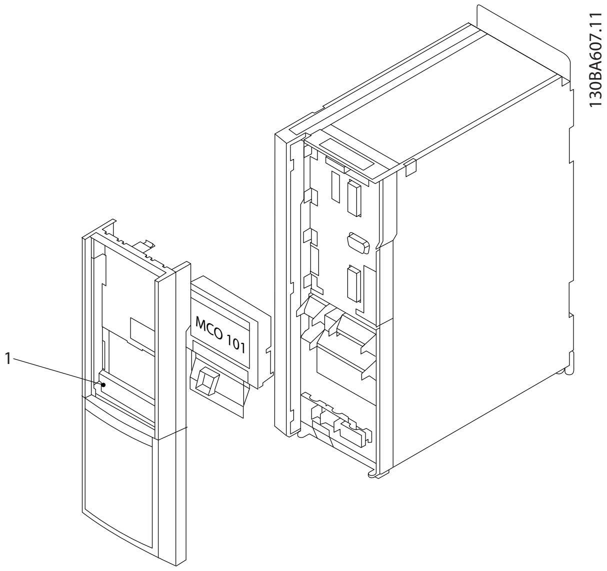
Illustration 7.12 MCB 114 Electrical Wiring

7.11.6 VLT® Extended Cascade Controller MCO 101

The MCO 101 option includes 3 pieces of change-over contacts and can be fitted into option slot B.

Max terminal load (AC)	240 V AC 2 A
Max terminal load (DC)	24 V DC 1 A
Min terminal load (DC)	5 V 10 mA
Max switching rate at rated load/min load	6 min^{-1}/20 s^{-1}

Table 7.61 MCO 101 Electrical Data



1	Dismount MCO 101 option to access RS485 termination (S801) or current/voltage switches (S201, S202)

Illustration 7.13 Mounting of B Option

How to add the MCO 101 option:

1. Disconnect power to the frequency converter.
2. Disconnect power to the live part connections on relay terminals.
3. Remove the LCP, the terminal cover and the cradle from the FC 202.
4. Fit the MCO 101 option in slot B.
5. Connect the control cables and relieve the cables by the enclosed cable strips.
6. Fit the extended cradle and terminal cover.
7. Remount the LCP.
8. Connect power to the frequency converter.

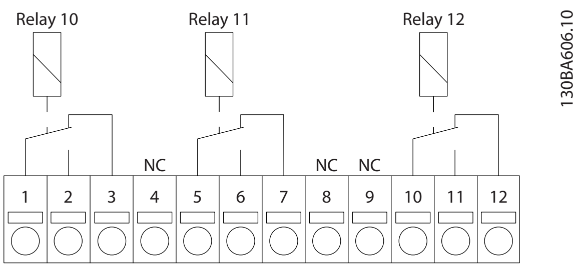


Illustration 7.14 Usage of Connections

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روبروی پالایشگاه نفت پارس، پلاک ۱۲

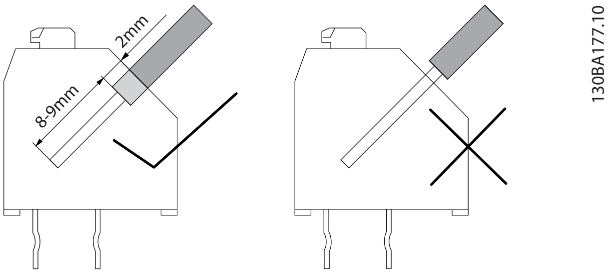
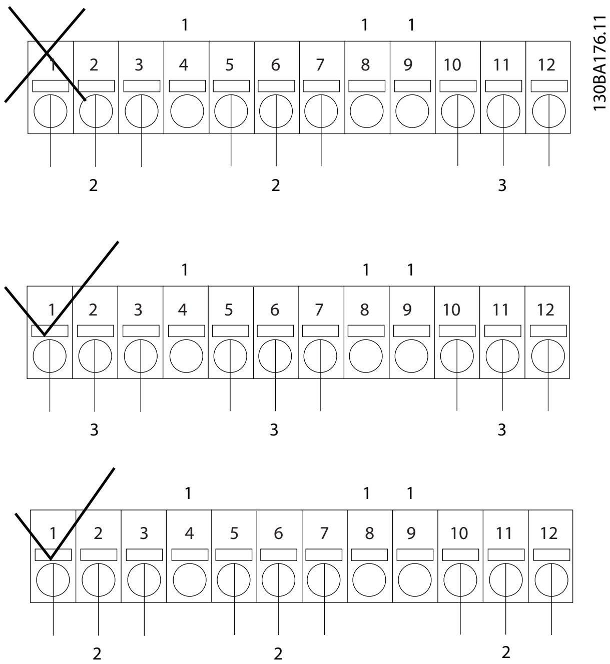


Illustration 7.15 Mounting of Cables

WARNING

Do not combine low voltage parts and PELV systems (see *Illustration 7.16*.



1	NC
2	Live part
3	PELV

Illustration 7.16 Incorrect and Correct Relay Wiring

7.11.7 VLT® Advanced Cascade Controller MCO 102

The VLT advanced cascade control card MCO 102 option is exclusively intended for use in option slot C1. The mounting position of C1 options is shown in *Illustration 7.17*.

Max terminal load (AC)	240 V AC 2 A
Max terminal load (DC)	24 V DC 1 A
Min terminal load (DC)	5 V 10 mA
Max switching rate at rated load/minimum load	6 min^{-1}/20 s^{-1}

Table 7.62 Electrical Data, MCO 102

Tools required
Some items are needed for the installation of a C option mounting kit (depending on the enclosure):

Type	Description	Ordering number
Options		
MCF 105	Mounting Kit frame size A2 and A3 (40 mm for one C Option)	130B7530
MCF 105	Mounting Kit Frame size A5	130B7532
MCF 105	Mounting Kit Frame size B, C, D, E , F1 and F3 (Except B3)	130B7533
MCF 105	Mounting Kit frame size B3 (40 mm for one C Option)	130B1413
Accessory bag		
MCO 102	Accessory Bag	130B0152

Table 7.63 Ordering Numbers for Mounting Kits and Accessory Bag

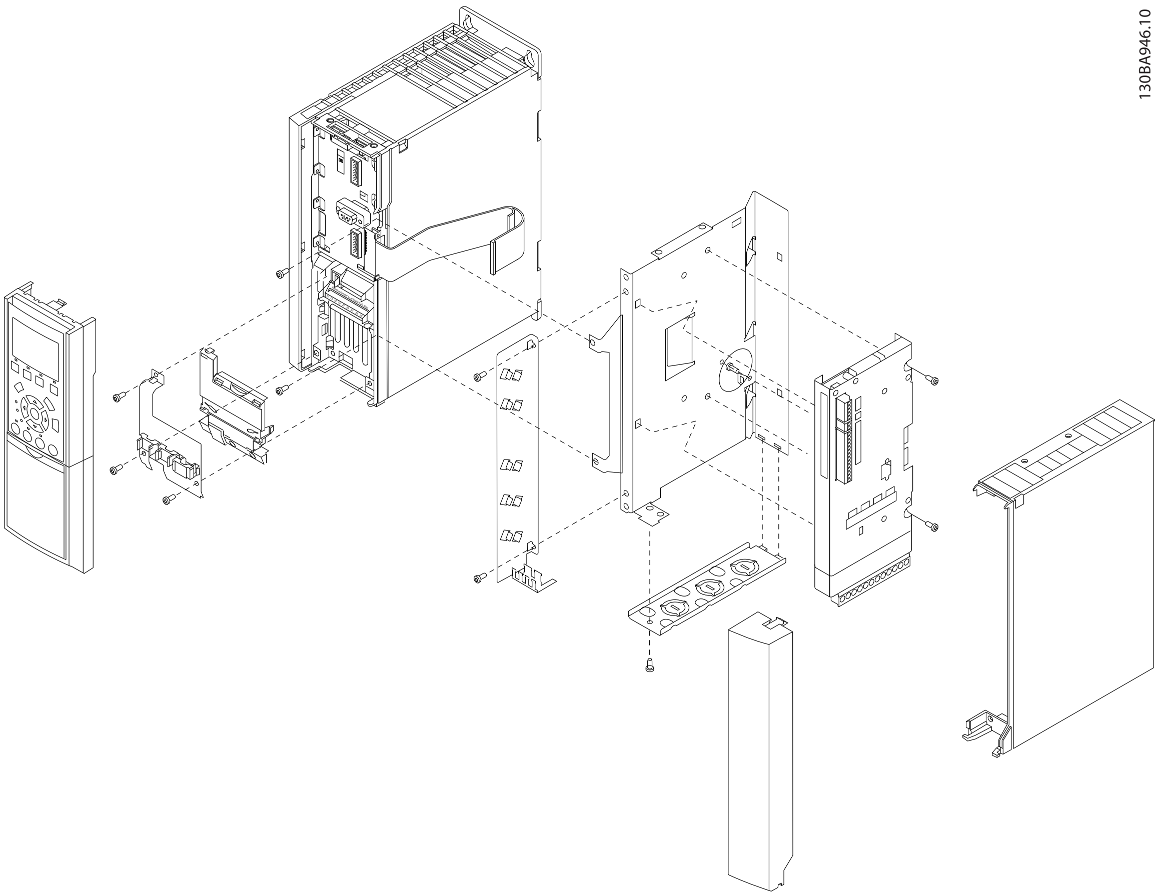


Illustration 7.17 Enclosure A2, A3 (and B3) 40 mm (only one C option)

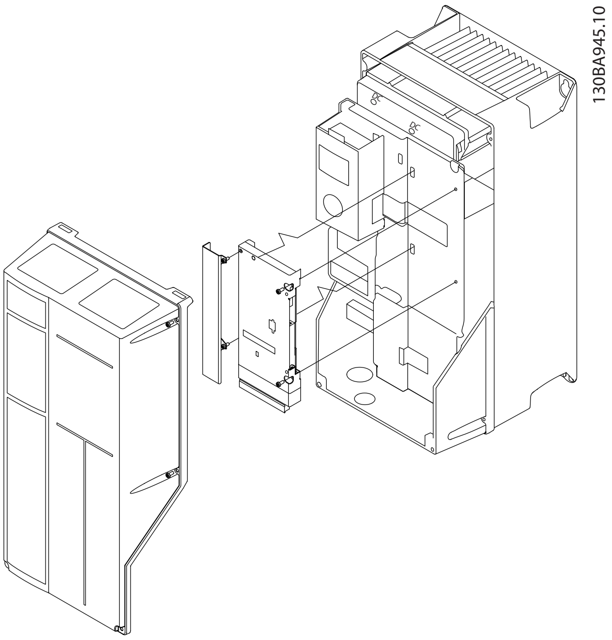


Illustration 7.18 Enclosures B (except B3) and C

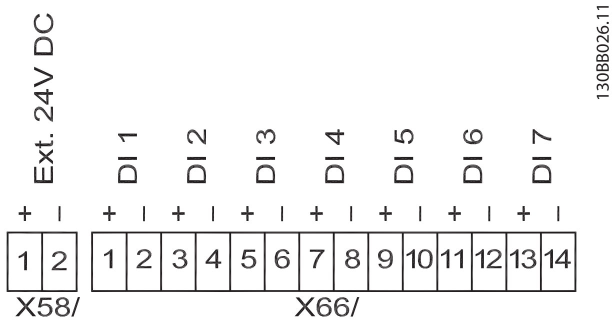


Illustration 7.20 Advanced Cascade Controller MCO 102 Terminal Connections to the 7 Digital Inputs and Access to the Internal 24 V DC

How to add the MCO 102 option

1. Disconnect power.
2. Disconnect power to the live part connections on relay terminals.
3. Remove the LCP, the terminal cover and the cradle from the FC 202.
4. Fit the MCO 102 option in slot C1.
5. Connect the control cables and relieve the cables by the enclosed cable strips.
6. Fit the extended cradle and terminal cover.
7. Remount the LCP.
8. Connect power to the frequency converter.

Wiring the Terminals

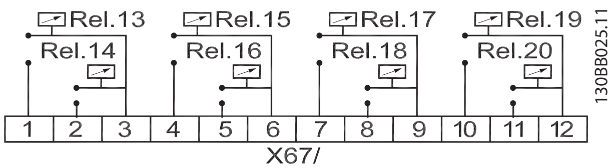


Illustration 7.19 Advanced Cascade Controller MCO 102 Terminal Connections, 8 Relays

8 Appendix - Selected Drawings

8.1 Mains Connection Drawings (3-phases)

This collection of drawings is intended to aid planning for access, in the design phase.
Refer to the *operating instructions* for installation procedures including:

- Safety requirements.
- Step-by-step installation procedures.
- Alternative configurations.
- Additional drawings.

Mains connection for enclosures A1, A2 and A3:

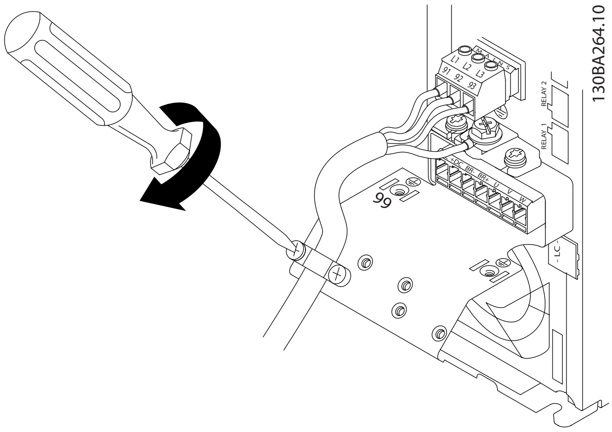


Illustration 8.1 Support Bracket

Mains connection for enclosures A4/A5

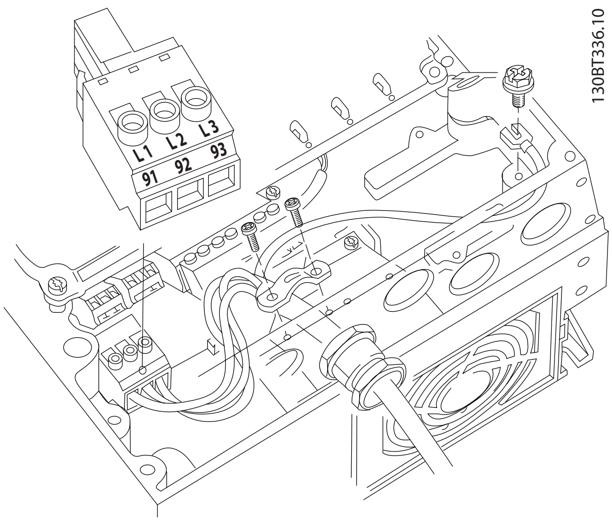


Illustration 8.2 Mains and Grounding without Disconnector

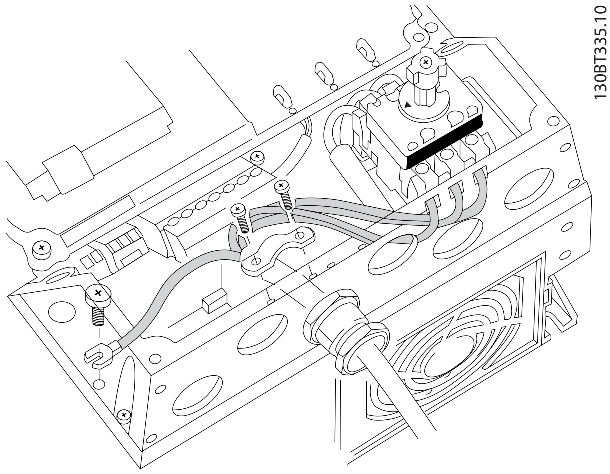


Illustration 8.3 Mains and Grounding with Disconnector (for S2 variants in enclosure size B2, the extra terminal block must be used for mains connection.

When disconnector is used (enclosures A4/A5), mount the PE on the left side of the frequency converter.

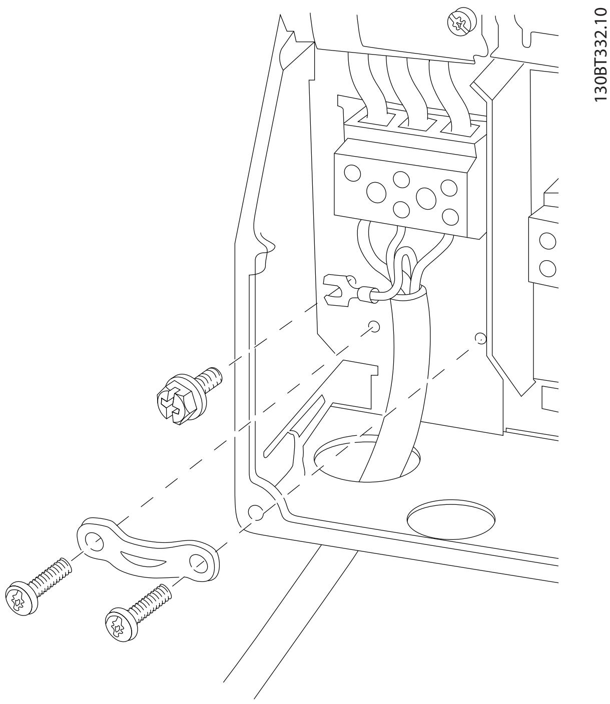


Illustration 8.4 Mains Connection Enclosures B1 and B2

8

8

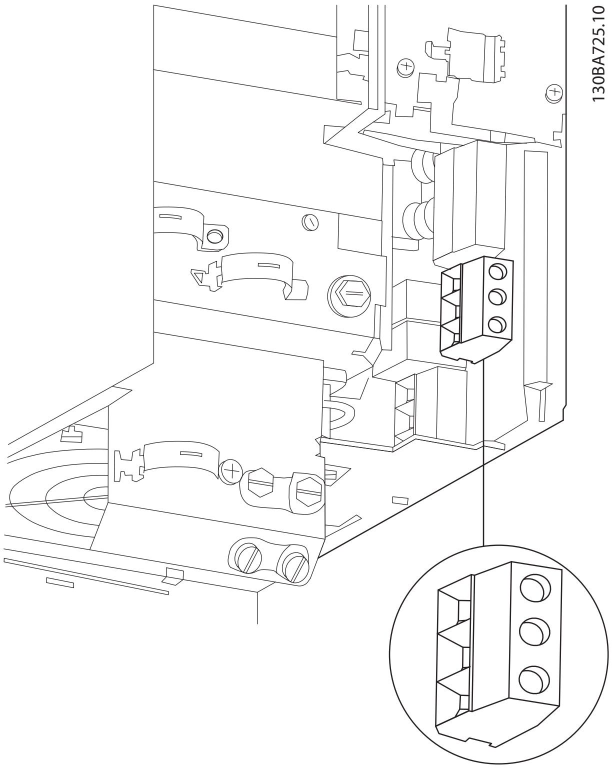


Illustration 8.5 Mains Connection Enclosure B3

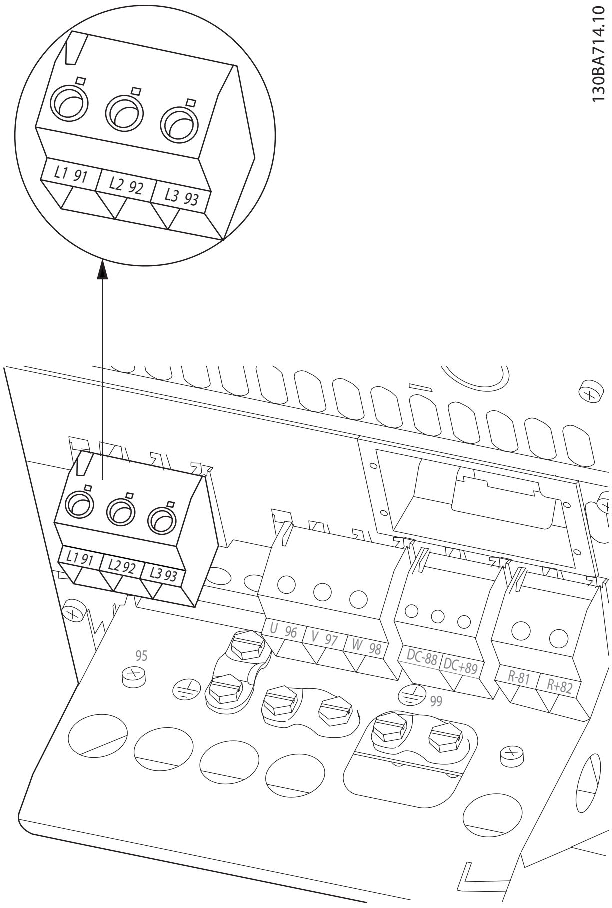


Illustration 8.6 Mains Connection Enclosure B4

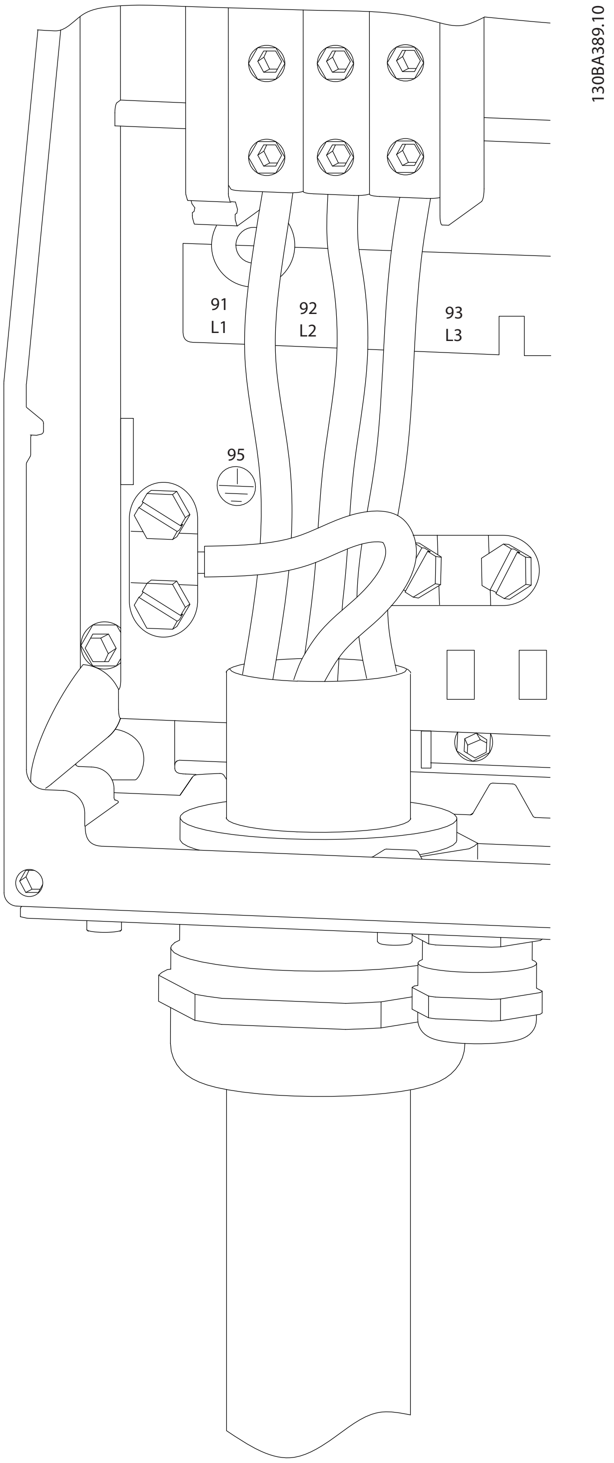


Illustration 8.7 Mains Connection Enclosures C1 and C2 (IP21/NEMA Type 1 and IP55/66/NEMA Type 12).

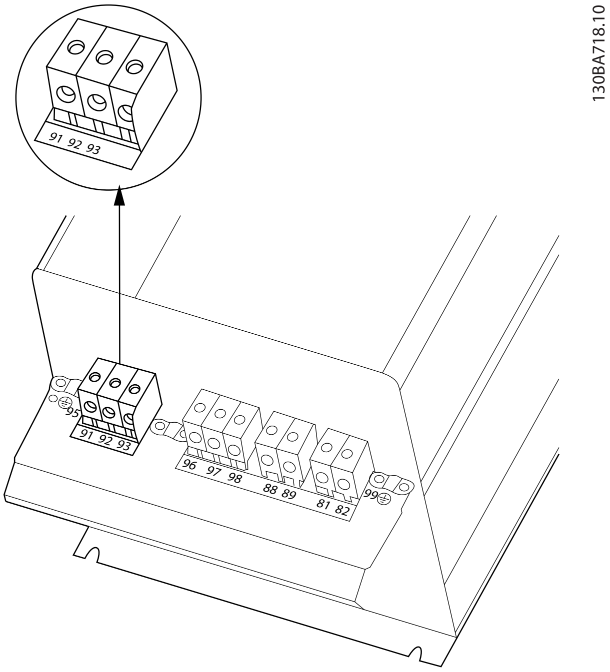


Illustration 8.8 Mains Connection Enclosures C3 (IP20).

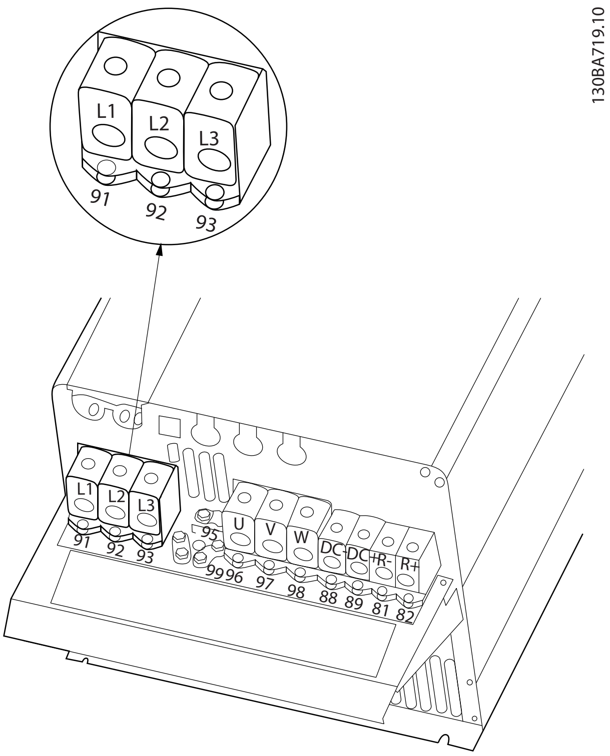


Illustration 8.9 Mains Connection Enclosures C4 (IP20).

8.2 Motor Connection Drawings

Motor connection

This collection of drawings is intended to aid planning for access in the design phase.

Refer to the *operating instructions* for installation procedures including:

- Safety requirements.
- Step-by-step installation procedures.
- Terminal descriptions.
- Alternative configurations.
- Additional drawings.

Terminal number	96	97	98	99	
	U	V	W	PE1)	Motor voltage 0–100% of mains voltage.
					3 wires out of motor
	U1	V1	W1	PE1)	Delta-connected
	W2	U2	V2		6 wires out of motor
	U1	V1	W1	PE1)	Star-connected U2, V2, W2 U2, V2 and W2 to be interconnected separately.

Table 8.1 Terminal Descriptions

1) Protected Ground Connection

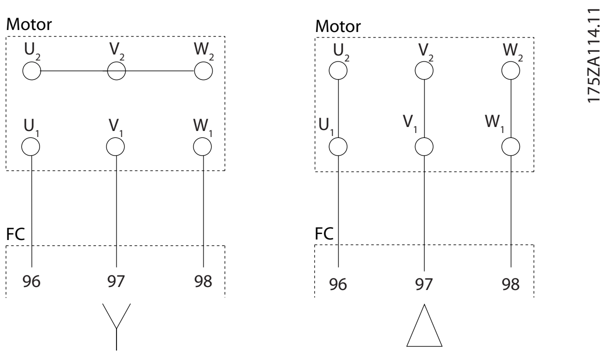


Illustration 8.10 Star and Delta Connections

All types of 3-phase asynchronous standard motors can be connected to the frequency converter. Normally, small motors are star-connected (230/400 V, Y). Large motors are normally delta-connected (400/690 V, Δ). Refer to the motor name plate for correct connection mode and voltage.

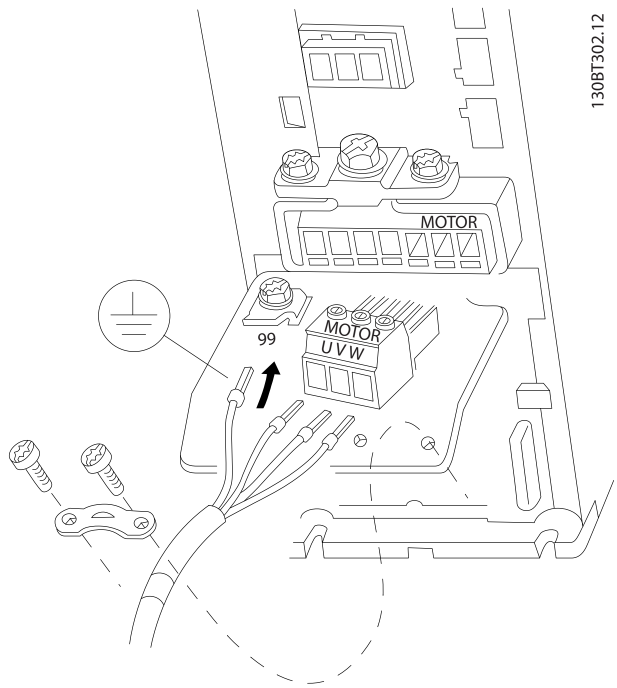


Illustration 8.11 Motor Connection for Enclosures A1, A2 and A3

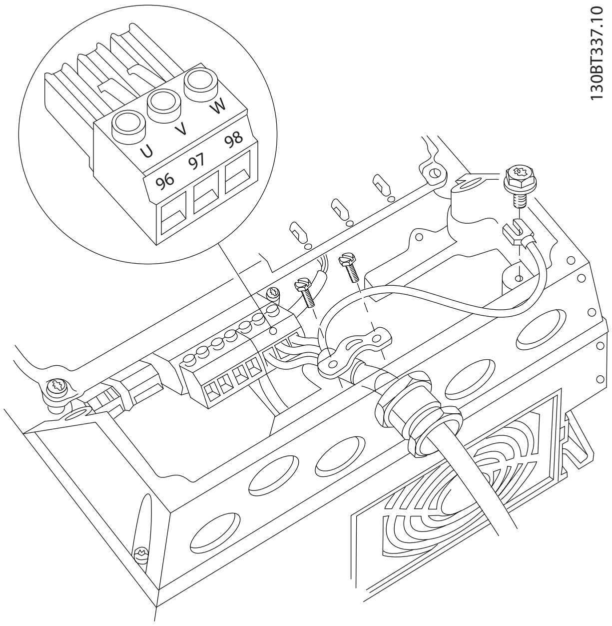


Illustration 8.12 Motor Connection for Enclosures A4/A5

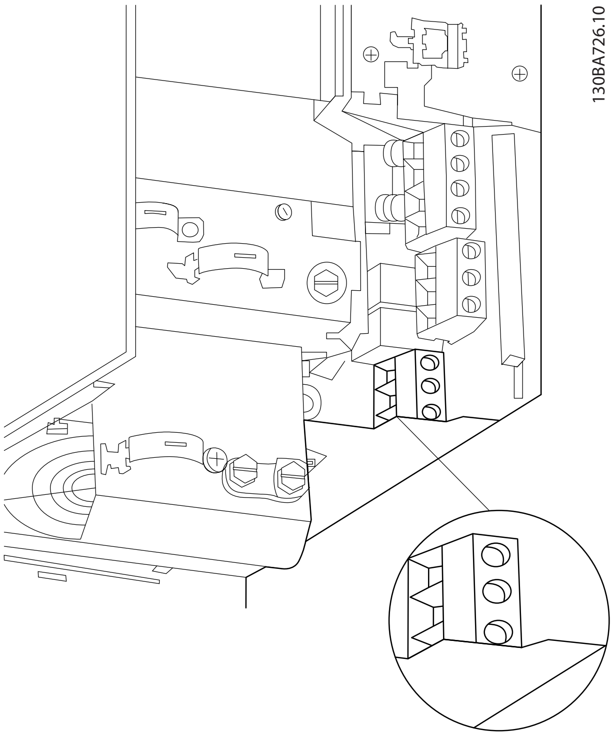


Illustration 8.14 Motor Connection for Enclosure B3

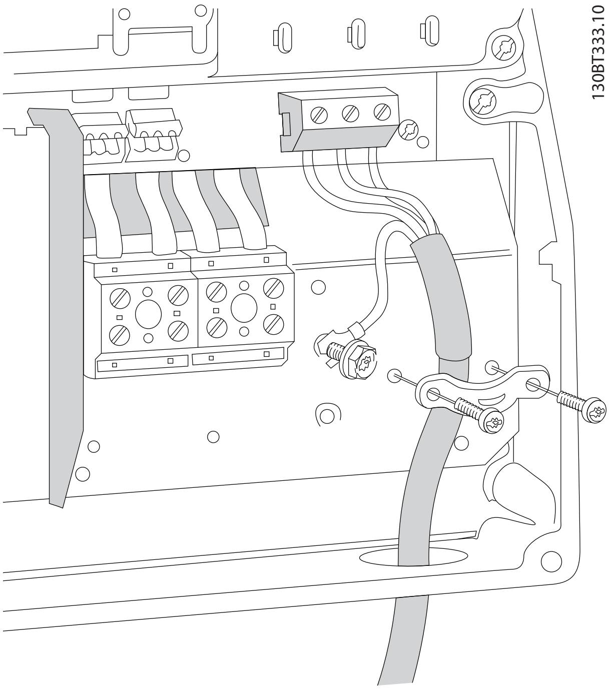


Illustration 8.13 Motor Connection for Enclosures B1 and B2

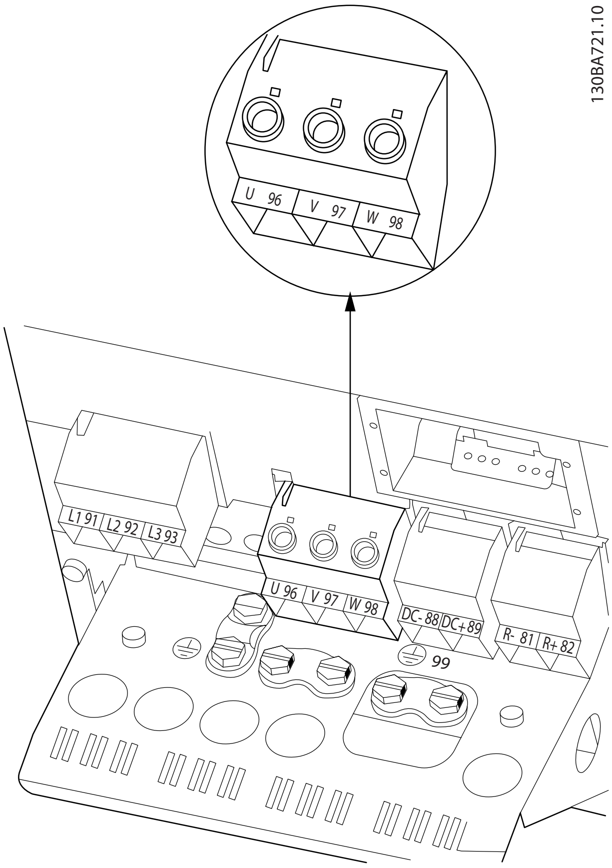


Illustration 8.15 Motor Connection for Enclosure B4

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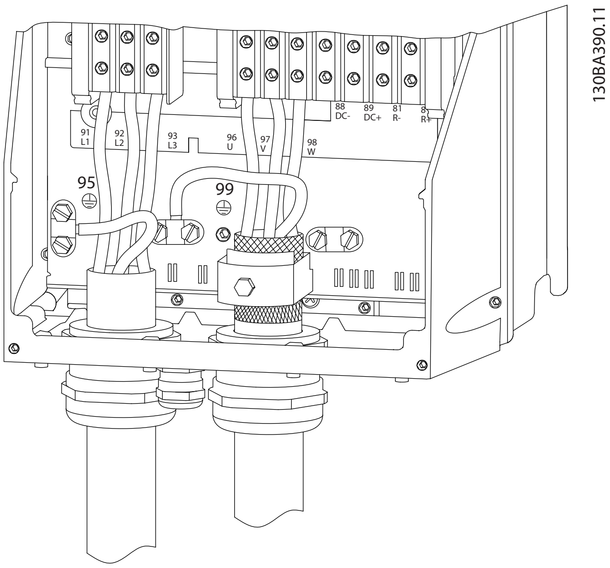


Illustration 8.16 Motor Connection Enclosures C1 and C2 (IP21/ NEMA Type 1 and IP55/66/NEMA Type 12)

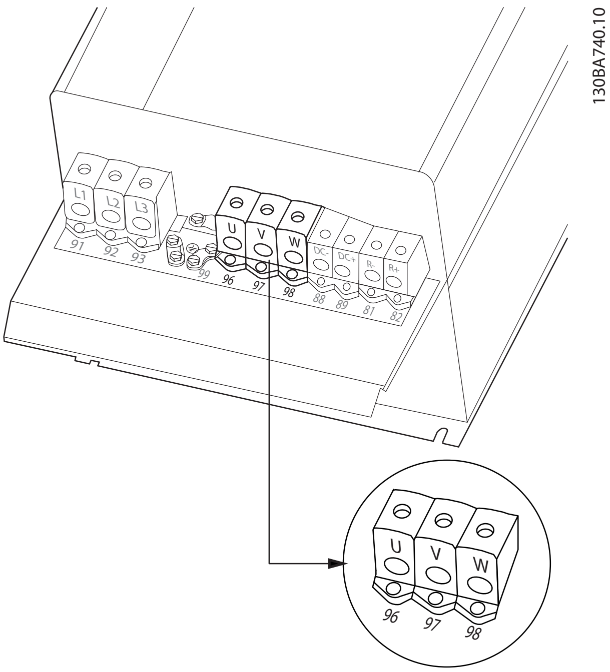


Illustration 8.17 Motor Connection for Enclosures C3 and C4

8.3 Relay Terminal Drawings

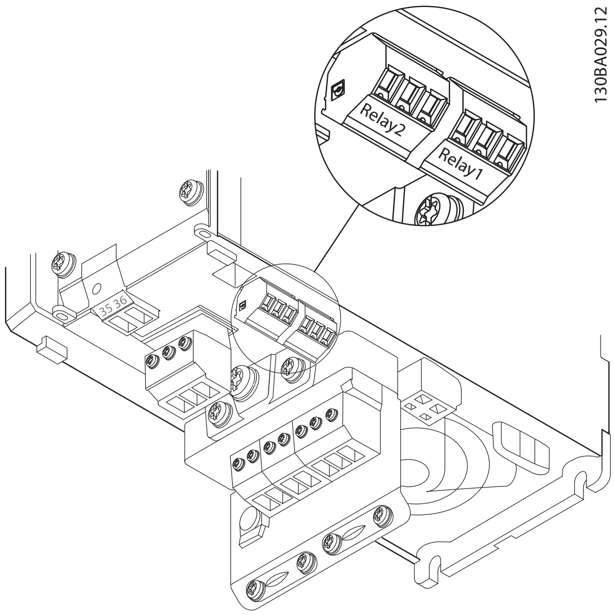


Illustration 8.18 Terminals for Relay Connection (Enclosure Sizes A1, A2 and A3).

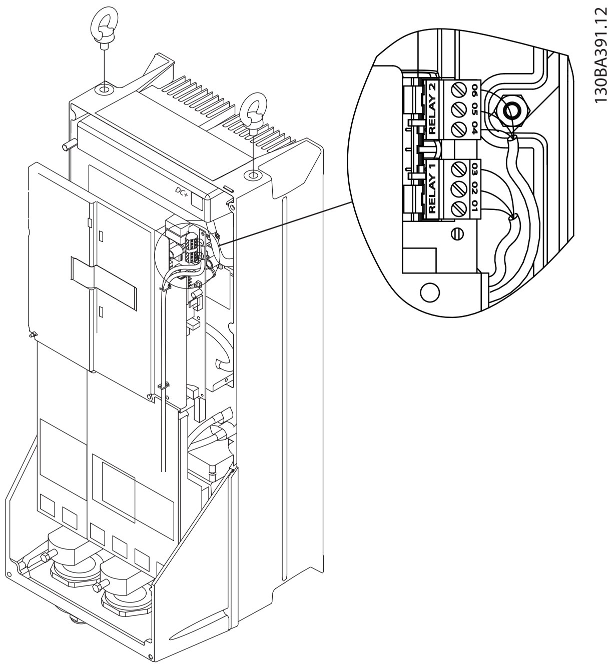


Illustration 8.19 Terminals for Relay Connection (Enclosure Sizes C1 and C2).

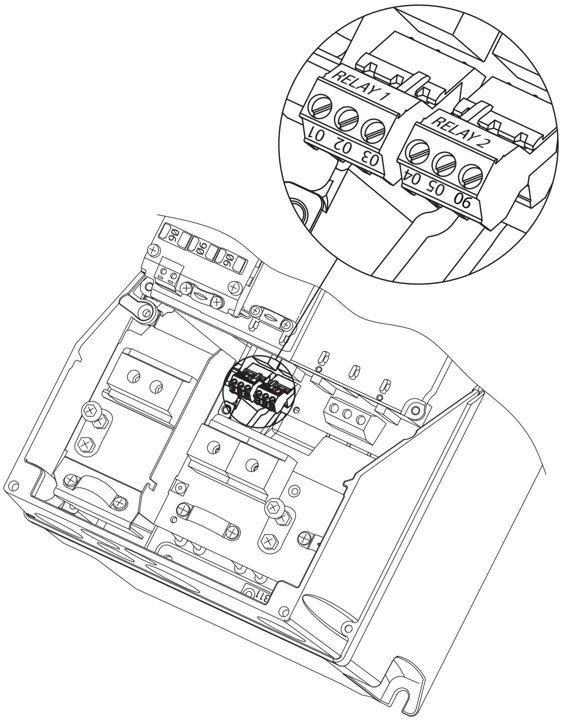
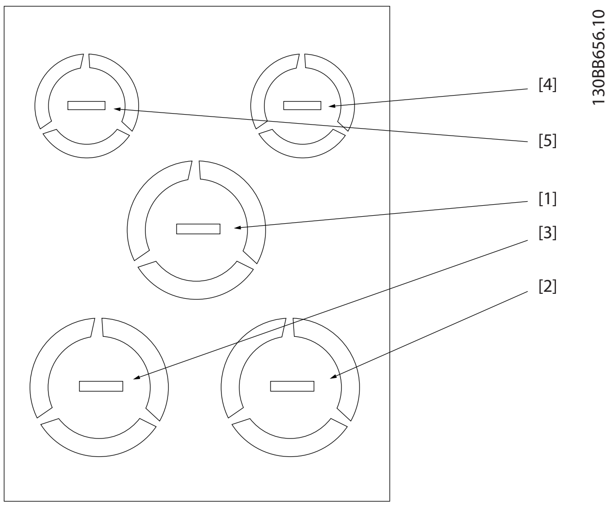


Illustration 8.20 Terminals for Relay Connection (Enclosure Sizes A5, B1 and B2).

8.4 Cable Entry Holes



Hole number and recommended use		Dimensions[1)] UL [in]	[mm]	Nearest metric
1	Mains	3/4	28.4	M25
2	Motor	3/4	28.4	M25
3	Brake/load sharing	3/4	28.4	M25
4	Control cable	1/2	22.5	M20
5	Control cable	1/2	22.5	M20
1) Tolerance ±0.2 mm				

Illustration 8.21 Enclosure Size A2, IP21

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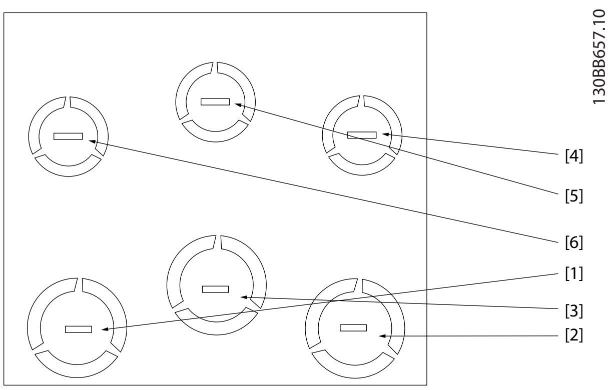
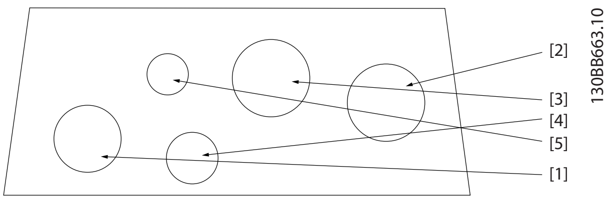


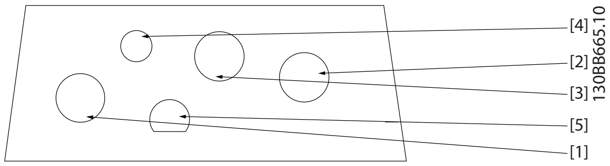
Hole number and recommended use		Dimensions[1)]		Nearest metric
		UL [in]	[mm]	
1	Mains	3/4	28.4	M25
2	Motor	3/4	28.4	M25
3	Brake/load sharing	3/4	28.4	M25
4	Control cable	1/2	22.5	M20
5	Control cable	1/2	22.5	M20
6	Control cable	1/2	22.5	M20
1) Tolerance ±0.2 mm				

Illustration 8.22 Enclosure Size A3, IP21



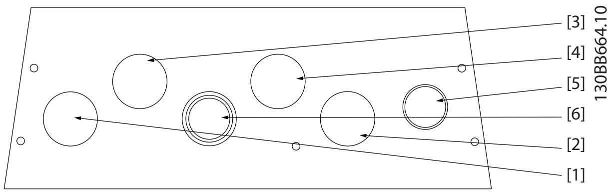
Hole number and recommended use		Dimensions[1)]		Nearest metric
		UL [in]	[mm]	
1	Mains	3/4	28.4	M25
2	Motor	3/4	28.4	M25
3	Brake/load sharing	3/4	28.4	M25
4	Control cable	1/2	22.5	M20
5	Removed	-	-	-
1) Tolerance ±0.2 mm				

Illustration 8.23 Enclosure Size A4, IP55



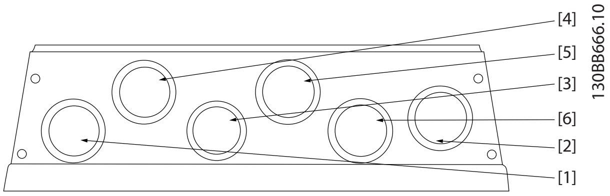
Hole number and recommended use		Nearest metric
1	Mains	M25
2	Motor	M25
3	Brake/load sharing	M25
4	Control cable	M16
5	Control cable	M20

Illustration 8.24 Enclsure Size A4, IP55 Threaded Gland Holes



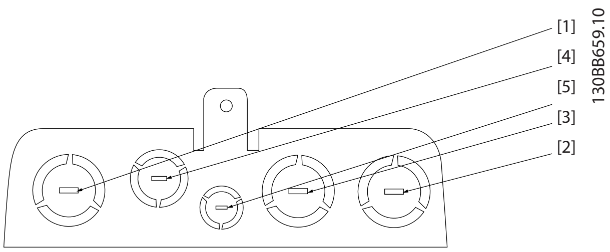
Hole number and recommended use		Dimensions[1)]		Nearest metric
		UL [in]	[mm]	
1	Mains	3/4	28.4	M25
2	Motor	3/4	28.4	M25
3	Brake/load sharing	3/4	28.4	M25
4	Control cable	3/4	28.4	M25
5	Control cable[2)]	3/4	28.4	M25
6	Control cable[2)]	3/4	28.4	M25
1) Tolerance ±0.2 mm				
2) Knock-out hole				

Illustration 8.25 Enclosure Size A5, IP55



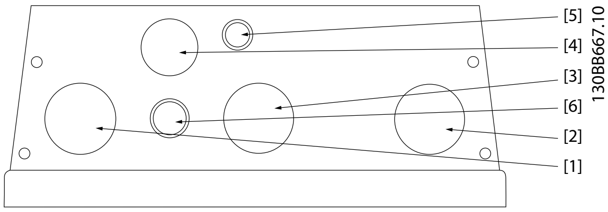
Hole number and recommended use		Nearest metric
1	Mains	M25
2	Motor	M25
3	Brake/load sharing	28.4 mm[1)]
4	Control cable	M25
5	Control cable	M25
6	Control cable	M25
1) Knock-out hole		

Illustration 8.26 Enclosure Size A5,IP55 Threaded Gland Holes



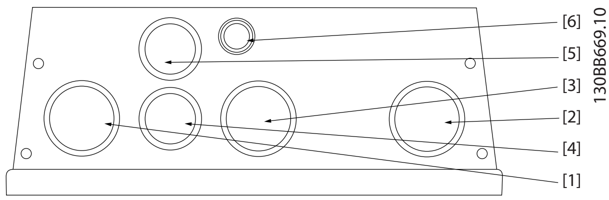
Hole number and recommended use		Dimensions[1)]		Nearest metric
		UL [in]	[mm]	
1	Mains	1	34.7	M32
2	Motor	1	34.7	M32
3	Brake/load sharing	1	34.7	M32
4	Control cable	1	34.7	M32
5	Control cable	1/2	22.5	M20
1) Tolerance ±0.2 mm				

Illustration 8.27 Enclosure Size B1, IP21



Hole number and recommended use		Dimensions[1)]		Nearest metric
		UL [in]	[mm]	
1	Mains	1	34.7	M32
2	Motor	1	34.7	M32
3	Brake/load sharing	1	34.7	M32
4	Control cable	3/4	28.4	M25
5	Control cable	1/2	22.5	M20
5	Control cable[2)]	1/2	22.5	M20
1) Tolerance ±0.2 mm				
2) Knock-out hole				

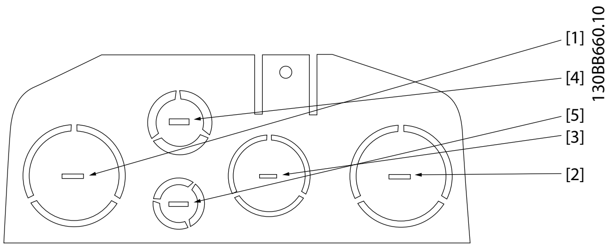
Illustration 8.28 Enclosure Size B1, IP55



Hole number and recommended use		Nearest metric
1	Mains	M32
2	Motor	M32
3	Brake/load sharing	M32
4	Control cable	M25
5	Control cable	M25
6	Control cable	22.5 mm[1)]
1) Knock-out hole		

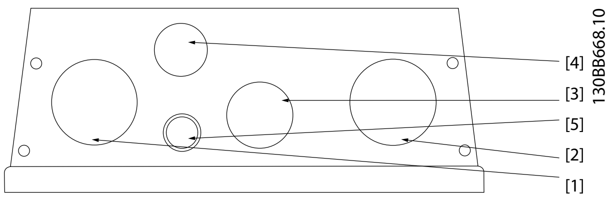
Illustration 8.29 Enclosure Size B1, IP55 Threaded Gland Holes

8



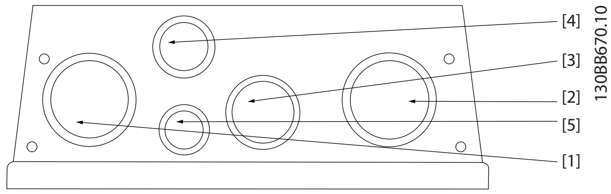
Hole number and recommended use		Dimensions[1) UL [in]	Dimensions[1) [mm]	Nearest metric
1	Mains	1 1/4	44.2	M40
2	Motor	1 1/4	44.2	M40
3	Brake/load sharing[2)	1	34.7	M32
4	Control cable	3/4	28.4	M25
5	Control cable	1/2	22.5	M20
1) Tolerance ±0.2 mm				
2) Mains for S2 variants with Mains Disconnect.				

Illustration 8.30 Enclosure Size B2, IP21



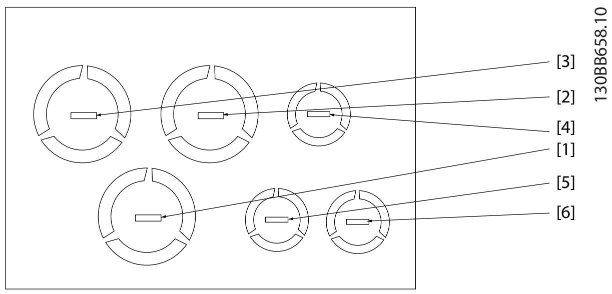
Hole number and recommended use		Dimensions[1) UL [in]	Dimensions[1) [mm]	Nearest metric
1	Mains	1 1/4	44.2	M40
2	Motor	1 1/4	44.2	M40
3	Brake/load sharing[3)	1	34.7	M32
4	Control cable	3/4	28.4	M25
5	Control cable[2)	1/2	22.5	M20
1) Tolerance ±0.2 mm				
2) Knock-out hole				
3) Mains for S2 variants with Mains Disconnect.				

Illustration 8.31 Enclosure Size B2, IP55



Hole number and recommended use		Nearest metric
1)	Mains	M40
2)	Motor	M40
3)	Brake/load sharing[1)	M32
4)	Control cable	M25
5)	Control cable	M20
1) Mains for S2 variants with Mains Disconnect.		

Illustration 8.32 Enclosure Size B2, IP55 Threaded Gland Holes



Hole number and recommended use		Dimensions[1) UL [in]	Dimensions[1) [mm]	Nearest metric
1	Mains	1	34.7	M32
2	Motor	1	34.7	M32
3	Brake/load sharing	1	34.7	M32
4	Control cable	1/2	22.5	M20
5	Control cable	1/2	22.5	M20
6	Control cable	1/2	22.5	M20
1) Tolerance ±0.2 mm				

Illustration 8.33 Enclosure Size B3, IP21

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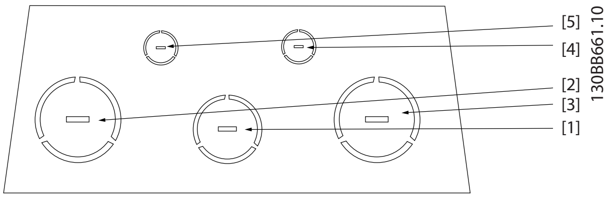

Hole number and recommended use		Dimensions[1)]		Nearest metric
		UL [in]	[mm]	
1	Mains	2	63.3	M63
2	Motor	2	63.3	M63
3	Brake/load sharing	1 1/2	50.2	M50
4	Control cable	3/4	28.4	M25
5	Control cable	1/2	22.5	M20
1) Tolerance ±0.2 mm				

Illustration 8.34 Enclosure Size C1, IP21

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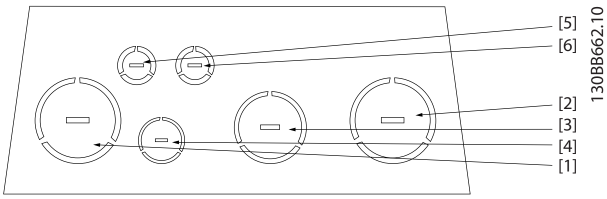

Hole number and recommended use		Dimensions[1)]		Nearest metric
		UL [in]	[mm]	
1	Mains	2	63.3	M63
2	Motor	2	63.3	M63
3	Brake/load sharing	1 1/2	50.2	M50
4	Control cable	3/4	28.4	M25
5	Control cable	1/2	22.5	M20
6	Control cable	1/2	22.5	M20
1) Tolerance ±0.2 mm				

Illustration 8.35 Enclosure Size C2, IP21

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130R0337 MG20N602 09/2014

Design Guide
VLT® AutomationDrive FC 301/302
0.25-75 kW

THE REAL DRIVE

Contents

1

1 Introduction

1.1 Purpose of the Design Guide

The Design Guide provides information required for integration of the frequency converter in a diversity of applications.

VLT® is a registered trademark.

1.2 Additional Resources

Other resources are available to understand advanced frequency converter operation, programming, and directives compliance.

- The *Operating Instructions* provide detailed information for the installation and start up of the frequency converter.
- The *Programming Guide* provides greater detail in how to work with parameters and many application examples.
- The *VLT® Safe Torque Off Operating Instructions* describe how to use Danfoss frequency converters in functional safety applications.
- Supplemental publications and manuals are available from Danfoss.

- Optional equipment is available that may change some of the information described in these publications. Be sure to see the instructions supplied with the options for specific requirements.

1.3 Abbreviations, Symbols and Conventions

Conventions
Numbered lists indicate procedures.
Bullet lists indicate other information and description of illustrations.
Italicised text indicates

- cross reference
- link
- footnote
- parameter name, parameter group name, parameter option

60° AVM	60° Asynchronous Vector Modulation
A	Ampere/AMP
AC	Alternating current
AD	Air discharge
AI	Analog Input
AMA	Automatic Motor Adaptation
AWG	American wire gauge
°C	Degrees Celsius
CD	Contant discharge
CM	Common mode
CT	Constand Torque
DC	Direct current
DI	Digital Input
DM	Differential mode
D-TYPE	Drive Dependent
EMC	Electro Magnetic Compatibility
ETR	Electronic Thermal Relay
f_{JOG}	Motor frequency when jog function is activated
f_M	Motor frequency
f_{MAX}	The maximum output frequency the frequency converter applies on its output
f_{MIN}	The minimum motor frequency from frequency converter
$f_{M,N}$	Nominal motor frequency
FC	Frequency converter
g	Gram
Hiperface®	Hiperface® is a registered trademark by Stegmann
hp	Horsepower
HTL	HTL encoder (10-30 V) pulses - High-voltage Transistor Logic
Hz	Hertz
I_{INV}	Rated Inverter Output Current
I_{LIM}	Current limit
$I_{M,N}$	Nominal motor current
$I_{VLT,MAX}$	The maximum output current
$I_{VLT,N}$	The rated output current supplied by the frequency converter
kHz	Kilohertz
LCP	Local Control Panel
lsb	Least significant bit
m	Meter
mA	Milliampere
MCM	Mille Circular Mil
MCT	Motion Control Tool
mH	Millihenry Inductance
min	Minute
ms	Millisecond
msb	Most significant bit

η_{VLT}	Efficiency of the frequency converter defined as ratio between power output and power input
nF	Nanofarad
NLCP	Numerical Local Control Panel
Nm	Newton Meters
n_s	Synchronous Motor Speed
On-line/Off-line Parameters	Changes to on-line parameters are activated immediately after the data value is changed
$P_{br,cont.}$	Rated power of the brake resistor (average power during continuous braking)
PCB	Printed Circuit Board
PCD	Process Data
PELV	Protective Extra Low Voltage
P_m	Frequency converter nominal output power as HO
$P_{M,N}$	Nominal motor power
PM motor	Permanent Magnet motor
Process PID	The PID regulator maintains the desired speed, pressure, temperature, etc.
$R_{br,nom}$	The nominal resistor value that ensures a brake power on motor shaft of 150/160% for 1 minute
RCD	Residual Current Device
Regen	Regenerative terminals
R_{min}	Minimum permissible brake resistor value by frequency converter
RMS	Root Mean Square
RPM	Revolutions Per Minute
R_{rec}	Resistor value and resistance of the brake resistor
s	Second
SFAVM	Stator Flux oriented Asynchronous Vector Modulation
STW	Status Word
SMPS	Switch Mode Power Supply
THD	Total Harmonic Distortion
T_{LIM}	Torque limit
TTL	TTL encoder (5 V) pulses - Transistor Transistor Logic
$U_{M,N}$	Nominal motor voltage
V	Volts
VT	Variable Torque
VVC^+	Voltage Vector Control

Table 1.1 Abbreviations

The following symbols are used in this document:

WARNING

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

CAUTION

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

NOTICE

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

1.4 Definitions

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

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.

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.

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

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*.

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

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

1

Trip
A state entered in fault situations, e.g. if the frequency converter is subject to an overtemperature 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.

Power Factor
The True Power Factor (lambda) takes all the harmonics into consideration and is always smaller than the Power Factor (cosphi) that only considers the 1st harmonics of current and voltage.

$$\cos\varphi = \frac{P\,[\mathrm{kW}]}{P\,[\mathrm{kVA}]} = \frac{U\lambda \ x\ I\lambda \ x \cos\varphi}{U\lambda \ x\ I\lambda}$$

Cosphi is also known as displacement power factor.

Both lambda and cosphi are stated for Danfoss VLT® frequency converters in *chapter 6.2.1 Mains Supply*.

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.

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.

1.5 Document and Software Version

This manual is regularly reviewed and updated. All suggestions for improvement are welcome. *Table 1.2* shows the document version and the corresponding software version.

Edition	Remarks	Software version
MG33BFxx	Replaces MG33BExx	6.72

Table 1.2 Document and Software Version

1.6 Regulatory Compliance

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

1.6.1 CE Mark

The CE mark (Communauté européenne) indicates that the product manufacturer conforms to all applicable EU directives. The 3 EU directives applicable to the design and manufacture of frequency converters are the directive low-voltage, the EMC directive, and (for units with an integrated safety function) the machinery directive.

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

1.6.1.1 Low Voltage Directive

Frequency converters are classified as electronic components and must be CE labelled in accordance with the low-voltage directive. The directive applies to all electrical equipment in the 50–1000 V AC and the 75–1600 V DC voltage ranges.

The directive mandates that the equipment design must ensure the safety and health of people and livestock are not endangered and the preservation of material worth so long as the equipment is properly installed, maintained, and used as intended. Danfoss CE-labels comply with the low-voltage directive and provide a declaration of conformity upon request.

1.6.1.2 EMC Directive

Electromagnetic compatibility (EMC) means that electro-magnetic interference between apparatus does not hinder their performance. The basic protection requirement of the EMC Directive 2004/108/EC states that devices that generate electromagnetic interference (EMI), or whose operation could be affected by EMI, must be designed to limit the generation of electromagnetic interference and shall have a suitable degree of immunity to EMI when properly installed, maintained, and used as intended.

A frequency converter can be used as stand-alone device or as part of a more complex installation. Devices used as stand alone or as part of a system must bear the CE mark. Systems must not be CE marked but must comply with the basic protection requirements of the EMC directive.

1.6.1.3 Machinery Directive

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

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

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

1.6.2 UL Compliance

UL Listed

Illustration 1.1 UL

NOTICE

Frequency converters of enclosure type T7 (525-690 V) are not certified for UL.

The frequency converter complies with UL508C thermal memory retention requirements. For more information, refer to the section *Motor Thermal Protection* in the *Design Guide*.

1.6.3 C-tick Compliance

1.6.4 Marine Compliance

For compliance with the European Agreement concerning International Carriage of Dangerous Goods by Inland Waterways (ADN), refer to .

1.7 Disposal Instruction

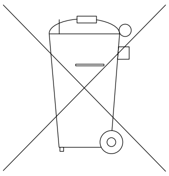
	Do not dispose of equipment containing electrical components together with domestic waste. Collect it separately in accordance with local and currently valid legislation.

Table 1.3 Disposal Instruction

1.8 Safety

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

Refer to the *Operating Instructions*, shipped with the unit and available online for:

- discharge time, and
- detailed safety instructions and warnings.

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

2

2 Safety

2.1 Safety Symbols

The following symbols are used in this document:

WARNING

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

CAUTION

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

NOTICE

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

2.2 Qualified Personnel

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

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

2.3 Safety Precautions

WARNING

HIGH VOLTAGE

Frequency converters contain high voltage when connected to AC mains input power. Failure to perform installation, start-up, and maintenance by qualified personnel could result in death or serious injury.

- **Installation, start-up, and maintenance must be performed by qualified personnel only.**

WARNING

UNINTENDED START

When the frequency converter is connected to AC mains, the motor may start at any time, causing risk of death, serious injury, equipment, or property damage. The motor can start by means of an external switch, a serial bus command, an input reference signal from the LCP, or after a cleared fault condition.

1. **Disconnect the frequency converter from mains whenever personal safety considerations make it necessary to avoid unintended motor start.**
2. **Press [Off] on the LCP, before programming parameters.**
3. **The frequency converter, motor, and any driven equipment must be in operational readiness when the frequency converter is connected to AC mains.**

WARNING

DISCHARGE TIME

The frequency converter contains DC-link capacitors, which can remain charged even when the frequency converter is not powered. Failure to wait the specified time after power has been removed before performing service or repair work, could result in death or serious injury.

1. **Stop motor.**
2. **Disconnect AC mains, permanent magnet type motors, and remote DC-link power supplies, including battery back-ups, UPS, and DC-link connections to other frequency converters.**
3. **Wait for the capacitors to discharge fully, before performing any service or repair work. The duration of waiting time is specified in *Table 2.1*.**

Voltage [V]	Minimum waiting time (minutes9		
	4	7	15
200-240	0.25-3.7 kW		5.5-37 kW
380-500	0.25-7.5 kW		11-75 kW
525-600	0.75-7.5 kW		11-75 kW
525-690		1.5-7.5 kW	11-75 kW
High voltage may be present even when the warning LED indicator lights are off.			

Table 2.1 Discharge Time

2

⚠WARNING

LEAKAGE CURRENT HAZARD

Leakage currents exceed 3.5 mA. Failure to ground the frequency converter properly could result in death or serious injury.

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

⚠WARNING

EQUIPMENT HAZARD

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

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

⚠CAUTION

WINDMILLING

Unintended rotation of permanent magnet motors causes risk of personal injury and equipment damage.

- **Ensure that permanent magnet motors are blocked to prevent unintended rotation.**

⚠CAUTION

POTENTIAL HAZARD IN THE EVENT OF INTERNAL FAILURE

Risk of personal injury when the frequency converter is not properly closed.

- **Before applying power, ensure all safety covers are in place and securely fastened.**

3 Basic Operating Principles

3.1 General

This chapter provides an overview of the frequency converter's primary assemblies and circuitry. It is intended to describe the internal electrical and signal processing functions. A description of the internal control structure is also included.

Also described are automated and optional frequency converter functions available for designing robust operating systems with sophisticated control and status reporting performance.

3.2 Description of Operation

The frequency converter supplies a regulated amount of mains AC power to a standard 3 phase induction motor to control the motor speed. The frequency converter supplies variable frequency and voltage to the motor.

The frequency converter is divided into four main modules.

- Rectifier
- Intermediate circuit
- Inverter
- Control and regulation

In *chapter 3.3 Sequence of Operation*, these modules are covered in greater detail and describe how power and control signals move within the frequency converter.

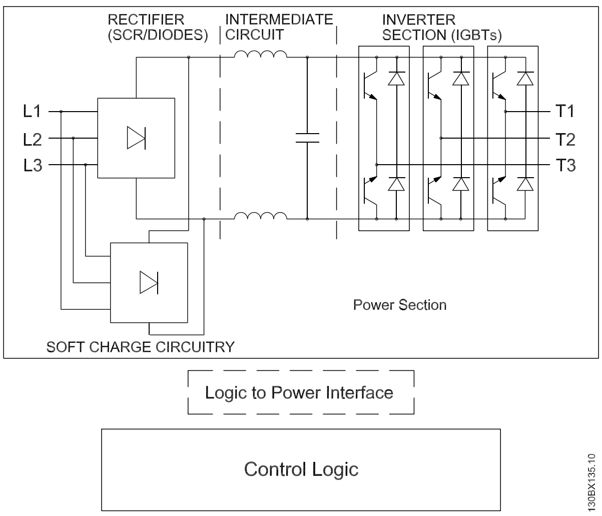


Illustration 3.1 Internal Control Logic

3.3 Sequence of Operation

3.3.1 Rectifier Section

When power is first applied to the frequency converter, it enters through the input terminals (L1, L2, and L3) and on to the disconnect and/or RFI filter option, depending on the unit's configuration.

3.3.2 Intermediate Section

Following the rectifier section, voltage passes to the intermediate section. This rectified voltage is smoothed by an sinewave filter circuit consisting of the DC bus inductor and the DC bus capacitor bank.

The DC bus inductor provides series impedance to changing current. This aids the filtering process while reducing harmonic distortion to the input AC current waveform normally inherent in rectifier circuits.

3.3.3 Inverter Section

In the inverter section, once a run command and speed reference are present, the IGBTs begin switching to create the output waveform. This waveform, as generated by the Danfoss VVC+ PWM principle at the control card, provides optimal performance and minimal losses in the motor.

3.3.4 Brake Option

For frequency converters equipped with the dynamic brake option, a brake IGBT along with terminals 81(R-) and 82(R+) are included for connecting an external brake resistor.

The function of the brake IGBT is to limit the voltage in the intermediate circuit, whenever the maximum voltage limit is exceeded. It does this by switching the externally mounted resistor across the DC bus to remove excess DC voltage present on the bus capacitors. Excess DC bus voltage is generally a result of an overhauling load causing regenerative energy returned to the DC bus. This occurs, for example, when the load drives the motor causing the voltage to return to the DC bus circuit.

Placing the brake resistor externally has the advantages of selecting the resistor based on application need, dissipating the energy outside of the control panel, and protecting the converter from overheating if the brake resistor is overloaded.

The brake IGBT gate signal originates on the control card and is delivered to the brake IGBT via the power card and gate drive card. Additionally, the power and control cards monitor the brake IGBT and brake resistor connection for short circuits and overloads.

3.3.5 Load Sharing

Units with the built-in load sharing option contain terminals (+) 89 DC and (–) 88 DC. Within the frequency converter, these terminals connect to the DC bus in front of the DC link reactor and bus capacitors.

The use of the load sharing terminals can take on 2 different configurations.

In one method, the terminals are used to tie the DC-bus circuits of multiple frequency converters together. This allows one unit that is in a regenerative mode to share its excess bus voltage with another unit that is running a motor. Load sharing in this manner can reduce the need for external dynamic brake resistors while also saving energy. In theory, the number of units that can be connected in this way is infinite, however, each unit must be the same voltage rating. In addition, depending on the size and number of units, it may be necessary to install DC reactors and DC fuses in the DC link connections and AC reactors on the mains. Attempting such a configuration requires specific considerations and should not be attempted without first consulting Danfoss application engineering.

In the second method, the frequency converter is powered exclusively from a DC source. This is a bit more complicated. First, a DC source is required. Second, a means to soft charge the DC bus at power up is also required. Last, a voltage source is required to power the fans within the unit. Again such a configuration should not be attempted with out first consulting Danfoss application engineering.

3.4 Control Interface

3.4.1 Control Principle

The frequency converter receives control input from several sources.

- Local control panel (hand mode)
- Programmable analog, digital, and analog/digital control terminals (auto mode)
- The RS-485, USB, or serial communication ports (auto mode)

When wired and properly programmed, the control terminals provide feedback, reference, and other input signals to the frequency converter; output status and fault conditions from the frequency converter, relays to operate auxiliary equipment, and serial communication interface. A 24 V common is also provided. Control terminals are programmable for various functions by selecting parameter options through the local control panel (LCP) on the front of the unit or external sources. Most control wiring is customer supplied unless factory ordered.

3.5 Wiring Schematic

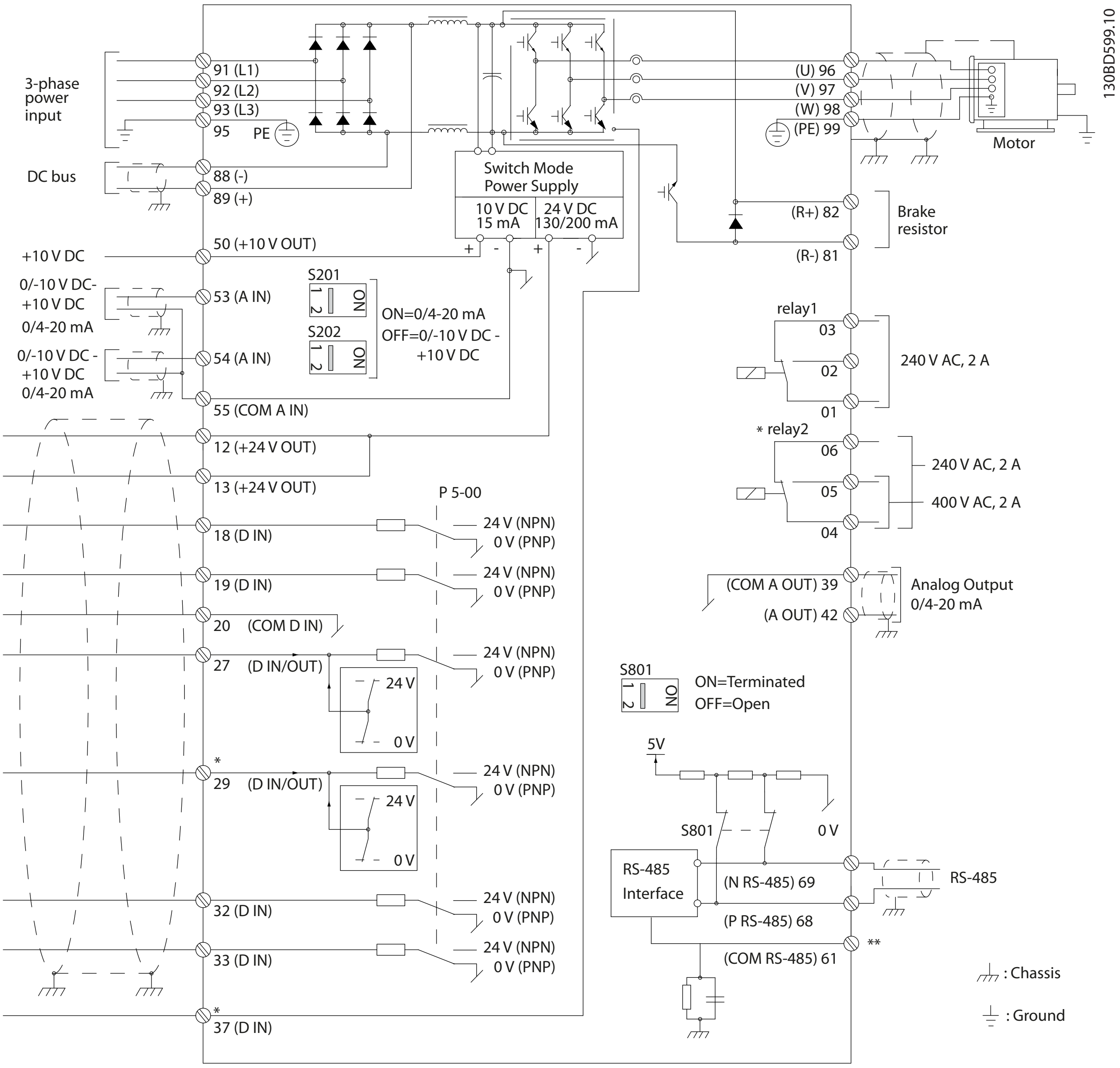
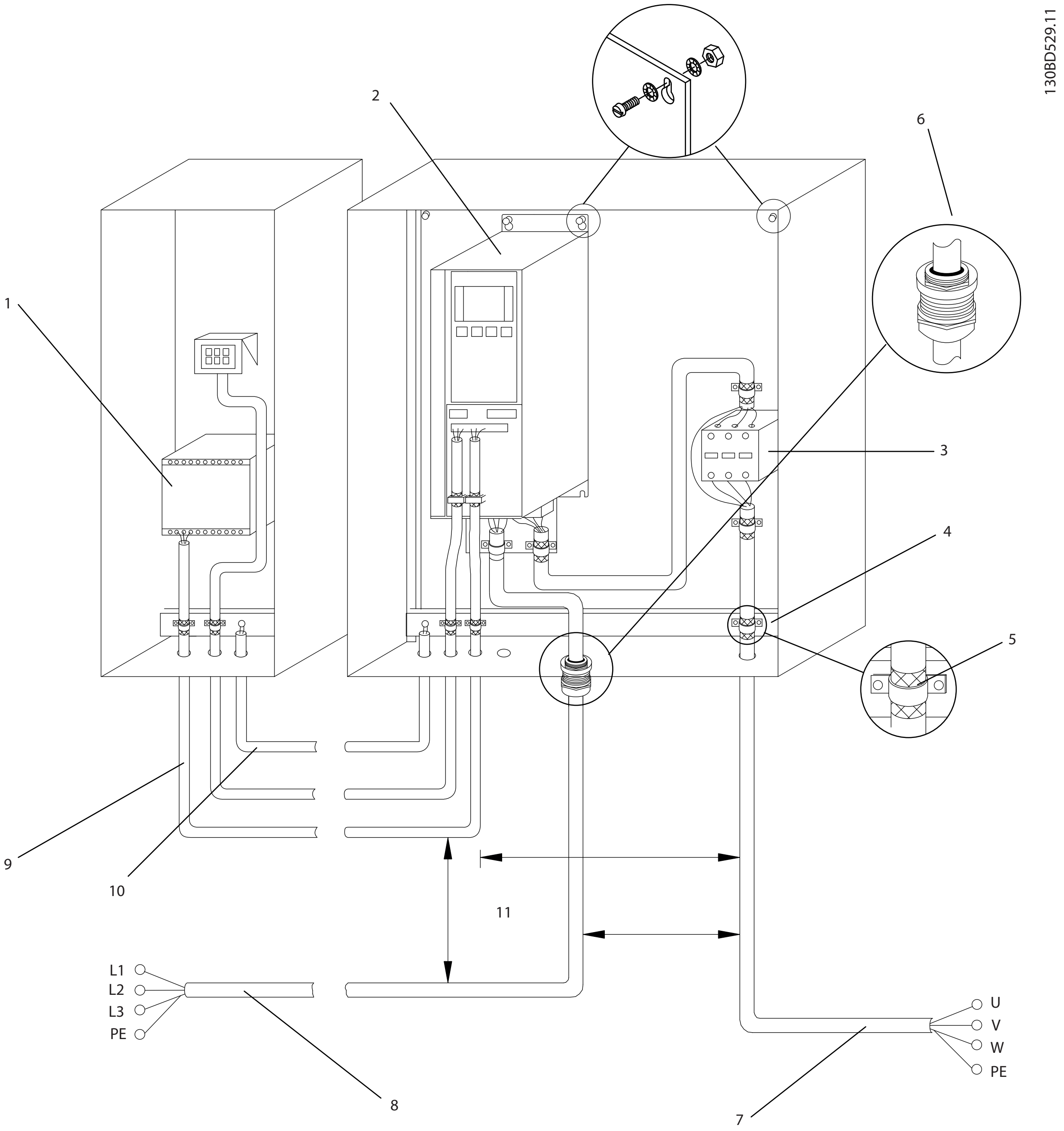


Illustration 3.2 Basic Wiring Schematic

A=Analog, D=Digital

*Terminal 37 (optional) is used for Safe Torque Off. For Safe Torque Off installation instructions, refer to the *Safe Torque Off Operating Instructions for Danfoss VLT® Frequency Converters*. Terminal 37 is not included in FC 301 (except enclosure type A1). Relay 2 and terminal 29 have no function in FC 301.

**Do not connect cable screen.



1	PLC	7	Motor, 3-phase and PE (screened)
2	Frequency converter	8	Mains, 3-phase and reinforced PE (not screened)
3	Output contactor	9	Control wiring (screened)
4	Cable clamp	10	Potential equalisation min. 16 mm² (0.025 in)
5	Cable insulation (stripped)	11	Clearance between control cable, motor cable and mains cable: Min. 200 mm
6	Cable gland		

Illustration 3.3 EMC-compliant Electrical Connection

For more information about EMC, see *chapter 4.1.15 EMC Compliance*

3

NOTICE

EMC INTERFERENCE

Use screened cables for motor and control wiring, and separate cables for input power, motor wiring and control wiring. Failure to isolate power, motor and control cables can result in unintended behaviour or reduced performance. Minimum 200 mm (7.9 in) clearance between power, motor and control cables is required.

3.6 Controls

3.6.1 Control Principle

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

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

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

Speed control

There are 2 types of speed control:

- Speed open loop control which 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 has higher accuracy than a speed open loop 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 VVC+ *[4] Torque open loop* or Flux control closed loop with *[2] motor speed feedback*. Torque setting is done by setting an analog, digital or bus controlled reference. The max speed limit factor is set in *4-21 Speed Limit Factor Source*. When running torque control, it is recommended to make a full AMA procedure 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 4 quadrants and at all motor speeds.
- Open loop in VVC+ 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 basic of current measurement internal in the frequency converter.

Speed/torque reference

The reference to these controls can either be a single refrence or be the sum of various references including relatively scaled references. The handling of references is explained in detail in *chapter 3.7 Reference Handling*.

3.6.2 FC 301 vs. FC 302 Control Principle

FC 301 is a general purpose frequency converter for variable speed applications. The control principle is based on Voltage Vector Control (VVC+).
FC 301 can handle both asynchronous and PM motors.
The current sensing principle in FC 301 is based on current measurement in the DC-link or motor phase. The ground fault protection on the motor side is solved by a de-saturation circuit in the IGBTs connected to the control board.
Short-circuit behaviour on FC 301 depends on the current transducer in the positive DC-link and the desaturation protection with feedback from the 3 lower IGBT's and the brake.

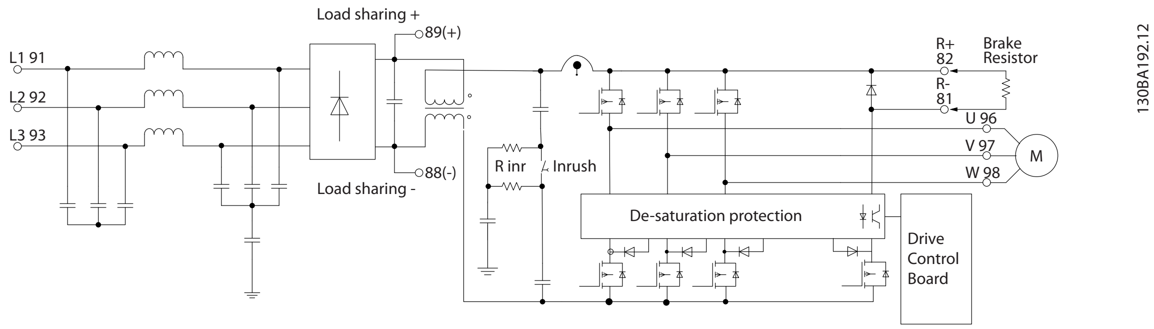


Illustration 3.4 Control Principle FC 301

FC 302 is a high performance frequency converter for demanding applications. The frequency converter can handle various kinds of motor control principles such as U/f special motor mode, VVC+ or Flux Vector motor control.
FC 302 is able to handle Permanent Magnet Synchronous Motors (Brushless servo motors) as well as normal squirrel cage asynchronous motors.
Short circuit behaviour on FC 302 depends on the 3 current transducers in the motor phases and the desaturation protection with feedback from the brake.

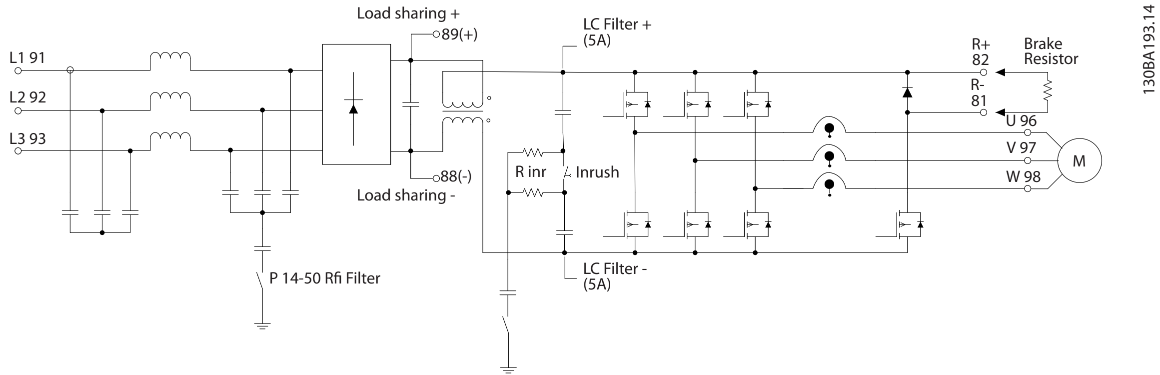


Illustration 3.5 Control Principle FC 302

3

3.6.3 Control Structure in VVC+

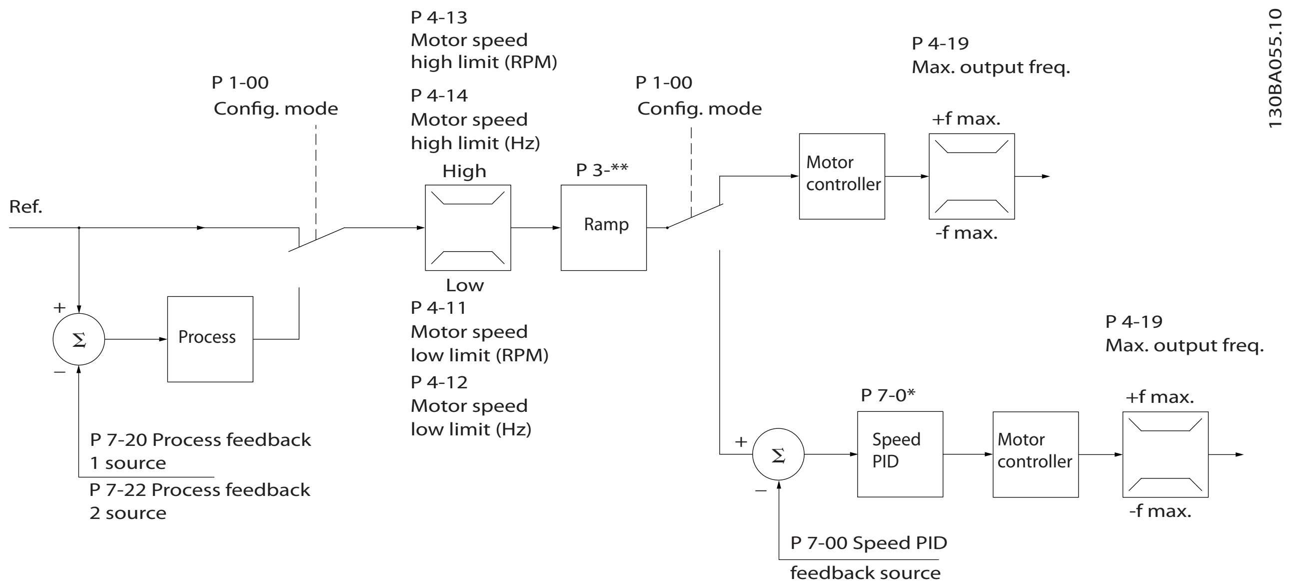


Illustration 3.6 Control Structure in VVC+ Open Loop and Closed Loop Configurations

See *Active/Inactive Parameters in Different Drive Control Modes* in the *Programming Guide* for an overview of which control configuration is available, depending on selection of AC motor or PM Non salient motor. In the configuration shown in *Illustration 3.6*, *1-01 Motor Control Principle* is set to *[1] VVC+* and *1-00 Configuration Mode* is set to *[0] Speed open loop*. The resulting reference from the reference handling system is received and fed through the ramp limitation and speed limitation before being sent to the motor control. The output of the motor control is then limited by the maximum frequency limit.

If *1-00 Configuration Mode* is set to *[1] Speed closed loop*, the resulting reference is passed from the ramp limitation and speed limitation into a speed PID control. The Speed PID control parameters are located in 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 e.g. speed or pressure in the controlled application. The Process PID parameters are located in parameter group *7-2* Process Ctrl. Feedb* and *7-3* Process PID Ctrl*.

3.6.4 Control Structure in Flux Sensorless (FC 302 only)

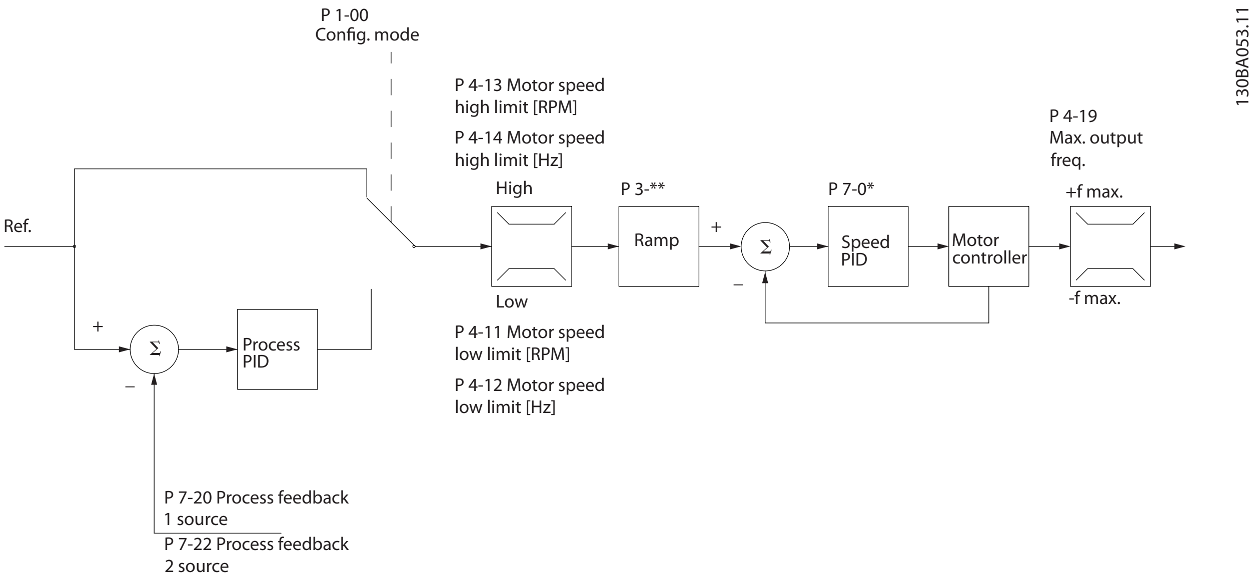


Illustration 3.7 Control Structure in Flux Sensorless Open Loop and Closed Loop Configurations

See *Active/Inactive Parameters in Different Drive Control Modes* in the *Programming Guide* for an overview of which control configuration is available, depending on selection of AC motor or PM Non salient motor. In the shown configuration, *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 control*).

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

3.6.5 Control Structure in Flux with Motor Feedback (FC 302 only)

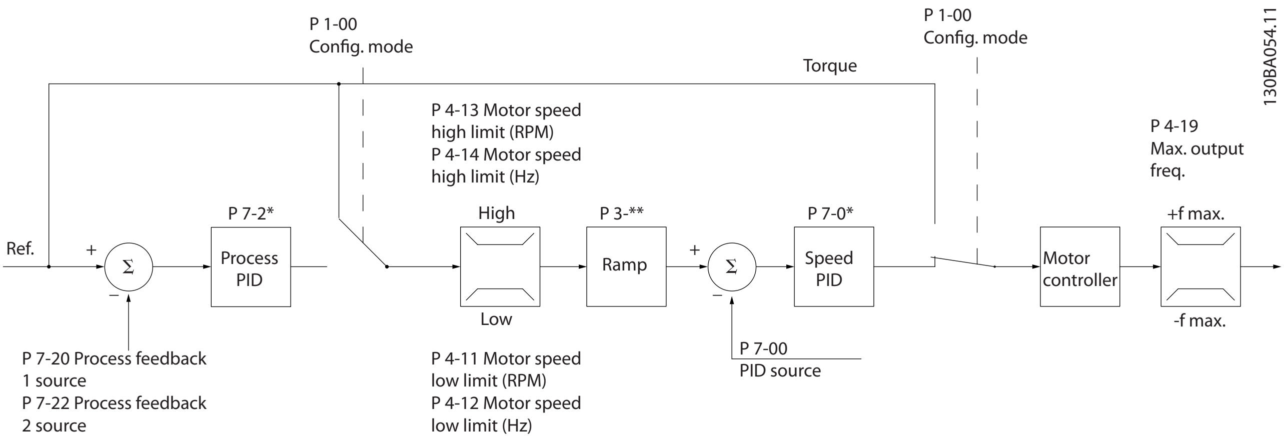


Illustration 3.8 Control Structure in Flux with Motor Feedback Configuration (only available in FC 302)

See *Active/Inactive Parameters in Different Drive Control Modes* in the *Programming Guide* for an overview of which control configuration is available, depending on selection of AC motor or PM Non salient motor. In the shown configuration, *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 or resolver 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 Control*.

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

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

3

3.6.6 PID

3.6.6.1 Speed PID Control

Speed PID Control maintains a constant motor speed regardless of the changing load on the motor.

1-00 Configuration Mode	1-01 Motor Control Principle			
	U/f	VVC+	Flux Sensorless	Flux w/ enc. feedb
[0] Speed open loop	ACTIVE	ACTIVE	ACTIVE	N.A.
[1] Speed closed loop	N.A.	Not Active	N.A.	ACTIVE
[2] Torque	N.A.	N.A.	N.A.	Not Active
[3] Process	Not Active	Not Active	Not Active	N.A.
[4] Torque open loop	N.A.	Not Active	N.A.	N.A.
[5] Wobble	Not Active	Not Active	Not Active	Not Active
[6] Surface Winder	Not Active	Not Active	Not Active	N.A.
[7] Extended PID Speed OL	Not Active	Not Active	Not Active	N.A.
[8] Extended PID Speed CL	N.A.	Not Active	N.A.	Not Active

Table 3.1 Control Configurations with Active Speed Control

"N.A." means that the specific mode is not available at all. "Not Active" means that the specific mode is available but the Speed Control is not active in that mode.

NOTICE

The Speed Control PID works under the default parameter setting, but tuning the parameters is highly recommended to optimise the motor control performance. The 2 Flux motor control principles are particularly dependant on proper tuning to yield their full potential.

Table 3.2 sums up the characteristics that can be set-up for speed control. See *VLT® AutomationDrive FC 301/FC 302 Programming Guide* for details on programming.

Parameter	Description of function
7-00 Speed PID Feedback Source	Select from which input the Speed PID should get its feedback.
7-02 Speed PID Proportional Gain	The higher the value - the quicker the control. However, too high value may lead to oscillations.
7-03 Speed PID Integral Time	Eliminates steady state speed error. Lower value means quick reaction. However, too low 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 that dampens oscillations on the feedback signal and improves steady state performance. However, too large filter time deteriorates the dynamic performance of the Speed PID control. Practical settings of parameter 7-06 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
7-07 Speed PID Feedback Gear Ratio	The frequency converter multiplies the speed feedback by this ratio.
7-08 Speed PID Feed Forward Factor	The reference signal bypasses the speed controller by the amount specified. This feature increases the dynamic performance of the speed control loop.
7-09 Speed PID Error Correction w/ Ramp	The speed error between ramp and actual speed is held up against the setting in this parameter. If the speed error exceeds this parameter entry, the speed error is corrected via ramping in a controlled way.

Table 3.2 Relevant Parameters for Speed Control

Programme in the order shown (see explanation of settings in the *Programming Guide*)
In *Table 3.3* it is assumed that all other parameters and switches remain at their default setting.

Function	Parameter	Setting
1) Make sure the motor runs properly. Do the following:		
Set the motor parameters using name plate data	1-2*	As specified by motor name plate
Perform an 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 [Hand On] on the LCP. 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, 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 frequency converter 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)

Function	Parameter	Setting
Check that the ramp settings are within frequency converter capabilities and allowed application operating specifications.	3-41 Ramp 1 Ramp Up Time 3-42 Ramp 1 Ramp Down Time	default setting default setting
Set acceptable limits for the motor speed and frequency.	4-11 Motor Speed Low Limit [RPM] 4-13 Motor Speed High Limit [RPM] 4-19 Max Output Frequency	0 RPM (default) 1500 RPM (default) 60 Hz (default 132 Hz)
4) Configure the Speed Control and select the Motor Control principle		
Activation of Speed Control	*1-00 Configuration Mode*	[1] Speed closed loop
Selection of Motor Control Principle	1-01 Motor Control Principle	[3] Flux w motor feedb
5) Configure and scale the reference to the Speed Control		
Set up Analog Input 53 as a reference Source	3-15 Reference Resource 1	Not necessary (default)
Scale Analog Input 53 0 RPM (0V) to 1500 RPM (10 V)	6-1*	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 HTL encoder inputs	5-14 Terminal 32 Digital Input 5-15 Terminal 33 Digital Input	[0] No operation (default)
Select terminal 32/33 as motor feedback	1-02 Flux Motor Feedback Source	Not necessary (default)
Select 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*	See the guidelines
8) Save to finish		
Save the parameter setting to the LCP for safe keeping	0-50 LCP Copy	[1] All to LCP

Table 3.3 Programming Order

3.6.6.2 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:

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

NOTICE

***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 *7-02 Speed PID Proportional Gain* calculation against the following formula (not required when using a high-resolution feedback such as a SinCos feedback):

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

The recommended 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 frequency converter) or *17-11 Resolution (PPR)* (5 V TTL on Encoder Option MCB 102).

Generally, the practical maximum limit of *7-02 Speed PID Proportional Gain* is determined by the encoder resolution and the feedback filter time, but other factors in the application might limit the *7-02 Speed PID Proportional Gain* to a lower value.

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

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

3

3.6.6.3 Process PID Control

Use the Process PID Control 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 3.4 shows the control configurations where the Process Control is possible. When a Flux Vector motor control principle is used, take care also to tune the Speed Control PID parameters. Refer to *chapter 3.6 Controls* to see where the Speed Control is active.

1-00 Configuration Mode	1-01 Motor Control Principle			
	U/f	VVC+	Flux Sensorless	Flux w/ enc. feedb
[3] Process	Not Active	Process	Process & Speed	Process & Speed

Table 3.4 Control Configurations with Process Control

NOTICE

The Process Control PID works under the default parameter setting, but tuning the parameters is highly recommended to optimise the application control performance. The 2 Flux motor control principles are specially dependant on proper Speed Control PID tuning (before tuning the Process Control PID) to yield their full potential.

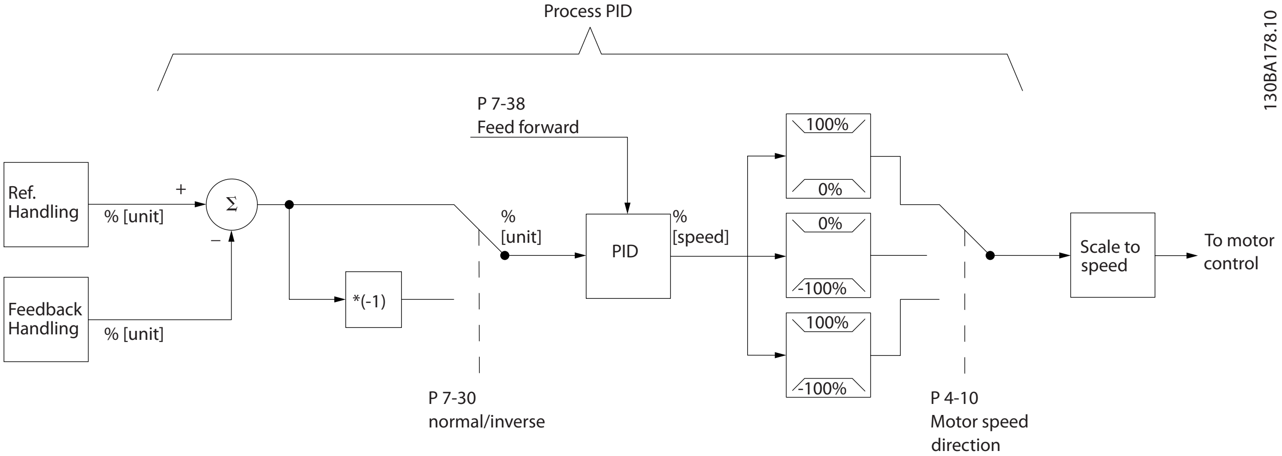


Illustration 3.9 Process PID Control Diagram

Table 3.5 sums up the characteristics that can be set up for the process control.

Parameter	Description of function
7-20 Process CL Feedback 1 Resource	Select from which Source (i.e. analog 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 2 feedback signals are added together before being used in the Process PID Control.
7-30 Process PID Normal/ Inverse Control	Under *[0] Normal operation*, the Process Control responds with an increase of the motor speed, if the feedback is getting lower than the reference. In the same situation, but under *[1] Inverse operation*, the Process Control responds with a decreasing motor speed instead.
7-31 Process PID Anti Windup	The anti-windup function ensures that when either a frequency limit or a torque limit is reached, the integrator is set to a gain that corresponds to the actual frequency. This avoids integrating on an error that cannot in any case be compensated for with 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*.

Parameter	Description of function
7-33 Process PID Proportional Gain	The higher the value - the quicker the control. However, too large value may lead to oscillations.
7-34 Process PID Integral Time	Eliminates steady state speed error. Lower value means quick reaction. However, too small 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 application where there is a good (and approximately linear) correlation between the process reference and the motor speed necessary for obtaining that reference, the Feed Forward Factor can be used to achieve better dynamic performance of the Process PID Control.
5-54 Pulse Filter Time Constant #29 (Pulse term. 29), 5-59 Pulse Filter Time Constant #33 (Pulse term. 33), 6-16 Terminal 53 Filter Time Constant (Analog term 53), 6-26 Terminal 54 Filter Time Constant (Analog term. 54) 6-36 Term. X30/11 Filter Time Constant 6-46 Term. X30/12 Filter Time Constant 35-46 Term. X48/2 Filter Time Constant	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 0.1s, the limit speed is 10 RAD/s (the reciprocal of 0.1 s), corresponding to (10/(2 x π)) = 1.6 Hz. This means that all currents/ voltages that vary by more than 1.6 oscillations per second is damped by the filter. The control is only carried out on a feedback signal that varies by a frequency (speed) of less than 1.6 Hz. The low-pass filter improves steady state performance, but selecting a too large filter time deteriorates the dynamic performance of the Process PID Control.

Table 3.5 Relevant Parameters for Process Control

3.6.6.4 Advanced PID Control

Consult the *VLT® AutomationDrive FC 301/FC 302 Programming Guide* for advanced PID control parameters

3.6.7 Internal Current Control in VVC+ Mode

When the motor current/torque exceed the torque limits set in *4-16 Torque Limit Motor Mode*, *4-17 Torque Limit Generator Mode* and *4-18 Current Limit*, the integral current limit control is activated.
When the frequency converter is at the current limit during motor operation or regenerative operation, it tries to get below the preset torque limits as quickly as possible without losing control of the motor.

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

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

After pressing [Auto On], the frequency converter enters 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*.

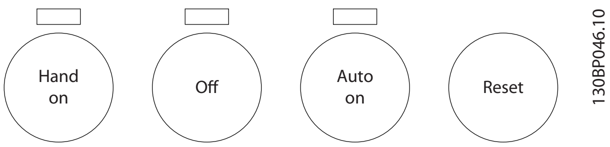


Illustration 3.10 Operation Keys

3

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 depends on which mode is active. (Hand mode or Auto mode).

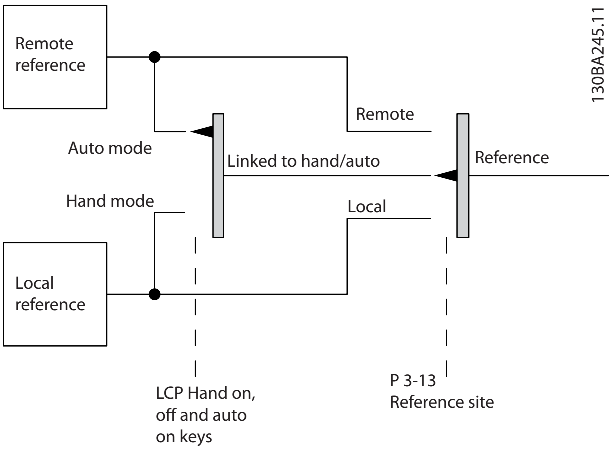


Illustration 3.11 Active Reference

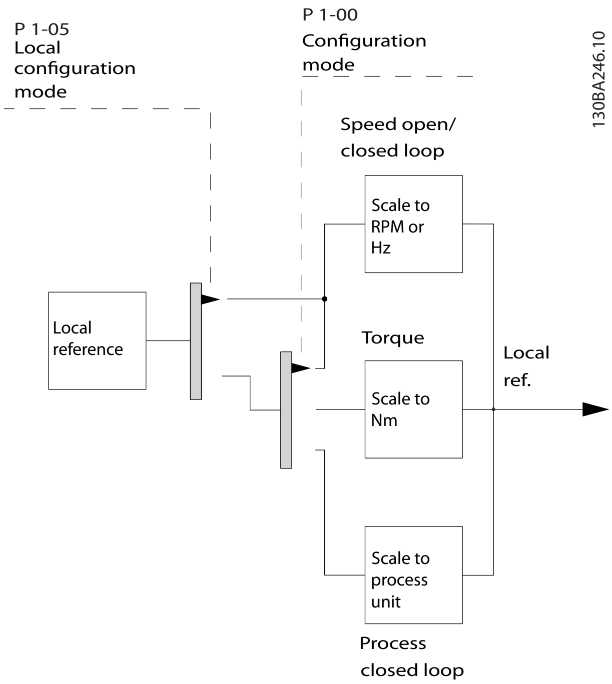


Illustration 3.12 Configuration Mode

[Hand On] [Auto on] Keys	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 3.6 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 cannot be active at the same time.

3.7 Reference Handling

3.7.1 References

Analog Reference
An analog signal applied to input 53 or 54. The signal can be either voltage 0-10 V (FC 301 and FC 302) or -10 to +10 V (FC 302). Current signal 0-20 mA or 4-20 mA.

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

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

Pulse Reference
A pulse reference applied to terminal 29 or 33, selected in *5-13 Terminal 29 Digital Input* or *5-15 Terminal 33 Digital Input [32] Pulse time based*. 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*.

Local Reference

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

Remote Reference

The reference handling system for calculating the remote reference is shown in *Illustration 3.13*.

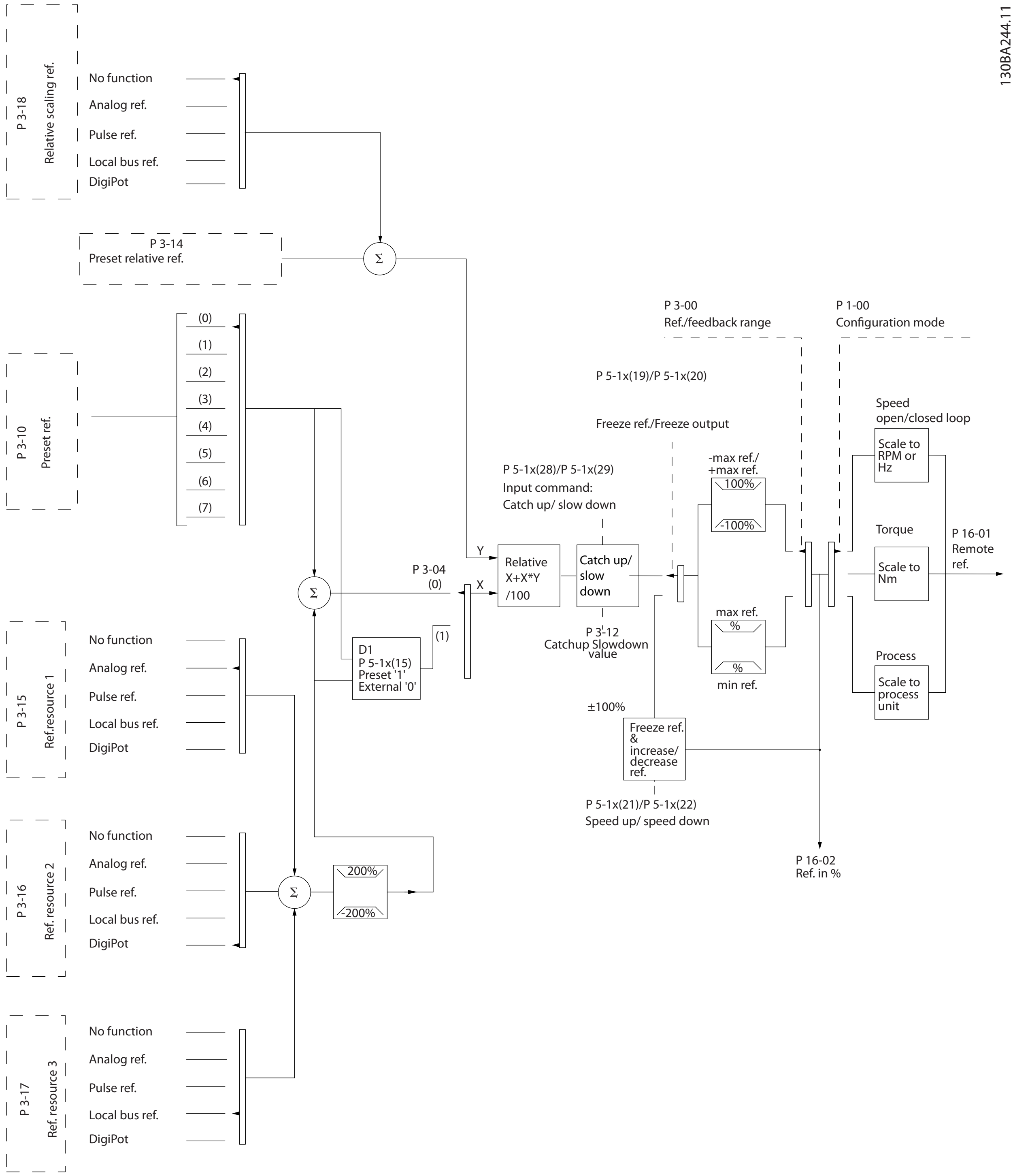


Illustration 3.13 Remote Reference

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

1. X (the actual reference): A sum (see *3-04 Reference Function*) of up to 4 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 analog 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 analog reference (*3-18 Relative Scaling Reference Resource*) in [%].

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

3.7.2 Reference Limits

3-00 Reference Range, *3-02 Minimum Reference* and *3-03 Maximum Reference* 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 in *Illustration 3.14*.

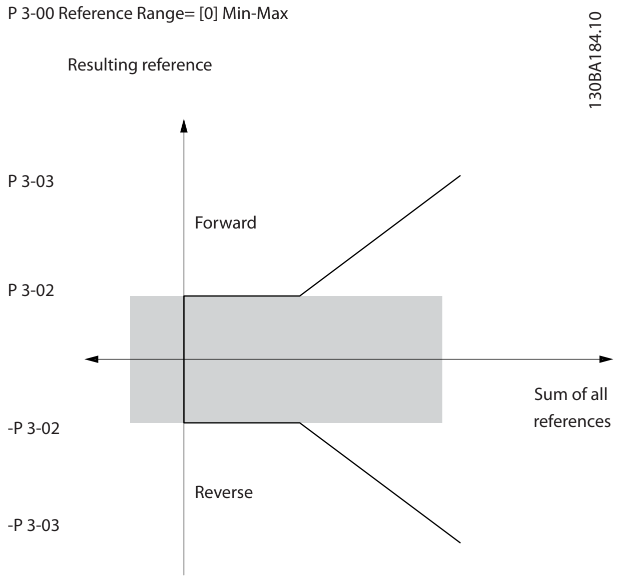


Illustration 3.14 Relation between Resulting Reference and the Sum of all References

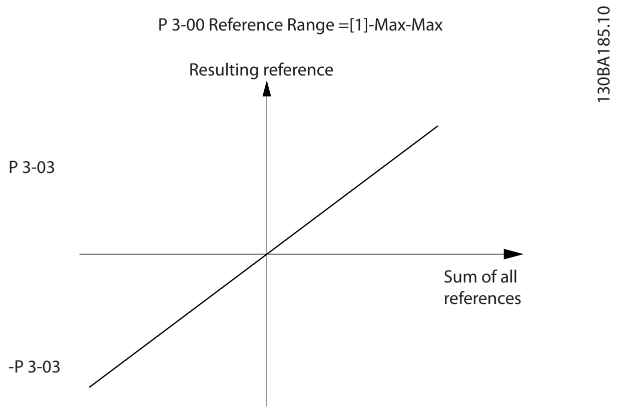


Illustration 3.15 Resulting Reference

The value of *3-02 Minimum Reference* cannot 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 shown in *Illustration 3.16*.

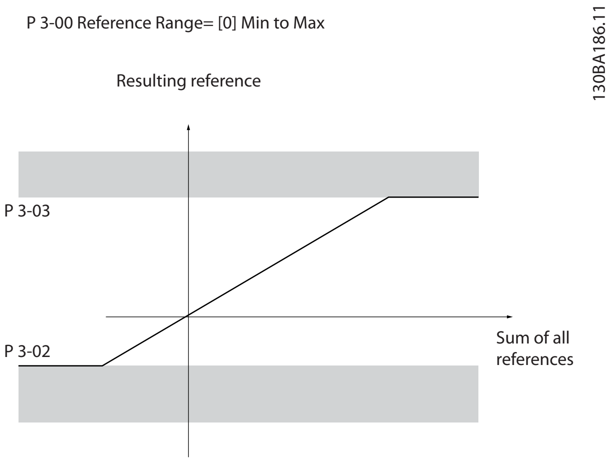


Illustration 3.16 Sum of all References with *1-00 Configuration Mode* set to *[3] Process*

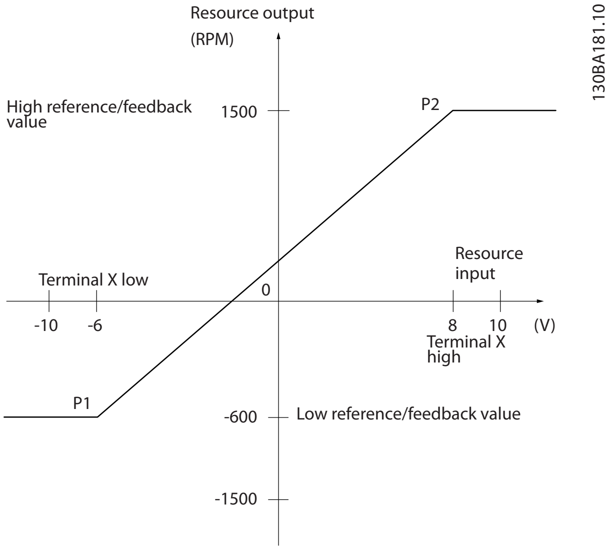


Illustration 3.17 Scaling of Analog and Pulse References and Feedback

3.7.3 Scaling of Preset References and Bus References

Preset references are scaled according to the following rules:

- When *3-00 Reference Range*: [0] Min - 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 - +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 - 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 - +Max -100% reference equals -Max Reference 100% reference equals Max Reference.

3.7.4 Scaling of Analog and Pulse References and Feedback

References and feedback are scaled from analog and pulse inputs in the same way. The only difference is that a reference above or below the specified minimum and maximum “endpoints” (P1 and P2 in *Illustration 3.17*) are clamped, whereas a feedback above or below is not.

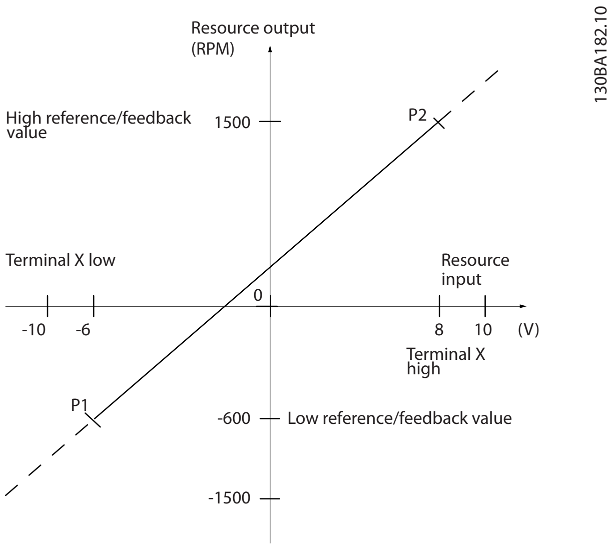


Illustration 3.18 Scaling of Reference Output

3.7.5 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 activate the dead band and to set the amount of dead band, set the following:

- Either Minimum Reference Value or Maximum Reference Value must be zero. In other words; Either P1 or P2 must be on the X-axis in *Illustration 3.19*.
- And both points defining the scaling graph are in the same quadrant.

3

The size of the dead band is defined by either P1 or P2 as shown in *Illustration 3.19*.

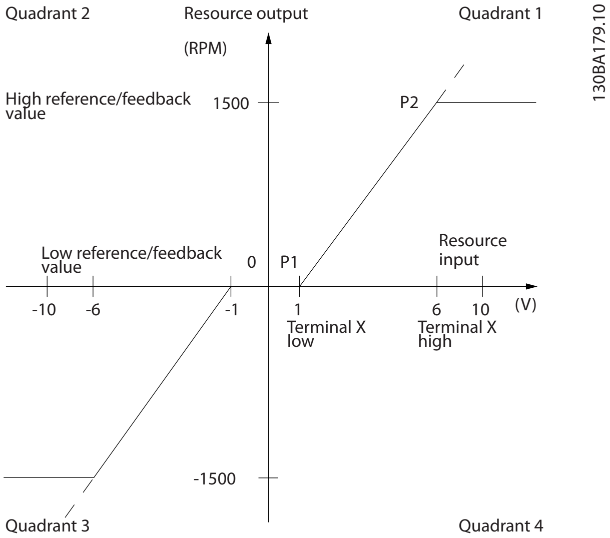


Illustration 3.19 Dead Band

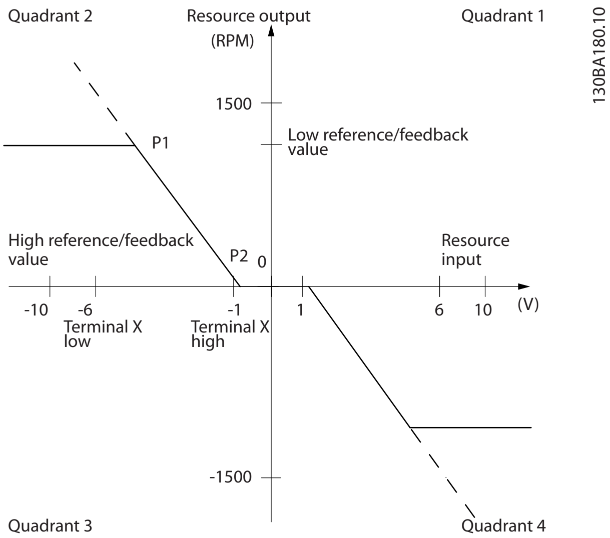


Illustration 3.20 Reverse Dead Band

Thus a reference endpoint of P1 = (0 V, 0 RPM) does not result in any dead band, but a reference endpoint of e.g. P1 = (1 V, 0 RPM) results 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.

Illustration 3.21 shows how reference input with limits inside Min – Max limits clamps.

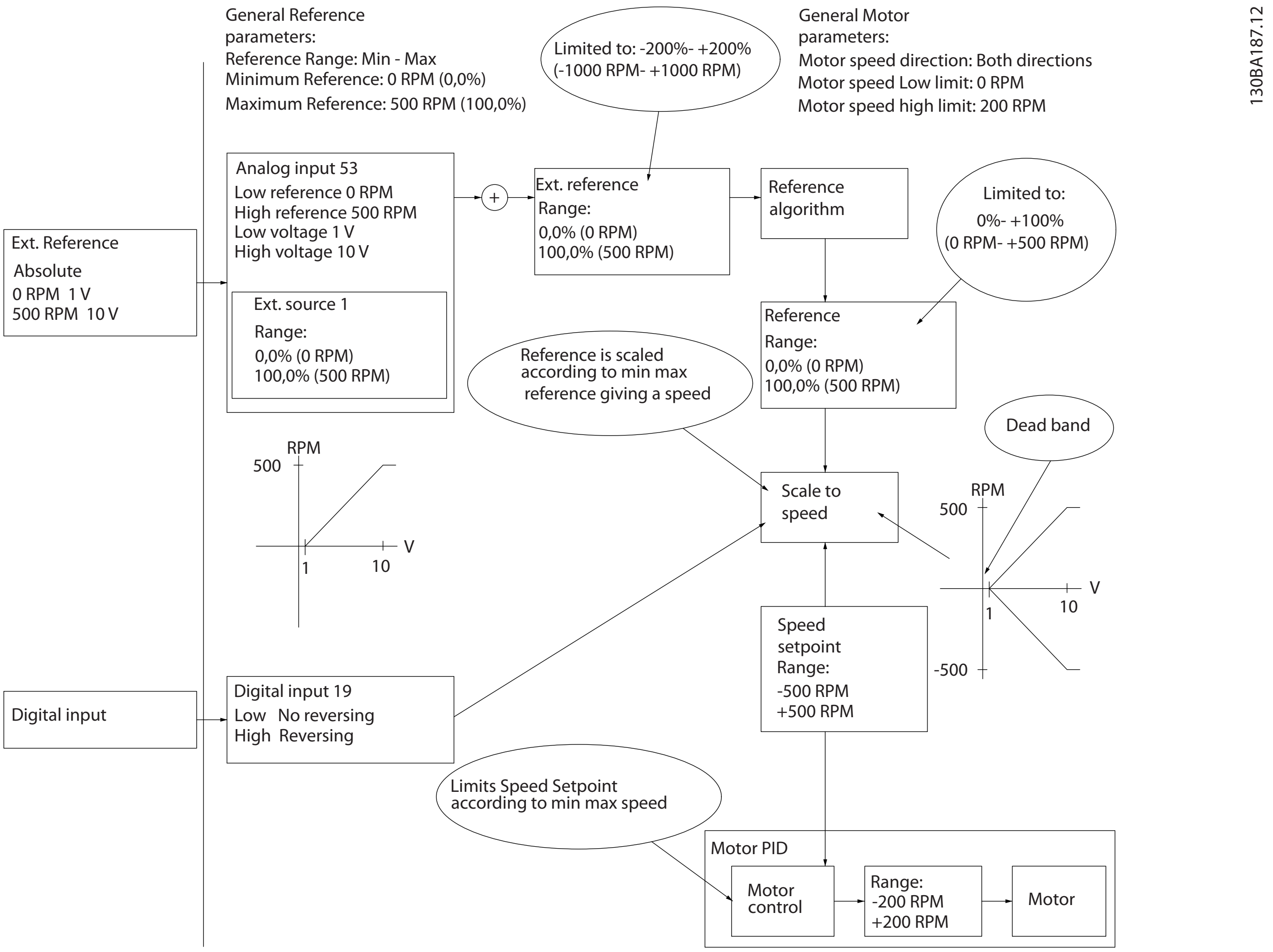


Illustration 3.21 Positive Reference with Dead Band, Digital input to Trigger Reverse

Illustration 3.22 shows how reference input with limits outside -Max to +Max limits clamps to the inputs low and high limits before being added to actual reference. *Illustration 3.22* also shows how the actual reference is clamped to -Max to +Max by the reference algorithm.

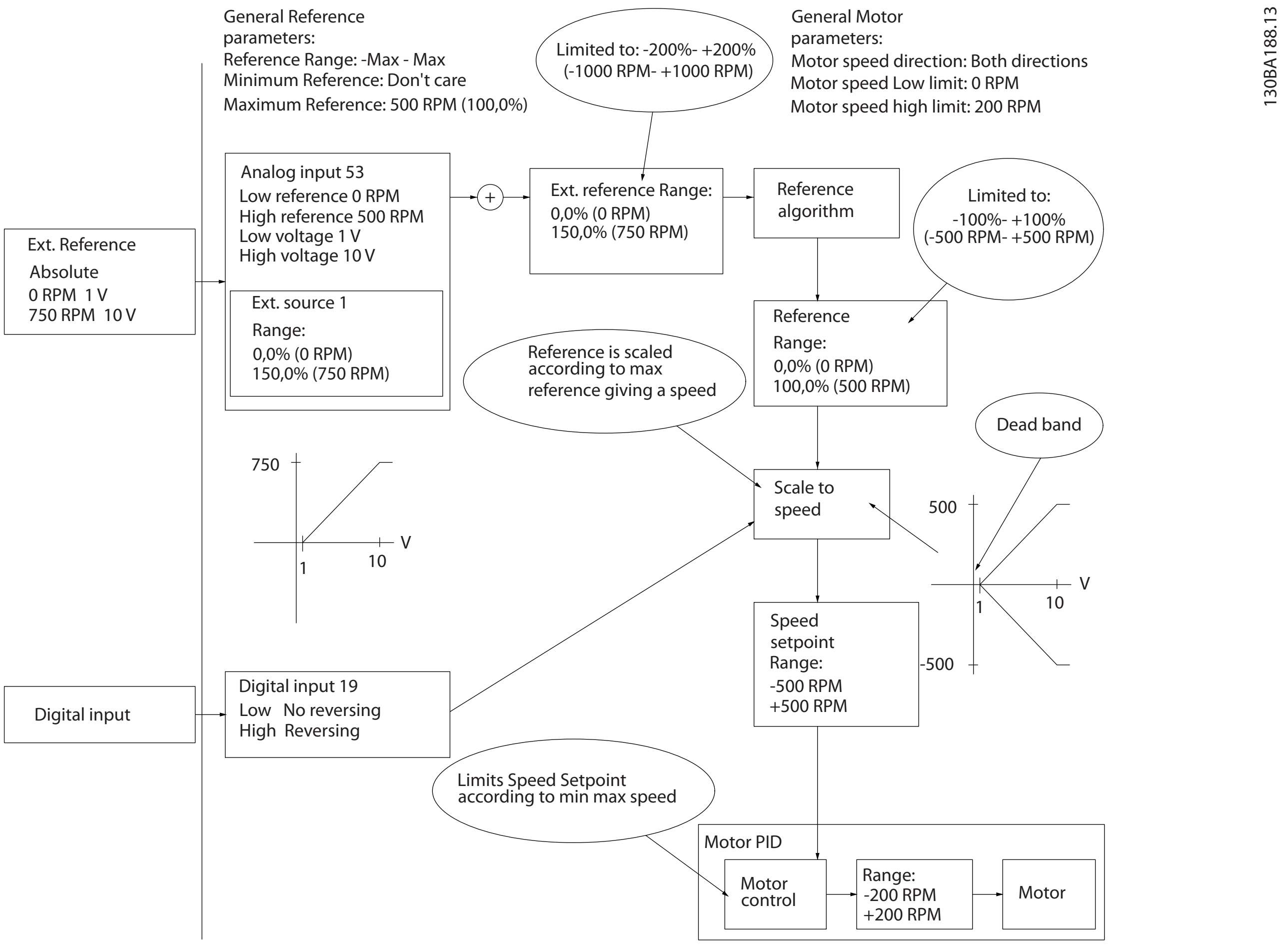


Illustration 3.22 Positive Reference with Dead Band, Digital Input to Trigger Reverse. Clamping Rules

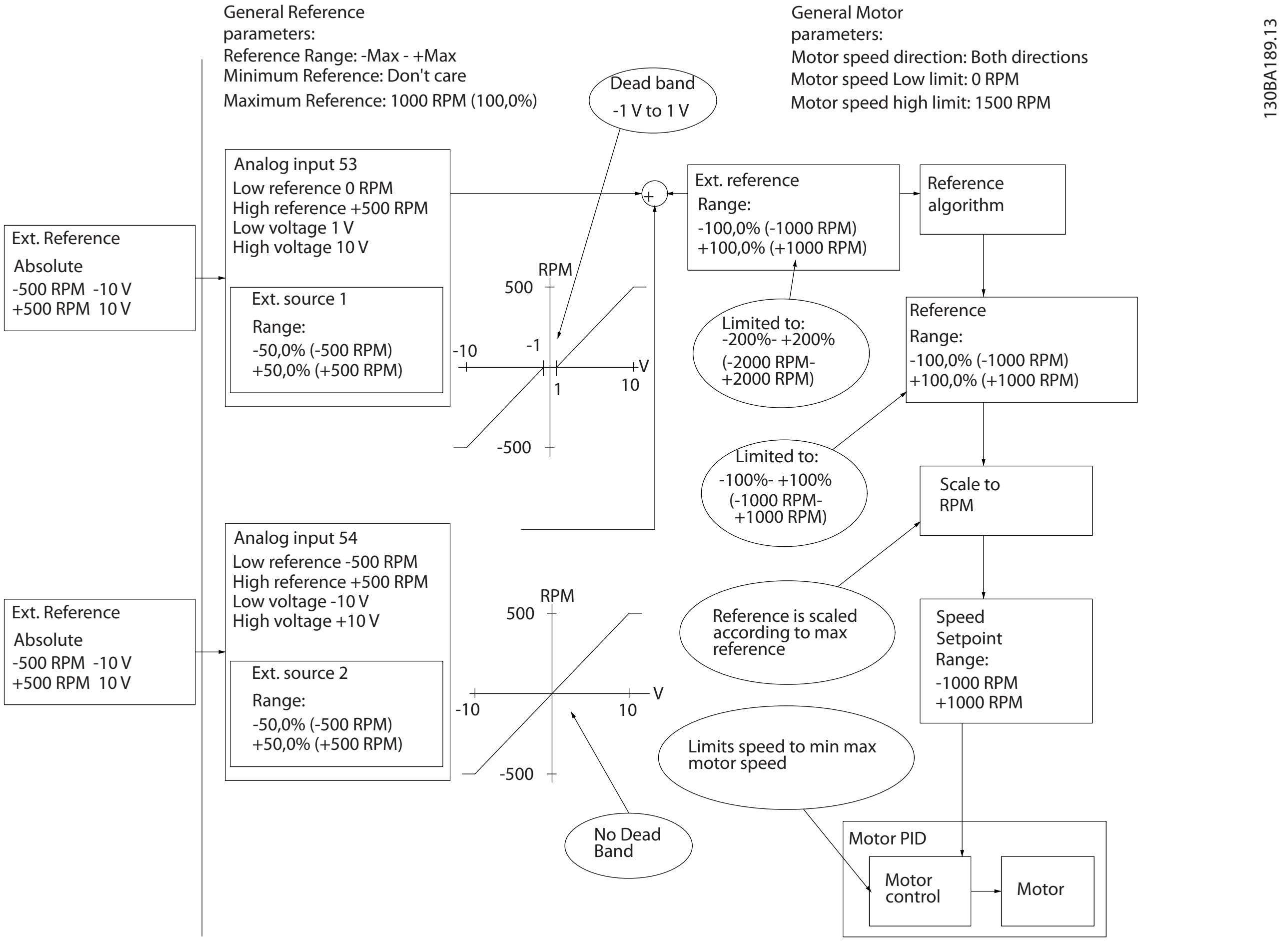


Illustration 3.23 Negative to Positive Reference with Dead Band, Sign Determines the Direction, -Max to +Max

4

4 Product Features

4.1 Automated Operational Features

These features are active as soon as the frequency converter is operating. They require no programming or set up. Understanding that these features are present can optimise a system design and possibly avoid introducing redundant components or functionality.

The frequency converter has a range of built-in protection functions to protect itself and the motor it is running.

4.1.1 Short Circuit Protection

Motor (phase-phase)
The frequency converter is protected against short circuits on the motor-side by current measurement in each of the 3 motor phases or in the DC-link. A short circuit between 2 output phases causes an overcurrent in the inverter. The inverter is turned off when the short circuit current exceeds the permitted value (Alarm 16 Trip Lock).

Mains side
A frequency converter that works correctly limits the current it can draw from the supply. Still, it is recommended to use fuses and/or circuit breakers on the supply side as protection in case of component break-down inside the frequency converter (first fault). See *chapter 9.3 Mains Connection* for more information.

NOTICE

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

Brake resistor
The frequency converter is protected from a short-circuit in the brake resistor.

Load sharing
To protect the DC bus against short-circuits and the frequency converters from overload, install DC-fuses in series with the load sharing terminals of all connected units. See *chapter 9.6.3 Load Sharing* for more information.

4.1.2 Overvoltage Protection

Motor-generated overvoltage
The voltage in the intermediate circuit is increased when the motor acts as a generator. This occurs in following cases:

- The load drives the motor (at constant output frequency from the frequency converter), ie. the load generates energy.
- 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.
- Incorrect slip compensation setting may cause higher DC-link voltage.
- Back-EMF from PM motor operation. If coasted at high RPM, the PM motor back-EMF may potentially exceed the maximum voltage tolerance of the frequency converter and cause damage. To help prevent this, the value of *4-19 Max Output Frequency* is automatically limited based on an internal calculation based on the value of *1-40 Back EMF at 1000 RPM*, *1-25 Motor Nominal Speed* and *1-39 Motor Poles*.

NOTICE

To avoid that the motor overspeeds (e.g. due to excessive windmilling effects), equip the frequency converter with a brake resistor.

The overvoltage can handled either via using a brake function (*2-10 Brake Function*) and/or using overvoltage control (*2-17 Over-voltage Control*).

Brake functions
Connect a brake resistor for dissipation of surplus brake energy. Connecting a brake resistor allows a higher DC-link voltage during braking.

AC brake is an alternative to improve breaking without using a brake resistor. This function controls an over-magnetisation of the motor when running generatoric. This function can improve the OVC. Increasing the electrical losses in the motor allows the OVC function to increase the breaking torque without exceeding the overvoltage limit.

NOTICE

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

Over Voltage Control (OVC)
OVC reduces the risk of the frequency converter tripping due to an overvoltage on the DC-link. This is managed by automatically extending the ramp-down time.

NOTICE

OVC can be activated for PM motor with all control core, PM VVC+, Flux OL and Flux CL for PM Motors.

NOTICE

Do not enable OVC in hoisting applications.

4.1.3 Missing Motor Phase Detection

The Missing Motor Phase Function (*4-58 Missing Motor Phase Function*) is enabled by default to avoid motor damage in the case that a motor phase is missing. The default setting is 1,000 ms, but it can be adjusted for a faster detection.

4.1.4 Mains Phase Imbalance Detection

Operation under severe main imbalance conditions reduces the lifetime of the motor. Conditions are considered severe if the motor is operated continuously near nominal load. The default setting trips the frequency converter in case of mains imbalance (*14-12 Function at Mains Imbalance*).

4.1.5 Switching on the Output

Adding a switch to the output between the motor and the frequency converter is permitted. Fault messages may appear. Enable flying start to catch a spinning motor.

4.1.6 Overload Protection

Torque Limit
The torque limit feature protects the motor against overload, independent of the speed. Torque limit is controlled in *4-16 Torque Limit Motor Mode* and or *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 frequency converter trips is controlled in *14-24 Trip Delay at Current Limit*.

Speed 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 for instance between 30 and 50/60Hz.
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
ETR is an electronic feature that simulates a bimetal relay based on internal measurements. The characteristic is shown in *Illustration 4.1*.

Voltage Limit
The inverter turns off to protect the transistors and the intermediate circuit capacitors when a certain hard-coded voltage level is reached.

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

4.1.7 Locked Rotor Protection

There may be situations when the rotor is locked due to excessive load or some other factors (bearing, or application create locked rotor situation). This leads to overheating of motor winding (free movement of rotor is required for proper cooling). The frequency converter is able to detect the locked rotor situation with open loop PM flux control, and PM VVC+ control (*30-22 Locked Rotor Protection*).

4.1.8 Automatic Derating

The frequency converter 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 converters can also force the PWM pattern to SFAVM.

NOTICE

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

4.1.9 Automatic Energy Optimisation

Automatic energy optimisation (AEO), directs the frequency converter to continuously monitor the load on the motor and adjust the output voltage to maximise efficiency. Under light load, the voltage is reduced and the motor current is minimised. The motor benefits from increased efficiency, reduced heating, and quieter operation. There is no need to select a V/Hz curve because the frequency converter automatically adjusts motor voltage.

4.1.10 Automatic Switching Frequency Modulation

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

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

4

4.1.11 Automatic Derating for High Carrier Frequency

The frequency converter is designed for continuous, full load operation at carrier frequencies between 3.0 and 4.5 kHz. A carrier frequency higher than 4.5 kHz generates increased heat in the frequency converter and requires the output current to be derated.

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

4.1.12 Power Fluctuation Performance

The frequency converter withstands mains fluctuations such as transients, momentary dropouts, short voltage drops and surges. The frequency converter automatically compensates for input voltages ±10% from the nominal to provide full rated motor voltage and torque. With auto restart selected, the frequency converter automatically powers up after a voltage trip. And with flying start, the frequency converter synchronises to motor rotation prior to start.

4.1.13 Resonance Damping

High frequency motor resonance noise can be eliminated through the use of resonance damping. Automatic or manually selected frequency damping is available.

4.1.14 Temperature-controlled Fans

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

4.1.15 EMC Compliance

Electromagnetic interference (EMI) or radio frequency interference (RFI, in case of radio frequency) is disturbance which can affect an electrical circuit due to electro-magnetic induction or radiation from an external source. The frequency converter is designed to comply with the EMC product standard for drives IEC 61800-3 as well as the European standard EN 55011. To comply with the emission levels in EN 55011, the motor cable must be shielded and properly terminated. For more information regarding EMC performance, see *chapter 5.2.1 EMC Test Results*.

4.1.16 Galvanic Isolation of Control Terminals

All control terminals and output relay terminals are galvan-ically isolated from mains power. This means the controller circuitry is completely protected from the input current. The output relay terminals require their own grounding. This isolations meets the stringent protective extra-low voltage (PELV) requirements for isolation.

The components that make up the galvanic isolation are

- Power supply, including signal isolation
- Gate drive for the IGBTs, the trigger transformers and optocouplers
- The output current Hall Effect transducers

4.2 Custom Application Features

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

4.2.1 Automatic Motor Adaptation

Automatic motor adaptation (AMA) is an automated test procedure used to measure the electrical characteristics of the motor. AMA provides an accurate electronic model of the motor. It allows the frequency converter to calculate optimal performance and efficiency with the motor. Running the AMA procedure also maximises the automatic energy optimisation feature of the frequency converter. AMA is performed without the motor rotating and without uncoupling the load from the motor.

4.2.2 Motor Thermal Protection

Motor thermal protection can be provided in 3 ways:

- Via direct temperature sensing via one of the following
  - PTC- or KTY sensor in the motor windings and connected on a standard AI or DI
  - PT100 or PT1000 in the motor windings and motor bearings, connected on Sensor Input Card MCB 114
  - PTC Thermistor input on PTC Thermistor Card MCB 112 (ATEX approved)
- Mechanical thermal switch (Klixon type) on a DI
- Via the built-in Electronic Thermal Relay (ETR).

ETR calculates motor temperature by measuring current, frequency, and operating time. The frequency converter displays the thermal load on the motor in percentage and can issue a warning at a programmable overload set-point. Programmable options at the overload allow the frequency converter to stop the motor, reduce output, or ignore the condition. Even at low speeds, the frequency converter meets I2t Class 20 electronic motor overload standards.

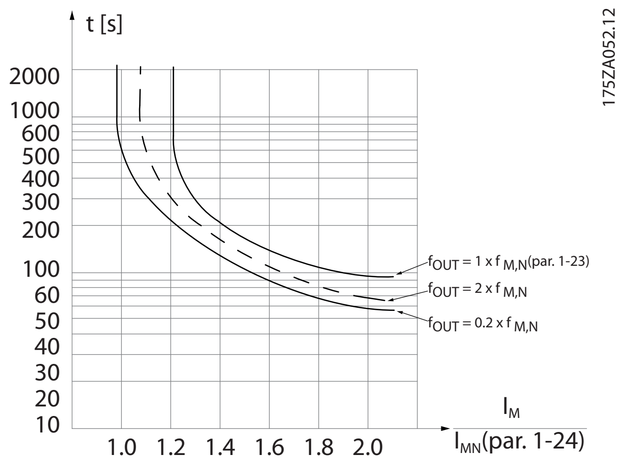


Illustration 4.1 ETR Characteristics

The X-axis shows the ratio between I_{motor} and I_{motor} nominal. The Y-axis shows the time in seconds before the ETR cuts off and trips the frequency converter. The curves show the characteristic nominal speed, at twice the nominal speed and at 0.2 x the nominal speed.
At lower speed, the ETR cuts off at lower heat due to less cooling of the motor. In that way, the motor is protected from being overheated even at low speed. The ETR feature 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*.

A special version of the ETR is also available for EX-e motors in ATEX areas. This function makes it possible to enter a specific curve to protect the Ex-e motor. The *Programming Guide* takes the user through the set-up.

4.2.3 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 frequency converter to coast.

The frequency converter can be configured (*14-10 Mains Failure*) to different types of behaviour during mains drop-out, e.g:

- Trip Lock once the DC-link is exhausted
- Coast with flying start whenever mains return (*1-73 Flying Start*)
- Kinetic back-up
- Controlled ramp-down

Flying start
This selection makes it possible to catch a motor that is spinning freely due to a mains drop-out. This option is very relevant for centrifuges and fans.

Kinetic back-up
This selection ensures that the frequency converter runs as long as there is energy in the system. For short mains drop-out the operation is restored upon mains return, without bringing the application to a stop or loosing control at any time. Several variants of kinetic back-up can be selected.

The behaviour of the frequency converter at mains drop-out can be configured in *14-10 Mains Failure* and *1-73 Flying Start*.

4.2.4 Built-in PID Controller

The built-in proportional, integral, derivative (PID) controller is available, eliminating the need for auxiliary control devices. The PID controller maintains constant control of closed loop systems where regulated pressure, flow, temperature, or other system requirements must be maintained. The frequency converter can provide self-reliant control the motor speed in response to feedback signals from remote sensors.

The frequency converter accommodates 2 feedback signals from 2 different devices. This feature allows regulating a system with different feedback requirements. The

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frequency converter makes control decisions by comparing the two signals to optimise system performance.

4.2.5 Automatic Restart

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

4.2.6 Flying Start

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

4.2.7 Full Torque at Reduced Speed

The frequency converter follows a variable V/Hz curve to provide full motor torque even at reduced speeds. Full output torque can coincide with the maximum designed operating speed of the motor. This is unlike variable torque converters that provide reduced motor torque at low speed, or constant torque converters that provide excess voltage, heat and motor noise at less than full speed.

4.2.8 Frequency Bypass

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

4.2.9 Motor Preheat

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

4.2.10 4 Programmable Set-ups

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

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

4.2.11 Dynamic Braking

Dynamic Brake is 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 overheats 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).

4.2.12 Open Loop Mechanical Brake Control

Parameters for controlling operation of an electro-magnetic (mechanical) brake, typically required in hoisting applications.
To control a mechanical brake, a relay output (relay 01 or relay 02) or a programmed digital output (terminal 27 or 29) is required. Normally, this output must be closed during periods when the frequency converter is unable to 'hold' the motor, e.g. due to an excessive load. Select *[32] Mechanical Brake Control* for applications with an electro-magnetic brake in *5-40 Function Relay*, *5-30 Terminal 27 Digital Output*, or *5-31 Terminal 29 Digital Output*. When selecting *[32] Mechanical brake control*, the mechanical brake is closed from start up until the output current is above the level selected in *2-20 Release Brake Current*. During stop, the mechanical brake activates when the speed drops below the level specified in *2-21 Activate Brake Speed [RPM]*. If the frequency converter enters an alarm condition or an overcurrent or overvoltage situation, the mechanical brake immediately cuts in. This is also the case during Safe Torque Off.

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NOTICE

Protection mode and trip delay features (*14-25 Trip Delay at Torque Limit* and *14-26 Trip Delay at Inverter Fault*) may delay the activation of the mechanical brake in an alarm condition. These features must be disabled in hoisting applications.

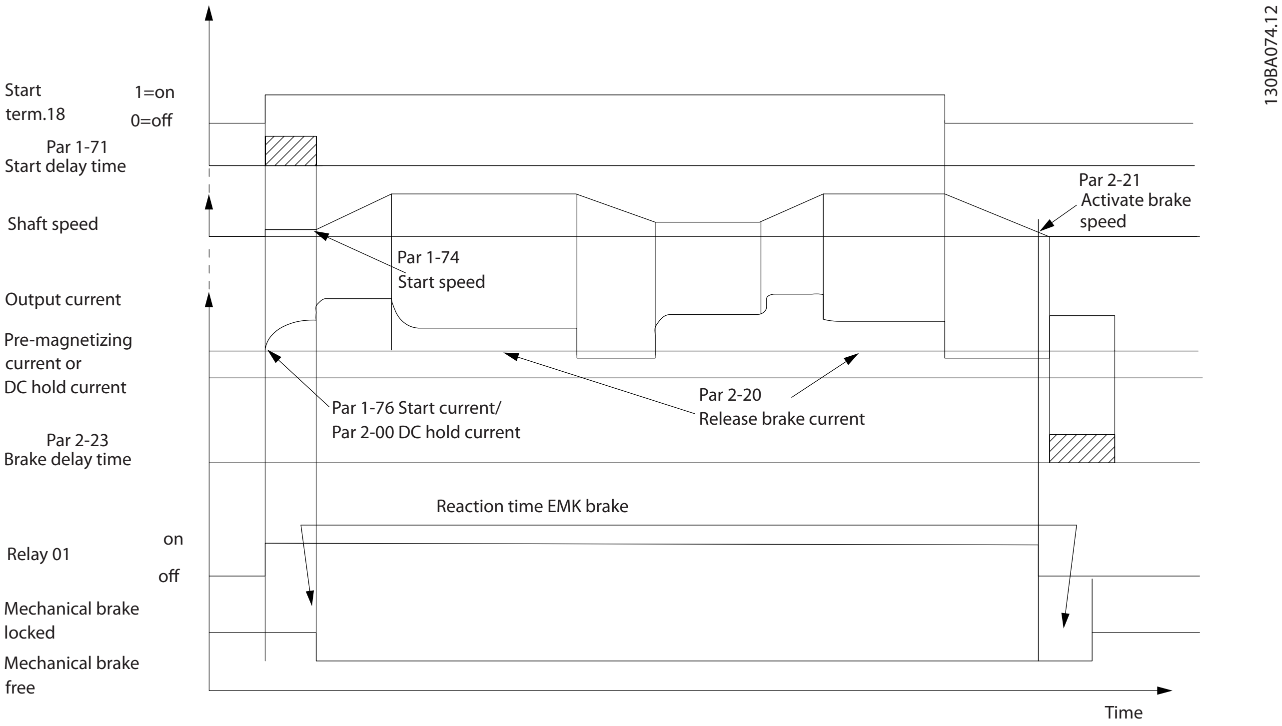

Illustration 4.2 Mechanical Brake

4.2.13 Closed Loop Mechancial Brake Control/Hoist Mechanical Brake

The hoist mechanical break control supports the following functions:

- 2 channels for mechanical brake feedback to offer further protection against unintended behaviour resulting from broken cable.
- Monitoring of mechanical brake feedback throughout the complete cycle. This helps protect the mechanical brake - especially if more frequency converters are connected to the same shaft.
- No ramp up until feedback confirms mechanical brake is open.
- Improved load control at stop. If *2-23 Activate Brake Delay* is set too short, W22 is activated and the torque is not allowed to ramp down.
- The transition when motor takes over the load from the brake can be configured. *2-28 Gain Boost Factor* can be increased to minimise the movement. For very smooth transition change the setting from the speed control to the position control during the change-over.
    - Set *2-28 Gain Boost Factor* to 0 to enable Position Control during *2-25 Brake Release Time*. This enables parameters *2-30 Position P Start Proportional Gain* to *2-33 Speed PID Start Lowpass Filter Time* which are PID parameters for the Position Control.

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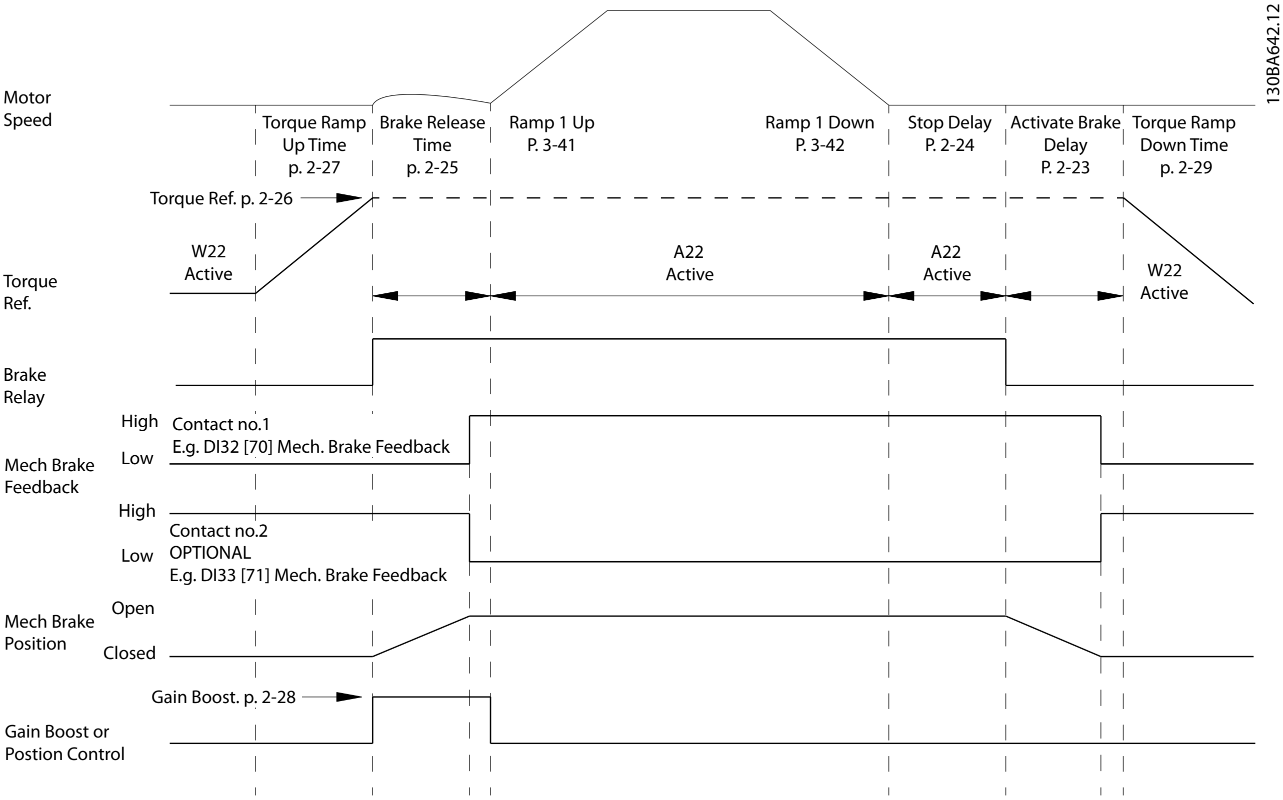

Illustration 4.3 Brake release sequence for hoist mechanical brake control. This brake control is available in FLUX with motor feedback only, available for asynchronous and non-salient PM motors.

2-26 Torque Ref to *2-33 Speed PID Start Lowpass Filter Time* are only available for the hoist mechanical brake control (FLUX with motor feedback). *2-30 Position P Start Proportional Gain* to *2-33 Speed PID Start Lowpass Filter Time* can be set up for very smooth transition change from speed control to position control during *2-25 Brake Release Time* - the time when the load is transferred from the mechanical brake to the frequency converter.
2-30 Position P Start Proportional Gain to *2-33 Speed PID Start Lowpass Filter Time* are activated when *2-28 Gain Boost Factor* is set to 0. See *Illustration 4.3* for more information.

NOTICE

For an example of advanced mechanical brake control for hoisting applications, see *chapter 10 Application Examples*.

4.2.14 Smart Logic Control (SLC)

Smart Logic Control (SLC) is a sequence of user-defined actions (see *13-52 SL Controller Action* [x]) executed by the SLC when the associated user defined *event* (see *13-51 SL Controller Event* [x]) is evaluated as TRUE by the SLC.
The condition for an event can be a particular status or that the output from a Logic Rule or a Comparator Operand becomes TRUE. That leads to an associated Action as shown in *Illustration 4.4*.

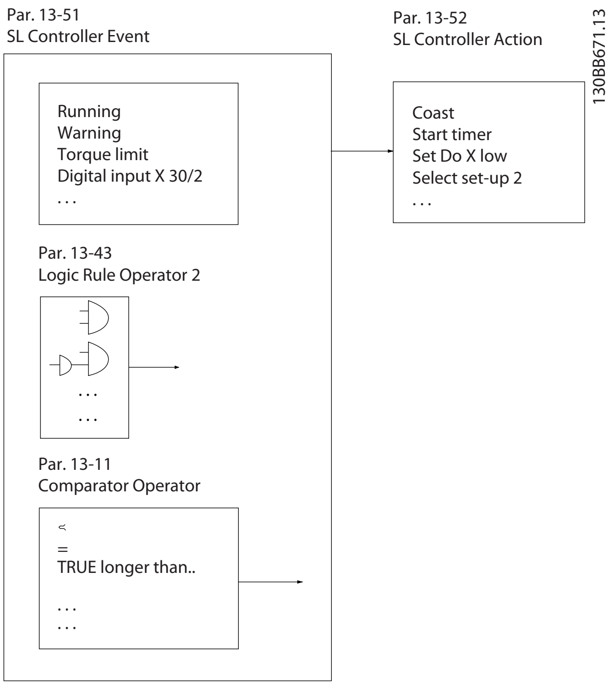

Illustration 4.4 SCL Event and Action

Events and actions are each numbered and linked in pairs (states). This means that when *event* [0] is fulfilled (attains the value TRUE), *action* [0] is executed. After this, the conditions of *event* [1] is evaluated and if evaluated TRUE, *action* [1] is executed and so on. Only one *event* is evaluated at any time. If an *event* is evaluated as FALSE, nothing happens (in the SLC) during the current scan interval and no other *events* are evaluated. This means that when the SLC starts, it evaluates *event* [0] (and only *event* [0]) each scan interval. Only when *event* [0] is evaluated TRUE, the SLC executes *action* [0] and starts evaluating *event* [1]. 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 *event* [0]/*action* [0]. *Illustration 4.5* shows an example with 4 event/actions:

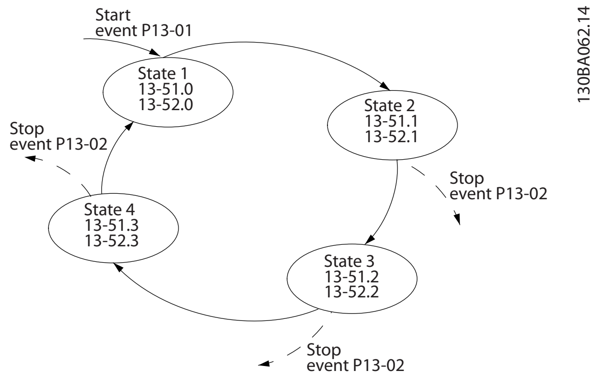

Illustration 4.5 Order of Execution when 4 Events/Actions are Programmed

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

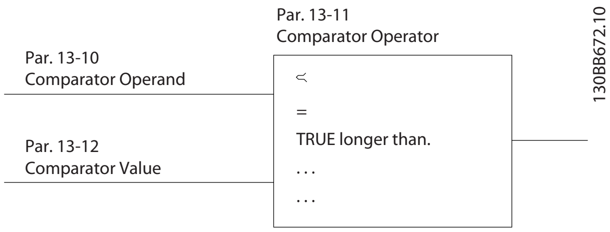

Illustration 4.6 Comparators

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

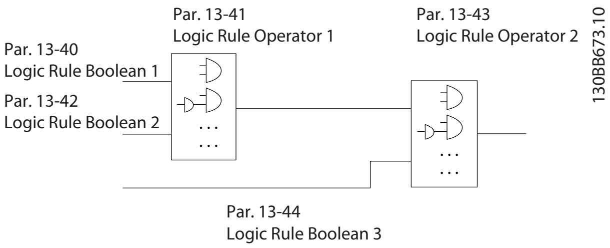

Illustration 4.7 Logic Rules

4.2.15 Safe Torque Off

For information about Safe Torque Off, refer to the *VLT® FC Series Safe Torque Off Operating Instructions*.

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4.3 Danfoss VLT® FlexConcept®

Danfoss VLT® FlexConcept® is an energy efficient, flexible and cost-efficient frequency converter solution, mainly for conveyors. The concept consists of the VLT® OneGearDrive® driven by the VLT® AutomationDrive FC 302 or VLT® Decentral Drive FCD 302.

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OneGearDrive is basically a permanent magnet motor with a bevel gear. The bevel gear can be delivered with different gear ratios.

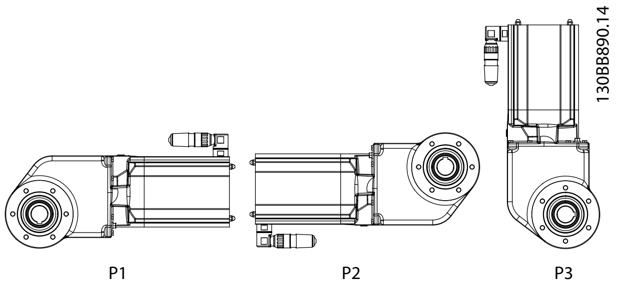

Illustration 4.8 OneGearDrive

The OneGearDrive can be driven by VLT® AutomationDrive FC 302 and VLT® Decentral Drive FCD 302 in the folllowing power sizes dependent on demands of the actual application:

- 0.75 kW
- 1.1 kW
- 1.5 kW
- 2.2 kW
- 3.0 kW

When *[1] PM, non salient SPM* has been selected in in either FC 302 or FCD 302, the OneGearDrive can be selected in *1-11 Motor Model*, and the recommended parameters are set automatically.

For further information, refer to the *VLT® AutomationDrive FC 301/FC 302 Programming Guide*, the *VLT®*

5 System Integration

5.1 Ambient Operating Conditions

5.1.1 Humidity

Although the frequency converter can operate properly at high humidity (up to 95% relative humidity), condensation must always be avoided. There is a specific risk of condensation when the frequency converter is colder than moist ambient air. Moisture in the air can also condense on the electronic components and cause short circuits. Condensation occurs to units without power. It is advisable to install a cabinet heater when condensation is possible due to ambient conditions. Avoid installation in areas subject to frost.

Alternatively, operating the frequency converter in stand-by mode (with the unit connected to the mains) reduces the risk of condensation. However, ensure the power dissipation is sufficient to keep the frequency converter circuitry free of moisture.

5.1.2 Temperature

Minimum and maximum ambient temperature limits are specified for all frequency converters. Avoiding extreme ambient temperatures prolongs the life of the equipment and maximises overall system reliability. Follow the recommendations listed for maximum performance and equipment longevity.

- Although converters can operate at temperatures down to -10 °C, proper operation at rated load is only guaranteed at 0 °C or higher.
- Do not exceed the maximum temperature limit.
- The lifetime of electronic components decreases by 50% for every 10 °C when operated above its design temperature.
- Even devices with IP54, IP55, or IP66 protection ratings must adhere to the specified ambient temperature ranges.
- Additional air conditioning of the cabinet or installation site may be required.

5.1.3 Temperature and Cooling

The frequency converters have built-in fans to ensure optimum cooling. The main fan forces the air flow along the cooling fins on the heat sink, ensuring a cooling of the internal air. Some power sizes have a small secundary fan close to the control card, ensuring that the internal air is circulated to avoid hot spots. The main fan is controlled by the internal temperature in the frequency converter and the speed gradually increases along with temperature, reducing noise and energy consumption when the need is low, and ensuring maximum cooling when the need is there. The fan control can be adapted via *14-52 Fan Control* to accommodate any application, also to protect against negative effets of cooling in very cold climates. In case of over-temperature inside the frequency converter, it derates the switching frequency and –pattern, see *chapter 5.1.4 Manual Derating* for more info.

Minimum and maximum ambient temperature limits are specified for all frequency converters. Avoiding extreme ambient temperatures prolongs the life of the equipment and maximizes overall system reliability. Follow the recommendations listed for maximum performance and equipment longevity.

- Although frequency converters can operate at temperatures down to -10 °C, proper operation at rated load is only guaranteed at 0 °C or higher.
- Do not exceed the maximum temperature limit.
- Do not exceed the maximum 24h average temperatue.
  (The 24h average temperature is the max. ambient temperature minus 5 °C.
  Example: Max. temperature is 50 °C, maximum 24h avg. temperature is 45 °C)
- Observe the minimum top and bottom clearance requirements (*chapter 8.2.1.1 Clearance*).
- As a rule of thumb, the lifetime of electronic components decreases by 50% for every 10 C when operated above its design temperature.
- Even devices with high protection ratings must adhere to the specified ambient temperature ranges.
- Additional air conditioning of the cabinet or installation site may be required.

5.1.4 Manual Derating

Consider derating when any of the following conditions are present.

- Operating above 1000 m (low air pressure)
- Low speed operation
- Long motor cables
- Cables with a large cross section

- High ambient temperature

For more information, refer to *chapter 6.2.6 Derating for Ambient Temperature*.

5.1.4.1 Derating for Running at Low Speed

When a motor is connected to a frequency converter, it is necessary to check that the cooling of the motor is adequate.
The level of heating depends on the load on the motor, as well as the operating speed and time.

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Constant torque applications (CT mode)

A problem may occur at low RPM values in constant torque applications. In a constant torque application, a motor may overheat at low speeds due to less cooling air from the motor integral fan.
Therefore, if the motor is to be run continuously at an RPM value lower than half of the rated value, the motor must be supplied with additional air-cooling (or a motor designed for this type of operation may be used).

An alternative is to reduce the load level of the motor by selecting a larger motor. However, the design of the frequency converter puts a limit to the motor size.

Variable (Quadratic) torque applications (VT)
In VT applications such as centrifugal pumps and fans, where the torque is proportional to the square of the speed and the power is proportional to the cube of the speed, there is no need for additional cooling or derating of the motor.

5.1.4.2 Derating for Low Air Pressure

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

Below 1000 m altitude no derating is necessary, but above 1000 m the ambient temperature (T_{AMB}) or max. output current (I_{out}) should be derated in accordance with *Illustration 5.1*.

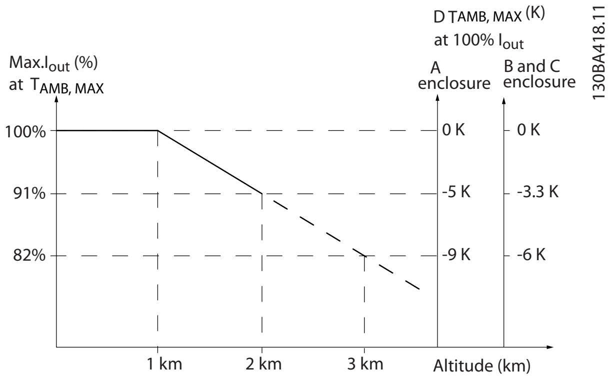


Illustration 5.1 Derating of output current versus altitude at $T_{AMB, MAX}$ for frame sizes A, B and C. At altitudes above 2,000 m, contact Danfoss regarding PELV.

An alternative is to lower the ambient temperature at high altitudes and thereby ensure 100% output current at high altitudes. As an example of how to read the graph, the situation at 2,000 m is elaborated for an enclosure type B with $T_{AMB, MAX}$ = 50° C. At a temperature of 45° C ($T_{AMB, MAX}$ - 3.3 K), 91% of the rated output current is available. At a temperature of 41.7° C, 100% of the rated output current is available.

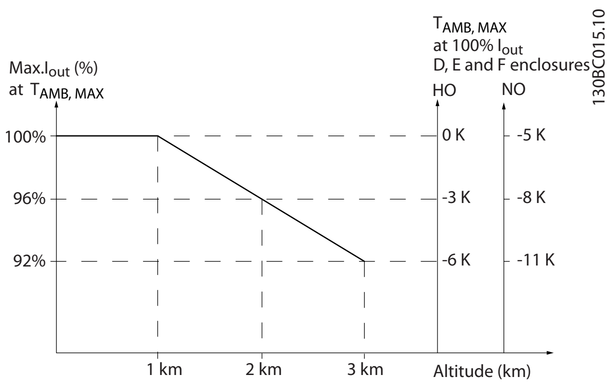


Illustration 5.2 Derating of output current versus altitude at $T_{AMB, MAX}$ for enclosure types D3h.

5.1.5 Acoustic Noise

Acoustic noise from the frequency converter comes from 3 sources

- DC-link (intermediate circuit) coils
- RFI filter choke
- Internal fans

See *chapter 6.2.9 Acoustic Noise* for acoustic noise ratings.

5.1.6 Vibration and Shock

The frequency converter tested according to a procedure based on the IEC 68-2-6/34/35 and 36. These tests subject the unit to 0.7 g forces, over the range of 18 to 1,000 Hz random, in 3 directions for 2 hours. All Danfoss frequency converters comply with requirements that correspond to these conditions when the unit is wall or floor mounted, as well as when mounted within panels bolted to walls or floors.

5.1.7 Aggressive Atmospheres

5.1.7.1 Gases

Aggressive gases, such as hydrogen sulphide, chlorine, or ammonia can damage frequency converter electrical and mechanical components. Contamination of the cooling air can also cause the gradual decomposition of PCB tracks and door seals. Aggressive contaminants are often present in sewage treatment plants or swimming pools. A clear sign of an aggressive atmosphere is corroded copper.

In aggressive atmospheres, restricted IP enclosures are recommended along with conformal-coated circuit boards. See *Table 5.1* for conformal-coating values.

NOTICE

The frequency converter comes standard with class 3C2 coating. On request, class 3C3 coating is available.

Gas type	Unit	Class				
		3C1	3C2		3C3	
			Average value	Max. value	Average value	Max. value
Sea salt	n/a	None	Salt mist		Salt mist	
Sulphur oxides	mg/m³	0.1	0.3	1.0	5.0	10
Hydrogen sulphide	mg/m³	0.01	0.1	0.5	3.0	10
Chlorine	mg/m³	0.01	0.1	0.03	0.3	1.0
Hydrogen chloride	mg/m³	0.01	0.1	0.5	1.0	5.0
Hydrogen fluoride	mg/m³	0.003	0.01	0.03	0.1	3.0
Ammonia	mg/m³	0.3	1.0	3.0	10	35
Ozone	mg/m³	0.01	0.05	0.1	0.1	0.3
Nitrogen	mg/m³	0.1	0.5	1.0	3.0	9.0

Table 5.1 Conformal-coating Class Ratings

Maximum values are transient peak values not to exceed 30 minutes per day.

5.1.7.2 Dust Exposure

Installation of frequency converters in environments with high dust exposure is often unavoidable. Dust affects wall or frame mounted units with IP55 or IP66 protection rating, and also cabinet mounted devices with IP21 or IP20 protection rating. Take the 3 aspects described below into account when frequency converters are installed in such environments.

Reduced Cooling
Dust forms deposits on the surface of the device and inside on circuit boards and the electronic components. These deposits act as insulation layers and hamper heat transfer to the ambient air, reducing the cooling capacity. The components become warmer. This causes accelerated aging of the electronic components, and the service life of the unit decreases. Dust deposits on the heat sink in the back of the unit also decrease the service life of the unit.

Cooling Fans
The airflow for cooling the unit is produced by cooling fans, usually located on the back of the device. The fan rotors have small bearings into which dust can penetrate and act as an abrasive. This leads to bearing damage and fan failure.

Filters
High-power frequency converters are equipped with cooling fans that expel hot air from the interior of the

device. Above a certain size, these fans are fitted with filter mats. These filters can become quickly clogged when used in very dusty environments. Preventative measures are necessary under these conditions.

Periodic Maintenance

Under the conditions described above, it is advisable to clean the frequency converter during periodic maintenance. Remove dust off the heat sink and fans and clean the filter mats.

5.1.7.3 Potentially Explosive Atmospheres

Systems operated in potentially explosive atmospheres must fulfil special conditions. EU Directive 94/9/EC describes the operation of electronic devices in potentially explosive atmospheres.

Motors controlled by frequency converters in potentially explosive atmospheres must be monitored for temperature using a PTC temperature sensor. Motors with ignition protection class d or e are approved for this environment.

- e classification consists of preventing any occurrence of a spark. The FC 302 with firmware version V6.3x or higher is equipped with an "ATEX ETR thermal monitoring" function for operation of specially approved Ex-e motors. When combined with an ATEX approved PTC monitoring device like the PTC Thermistor Card MCB 112 the installation does not need an individual approval from an approbated organisation, i.e. no need for matched pairs.
- d classification consists of ensuring that if a spark occurs, it is contained in a protected area. While not requiring approval, special wiring and containment are required.
- d/e combination is the most often used in potentially explosive atmospheres. The motor itself has a e ignition protection class, while the motor cabling and connection environment is in compliance with the e classification. The restriction on the e connection space consists of the maximum voltage allowed in this space. The output voltage of a frequency converter is usually limited to the mains voltage. The modulation of the output voltage may generate unallowable high peak voltage for e classification. In practice, using a sine-wave filter at the frequency converter output has proven to be an effective means to attenuate the high peak voltage.

NOTICE

Do not install a frequency converter in a potentially explosive atmosphere. Install the frequency converter in a cabinet outside of this area. Using a sine-wave filter at the output of the frequency converter is also recommended to attenuate the dU/dt voltage rise and peak voltage. Keep the motor cables as short as possible.

NOTICE

VLT® AutomationDrive units with the MCB 112 option have PTB-certified motor thermistor sensor monitoring capability for potentially explosive atmospheres. Shielded motor cables are not necessary when frequency converters are operated with sine-wave output filters.

5.1.8 Maintenance

Danfoss frequency converter models up to 90 kW are maintenance free. High power frequency converters (rated at 110 kW or higher) have built-in filter mats which require periodic cleaning by the operator, depending on the exposure to dust and contaminants. Maintenance intervals for the cooling fans (approximately 3 years) and capacitors (approximately 5 years) are recommended in most environments.

5.1.9 Storage

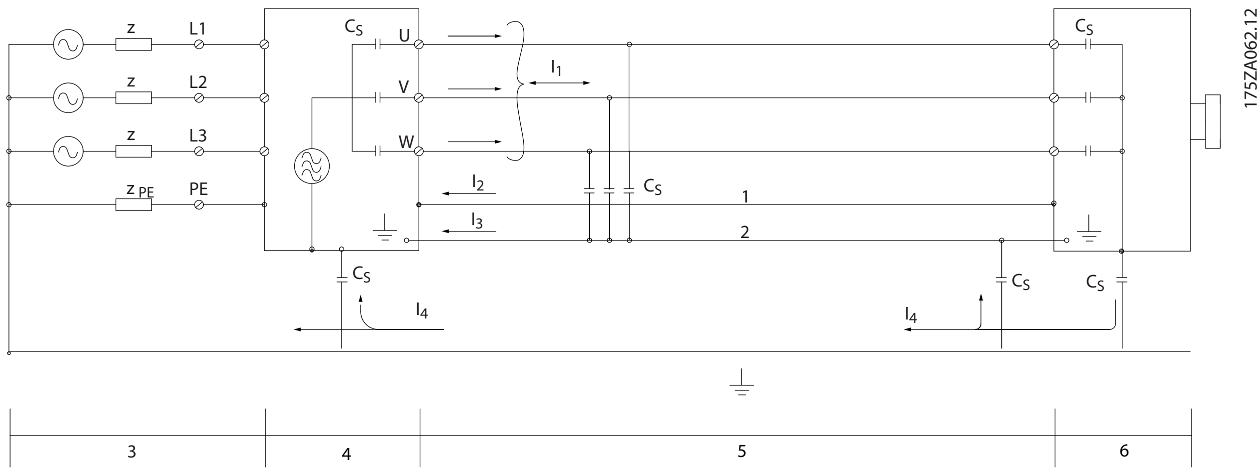
Like all electronic equipment, frequency converters must be stored in a dry location. Periodic forming (capacitor charging) is not necessary during storage.

It is recommended to keep the equipment sealed in its packaging until installation.

5.2 General Aspects of EMC

Electrical interference is usually 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 5.3*, capacitance 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 5.3*) because screened cables have higher capacitance to ground than unscreened cables. If the leakage current is not filtered, it causes greater interference on the mains in the radio frequency range below approximately 5 MHz. Since the leakage current (I_1) is carried back to the unit through the screen (I_3), there is in principle only a small electro-magnetic field (I_4) from the screened motor cable according to *Illustration 5.3*.

The screen reduces the radiated interference, but increases the low-frequency interference on the mains. Connect the motor cable screen to the frequency converter enclosure as well as on the motor enclosure. This is best done by using integrated screen clamps so as to avoid twisted screen ends (pigtails). Pigtails 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 relay, control cable, signal interface and brake, mount the screen on the enclosure at both ends. In some situations, however, it is necessary to break the screen to avoid current loops.



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

Illustration 5.3 Situation that Generates Leakage Currents

If the screen is to be placed on a mounting plate for the frequency converter, the mounting plate must be made of metal, to convey the screen currents back to the unit. Moreover, 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 most immunity requirements are observed.

To reduce the interference level from the entire system (unit+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 especially generated by the control electronics.

5.2.1 EMC Test Results

The following test results have been obtained using a system with a frequency converter, a screened control cable, a control box with potentiometer, as well as a single motor and screened motor cable (Ölflex Classic 100 CY) at nominal switching frequency. *Table 5.2* states the maximum motor cable lengths for compliance.

NOTICE

Conditions may change significantly for other set-ups.

NOTICE

Consult *Table 9.19* for parallel motor cables.

RFI filter type		**Conducted emission**			**Radiated emission**		
		Cable length [m]					
Standards and requirements	**EN 55011/CISPR 11**	**Class B**	**Class A Group 1**	**Class A Group 2**	**Class B**	**Class A Group 1**	**Class A Group 2**
	EN/IEC 61800-3	**Category C1**	**Category C2**	**Category C3**	**Category C1**	**Category C2**	**Category C3**
H1							
FC 301	0-37 kW 200-240 V	10	50	50	No	Yes	Yes
	0-75 kW 380-480 V	10	50	50	No	Yes	Yes
FC 302	0-37 kW 200-240 V	50	150	150	No	Yes	Yes
	0-75 kW 380-480 V	50	150	150	No	Yes	Yes
H2/H5							
FC 301	0-3.7 kW 200-240 V	No	No	5	No	No	Yes
FC 302	5.5-37 kW 200-240 V[2)]	No	No	25	No	No	Yes
	0-7.5 kW 380-500 V	No	No	5	No	No	Yes
	11-75 kW 380-500 V[2)]	No	No	25	No	No	Yes
	11-22 kW 525-690 V[2)]	No	No	25	No	No	Yes
	30-75 kW 525-690 V[2)]	No	No	25	No	No	Yes
H3							
FC 301	0-1.5 kW 200-240V	2.5	25	25	No	Yes	Yes
	0-1.5 kW 380-480V	2.5	25	25	No	Yes	Yes
H4							
FC 302	1.1-7.5 kW 525-690 V	No	100	100	No	Yes	Yes
	11-22 kW 525-690 V	No	100	100	No	Yes	Yes
	11-37 kW 525-690 V[3]	No	150	150	No	Yes	Yes
	30-75 kW 525-690 V	No	150	150	No	Yes	Yes
Hx[1)]							
FC 302	0.75-75 kW 525-600 V	No	No	No	No	No	No

Table 5.2 EMC Test Results (Emission) Maximum Motor Cable Length

1) Hx versions can be used according to EN/IEC 61800-3 category C4

2) T5, 22-45 kW and T7, 22-75 kW comply with class A group 1 with 25 m motor cable. Some restrictions for the installation apply (contact Danfoss for details).

Hx, H1, H2, H3, H4 or H5 is defined in the type code pos. 16-17 for EMC filters, see Table 7.1.

3) IP20

5.2.2 Emission Requirements

The EMC product standard for frequency converters defines 4 categories (C1, C2, C3 and C4) with specified requirements for emission and immunity. *Table 5.3* states the definition of the 4 categories and the equivalent classification from EN 55011.

Category	Definition	Equivalent emission class 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, which are neither plug-in nor movable and are intended to be installed and commissioned by a professional.	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. An EMC plan should be made.

Table 5.3 Correlation between IEC 61800-3 and EN 55011

When the generic (conducted) emission standards are used, the frequency converters are required to comply with the limits in *Table 5.4*.

Environment	Generic emission standard	Equivalent emission class 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 5.4 Correlation between Generic Emission Standards and EN 55011

5.2.3 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 from electrical phenomena, the following immunity tests have been made in accordance with 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 e.g. by lightning that strikes near installations.
- **EN 61000-4-6 (IEC 61000-4-6):** RF Common mode: Simulation of the effect from radio-transmission equipment joined by connection cables.

See *Table 5.5*.

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**
Voltage range: 200-240 V, 380-500 V, 525-600 V, 525-690 V					
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	10V/m	—

Table 5.5 EMC Immunity Form

[1] *Injection on cable shield*

5.2.4 Motor Insulation

Modern design of motors for use with frequency converters have a high degree of insulation to account for new generation high-efficiency IGBTs with high dU/dt. For retrofit in old motors it is necessary to confirm the motor insulation or to mitigate with dU/dt filter or if necessary a sine-wave filter. dU/dt

For motor cable lengths ≤ the maximum cable length listed in *chapter 6.2 General Specifications*, the motor insulation ratings listed in *Table 5.6* are recommended. If a motor has lower insulation rating, it is recommended to use a dU/dt or sine-wave filter.

Nominal Mains Voltage [V]	Motor Insulation [V]
$U_N \leq 420$	Standard U_{LL} = 1300
420 V < $U_N \leq 500$	Reinforced U_{LL} = 1600
500 V < $U_N \leq 600$	Reinforced U_{LL} = 1800
600 V < $U_N \leq 690$	Reinforced U_{LL} = 2000

Table 5.6 Motor Insulation

5.2.5 Motor Bearing Currents

To minimise bearing and shaft currents, ground the following to the driven machine:

- frequency converter
- motor
- driven machine
- motor

Standard Mitigation Strategies

1. Use an insulated bearing.
2. Apply rigorous installation procedures
   - 2a Ensure the motor and load motor are aligned.
   - 2b Strictly follow the EMC Installation guideline.
   - 2c Reinforce the PE so the high frequency impedance is lower in the PE than the input power leads.
   - 2d 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.

2e Make sure that the impedance from frequency converter to building ground is lower that the grounding impedance of the machine. This can be difficult for pumps.

2f Make a direct ground 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 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.

5.3 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	250	350

Table 5.7 Transformed Non-sinusoidal Current

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.

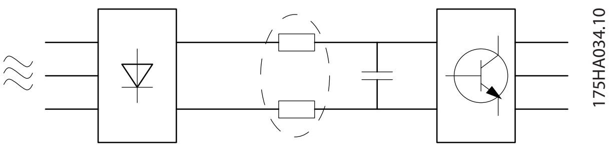


Illustration 5.4 Intermediate Circuit Coils

NOTICE

Some of the harmonic currents might disturb communication equipment connected to the same transformer or cause resonance in connection with power-factor correction units.

	Input current
I_{RMS}	1.0
I_1	0.9
I_5	0.4
I_7	0.2
I_{11-49}	< 0.1

Table 5.8 Harmonic Currents Compared to the RMS Input Current

To ensure low harmonic currents, the frequency converter is equipped with intermediate circuit coils as standard. DC-coils reduce the total harmonic distortion (THD) to 40%.

5.3.1 The Effect of Harmonics in a Power Distribution System

In *Illustration 5.5* 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.

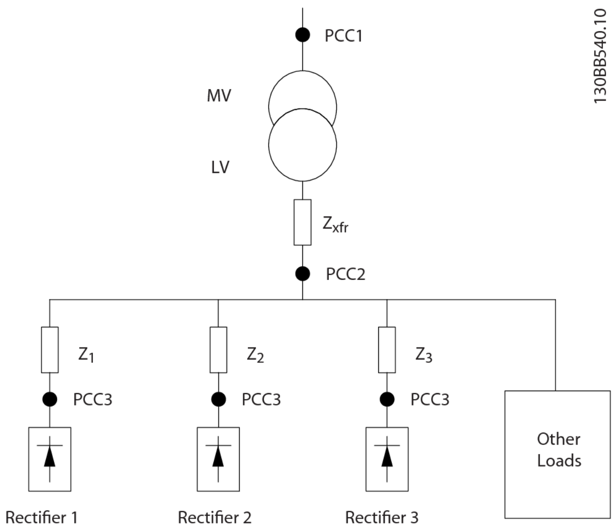


Illustration 5.5 Small Distribution System

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

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

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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}).

$$Rsce = \frac{Sce}{Sequ}$$

where $Ssc = \frac{U^2}{Zsupply}$ and $Sequ = U \times Iequ$

The negative effect of harmonics is 2-fold

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

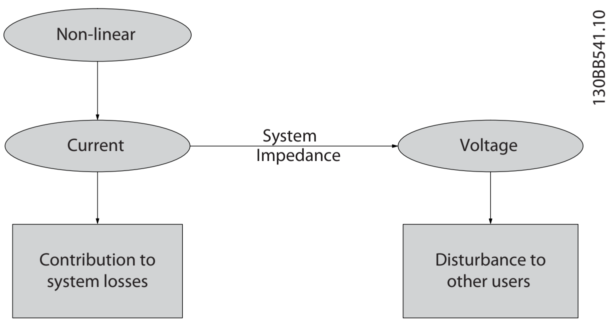

Illustration 5.6 Negative Effects of Harmonics

5.3.2 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 2 110 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 is undersized, if both motors are frequency converter supplied. Using additional means of harmonic reduction within the installation or selecting low harmonic drive variants makes it possible for both motors to run with frequency converters.

There are various harmonic mitigation standards, regulations and recommendations. 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 *AHF 005/010 Design Guide* for specific details on each standard.

In Europe, the maximum THVD is 8% if the plant is connected via the public grid. If the plant has its own transformer, the limit is 10% THVD. The VLT® AutomationDrive is designed to withstand 10% THVD.

5.3.3 Harmonic Mitigation

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

- 12-pulse drives
- AHF filters
- Low Harmonic Drives
- 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.)

Always consider harmonic mitigation if the transformer load has a non-linear contribution of 40% or more.

5.3.4 Harmonic Calculation

Danfoss offers tools for calculation of harmonics, see *chapter 9.6.5 PC Software*.

5.4 Galvanic Isolation (PELV)

5.4.1 PELV - Protective Extra Low Voltage

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), with the exception of grounded Delta leg above 400 V.

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

The components that make up the electrical isolation, as described below, also comply with the requirements for higher isolation and the relevant test as described in EN 61800-5-1.
The PELV galvanic isolation can be shown in 6 locations (see *Illustration 5.7*):

To maintain PELV, all connections made to the control terminals must be PELV, e.g. thermistor must be reinforced/double insulated.

1. Power supply (SMPS) incl. signal isolation of DC-link.
2. Gate drive that runs the IGBTs (trigger transformers/opto-couplers).
3. Current transducers.
4. Opto-coupler, brake module.
5. Internal inrush, RFI, and temperature measurement circuits.
6. Custom relays.
7. Mechanical brake.

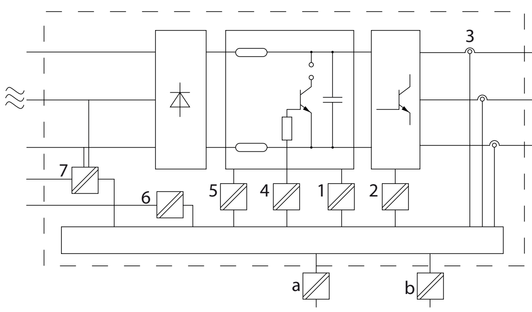

Illustration 5.7 Galvanic Isolation

The functional galvanic isolation (a and b on drawing) is for the 24 V back-up option and for the RS-485 standard bus interface.

WARNING

Installation at high altitude:
At altitudes above 2,000 m, contact Danfoss regarding PELV.

WARNING

Touching the electrical parts could be fatal - even after the equipment has been disconnected from mains.
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.
Before touching any electrical parts, wait at least the amount of time indicated in *Table 2.1*.
Shorter time is allowed only if indicated on the nameplate for the specific unit.

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5.5 Brake Functions

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

5.5.1 Selection of Brake Resistor

The brake resistor ensures that the energy is absorbed in the brake resistor and not in the frequency converter. For more information see the *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 5.8* shows a typical braking cycle.

NOTICE

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

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

Duty cycle = t_b/T

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

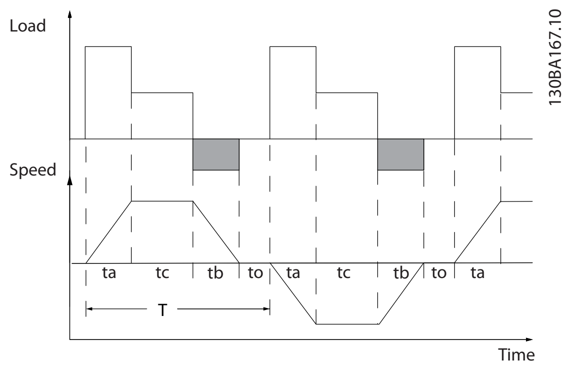

Illustration 5.8 Typical Braking Cycle

	Cycle time (s)	Braking duty cycle at 100% torque	Braking duty cycle at over torque (150/160%)
200-240 V			
PK25-P11K	120	Continuous	40%
P15K-P37K	300	10%	10%
380-500 V			
PK37-P75K	120	Continuous	40%
P90K-P160	600	Continuous	10%
P200-P800	600	40%	10%
525-600 V			
PK75-P75K	120	Continuous	40%
525-690 V			
P37K-P400	600	40%	10%
P500-P560	600	40% 1)	10% 2)
P630-P1M0	600	40%	10%

Table 5.9 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 is used on dissipating excess heat.

NOTICE

Make sure the resistor is designed to handle the required braking time.

The max. permissible load on the brake resistor is stated as a peak power at a given intermittent duty cycle and can be calculated as:

$$ED\,(dutycycle) = \frac{tb}{T\,cycle}$$

where tb is the braking time in seconds and T cycle is the total cycle time.

The brake resistance is calculated as shown:

$$Rbr\,[\Omega] = \frac{U_{dc}^2}{Ppeak}$$

where

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

The brake resistance depends on the intermediate circuit voltage (U_{dc}).
The FC 301 and FC 302 brake function is settled in 4 areas of mains.

Size	Brake active	Warning before cut out	Cut out (trip)
FC 301/FC 302 200-240 V	390 V	405 V	410 V
FC 301 380-480 V	778 V	810 V	820 V
FC 302 380-500 V	810 V	840 V	850 V
FC 302 525-600 V	943 V	965 V	975 V
FC 302 525-690 V	1084 V	1109 V	1130 V

Table 5.10 Brake Limits [UDC]

NOTICE

Check that the brake resistor can cope with 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:

$$Rrec\,[\Omega] = \frac{U_{dc}^2 \times 100}{Pmotor \times Mbr_{(\%)} \times \eta_{VLT} \times \eta_{motor}}$$

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

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

$$200V:\ Rrec = \frac{107780}{Pmotor}\,[\Omega]$$

$$480V:\ Rrec = \frac{375300}{Pmotor}\,[\Omega]\ 1)$$

$$480V:\ Rrec = \frac{428914}{Pmotor}\,[\Omega]\ 2)$$

$$500V:\ Rrec = \frac{464923}{Pmotor}\,[\Omega]$$

$$600V:\ Rrec = \frac{630137}{Pmotor}\,[\Omega]$$

$$690V:\ Rrec = \frac{832664}{Pmotor}\,[\Omega]$$

1) For frequency converters ≤ 7.5 kW shaft output
2) For frequency converters 11-75 kW shaft output

NOTICE

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.

NOTICE

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).

CAUTION

The brake resistor gets hot during and after braking.

- **To avoid personal injury, do not touch the brake resistor**
- **Place the brake resistor in a secure environment to avoid fire risk.**

CAUTION

Enclosure types D-F frequency converters contain more than one brake chopper. Consequently, use one brake resistor per brake chopper for those enclosure types.

5.5.2 Brake Resistor Cabling

EMC (twisted cables/shielding)
To meet the specified EMC performance of the frequency converter, use screened cables/wires. If unscreened wires are used, it is recommended to twist the wires to reduce the electrical noise from the wires between the brake resistor and the frequency converter.

For enhanced EMC performance, use a metal screen.

5.5.3 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 enables reading out the momentary power and the mean power for the latest 120 s. The brake can also monitor the power energising and ensure that it does not exceed the 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)*.

NOTICE

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.

Overvoltage 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.

NOTICE

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

6 Product Specifications

6.1 Electrical Data

6.1.1 Mains Supply 200-240 V

Type Designation	PK25	PK37	PK55	PK75	P1K1	P1K5	P2K2	P3K0	P3K7
Typical Shaft Output [kW]	0.25	0.37	0.55	0,75	1.1	1.5	2.2	3.0	3.7
Enclosure IP20 (FC 301 only)	A1	A1	A1	A1	A1	A1	-	-	-
Enclosure IP20/IP21	A2	A2	A2	A2	A2	A2	A2	A3	A3
Enclosure IP55, IP66	A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A5	A5
Output current									
Continuous (200-240 V) [A]	1.8	2.4	3.5	4.6	6.6	7.5	10.6	12.5	16.7
Intermittent (200-240 V) [A]	2.9	3.8	5.6	7.4	10.6	12.0	17.0	20.0	26.7
Continuous kVA (208 V) [kVA]	0.65	0.86	1.26	1.66	2.38	2.70	3.82	4.50	6.00
Max. input current									
Continuous (200-240 V) [A]	1.6	2.2	3.2	4.1	5.9	6.8	9.5	11.3	15.0
Intermittent (200-240 V) [A]	2.6	3.5	5.1	6.6	9.4	10.9	15.2	18.1	24.0
Additional Specifications									
Max. cable cross section [4] for mains, motor, brake and load sharing [mm^2] ([AWG])	4,4,4 (12,12,12) (min. 0.2 (24))								
Max. cable cross section [4] for disconnect [mm^2] ([AWG])	6,4,4 (10,12,12)								
Estimated power loss at rated max. load [W] [3]	21	29	42	54	63	82	116	155	185
Efficiency [2]	0.94	0.94	0.95	0.95	0.96	0.96	0.96	0.96	0.96

Table 6.1 Mains Supply 200-240 V, PK25-P3K7

Type Designation	P5K5		P7K5		P11K	
High/Normal Overload[1)]	HO	NO	HO	NO	HO	NO
Typical Shaft Output [kW]	5.5	7.5	7.5	11	11	15
Enclosure IP20	B3		B3		B4	
Enclosure IP21, IP55, IP66	B1		B1		B2	
Output current						
Continuous (200-240 V) [A]	24.2	30.8	30.8	46.2	46.2	59.4
Intermittent (60 s overload) (200-240 V) [A]	38.7	33.9	49.3	50.8	73.9	65.3
Continuous kVA (208 V) [kVA]	8.7	11.1	11.1	16.6	16.6	21.4
Max. input current						
Continuous (200-240 V) [A]	22.0	28.0	28.0	42.0	42.0	54.0
Intermittent (60 s overload) (200-240 V) [A]	35.2	30.8	44.8	46.2	67.2	59.4
Additional Specifications						
IP20 max. cable cross-section [4)] for mains, brake, motor and load sharing [mm^2] ([AWG])	10,10,- (8,8,-)		10,10,- (8,8,-)		35,-,- (2,-,-)	
IP21 max. cable cross-section [4)] for mains, brake and load sharing [mm^2] ([AWG])	16,10,16 (6,8,6)		16,10,16 (6,8,6)		35,-,- (2,-,-)	
IP21 max. cable cross-section [4)] for motor [mm^2] ([AWG])	10,10,- (8,8,-)		10,10,- (8,8,-)		35,25,25 (2,4,4)	
Max. cable cross-section [4)] for Disconnect [mm^2] ([AWG])	16,10,10 (6,8,8)					
Estimated power loss at rated max. load [W] [3)]	239	310	371	514	463	602
Efficiency [2)]	0.96		0.96		0.96	

Table 6.2 Mains Supply 200-240 V, P5K5-P11K

Type Designation	P15K		P18K		P22K		P30K		P37K	
High/Normal Overload[1)]	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft Output [kW]	15	18.5	18.5	22	22	30	30	37	37	45
Enclosure IP20	B4		C3		C3		C4		C4	
Enclosure IP21, IP55, IP66	C1		C1		C1		C2		C2	
Output current										
Continuous (200-240 V) [A]	59.4	74.8	74.8	88.0	88.0	115	115	143	143	170
Intermittent (60 s overload) (200-240 V) [A]	89.1	82.3	112	96.8	132	127	173	157	215	187
Continuous kVA (208 V [kVA]	21.4	26.9	26.9	31.7	31.7	41.4	41.4	51.5	51.5	61.2
Max. input current										
Continuous (200-240 V) [A]	54.0	68.0	68.0	80.0	80.0	104	104	130	130	154
Intermittent (60 s overload) (200-240 V) [A]	81.0	74.8	102	88.0	120	114	156	143	195	169
Additional Specifications										
IP20 max. cable cross-section for mains, brake, motor and load sharing [mm^2] ([AWG])	35 (2)		50 (1)		50 (1)		150 (300MCM)		150 (300MCM)	
IP21, IP55, IP66 max. cable cross-section for mains and motor [mm^2] ([AWG])	50 (1)		50 (1)		50 (1)		150 (300MCM)		150 (300MCM)	
IP21, IP55, IP66 max. cable cross-section for brake and load sharing [mm^2] ([AWG])	50 (1)		50 (1)		50 (1)		95 (3/0)		95 (3/0)	
Max. cable cross-section [4)] for Disconnect [mm^2] ([AWG])	50, 35, 35 (1, 2, 2)						95, 70, 70 (3/0, 2/0, 2/0)		185, 150, 120 (350MCM, 300MCM, 4/0)	
Estimated power loss at rated max. load [W] [3)]	624	737	740	845	874	1140	1143	1353	1400	1636
Efficiency [2)]	0.96		0.97		0.97		0.97		0.97	

Table 6.3 Mains Supply 200-240 V, P15K-P37K

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6.1.2 Mains Supply 380-500 V

Type Designation	PK37	PK55	PK75	P1K1	P1K5	P2K2	P3K0	P4K0	P5K5	P7K5
Typical Shaft Output [kW]	0.37	0.55	0,75	1.1	1.5	2.2	3.0	4.0	5.5	7.5
Enclosure IP20 (FC 301 only)	A1	A1	A1	A1	A1	-	-	-	-	-
Enclosure IP20/IP21	A2	A2	A2	A2	A2	A2	A2	A2	A3	A3
Enclosure IP55, IP66	A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A5	A5
Output current High overload 160% for 1 min										
Shaft output [kW]	0.37	0.55	0.75	1.1	1.5	2.2	3	4	5.5	7.5
Continuous (380-440 V) [A]	1.3	1.8	2.4	3.0	4.1	5.6	7.2	10	13	16
Intermittent (380-440 V) [A]	2.1	2.9	3.8	4.8	6.6	9.0	11.5	16	20.8	25.6
Continuous (441-500 V) [A]	1.2	1.6	2.1	2.7	3.4	4.8	6.3	8.2	11	14.5
Intermittent (441-500 V) [A]	1.9	2.6	3.4	4.3	5.4	7.7	10.1	13.1	17.6	23.2
Continuous kVA (400 V) [kVA]	0.9	1.3	1.7	2.1	2.8	3.9	5.0	6.9	9.0	11
Continuous kVA (460 V) [kVA]	0.9	1.3	1.7	2.4	2.7	3.8	5.0	6.5	8.8	11.6
Max. input current										
Continuous (380-440 V) [A]	1.2	1.6	2.2	2.7	3.7	5.0	6.5	9.0	11.7	14.4
Intermittent (380-440 V) [A]	1.9	2.6	3.5	4.3	5.9	8.0	10.4	14.4	18.7	23
Continuous (441-500 V) [A]	1.0	1.4	1.9	2.7	3.1	4.3	5.7	7.4	9.9	13
Intermittent (441-500 V) [A]	1.6	2.2	3.0	4.3	5.0	6.9	9.1	11.8	15.8	20.8
Additional Specifications										
IP20, IP21 max. cable cross-section [4] for mains, motor, brake and load sharing [mm²] ([AWG])	4,4,4 (12,12,12) (min. 0.2(24))									
IP55, IP66 max. cable cross-section [4] for mains, motor, brake and load sharing [mm²] ([AWG])	4,4,4 (12,12,12)									
Max. cable cross-section [4] for disconnect [mm²] ([AWG])	6,4,4 (10,12,12)									
Estimated power loss at rated max. load [W] [3]	35	42	46	58	62	88	116	124	187	255
Efficiency [2]	0.93	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.97

Table 6.4 Mains Supply 380-500 V (FC 302), 380-480 V (FC 301), PK37-P7K5

Type Designation	P11K		P15K		P18K		P22K	
High/Normal Overload[1)]	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft output [kW]	11	15	15	18.5	18.5	22.0	22.0	30.0
Enclosure IP20	B3		B3		B4		B4	
Enclosure IP21	B1		B1		B2		B2	
Enclosure IP55, IP66	B1		B1		B2		B2	
Output current								
Continuous (380-440 V) [A]	24	32	32	37.5	37.5	44	44	61
Intermittent (60 s overload) (380-440 V) [A]	38.4	35.2	51.2	41.3	60	48.4	70.4	67.1
Continuous (441-500 V) [A]	21	27	27	34	34	40	40	52
Intermittent (60 s overload) (441-500 V) [A]	33.6	29.7	43.2	37.4	54.4	44	64	57.2
Continuous kVA (400 V) [kVA]	16.6	22.2	22.2	26	26	30.5	30.5	42.3
Continuous kVA (460 V) [kVA]		21.5		27.1		31.9		41.4
Max. input current								
Continuous (380-440 V) [A]	22	29	29	34	34	40	40	55
Intermittent (60 s overload) (380-440 V) [A]	35.2	31.9	46.4	37.4	54.4	44	64	60.5
Continuous (441-500 V) [A]	19	25	25	31	31	36	36	47
Intermittent (60 s overload) (441-500 V) [A]	30.4	27.5	40	34.1	49.6	39.6	57.6	51.7
Additional specifications								
IP21, IP55, IP66 max. cable cross-section [4)] for mains, brake and load sharing [mm²] ([AWG])	16, 10, 16 (6, 8, 6)		16, 10, 16 (6, 8, 6)		35,-,-(2,-,-)		35,-,-(2,-,-)	
IP21, IP55, IP66 max. cable cross-section [4)] for motor [mm²] ([AWG])	10, 10,- (8, 8,-)		10, 10,- (8, 8,-)		35, 25, 25 (2, 4, 4)		35, 25, 25 (2, 4, 4)	
IP20 max. cable cross-section [4)] for mains, brake, motor and load sharing [mm²] ([AWG])	10, 10,- (8, 8,-)		10, 10,- (8, 8,-)		35,-,-(2,-,-)		35,-,-(2,-,-)	
Max. cable cross-section [4)] for Disconnect [mm²] ([AWG])	16, 10, 10 (6, 8, 8)							
Estimated power loss at rated max. load [W] [3)]	291	392	379	465	444	525	547	739
Efficiency [2)]	0.98		0.98		0.98		0.98	

Table 6.5 Mains Supply 380-500 V (FC 302), 380-480 V (FC 301), P11K-P22K

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Type Designation	P30K		P37K		P45K		P55K		P75K	
High/Normal Overload[1]	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft output [kW]	30	37	37	45	45	55	55	75	75	90
Enclosure IP21	C1		C1		C1		C2		C2	
Enclosure IP20	B4		C3		C3		C4		C4	
Enclosure IP55, IP66	C1		C1		C1		C2		C2	
Output current										
Continuous (380-440 V) [A]	61	73	73	90	90	106	106	147	147	177
Intermittent (60 s overload) (380-440 V) [A]	91.5	80.3	110	99	135	117	159	162	221	195
Continuous (441-500 V) [A]	52	65	65	80	80	105	105	130	130	160
Intermittent (60 s overload) (441-500 V) [A]	78	71.5	97.5	88	120	116	158	143	195	176
Continuous kVA (400 V) [kVA]	42.3	50.6	50.6	62.4	62.4	73.4	73.4	102	102	123
Continuous kVA (460 V) [kVA]		51.8		63.7		83.7		104		128
Max. input current										
Continuous (380-440 V) [A]	55	66	66	82	82	96	96	133	133	161
Intermittent (60 s overload) (380-440 V) [A]	82.5	72.6	99	90.2	123	106	144	146	200	177
Continuous (441-500 V) [A]	47	59	59	73	73	95	95	118	118	145
Intermittent (60 s overload) (441-500 V) [A]	70.5	64.9	88.5	80.3	110	105	143	130	177	160
Additional specifications										
IP20 max. cable cross-section for mains and motor [mm^2] ([AWG])	35 (2)		50 (1)		50 (1)		150 (300 MCM)		150 (300 MCM)	
IP20 max. cable cross-section for brake and load sharing [mm^2] ([AWG])	35 (2)		50 (1)		50 (1)		95 (4/0)		95 (4/0)	
IP21, IP55, IP66 max. cable cross-section for mains and motor [mm^2] ([AWG])	50 (1)		50 (1)		50 (1)		150 (300 MCM)		150 (300MCM)	
IP21, IP55, IP66 max. cable cross-section for brake and load sharing [mm^2] ([AWG])	50 (1)		50 (1)		50 (1)		95 (3/0)		95 (3/0)	
Max cable cross-section [4] for mains disconnect [mm^2] ([AWG])	50, 35, 35 (1, 2, 2)						95, 70, 70 (3/0, 2/0, 2/0)		185, 150, 120 (350 MCM, 300 MCM, 4/0)	
Estimated power loss at rated max. load [W] [3]	570	698	697	843	891	1083	1022	1384	1232	1474
Efficiency [2]	0.98		0.98		0.98		0.98		0.99	

Table 6.6 Mains Supply 380-500 V (FC 302), 380-480 V (FC 301), P30K-P75K

6.1.3 Mains Supply 525-600 V (FC 302 only)

Type Designation	PK75	P1K1	P1K5	P2K2	P3K0	P4K0	P5K5	P7K5
Typical Shaft Output [kW]	0.75	1.1	1.5	2.2	3	4	5.5	7.5
Enclosure IP20, IP21	A3	A3	A3	A3	A3	A3	A3	A3
Enclosure IP55	A5	A5	A5	A5	A5	A5	A5	A5
Output current								
Continuous (525-550 V) [A]	1.8	2.6	2.9	4.1	5.2	6.4	9.5	11.5
Intermittent (525-550 V) [A]	2.9	4.2	4.6	6.6	8.3	10.2	15.2	18.4
Continuous (551-600 V) [A]	1.7	2.4	2.7	3.9	4.9	6.1	9.0	11.0
Intermittent (551-600 V) [A]	2.7	3.8	4.3	6.2	7.8	9.8	14.4	17.6
Continuous kVA (525 V) [kVA]	1.7	2.5	2.8	3.9	5.0	6.1	9.0	11.0
Continuous kVA (575 V) [kVA]	1.7	2.4	2.7	3.9	4.9	6.1	9.0	11.0
Max. input current								
Continuous (525-600 V) [A]	1.7	2.4	2.7	4.1	5.2	5.8	8.6	10.4
Intermittent (525-600 V) [A]	2.7	3.8	4.3	6.6	8.3	9.3	13.8	16.6
Additional specifications								
Max. cable cross-section [4] for mains, motor, brake and load sharing [mm²] ([AWG])	4,4,4 (12,12,12) (min. 0.2 (24))							
Max. cable cross-section [4] for disconnect [mm²] ([AWG])	6,4,4 (10,12,12)							
Estimated power loss at rated max. load [W] [3]	35	50	65	92	122	145	195	261
Efficiency [2]	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97

Table 6.7 Mains Supply 525-600 V (FC 302 only), PK75-P7K5

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Type Designation	P11K		P15K		P18K		P22K		P30K	
High/Normal Overload[1]	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft Output [kW]	11	15	15	18.5	18.5	22	22	30	30	37
Enclosure IP20	B3		B3		B4		B4		B4	
Enclosure IP21, IP55, IP66	B1		B1		B2		B2		C1	
Output current										
Continuous (525-550 V) [A]	19	23	23	28	28	36	36	43	43	54
Intermittent (525-550 V) [A]	30	25	37	31	45	40	58	47	65	59
Continuous (551-600 V) [A]	18	22	22	27	27	34	34	41	41	52
Intermittent (551-600 V) [A]	29	24	35	30	43	37	54	45	62	57
Continuous kVA (550 V) [kVA]	18.1	21.9	21.9	26.7	26.7	34.3	34.3	41.0	41.0	51.4
Continuous kVA (575 V) [kVA]	17.9	21.9	21.9	26.9	26.9	33.9	33.9	40.8	40.8	51.8
Max. input current										
Continuous at 550 V [A]	17.2	20.9	20.9	25.4	25.4	32.7	32.7	39	39	49
Intermittent at 550 V [A]	28	23	33	28	41	36	52	43	59	54
Continuous at 575 V [A]	16	20	20	24	24	31	31	37	37	47
Intermittent at 575 V [A]	26	22	32	27	39	34	50	41	56	52
Additional specifications										
IP20 max. cable cross-section [4] for mains, brake, motor and load sharing [mm²] ([AWG])	10, 10,- (8, 8,-)		10, 10,- (8, 8,-)		35,-,-(2,-,-)		35,-,-(2,-,-)		35,-,-(2,-,-)	
IP21, IP55, IP66 max. cable cross-section [4] for mains, brake and load sharing [mm²] ([AWG])	16, 10, 10 (6, 8, 8)		16, 10, 10 (6, 8, 8)		35,-,-(2,-,-)		35,-,-(2,-,-)		50,-,- (1,-,-)	
IP21, IP55, IP66 max. cable cross-section [4] for motor [mm²] ([AWG])	10, 10,- (8, 8,-)		10, 10,- (8, 8,-)		35, 25, 25 (2, 4, 4)		35, 25, 25 (2, 4, 4)		50,-,- (1,-,-)	
Max. cable cross-section [4] for Disconnect [mm²] ([AWG])	16, 10, 10 (6, 8, 8)								50, 35, 35 (1, 2, 2)	
Estimated power loss at rated max. load [W] [3]	220	300	300	370	370	440	440	600	600	740
Efficiency [2]	0.98		0.98		0.98		0.98		0.98	

Table 6.8 Mains Supply 525-600 V (FC 302 only), P11K-P30K

Type Designation	P37K		P45K		P55K		P75K	
High/Normal Overload[1)]	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft Output [kW]	37	45	45	55	55	75	75	90
Enclosure IP20	C3	C3	C3		C4		C4	
Enclosure IP21, IP55, IP66	C1	C1	C1		C2		C2	
Output current								
Continuous (525-550 V) [A]	54	65	65	87	87	105	105	137
Intermittent (525-550 V) [A]	81	72	98	96	131	116	158	151
Continuous (551-600 V) [A]	52	62	62	83	83	100	100	131
Intermittent (551-600 V) [A]	78	68	93	91	125	110	150	144
Continuous kVA (550 V) [kVA]	51.4	61.9	61.9	82.9	82.9	100.0	100.0	130.5
Continuous kVA (575 V) [kVA]	51.8	61.7	61.7	82.7	82.7	99.6	99.6	130.5
Max. input current								
Continuous at 550 V [A]	49	59	59	78.9	78.9	95.3	95.3	124.3
Intermittent at 550 V [A]	74	65	89	87	118	105	143	137
Continuous at 575 V [A]	47	56	56	75	75	91	91	119
Intermittent at 575 V [A]	70	62	85	83	113	100	137	131
Additional specifications								
IP20 max. cable cross-section for mains and motor [mm^2] ([AWG])	50 (1)				150 (300 MCM)			
IP20 max. cable cross-section for brake and load sharing [mm^2] ([AWG])	50 (1)				95 (4/0)			
IP21, IP55, IP66 max. cable cross-section for mains and motor [mm^2] ([AWG])	50 (1)				150 (300 MCM)			
IP21, IP55, IP66 max. cable cross-section for brake and load sharing [mm^2] ([AWG])	50 (1)				95 (4/0)			
Max cable cross-section [4)] for mains disconnect [mm^2] ([AWG])	50, 35, 35 (1, 2, 2)				95, 70, 70 (3/0, 2/0, 2/0)		185, 150, 120 (350MCM, 300MCM, 4/0)	
Estimated power loss at rated max. load [W] [3)]	740	900	900	1100	1100	1500	1500	1800
Efficiency [2)]	0.98		0.98		0.98		0.98	

Table 6.9 Mains Supply 525-600 V (FC 302 only), P37K-P75K

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6.1.4 Mains Supply 525-690 V (FC 302 only)

Type Designation	P1K1	P1K5	P2K2	P3K0	P4K0	P5K5	P7K5
High/Normal Overload1)	HO/NO	HO/NO	HO/NO	HO/NO	HO/NO	HO/NO	HO/NO
Typical Shaft output (kW)	1.1	1.5	2.2	3.0	4.0	5.5	7.5
Enclosure IP20	A3	A3	A3	A3	A3	A3	A3
Output current							
Continuous (525-550V) [A]	2.1	2.7	3.9	4.9	6.1	9.0	11.0
Intermittent (525-550V) [A]	3.4	4.3	6.2	7.8	9.8	14.4	17.6
Continuous (551-690V) [A]	1.6	2.2	3.2	4.5	5.5	7.5	10.0
Intermittent (551-690V) [A]	2.6	3.5	5.1	7.2	8.8	12.0	16.0
Continuous KVA 525 V	1.9	2.5	3.5	4.5	5.5	8.2	10.0
Continuous KVA 690 V	1.9	2.6	3.8	5.4	6.6	9.0	12.0
Max. input current							
Continuous (525-550V) [A]	1.9	2.4	3.5	4.4	5.5	8.1	9.9
Intermittent (525-550V) [A]	3.0	3.9	5.6	7.0	8.8	12.9	15.8
Continuous (551-690V) [A]	1.4	2.0	2.9	4.0	4.9	6.7	9.0
Intermittent (551-690V) [A]	2.3	3.2	4.6	6.5	7.9	10.8	14.4
Additional specifications							
Max. cable cross-section 4) for mains, motor, brake and load sharing [mm^2] ([AWG])	4, 4, 4 (12, 12, 12) (min. 0.2 (24)						
Max. Cable cross-section 4) for disconnect [mm^2] ([AWG])	6, 4, 4 (10, 12, 12)						
Estimated power loss at rated max. load (W) 3)	44	60	88	120	160	220	300
Efficiency 2)	0.96	0.96	0.96	0.96	0.96	0.96	0.96

Table 6.10 A3 Enclosure, Mains Supply 525-690 V IP20/Protected Chassis, P1K1-P7K5

Type Designation	P11K		P15K		P18K		P22K	
High/Normal Overload1)	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft output at 550 V [kW]	7.5	11	11	15	15	18.5	18.5	22
Typical Shaft output at 690 V [kW]	11	15	15	18.5	18.5	22	22	30
Enclosure IP20	B4		B4		B4		B4	
Enclosure IP21, IP55	B2		B2		B2		B2	
Output current								
Continuous (525-550V) [A]	14.0	19.0	19.0	23.0	23.0	28.0	28.0	36.0
Intermittent (60 s overload) (525-550V) [A]	22.4	20.9	30.4	25.3	36.8	30.8	44.8	39.6
Continuous (551-690V) [A]	13.0	18.0	18.0	22.0	22.0	27.0	27.0	34.0
Intermittent (60 s overload) (551-690V) [A]	20.8	19.8	28.8	24.2	35.2	29.7	43.2	37.4
continuous KVA (at 550 V) [KVA]	13.3	18.1	18.1	21.9	21.9	26.7	26.7	34.3
continuous KVA (at 690 V) [KVA]	15.5	21.5	21.5	26.3	26.3	32.3	32.3	40.6
Max. input current								
Continuous (at 550 V) (A)	15.0	19.5	19.5	24.0	24.0	29.0	29.0	36.0
Intermittent (60 s overload) (at 550 V) (A)	23.2	21.5	31.2	26.4	38.4	31.9	46.4	39.6
Continuous (at 690 V) (A)	14.5	19.5	19.5	24.0	24.0	29.0	29.0	36.0
Intermittent (60 s overload) (at 690 V) (A)	23.2	21.5	31.2	26.4	38.4	31.9	46.4	39.6
Additional specifications								
Max. cable cross-section 4) for mains/motor, load share and brake [mm^2] ([AWG])	35, 25, 25 (2, 4, 4)							
Max cable cross-section 4) for mains disconnect [mm^2] ([AWG])	16,10,10 (6, 8, 8)							
Estimated power loss at rated max. load (W) 3)	150	220	220	300	300	370	370	440
Efficiency 2)	0.98		0.98		0.98		0.98	

Table 6.11 B2/B4 Enclosure, Mains Supply 525-690 V IP20/IP21/IP55 - Chassis/NEMA 1/NEMA 12 (FC 302 only), P11K-P22K

Type Designation	P30K		P37K		P45K		P55K		P75K	
High/Normal Overload[1)]	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft output at 550 V (kW)	22	30	30	37	37	45	45	55	50	75
Typical Shaft output at 690 V [kW]	30	37	37	45	45	55	55	75	75	90
Enclosure IP20	B4		C3		C3		D3h		D3h	
Enclosure IP21, IP55	C2		C2		C2		C2		C2	
Output current										
Continuous (525-550V) [A]	36.0	43.0	43.0	54.0	54.0	65.0	65.0	87.0	87.0	105
Intermittent (60 s overload) (525-550V) [A]	54.0	47.3	64.5	59.4	81.0	71.5	97.5	95.7	130.5	115.5
Continuous (551-690V) [A]	34.0	41.0	41.0	52.0	52.0	62.0	62.0	83.0	83.0	100
Intermittent (60 s overload) (551-690V) [A]	51.0	45.1	61.5	57.2	78.0	68.2	93.0	91.3	124.5	110
continuous KVA (at 550 V) [KVA]	34.3	41.0	41.0	51.4	51.4	61.9	61.9	82.9	82.9	100
continuous KVA (at 690 V) [KVA]	40.6	49.0	49.0	62.1	62.1	74.1	74.1	99.2	99.2	119.5
Max. input current										
Continuous (at 550 V) [A]	36.0	49.0	49.0	59.0	59.0	71.0	71.0	87.0	87.0	99.0
Intermittent (60 s overload) (at 550 V) [A]	54.0	53.9	72.0	64.9	87.0	78.1	105.0	95.7	129	108.9
Continuous (at 690 V) [A]	36.0	48.0	48.0	58.0	58.0	70.0	70.0	86.0	-	-
Intermittent (60 s overload) (at 690 V) [A]	54.0	52.8	72.0	63.8	87.0	77.0	105	94.6	-	-
Additional specifications										
Max. cable-cross section for mains and motor [mm^2] ([AWG])	150 (300 MCM)									
Max. cable cross-section for load share and brake [mm^2] ([AWG])	95 (3/0)									
Max cable cross-section [4)] for mains disconnect [mm^2] ([AWG])	95, 70, 70 (3/0, 2/0, 2/0)						185, 150, 120 (350 MCM, 300 MCM, 4/0)		-	
Estimated power loss at rated max. load [W] [3)]	600	740	740	900	900	1100	1100	1500	1500	1800
Efficiency [2)]	0,98		0,98		0,98		0,98		0,98	

Table 6.12 B4, C2, C3 Enclosure, Mains Supply 525-690 V IP20/IP21/IP55 - Chassis/NEMA1/NEMA 12 (FC 302 only), P30K-P75K

For fuse ratings, see chapter 9.3.1 Fuses and Circuit Breakers.

[1)] High overload=150% or 160% torque during 60 s. Normal overload=110% torque during 60 s.

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

[3)] The typical power loss is at nominal load conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions).
Values are based on a typical motor efficiency (eff2/eff3 border line). Motors with lower efficiency 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)] The 3 values for the max. cable cross section are for single core, flexible wire and flexible wire with sleeve, respectively.

6.2 General Specifications

6.2.1 Mains Supply

Mains supply	
Supply Terminals (6-Pulse)	L1, L2, L3
Supply voltage	200-240 V ±10%
Supply voltage	FC 301: 380-480 V/FC 302: 380-500 V ±10%
Supply voltage	FC 302: 525-600 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.

6

Supply frequency	50/60 Hz ±5%
Max. imbalance temporary between mains phases	3.0 % of rated supply voltage
True Power Factor (λ)	≥ 0.9 nominal at rated load
Displacement Power Factor (cos ϕ)	near unity (> 0.98)
Switching on input supply L1, L2, L3 (power-ups) ≤ 7.5 kW	maximum 2 times/min.
Switching on input supply L1, L2, L3 (power-ups) 11-75 kW	maximum 1 time/min.
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.

6.2.2 Motor Output and Motor Data

Motor output (U, V, W)	
Output voltage	0-100% of supply voltage
Output frequency	0-590 Hz[3)]
Output frequency in Flux Mode	0-300 Hz
Switching on output	Unlimited
Ramp times	0.01-3600 s

Torque characteristics	
Starting torque (constant torque)	maximum 160% for 60 s[1)] once in 10 min.
Starting/overload torque (variable torque)	maximum 110% up to 0.5 s[1)] once in 10 min.
Torque rise time in FLUX (for 5 kHz fsw)	1 ms
Torque rise time in VVC+ (independent of fsw)	10 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.
3) Special customer versions with output frequency 0-1000 Hz are available.

6.2.3 Ambient Conditions

Environment	
Enclosure	IP20/Chassis, IP21/Type 1, IP55/ Type 12, IP66/ Type 4X
Vibration test	1.0 g
Max. THVD	10%
Max. relative humidity	5% - 93% (IEC 721-3-3; Class 3K3 (non-condensing) during operation
Aggressive environment (IEC 60068-2-43) H_2S test	class Kd
Ambient temperature	Max. 50 °C (24-hour average maximum 45 °C)
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 without derating	1000 m
EMC standards, Emission	EN 61800-3, EN 55011[1)]
EMC standards, Immunity	EN61800-3, EN 61000-6-1/2

1) See chapter 5.2.1 EMC Test Results

6

6.2.4 Cable Specifications

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 electrical tables in chapter 6.1 Electrical Data.

6.2.5 Control Input/Output and Control Data

6.2.5.1 Digital Inputs

Digital inputs	
Programmable digital inputs	FC 301: 4 (5)[1)]/FC 302: 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 VLT® Frequency Converters - Safe Torque Off Operating Instructions 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.

6

Analog inputs	
Number of analog inputs	2
Terminal number	53, 54
Modes	Voltage or current
Mode select	Switch S201 and switch S202
Voltage mode	Switch S201/switch S202 = OFF (U)
Voltage level	-10 to +10 V (scaleable)
Input resistance, R_i	approx. 10 kΩ
Max. voltage	± 20 V
Current mode	Switch S201/switch S202 = ON (I)
Current level	0/4 to 20 mA (scaleable)
Input resistance, R_i	approx. 200 Ω
Max. current	30 mA
Resolution for analog inputs	10 bit (+ sign)
Accuracy of analog inputs	Max. error 0.5% of full scale
Bandwidth	100 Hz

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

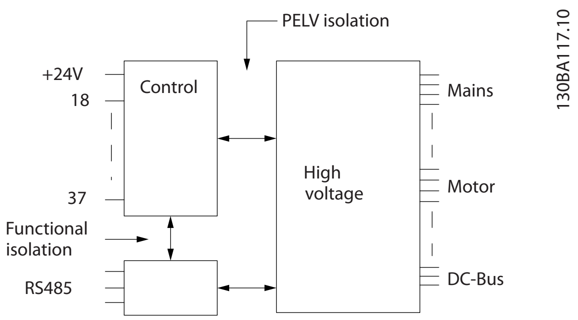

Illustration 6.1 PELV Isolation

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 section on Digital input
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

6

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.

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

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

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

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

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.

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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).

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.

Relay outputs	
Programmable relay outputs	FC 301 all kW: 1/FC 302 all kW: 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 AC 2A

Control card performance	
Scan interval	1 ms

Control characteristics	
Resolution of output frequency at 0-590 Hz	±0.003 Hz
Repeat accuracy of Precise start/stop (terminals 18, 19)	≤±0.1 ms
System response time (terminals 18, 19, 27, 29, 32, 33)	≤ 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

6.2.6 Derating for Ambient Temperature

6.2.6.1 Derating for Ambient Temperature, Enclosure Type A

60° AVM - Pulse Width Modulation

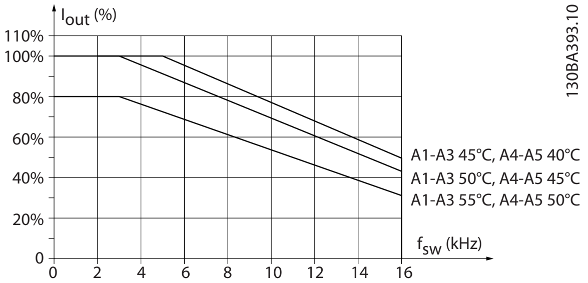

Illustration 6.2 Derating of I_{out} for Different $T_{AMB, MAX}$ for Enclosure Type A, using 60° AVM

SFAVM - Stator Frequency Asyncron Vector Modulation

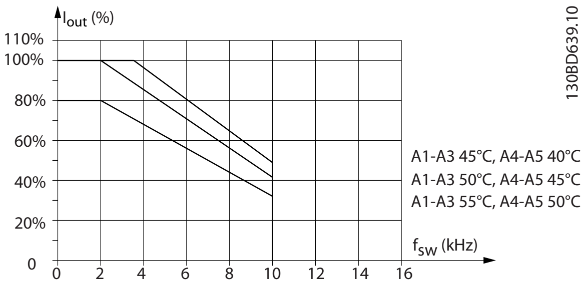

Illustration 6.3 Derating of I_{out} for Different $T_{AMB, MAX}$ for Enclosures Type A, using SFAVM

When using only 10 m motor cable or less in enclosure type A, less derating is necessary. This is due to the fact that the length of the motor cable has a relatively high impact on the recommended derating.

60° AVM

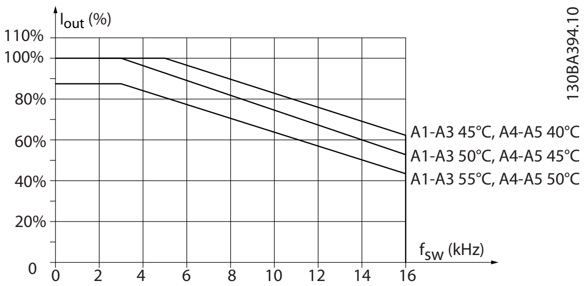

Illustration 6.4 Derating of I_{out} for Different $T_{AMB, MAX}$ for Enclosures Type A, using 60° AVM and maximum 10 m motor cable

SFAVM

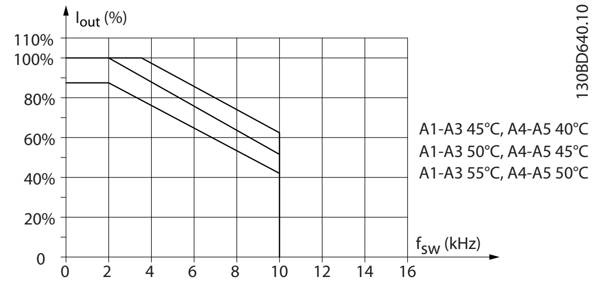

Illustration 6.5 Derating of I_{out} for Different $T_{AMB, MAX}$ for Enclosures Type A, using SFAVM and maximum 10 m motor cable

6

6.2.6.2 Derating for Ambient Temperature, Enclosure Types B

Enclosure B, T2, T4 and T5

For the enclosure types B and C the derating also depends on the overload mode selected in *1-04 Overload Mode*

60° AVM - Pulse Width Modulation

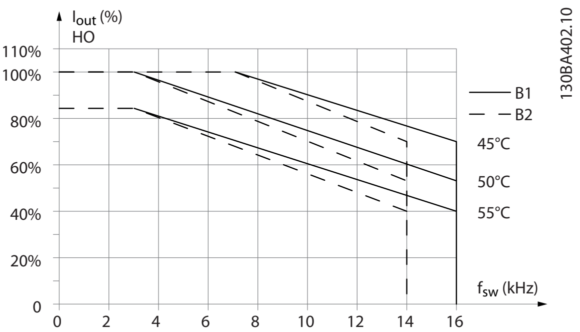

Illustration 6.6 Derating of I_{out} for different $T_{AMB, MAX}$ for Enclosure Types B1 and B2, using 60° AVM in High overload mode (160% over torque)

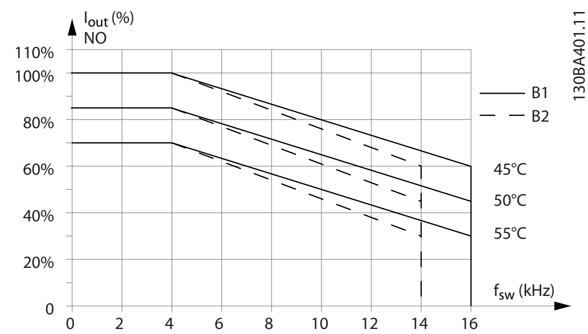

Illustration 6.7 Derating of I_{out} for different $T_{AMB, MAX}$ for Enclosure Types B1 and B2, using 60° AVM in Normal overload mode (110% over torque)

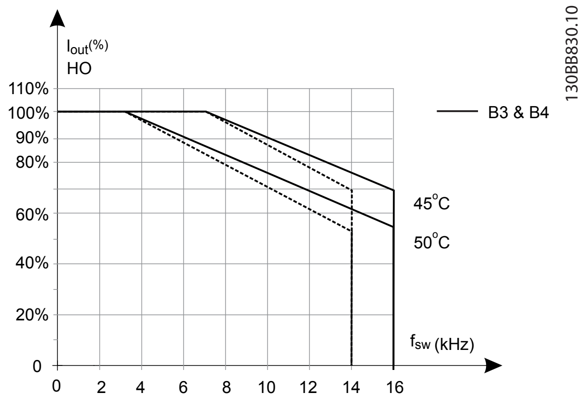

Illustration 6.8 Derating of I_{out} for different $T_{AMB, MAX}$ for Enclosure Types B3 and B4, using 60° AVM in High overload mode (160% over torque)

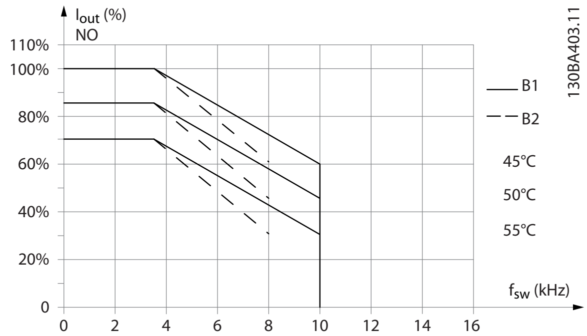

Illustration 6.11 Derating of I_{out} for different $T_{AMB, MAX}$ for Enclosure Types B1 and B2, using SFAVM in Normal overload mode (110% over torque)

6

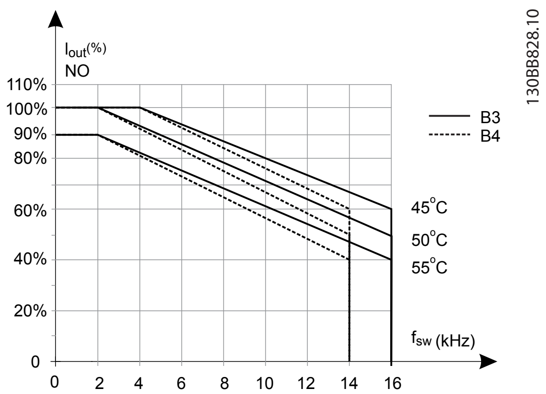

Illustration 6.9 Derating of I_{out} for different $T_{AMB, MAX}$ for Enclosure Types B3 and B4, using 60° AVM in Normal overload mode (110% over torque)

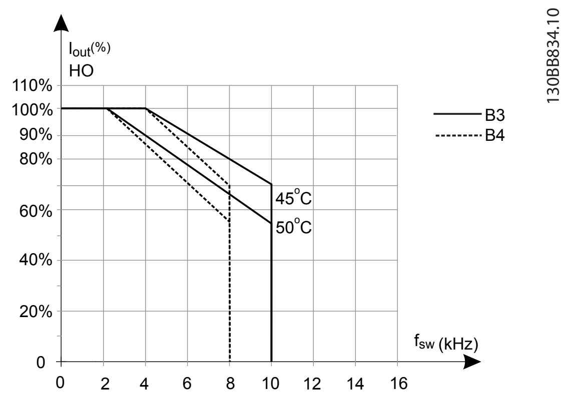

Illustration 6.12 Derating of I_{out} for different $T_{AMB, MAX}$ for Enclosure Types B3 and B4, using SFAVM in High overload mode (160% over torque)

SFAVM - Stator Frequency Asyncron Vector Modulation

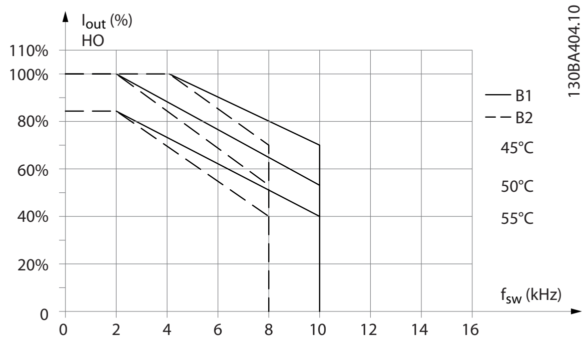

Illustration 6.10 Derating of I_{out} for different $T_{AMB, MAX}$ for Enclosure Types B1 and B2, using SFAVM in High overload mode (160% over torque)

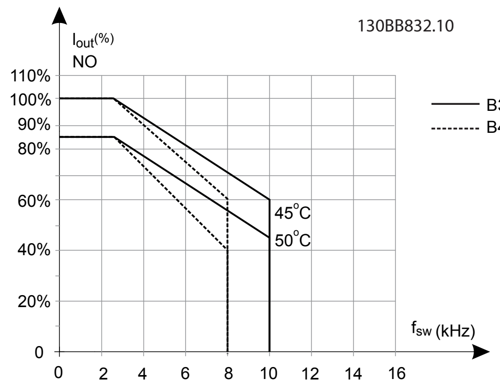

Illustration 6.13 Derating of I_{out} for different $T_{AMB, MAX}$ for Enclosure Types B3 and B4, using SFAVM in Normal overload mode (110% over torque)

Enclosures B, T6
60° AVM - Pulse Width Modulation

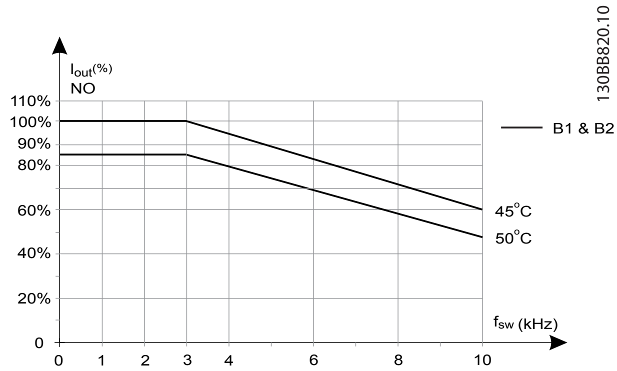

Illustration 6.14 Output current derating with switching frequency and ambient temperature for 600 V frequency converters, enclosure types B, 60 AVM, NO

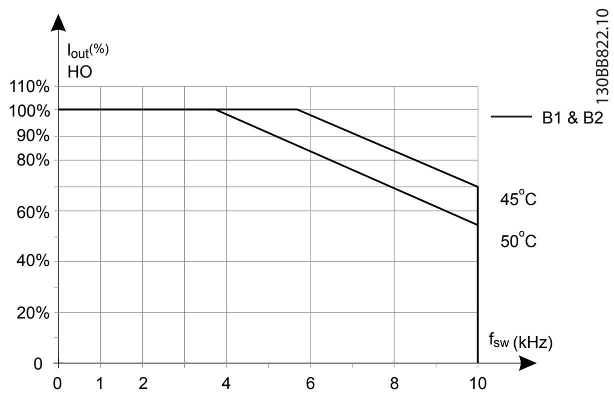

Illustration 6.15 Output current derating with switching frequency and ambient temperature for 600 V frequency fonverters, enclosure type B, 60 AVM, HO

SFAVM - Stator Frequency Asyncron Vector Modulation

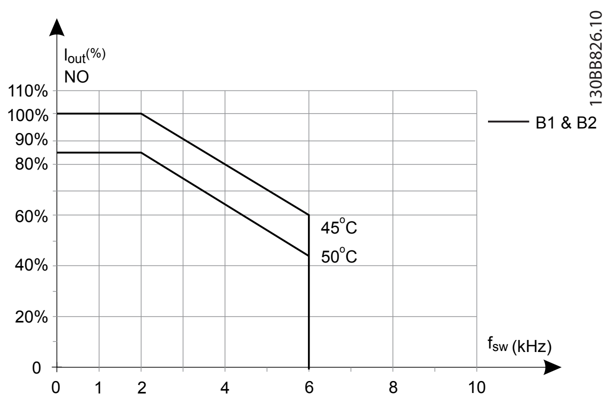

Illustration 6.16 Output current derating with switching frequency and ambient temperature for 600 V frequency converters, enclosure type B; SFAVM, NO

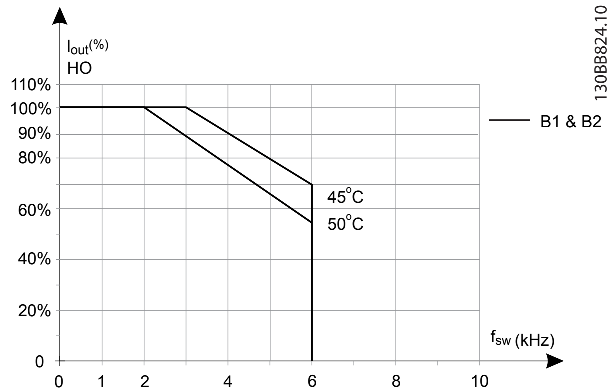

Illustration 6.17 Output current derating with switching frequency and ambient temperature for 600 V frequency converters, enclosure type B; SFAVM, HO

Enclosures B, T7
Enclosures B2 and B4, 525-690 V
60° AVM - Pulse Width Modulation

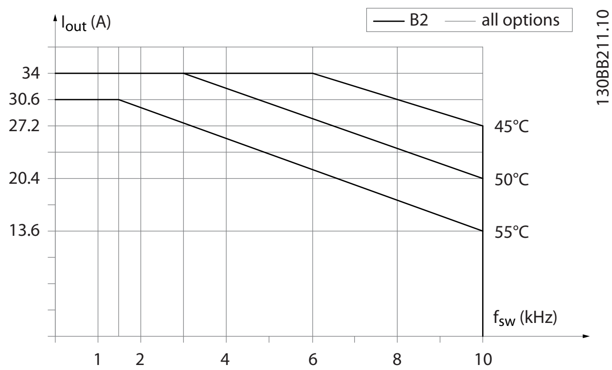

Illustration 6.18 Output current derating with switching frequency and ambient temperature for enclosure types B2 and B4, 60° AVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.

SFAVM - Stator Frequency Asyncron Vector Modulation

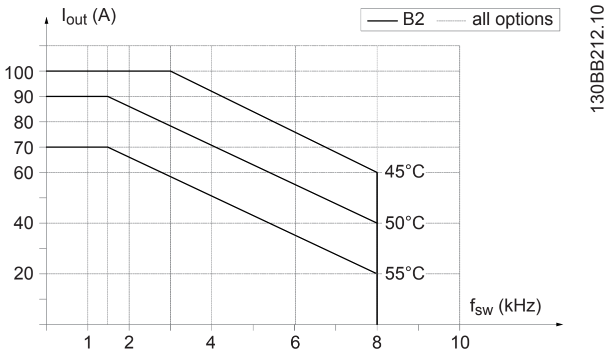

Illustration 6.19 Output current derating with switching frequency and ambient temperature for enclosure types B2 and B4, SFAVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.

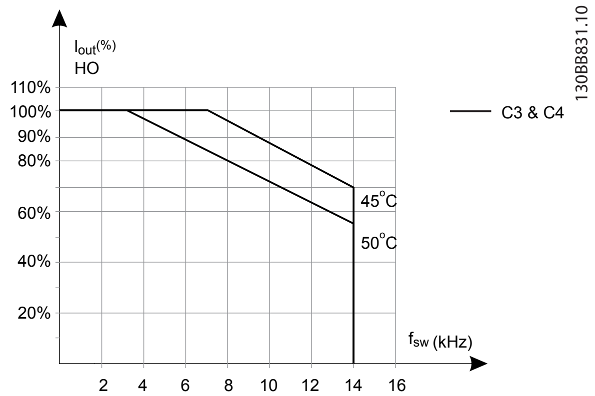

Illustration 6.22 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types C3 and C4, using 60° AVM in High overload mode (160% over torque)

6.2.6.3 Derating for Ambient Temperature, Enclosure Types C

Enclosures C, T2, T4 and T5
60° AVM - Pulse Width Modulation

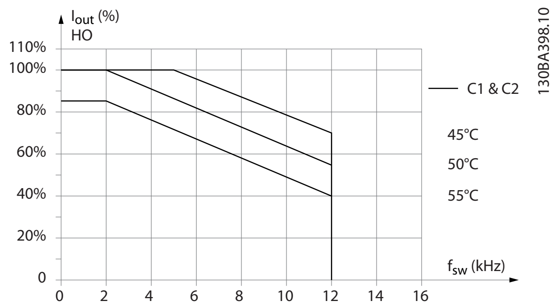

Illustration 6.20 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types C1 and C2, using 60° AVM in High overload mode (160% over torque)

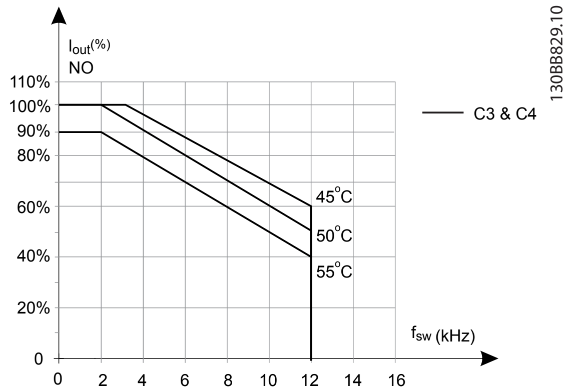

Illustration 6.23 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types C3 and C4, using 60° AVM in Normal overload mode (110% over torque)

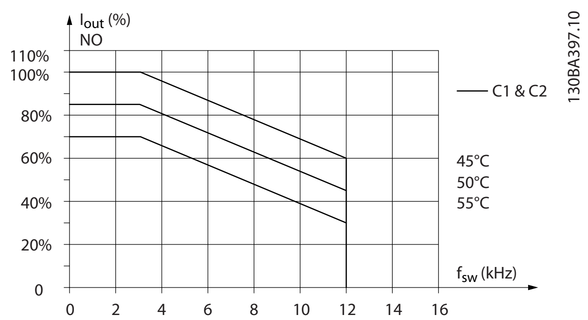

Illustration 6.21 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types C1 and C2, using 60° AVM in Normal overload mode (110% over torque)

SFAVM - Stator Frequency Asyncron Vector Modulation

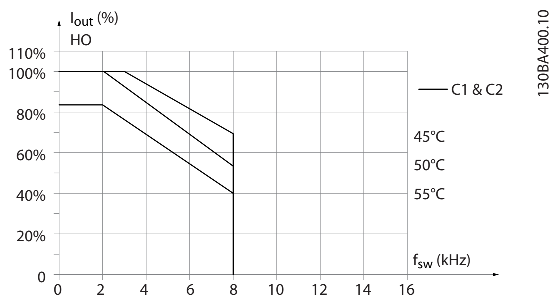

Illustration 6.24 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types C1 and C2, using SFAVM in High overload mode (160% over torque)

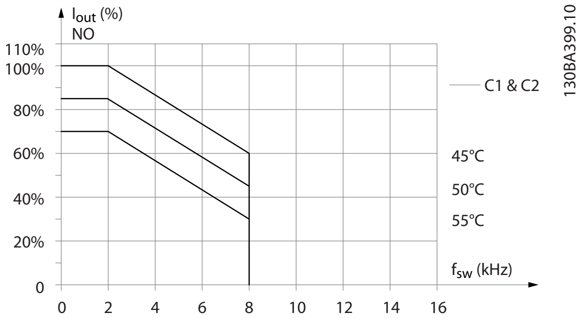

Illustration 6.25 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types C1 and C2, using SFAVM in Normal overload mode (110% over torque)

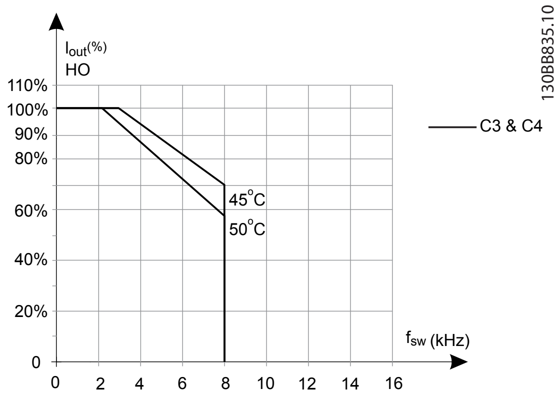

Illustration 6.26 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types C3 and C4, using SFAVM in High overload mode (160% over torque)

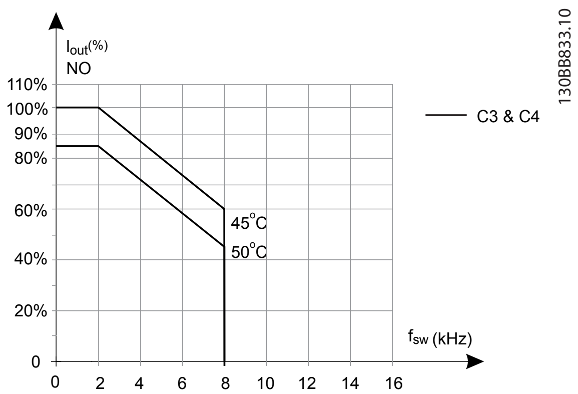

Illustration 6.27 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types C3 and C4, using SFAVM in Normal overload mode (110% over torque)

Enclosure Types C, T6

60° AVM - Pulse Width Modulation

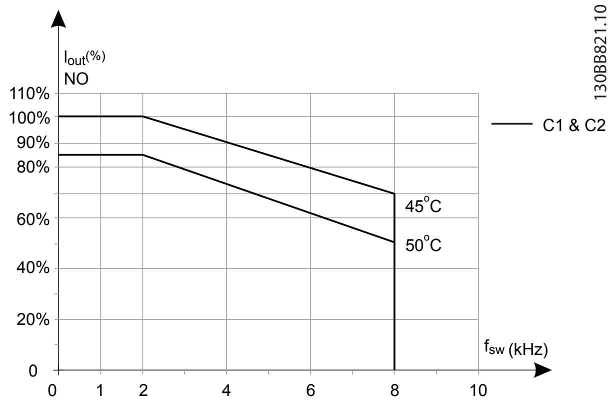

Illustration 6.28 Output current derating with switching frequency and ambient temperature for 600 V frequency converters, enclosure types C, 60 AVM, NO

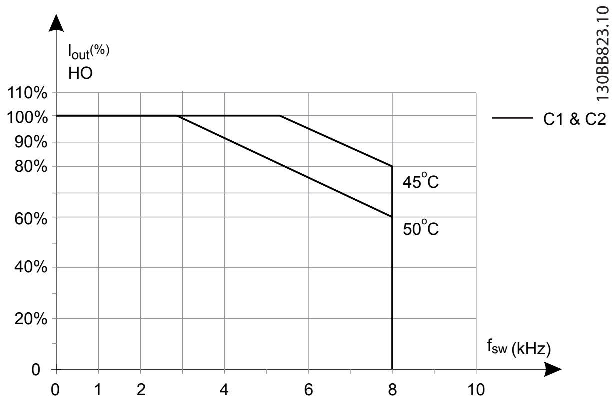

Illustration 6.29 Output current derating with switching frequency and ambient temperature for 600 V frequency converters, enclosure types C, 60 AVM, HO

SFAVM - Stator Frequency Asyncron Vector Modulation

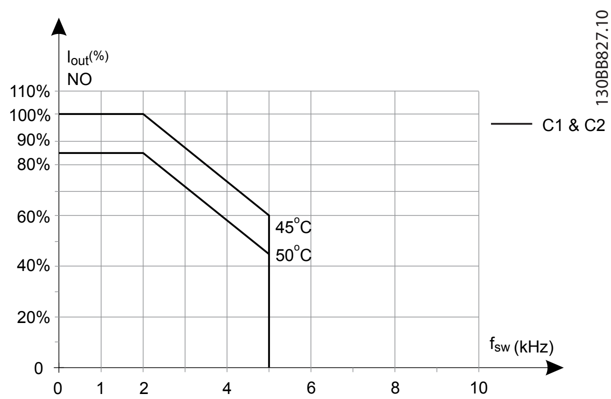

Illustration 6.30 Output current derating with switching frequency and ambient temperature for 600 V frequency converters, enclosure types C; SFAVM, NO

6

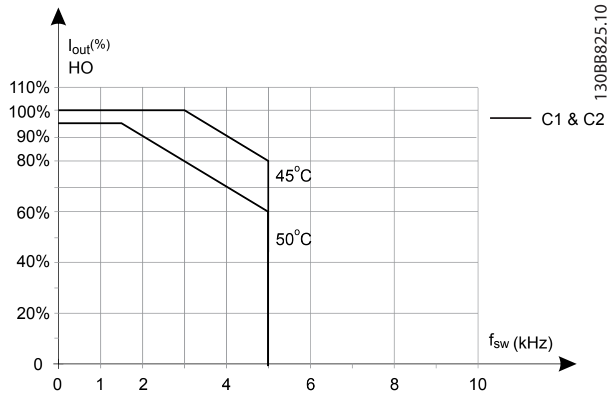

Illustration 6.31 Output current derating with switching frequency and ambient temperature for 600 V frequency converters, enclosure types C; SFAVM, HO

Enclosure Type C, T7

60° AVM - Pulse Width Modulation

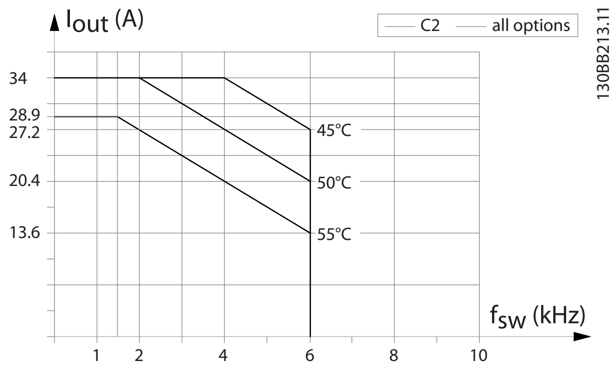

Illustration 6.32 Output current derating with switching frequency and ambient temperature for enclosure type C2, 60° AVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.

SFAVM - Stator Frequency Asyncron Vector Modulation

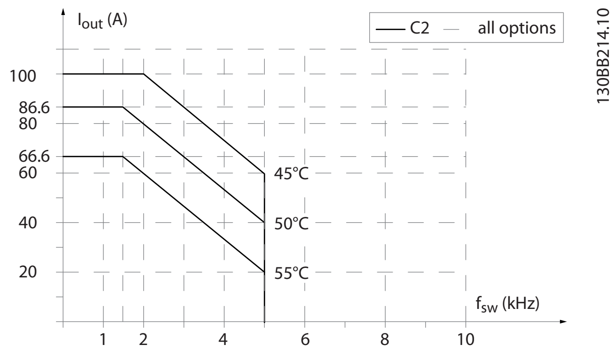

Illustration 6.33 Output current derating with switching frequency and ambient temperature for enclosure type C2, SFAVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.

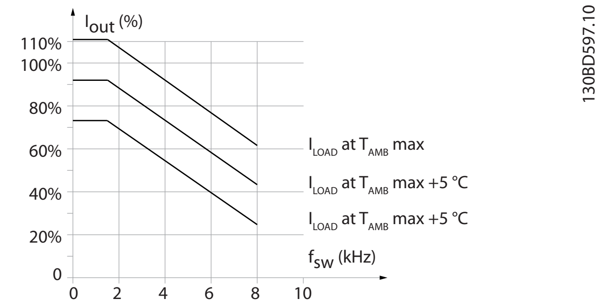

Illustration 6.34 Output current derating with switching frequency and ambient temperature for enclosure type C3

6.2.7 Measured Values for dU/dt Testing

To avoid damage to motors without phase insulation paper or other insulation reinforcement designed for operation of the frequency converter, it is strongly recommend to install a dU/dt filter or LC filter on the output of the frequency converter.

When a transistor in the inverter bridge switches, the voltage across the motor increases by a dU/dt ratio depending on:

- Motor inductance
- Motor cable (type, cross section, length, screened, or unscreened)

The natural induction causes an overshoot voltage peak in the motor voltage before it stabilises. The level depends on the voltage in the DC-link.

Peak voltage on the motor terminals is caused by the switching of the IGBTs. The rise time and the peak voltage affect the service life of the motor. If the peak voltage is too high, motors without phase coil insulation can be adversely affected over time.

With short motor cables (a few metres), the rise time and peak voltage are lower. The rise time and peak voltage increase with cable length (100 m).

The frequency converter complies with IEC 60034-25 and IEC 60034-17 for motor design.

200-240 V (T2)

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
5	240	0.13	0.510	3.090
50	240	0.23		2.034
100	240	0.54	0.580	0.865
150	240	0.66	0.560	0.674

Table 6.13 P5K5T2

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
36	240	0.264	0.624	1.890
136	240	0.536	0.596	0.889
150	240	0.568	0.568	0.800

Table 6.14 P7K5T2

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
30	240	0.556	0.650	0.935
100	240	0.592	0.594	0.802
150	240	0.708	0.587	0.663

Table 6.15 P11KT2

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
36	240	0.244	0.608	1.993
136	240	0.568	0.580	0.816
150	240	0.720	0.574	0.637

Table 6.16 P15KT2

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
36	240	0.244	0.608	1.993
136	240	0.568	0.580	0.816
150	240	0.720	0.574	0.637

Table 6.17 P18KT2

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
15	240	0.194	0.626	2.581
50	240	0.252	0.574	1.822
150	240	0.488	0.538	0.882

Table 6.18 P22KT2

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
30	240	0.300	0.598	1.594
100	240	0.536	0.566	0.844
150	240	0.776	0.546	0.562

Table 6.19 P30KT2

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
30	240	0.300	0.598	1.594
100	240	0.536	0.566	0.844
150	240	0.776	0.546	0.562

Table 6.20 P37KT2

380-500 V (T4)

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
5	480	0.640	0.690	0.862
50	480	0.470	0.985	0.985
150	480	0.760	1.045	0.947

Table 6.21 P1K5T4

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
5	480	0.172	0.890	4.156
50	480	0.310		2.564
150	480	0.370	1.190	1.770

Table 6.22 P4K0T4

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
5	480	0.04755	0.739	8.035
50	480	0.207		4.548
150	480	0.6742	1.030	2.828

Table 6.23 P7K5T4

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
36	480	0.396	1.210	2.444
100	480	0.844	1.230	1.165
150	480	0.696	1.160	1.333

Table 6.24 P11KT4

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
36	480	0.396	1.210	2.444
100	480	0.844	1.230	1.165
150	480	0.696	1.160	1.333

Table 6.25 P15KT4

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
36	480	0.312		2.846
100	480	0.556	1.250	1.798
150	480	0.608	1.230	1.618

Table 6.26 P18KT4

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
15	480	0.288		3.083
100	480	0.492	1.230	2.000
150	480	0.468	1.190	2.034

Table 6.27 P22KT4

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
5	480	0.368	1.270	2.853
50	480	0.536	1.260	1.978
100	480	0.680	1.240	1.426
150	480	0.712	1.200	1.334

Table 6.28 P30KT4

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
5	480	0.368	1.270	2.853
50	480	0.536	1.260	1.978
100	480	0.680	1.240	1.426
150	480	0.712	1.200	1.334

Table 6.29 P37KT4

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
15	480	0.256	1.230	3.847
50	480	0.328	1.200	2.957
100	480	0.456	1.200	2.127
150	480	0.960	1.150	1.052

Table 6.30 P45KT4

380-500 V (T5)

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
5	480	0.371	1.170	2.523

Table 6.31 P55KT5

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
5	480	0.371	1.170	2.523

Table 6.32 P75KT5

600 V (T6)

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
36	600	0.304	1.560	4.105
50	600	0.300	1.550	4.133
100	600	0.536	1.640	2.448
150	600	0.576	1.640	2.278

Table 6.33 P15KT6

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
36	600	0.084	1.560	7.962
50	600	0.120	1.540	5.467
100	600	0.165	1.472	3.976
150	600	0.190	1.530	3.432

Table 6.34 P30KT6

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
15	600	0.276	1.184	4.290

Table 6.35 P75KT6

525-690 V (T7)

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
80	690	0.58	1.728	2369
130	690	0.93	1.824	1569
180	690	0.925	1.818	1570

Table 6.36 P7K5T7

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
6	690	0.238	1416	4739
50	690	0.358	1764	3922
150	690	0.465	1872	3252

Table 6.37 P45KT7

6.2.8 Efficiency

Efficiency of the frequency converter
The load on the frequency converter has little effect on its efficiency.

This also means that the frequency converter efficiency does not change when other U/f characteristics are chosen. However, the U/f characteristics do influence the efficiency of the motor.

The efficiency declines a little when the switching frequency is set to a value above 5 kHz. The efficiency is also slightly reduced when the motor cable is longer than 30 m.

Efficiency calculation
Calculate the efficiency of the frequency converter at different loads based on *Illustration 6.35*. Multiply the factor in this graph with the specific efficiency factor listed in *chapter 6.2 General Specifications*.

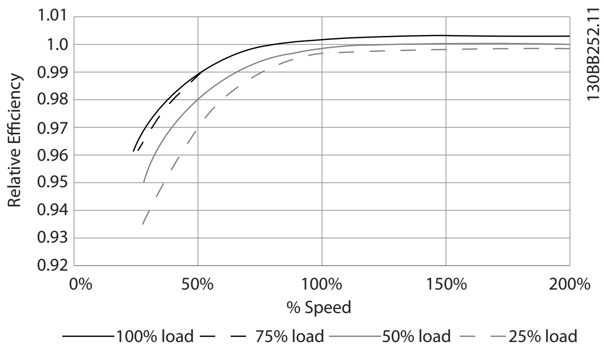

Illustration 6.35 Typical Efficiency Curves

Example: Assume a 55 kW, 380-480 V AC frequency converter with 25% load at 50% speed. The graph is showing 0.97 rated efficiency for a 55 kW frequency converter is 0.98. The actual efficiency is then: 0.97 x 0.98=0.95.

Motor efficiency
The efficiency of a motor connected to the frequency converter depends on magnetising level. 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 it is controlled by the frequency converter and when it runs directly on mains.
- The influence from the U/f characteristic on small motors is marginal. However, in motors from 11 kW and up, the efficiency advantage is significant.
- The switching frequency does not affect the efficiency of small motors. Motors from 11 kW and up have their efficiency improved 1-2%. This is because the sine shape of the motor current is almost perfect at high switching frequency.

System efficiency
To calculate the system efficiency, the efficiency of the frequency converter is multiplied by the efficiency of the motor.

6.2.9 Acoustic Noise

Acoustic noise from the frequency converter comes from 3 sources

- DC-link (intermediate circuit) coils
- RFI filter choke
- Internal fans

See *Table 6.38* for acoustic noise ratings.

Enclosure type	50% fan speed [dBA]	Full fan speed [dBA]
A1	51	60
A2	51	60
A3	51	60
A4	51	60
A5	54	63
B1	61	67
B2	58	70
B4	52	62
C1	52	62
C2	55	65
C4	56	71
D3h	58	71

Table 6.38 Acoustic Noise Ratings

Values are measured 1 m from the unit.

6

7 How to Order

7.1 Drive Configurator

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

130BB836.10

Illustration 7.1 Type Code Example

Configure the right frequency converter for the right application from the Internet based Drive Configurator and generate the type code string. The Drive Configurator automatically generates an 8-digit sales number to be delivered to the local sales office.
Furthermore, it is possible to establish a project list with several products and send it to a Danfoss sales representative.

7.1.1 Type Code

An example of the type code is:

FC-302PK75T5E20H1BGCXXXSXXXXA0BXCXXXXD0

The meaning of the characters in the string can be found in *Table 7.1* and *Table 7.2*. In the example above, a Profibus DP V1 and a 24 V back-up option is built-in.

Description	Pos	Possible choices
Product group	1-3	FC 30x
Drive series	4-6	301: FC 301 302: FC 302
Power rating	8-10	0.25-75 kW
Phases	11	Three phases (T)
Mains voltage	11-12	T2: 200-240 V T4: 380-480 V T5: 380-500 V T6: 525-600 V T7: 525-690 V
Enclosure	13-15	E20: IP20 E55: IP 55/NEMA Type 12 P20: IP20 (with back plate) P21: IP21/ NEMA Type 1 (with back plate) P55: IP55/ NEMA Type 12 (with back plate) Z20: IP 20[1] E66: IP 66

Description	Pos	Possible choices
RFI filter	16-17	Hx: No EMC filters built in the frequency converter (600 V units only) H1: Integrated EMC filter. Fulfil EN 55011 Class A1/B and EN/IEC 61800-3 Category 1/2 H2: No additional EMC filter. Fulfil EN 55011 Class A2 and EN/IEC 61800-3 Category 3 H3: H3 - Integrated EMC filter. Fulfil EN 55011 class A1/B and EN/IEC 61800-3 Category 1/2 (Enclosure type A1 only)[1] H4: Integrated EMC filter. Fulfil EN 55011 class A1 and EN/IEC 61800-3 Category 2 H5: Marine versions. Fulfill same emissions levels as H2 versions
Brake	18	B: Brake chopper included X: No brake chopper included T: Safe Stop No brake[1] U: Safe stop brake chopper[1]
Display	19	G: Graphical Local Control Panel (LCP) N: Numerical Local Control Panel (LCP) X: No Local Control Panel
Coating PCB	20	C: Coated PCB R: Ruggedised X: No coated PCB
Mains option	21	X: No mains option 1: Mains disconnect 3: Mains disconnect and Fuse[2] 5: Mains disconnect, Fuse and Load sharing[2, 3] 7: Fuse[2] 8: Mains disconnect and Load sharing[3] A: Fuse and Load sharing [2, 3] D: Load sharing [3]
Adaptation	22	X: Standard cable entries O: European metric thread in cable entries (A4, A5, B1, B2, C1, C2 only) S: Imperial cable entries (A5, B1, B2, C1 and C2 only)
Adaptation	23	X: No adaptation

Description	Pos	Possible choices
Software release	24-27	SXXX: Latest release - standard software
Software language	28	X: Not used
1): FC 301/enclosure type A1 only 2) US Market only 3): A and B3 frames have load-sharing built-in by default		

Table 7.1 Ordering Type Code Enclosure types A, B and C

Description	Pos	Possible choices
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 VLT 3000 AU: MCA 114 Profibus Converter VLT 5000 AY: MCA 123 Powerlink A8: MCA 124 EtherCAT
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 B6: MCB 150 Safe Option TTL B7: MCB 151 Safe Option HTL
C0 options	33-34	CX: No option C4: MCO 305, Programmable Motion Controller
C1 options	35	X: No option R: MCB 113 Ext. Relay Card Z: MCA 140 Modbus RTU OEM option
C option software/E1 options	36-37	XX: Standard controller 10: MCO 350 Synchronizing control 11: MCO 351 Positioning control
D options	38-39	DX: No option D0: MCB 107 Ext. 24 V DC back-up

Table 7.2 Ordering Type Code, Options

NOTICE

For power sizes over 75 kW, see the *VLT® AutomationDrive FC 300 90-1400 kW Design Guide*.

7

7.1.2 Language

Frequency converters are automatically delivered with a language package relevant to the region from which it is ordered. 4 regional language packages cover the following languages:

Language package 1	Language package 2	Language package 3	Language package 4
English	English	English	English
German	German	German	German
French	Chinese	Slovenian	Spanish
Danish	Korean	Bulgarian	English US
Dutch	Japanese	Serbian	Greek
Spanish	Thai	Romanian	Brazilian Portuguese
Swedish	Traditional Chinese	Hungarian	Turkish
Italian	Bahasa Indonesian	Czech	Polish
Finnish		Russian	

Table 7.3 Language Packages

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

7.2 Ordering Numbers

7.2.1 Options and Accessories

Description	Ordering no.	
	Uncoated	Coated
Miscellaneous hardware		
VLT® Panel through kit enclosure type A5	130B1028	
VLT® Panel through kit enclosure type B1	130B1046	
VLT® Panel through kit enclosure type B2	130B1047	
VLT® Panel through kit enclosure type C1	130B1048	
VLT® Panel through kit enclosure type C2	130B1049	
VLT® Mounting brackets for enclosure type A5	130B1080	
VLT® Mounting brackets for enclosure type B1	130B1081	
VLT® Mounting brackets for enclosure type B2	130B1082	
VLT® Mounting brackets for enclosure type C1	130B1083	
VLT® Mounting brackets for enclosure type C2	130B1084	
VLT® IP 21/Type 1 Kit, enclosure type A1	130B1121	
VLT® IP 21/Type 1 Kit, enclosure type A2	130B1122	
VLT® IP 21/Type 1 Kit, enclosure type A3	130B1123	
VLT® IP 21/Type 1 Top Kit, enclosure type A2	130B1132	
VLT® IP 21/Type 1 Top Kit, enclosure type A3	130B1133	
VLT® Back plate IP55/Type12, enclosure type A5	130B1098	
VLT® Back plate IP21/Type 1, IP55/Type 12, enclosure type B1	130B3383	
VLT® Back plate IP21/Type 1, IP55/Type 12, enclosure type B2	130B3397	
VLT® Back plate IP20/Type 1, enclosure type B4	130B4172	
VLT® Back plate IP21/Type 1, IP55/Type 12, enclosure type C1	130B3910	
VLT® Back plate IP21/Type 1, IP55/Type 12, enclosure type C2	130B3911	
VLT® Back plate IP20/Type 1, enclosure type C3	130B4170	
VLT® Back plate IP20/Type 1, enclosure type C4	130B4171	
VLT® Back plate IP66/Type 4X, enclosure type A5	130B3242	
VLT® Back plate in stainless steel IP66/Type 4X, enclosure type B1	130B3434	
VLT® Back plate in stainless steel IP66/Type 4X, enclosure type B2	130B3465	
VLT® Back plate in stainless steel IP66/Type 4X, enclosure type C1	130B3468	
VLT® Back plate in stainless steel IP66/Type 4X, enclosure type C2	130B3491	
VLT® Profibus Adapter Sub-D9 Connector	130B1112	
Profibus screen plate kit for IP20, enclosure types A1, A2 and A3	130B0524	
Terminal block for DC link connection on enclosure types A2/A3	130B1064	
VLT® Screw terminals	130B1116	
VLT® USB extension, 350 mm cable	130B1155	
VLT® USB extension, 650 mm cable	130B1156	
VLT® Back frame A2 for 1 brakeresistor	175U0085	
VLT® Back frame A3 for 1 brakeresistor	175U0088	
VLT® Back frame A2 for 2 brake resistors	175U0087	
VLT® Back A3 for 2 brake resistors	175U0086	
Local Control Panel		
VLT® LCP 101 Numeric Local Contral Pad	130B1124	
VLT® LCP 102 Graphical Local Control Pad	130B1107	
VLT® Cable for LCP 2, 3 m	175Z0929	
VLT® Panel Mounting Kit for all LCP types	130B1170	
VLT® Panel Mounting Kit, graphical LCP	130B1113	

Description	Ordering no.	
	Uncoated	Coated
VLT® Panel Mounting Kit, numerical LCP	130B1114	
VLT® LCP Mounting Kit, w/ no LCP	130B1117	
VLT® LCP Mounting Kit Blind Cover IP55/66, 8 m	130B1129	
VLT® Control Panel LCP 102, graphical	130B1078	
VLT® Blindcover, w/ Danfoss logo, IP55/66	130B1077	
Options for slot A		
VLT® Profibus DP V1 MCA 101	130B1100	130B1200
VLT® DeviceNet MCA 104	130B1102	130B1202
VLT® CAN Open MCA 105	130B1103	130B1205
VLT® PROFIBUS Converter MCA 113	130B1245	
VLT® PROFIBUS Converter MCA 114		130B1246
VLT® PROFINET MCA 120	130B1135	130B1235
VLT® EtherNet/IP MCA 121	130B1119	130B1219
VLT® Modbus TCP MCA 122	130B1196	130B1296
POWERLINK	130B1489	130B1490
EtherCAT	130B5546	130B5646
VLT® DeviceNet MCA 104	130B1102	130B1202
Options for slot B		
VLT® General Purpose I/O MCB 101	130B1125	130B1212
VLT® Encoder Input MCB 102	130B1115	130B1203
VLT® Resolver Input MCB 103	130B1127	130B1227
VLT® Relay Option MCB 105	130B1110	130B1210
VLT® Safe PLC I/O MCB 108	130B1120	130B1220
VLT® PTC Thermistor Card MCB 112		130B1137
VLT® Safe Option MCB 140	130B6443	
VLT® Safe Option MCB 141	130B6447	
VLT® Safe option MCB 150		130B3280
VLT® Safe option MCB 151		130B3290
Mounting Kits for C options		
VLT® Mounting Kit for C Option, 40 mm, enclosure types A2/A3	130B7530	
VLT® Mounting Kit for C Option, 60 mm, enclosure types A2/A3	130B7531	
VLT® Mounting Kit for C Option, enclosure type A5	130B7532	
VLT® Mounting Kit for C Option, enclosure types B/C/D/E/F (except B3)	130B7533	
VLT® Mounting Kit for C Option, 40 mm, enclosure type B3	130B1413	
VLT® Mounting Kit for C Option, 60 mm, enclosure type B3	130B1414	
Options for Slot C		
VLT® Motion Control MCO 305	130B1134	130B1234
VLT® Synchronizing Contr. MCO 350	130B1152	130B1252
VLT® Position. Controller MCO 351	130B1153	120B1253
Center Winder Controller	130B1165	130B1166
VLT® Extended Relay Card MCB 113	130B1164	130B1264
VLT® C Option Adapter MCF 106		130B1230
Option for Slot D		
VLT® 24 V DC Supply MCB 107	130B1108	130B1208
VLT® EtherNet/IP MCA 121	175N2584	
VLT® Leakage Current Monitor Kit, enclosure types A2/A3	130B5645	
VLT® Leakage Current Monitor Kit, enclosure type B3	130B5764	
VLT® Leakage Current Monitor Kit, enclosure type B4	130B5765	
VLT® Leakage Current Monitor Kit, enclosure type C3	130B6226	

Description	Ordering no.	
	Uncoated	Coated
VLT® Leakage Current Monitor Kit, enclosure type C4	130B5647	
PC Software		
VLT® Motion Ctrl Tool MCT 10, 1 license	130B1000	
VLT® Motion Ctrl Tool MCT 10, 5 licenses	130B1001	
VLT® Motion Ctrl Tool MCT 10, 10 licenses	130B1002	
VLT® Motion Ctrl Tool MCT 10, 25 licenses	130B1003	
VLT® Motion Ctrl Tool MCT 10, 50 licenses	130B1004	
VLT® Motion Ctrl Tool MCT 10, 100 licenses	130B1005	
VLT® Motion Ctrl Tool MCT 10, >100 licenses	130B1006	
Options can be ordered as factory built-in options, see ordering information, *chapter 7.1 Drive Configurator*.		

Table 7.4 Ordering Numbers for Options and Accessories

7.2.2 Spare Parts

7

7.2.3 Accessory Bags

Type	Description	Ordering no.
Accessory Bags		
Accessory bag A1	Accessory bag, enclosure type A1	130B1021
Accessory bag A2/A3	Accessory bag, enclosure type A2/A3	130B1022
Accessory bag A5	Accessory bag, enclosure type A5	130B1023
Accessory bag A1–A5	Accessory bag, enclosure type A1-A5 Brake and load sharing connector	130B0633
Accessory bag B1	Accessory bag, enclosure type B1	130B2060
Accessory bag B2	Accessory bag, enclosure type B2	130B2061
Accessory bag B3	Accessory bag, enclosure type B3	130B0980
Accessory bag B4	Accessory bag, enclosure type B4, 18.5-22 kW	130B1300
Accessory bag B4	Accessory bag, enclosure type B4, 30 kW	130B1301
Accessory bag C1	Accessory bag, enclosure type C1	130B0046
Accessory bag C2	Accessory bag, enclosure type C2	130B0047
Accessory bag C3	Accessory bag, enclosure type C3	130B0981
Accessory bag C4	Accessory bag, enclosure type C4, 55 kW	130B0982
Accessory bag C4	Accessory bag, enclosure type C4, 75 kW	130B0983

Table 7.5 Ordering Numbers for Accessory Bags

7.2.4 VLT AutomationDrive FC 301

T2, Horizontal Braking 10% Duty Cycle

FC 301				Horizontal braking 10% duty cycle							
Frequency converter data				Brake resistor data						Installation	
						Danfoss part number					
Mains type	P_m [kW]	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20	Cable cross section [mm²]	Thermo relay [A]
T2	0.25	368	415.9	410	0.100	175u3004	-	-	-	1.5	0.5
T2	0.37	248	280.7	300	0.100	175u3006	-	-	-	1.5	0.6
T2	0.55	166	188.7	200	0.100	175u3011	-	-	-	1.5	0.7
T2	0.75	121	138.4	145	0.100	175u3016	-	-	-	1.5	0.8
T2	1.1	81.0	92.0	100	0.100	175u3021	-	-	-	1.5	0.9
T2	1.5	58.5	66.5	70	0.200	175u3026	-	-	-	1.5	1.6
T2	2.2	40.2	44.6	48	0.200	175u3031	-	-	-	1.5	1.9
T2	3	29.1	32.3	35	0.300	175u3325	-	-	-	1.5	2.7
T2	3.7	22.5	25.9	27	0.360	175u3326	175u3477	175u3478	-	1.5	3.5
T2	5.5	17.7	19.7	18	0.570	175u3327	175u3442	175u3441	-	1.5	5.3
T2	7.5	12.6	14.3	13	0.680	175u3328	175u3059	175u3060	-	1.5	6.8
T2	11	8.7	9.7	9	1.130	175u3329	175u3068	175u3069	-	2.5	10.5
T2	15	5.3	7.5	5.7	1.400	175u3330	175u3073	175u3074	-	4	15
T2	18.5	5.1	6.0	5.7	1.700	175u3331	175u3483	175u3484	-	4	16
T2	22	3.2	5.0	3.5	2.200	175u3332	175u3080	175u3081	-	6	24
T2	30	3.0	3.7	3.5	2.800	175u3333	175u3448	175u3447	-	10	27
T2	37	2.4	3.0	2.8	3.200	175u3334	175u3086	175u3087	-	16	32

Table 7.6 T2, Horizontal Braking 10% Duty Cycle

FC 301				Vertical braking 40% duty cycle							
Frequency converter data				Brake resistor data						Installation	
						Danfoss part number					
Mains type	P_m [kW]	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20	Cable cross section [mm^2]	Thermo relay [A]
T2	0.25	368	415.9	410	0.100	175u3004	-	-	-	1.5	0.5
T2	0.37	248	280.7	300	0.200	175u3096	-	-	-	1.5	0.8
T2	0.55	166	188.7	200	0.200	175u3008	-	-	-	1.5	0.9
T2	0.75	121	138.4	145	0.300	175u3300	-	-	-	1.5	1.3
T2	1.1	81.0	92.0	100	0.450	175u3301	175u3402	175u3401	-	1.5	2
T2	1.5	58.5	66.5	70	0.570	175u3302	175u3404	175u3403	-	1.5	2.7
T2	2.2	40.2	44.6	48	0.960	175u3303	175u3406	175u3405	-	1.5	4.2
T2	3	29.1	32.3	35	1.130	175u3304	175u3408	175u3407	-	1.5	5.4
T2	3.7	22.5	25.9	27	1.400	175u3305	175u3410	175u3409	-	1.5	6.8
T2	5.5	17.7	19.7	18	2.200	175u3306	175u3412	175u3411	-	1.5	10.4
T2	7.5	12.6	14.3	13	3.200	175u3307	175u3414	175u3413	-	2.5	14.7
T2	11	8.7	9.7	9	5.500	-	175u3176	175u3177	-	4	23
T2	15	5.3	7.5	5.7	6.000	-	-	-	175u3233	10	33
T2	18.5	5.1	6.0	5.7	8.000	-	-	-	175u3234	10	38
T2	22	3.2	5.0	3.5	9.000	-	-	-	175u3235	16	51
T2	30	3.0	3.7	3.5	14.000	-	-	-	175u3224	25	63
T2	37	2.4	3.0	2.8	17.000	-	-	-	175u3227	35	78

Table 7.7 T2, Vertical Braking 40% Duty Cycle

FC 301				Horizontal braking 10% duty cycle							
Frequency converter data				Brake resistor data						Installation	
						Danfoss part number				Cable cross section [mm²]	Thermo relay [A]
Mains type	P_m [kW]	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20		
T4	0.37	1000	1121.4	1200	0.100	175u3000	-	-	-	1.5	0.3
T4	0.55	620	749.8	850	0.100	175u3001	-	-	-	1.5	0.4
T4	0.75	485	547.6	630	0.100	175u3002	-	-	-	1.5	0.4
T4	1.1	329	365.3	410	0.100	175u3004	-	-	-	1.5	0.5
T4	1.5	240	263.0	270	0.200	175u3007	-	-	-	1.5	0.8
T4	2.2	161	176.5	200	0.200	175u3008	-	-	-	1.5	0.9
T4	3	117	127.9	145	0.300	175u3300	-	-	-	1.5	1.3
T4	4	86.9	94.6	110	0.450	175u3335	175u3450	175u3449	-	1.5	1.9
T4	5.5	62.5	68.2	80	0.570	175u3336	175u3452	175u3451	-	1.5	2.5
T4	7.5	45.3	49.6	56	0.680	175u3337	175u3027	175u3028	-	1.5	3.3
T4	11	34.9	38.0	38	1.130	175u3338	175u3034	175u3035	-	1.5	5.2
T4	15	25.3	27.7	28	1.400	175u3339	175u3039	175u3040	-	1.5	6.7
T4	18.5	20.3	22.3	22	1.700	175u3340	175u3047	175u3048	-	1.5	8.3
T4	22	16.9	18.7	19	2.200	175u3357	175u3049	175u3050	-	1.5	10.1
T4	30	13.2	14.5	14	2.800	175u3341	175u3055	175u3056	-	2.5	13.3
T4	37	10.6	11.7	12	3.200	175u3359	175u3061	175u3062	-	2.5	15.3
T4	45	8.7	9.6	9.5	4.200	-	175u3065	175u3066	-	4	20
T4	55	6.6	7.8	7.0	5.500	-	175u3070	175u3071	-	6	26
T4	75	4.2	5.7	5.5	7.000	-	-	-	175u3231	10	36

Table 7.8 T4, Horizontal Braking 10% Duty Cycle

7

FC 301				Vertical braking 40% duty cycle							
Frequency converter data				Brake resistor data						Installation	
						Danfoss part number					
Mains type	P_m [kW]	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20	Cable cross section [mm^2]	Thermo relay [A]
T4	0.37	1000	1121.4	1200	0.200	175u3101	-	-	-	1.5	0.4
T4	0.55	620	749.8	850	0.200	175u3308	-	-	-	1.5	0.5
T4	0.75	485	547.6	630	0.300	175u3309	-	-	-	1.5	0.7
T4	1.1	329	365.3	410	0.450	175u3310	175u3416	175u3415	-	1.5	1
T4	1.5	240	263.0	270	0.570	175u3311	175u3418	175u3417	-	1.5	1.4
T4	2.2	161	176.5	200	0.960	175u3312	175u3420	175u3419	-	1.5	2.1
T4	3	117	127.9	145	1.130	175u3313	175u3422	175u3421	-	1.5	2.7
T4	4	86.9	94.6	110	1.700	175u3314	175u3424	175u3423	-	1.5	3.7
T4	5.5	62.5	68.2	80	2.200	175u3315	175u3138	175u3139	-	1.5	5
T4	7.5	45.3	49.6	56	3.200	175u3316	175u3428	175u3427	-	1.5	7.1
T4	11	34.9	38.0	38	5.000	-	-	-	175u3236	1.5	11.5
T4	15	25.3	27.7	28	6.000	-	-	-	175u3237	2.5	14.7
T4	18.5	20.3	22.3	22	8.000	-	-	-	175u3238	4	19
T4	22	16.9	18.7	19	10.000	-	-	-	175u3203	4	23
T4	30	13.2	14.5	14	14.000	-	-	-	175u3206	10	32
T4	37	10.6	11.7	12	17.000	-	-	-	175u3210	10	38
T4	45	8.7	9.6	9.5	21.000	-	-	-	175u3213	16	47
T4	55	6.6	7.8	7.0	26.000	-	-	-	175u3216	25	61
T4	75	4.2	5.7	5.5	36.000	-	-	-	175u3219	35	81

Table 7.9 T4, Vertical Braking 40% Duty Cycle

7.2.5 Brake Resistors for FC 302

FC 302				Horizontal braking 10% duty cycle							
Frequency converter data				Brake resistor data						Installation	
						Danfoss part number					
Mains type	P_m [kW]	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20	Cable cross section [mm²]	Thermo relay [A]
T2	0.25	380	475.3	410	0.100	175u3004	-	-	-	1.5	0.5
T2	0.37	275	320.8	300	0.100	175u3006	-	-	-	1.5	0.6
T2	0.55	188	215.7	200	0.100	175u3011	-	-	-	1.5	0.7
T2	0.75	130	158.1	145	0.100	175u3016	-	-	-	1.5	0.8
T2	1.1	81.0	105.1	100	0.100	175u3021	-	-	-	1.5	0.9
T2	1.5	58.5	76.0	70	0.200	175u3026	-	-	-	1.5	1.6
T2	2.2	45.0	51.0	48	0.200	175u3031	-	-	-	1.5	1.9
T2	3	31.5	37.0	35	0.300	175u3325	-	-	-	1.5	2.7
T2	3.7	22.5	29.7	27	0.360	175u3326	175u3477	175u3478	-	1.5	3.5
T2	5.5	17.7	19.7	18	0.570	175u3327	175u3442	175u3441	-	1.5	5.3
T2	7.5	12.6	14.3	13.0	0.680	175u3328	175u3059	175u3060	-	1.5	6.8
T2	11	8.7	9.7	9.0	1.130	175u3329	175u3068	175u3069	-	2.5	10.5
T2	15	5.3	7.5	5.7	1.400	175u3330	175u3073	175u3074	-	4	14.7
T2	18.5	5.1	6.0	5.7	1.700	175u3331	175u3483	175u3484	-	4	16
T2	22	3.2	5.0	3.5	2.200	175u3332	175u3080	175u3081	-	6	24
T2	30	3.0	3.7	3.5	2.800	175u3333	175u3448	175u3447	-	10	27
T2	37	2.4	3.0	2.8	3.200	175u3334	175u3086	175u3087	-	16	32

Table 7.10 T2, Horizontal Braking 10% Duty Cycle

FC 302				Vertical braking 40% duty cycle							
Frequency converter data				Brake resistor data						Installation	
						Danfoss part number				Cable cross section [mm^2]	Thermo relay [A]
Mains type	P_m [kW]	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20		
T2	0.25	380	475.3	410	0.100	175u3004	-	-	-	1.5	0.5
T2	0.37	275	320.8	300	0.200	175u3096	-	-	-	1.5	0.8
T2	0.55	188	215.7	200	0.200	175u3008	-	-	-	1.5	0.9
T2	0.75	130	158.1	145	0.300	175u3300	-	-	-	1.5	1.3
T2	1.1	81.0	105.1	100	0.450	175u3301	175u3402	175u3401	-	1.5	2
T2	1.5	58.5	76.0	70	0.570	175u3302	175u3404	175u3403	-	1.5	2.7
T2	2.2	45.0	51.0	48	0.960	175u3303	175u3406	175u3405	-	1.5	4.2
T2	3	31.5	37.0	35	1.130	175u3304	175u3408	175u3407	-	1.5	5.4
T2	3.7	22.5	29.7	27	1.400	175u3305	175u3410	175u3409	-	1.5	6.8
T2	5.5	17.7	19.7	18	2.200	175u3306	175u3412	175u3411	-	1.5	10.4
T2	7.5	12.6	14.3	13.0	3.200	175u3307	175u3414	175u3413	-	2.5	14.7
T2	11	8.7	9.7	9.0	5.500	-	175u3176	175u3177	-	4	23
T2	15	5.3	7.5	5.7	6.000	-	-	-	175u3233	10	33
T2	18.5	5.1	6.0	5.7	8.000	-	-	-	175u3234	10	38
T2	22	3.2	5.0	3.5	9.000	-	-	-	175u3235	16	51
T2	30	3.0	3.7	3.5	14.000	-	-	-	175u3224	25	63
T2	37	2.4	3.0	2.8	17.000	-	-	-	175u3227	35	78

Table 7.11 T2, Vertical Braking 40% Duty Cycle

FC 302				Horizontal braking 10% duty cycle							
Frequency converter data				Brake resistor data						Installation	
						Danfoss part number				Cable cross section	Thermo relay
Mains type	P_m [kW]	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20	[mm^2]	[A]
T5	0.37	1000	1389.2	1200	0.100	175u3000	-	-	-	1.5	0.3
T5	0.55	620	928.8	850	0.100	175u3001	-	-	-	1.5	0.4
T5	0.75	558	678.3	630	0.100	175u3002	-	-	-	1.5	0.4
T5	1.1	382	452.5	410	0.100	175u3004	-	-	-	1.5	0.5
T5	1.5	260	325.9	270	0.200	175u3007	-	-	-	1.5	0.8
T5	2.2	189	218.6	200	0.200	175u3008	-	-	-	1.5	0.9
T5	3	135	158.5	145	0.300	175u3300	-	-	-	1.5	1.3
T5	4	99.0	117.2	110	0.450	175u3335	175u3450	175u3449	-	1.5	1.9
T5	5.5	72.0	84.4	80	0.570	175u3336	175u3452	175u3451	-	1.5	2.5
T5	7.5	50.0	61.4	56	0.680	175u3337	175u3027	175u3028	-	1.5	3.3
T5	11	36.0	41.2	38	1.130	175u3338	175u3034	175u3035	-	1.5	5.2
T5	15	27.0	30.0	28	1.400	175u3339	175u3039	175u3040	-	1.5	6.7
T5	18.5	20.3	24.2	22	1.700	175u3340	175u3047	175u3048	-	1.5	8.3
T5	22	18.0	20.3	19	2.200	175u3357	175u3049	175u3050	-	1.5	10.1
T5	30	13.4	15.8	14	2.800	175u3341	175u3055	175u3056	-	2.5	13.3
T5	37	10.8	12.7	12	3.200	175u3359	175u3061	175u3062	-	2.5	15.3
T5	45	8.8	10.4	9.5	4.200	-	175u3065	175u3066	-	4	20
T5	55	6.5	8.5	7.0	5.500	-	175u3070	175u3071	-	6	26
T5	75	4.2	6.2	5.5	7.000	-	-	-	175u3231	10	36

Table 7.12 T5, Horizontal Braking 10% Duty Cycle

FC 302				Vertical braking 40% duty cycle							
Frequency converter data				Brake resistor data						Installation	
						Danfoss part number				Cable cross section $[mm^2]$	Thermo relay [A]
Mains type	P_m [kW]	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20		
T5	0.37	1000	1389.2	1200	0.200	175u3101	-	-	-	1.5	0.4
T5	0.55	620	928.8	850	0.200	175u3308	-	-	-	1.5	0.5
T5	0.75	558	678.3	630	0.300	175u3309	-	-	-	1.5	0.7
T5	1.1	382	452.5	410	0.450	175u3310	175u3416	175u3415	-	1.5	1
T5	1.5	260	325.9	270	0.570	175u3311	175u3418	175u3417	-	1.5	1.4
T5	2.2	189	218.6	200	0.960	175u3312	175u3420	175u3419	-	1.5	2.1
T5	3	135	158.5	145	1.130	175u3313	175u3422	175u3421	-	1.5	2.7
T5	4	99.0	117.2	110	1.700	175u3314	175u3424	175u3423	-	1.5	3.7
T5	5.5	72.0	84.4	80	2.200	175u3315	175u3138	175u3139	-	1.5	5
T5	7.5	50.0	61.4	56	3.200	175u3316	175u3428	175u3427	-	1.5	7.1
T5	11	36.0	41.2	38	5.000	-	-	-	175u3236	1.5	11.5
T5	15	27.0	30.0	28	6.000	-	-	-	175u3237	2.5	14.7
T5	18.5	20.3	24.2	22	8.000	-	-	-	175u3238	4	19
T5	22	18.0	20.3	19	10.000	-	-	-	175u3203	4	23
T5	30	13.4	15.8	14	14.000	-	-	-	175u3206	10	32
T5	37	10.8	12.7	12	17.000	-	-	-	175u3210	10	38
T5	45	8.8	10.4	9.5	21.000	-	-	-	175u3213	16	47
T5	55	6.5	8.5	7.0	26.000	-	-	-	175u3216	25	61
T5	75	4.2	6.2	5.5	36.000	-	-	-	175u3219	35	81

Table 7.13 T5, Vertical Braking 40% Duty Cycle

FC 302				Horizontal braking 10% duty cycle							
Frequency converter data				Brake resistor data						Installation	
						Danfoss part number					
Mains type	P_m [kW]	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20	Cable cross section [mm²]	Thermo relay [A]
T6	0.75	620	914.2	850	0.100	175u3001	-	-	-	1.5	0.4
T6	1.1	550	611.3	570	0.100	175u3003	-	-	-	1.5	0.4
T6	1.5	380	441.9	415	0.200	175u3005	-	-	-	1.5	0.7
T6	2.2	260	296.4	270	0.200	175u3007	-	-	-	1.5	0.8
T6	3	189	214.8	200	0.300	175u3342	-	-	-	1.5	1.1
T6	4	135	159.2	145	0.450	175u3343	175u3012	175u3013	-	1.5	1.7
T6	5.5	99.0	114.5	100	0.570	175u3344	175u3136	175u3137	-	1.5	2.3
T6	7.5	69.0	83.2	72	0.680	175u3345	175u3456	175u3455	-	1.5	2.9
T6	11	48.6	56.1	52	1.130	175u3346	175u3458	175u3457	-	1.5	4.4
T6	15	35.1	40.8	38	1.400	175u3347	175u3460	175u3459	-	1.5	5.7
T6	18.5	27.0	32.9	31	1.700	175u3348	175u3037	175u3038	-	1.5	7
T6	22	22.5	27.6	27	2.200	175u3349	175u3043	175u3044	-	1.5	8.5
T6	30	17.1	21.4	19	2.800	175u3350	175u3462	175u3461	-	2.5	11.4
T6	37	13.5	17.3	14	3.200	175u3358	175u3464	175u3463	-	2.5	14.2
T6	45	10.8	14.2	13.5	4.200	-	175u3057	175u3058	-	4	17
T6	55	8.8	11.6	11	5.500	-	175u3063	175u3064	-	6	21
T6	75	6.6	8.4	7.0	7.000	-	-	-	175u3245	10	32

Table 7.14 T6, Horizontal Braking 10% Duty Cycle

FC 302				Vertical braking 40% duty cycle							
Frequency converter data				Brake resistor data						Installation	
						Danfoss part number				Cable cross section [mm²]	Thermo relay [A]
Mains type	P_m [kW]	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20		
T6	0.75	620	914.2	850	0.280	175u3317	175u3104	175u3105	-	1.5	0.6
T6	1.1	550	611.3	570	0.450	175u3318	175u3430	175u3429	-	1.5	0.9
T6	1.5	380	441.9	415	0.570	175u3319	175u3432	175u3431	-	1.5	1.1
T6	2.2	260	296.4	270	0.960	175u3320	175u3434	175u3433	-	1.5	1.8
T6	3	189	214.8	200	1.130	175u3321	175u3436	175u3435	-	1.5	2.3
T6	4	135	159.2	145	1.700	175u3322	175u3126	175u3127	-	1.5	3.3
T6	5.5	99.0	114.5	100	2.200	175u3323	175u3438	175u3437	-	1.5	4.4
T6	7.5	69.0	83.2	72	3.200	175u3324	175u3440	175u3439	-	1.5	6.3
T6	11	48.6	56.1	52	5.500	-	175u3148	175u3149	-	1.5	9.7
T6	15	35.1	40.8	38	6.000	-	-	-	175u3239	2.5	12.6
T6	18.5	27.0	32.9	31	8.000	-	-	-	175u3240	4	16
T6	22	22.5	27.6	27	10.000	-	-	-	175u3200	4	19
T6	30	17.1	21.4	19	14.000	-	-	-	175u3204	10	27
T6	37	13.5	17.3	14	17.000	-	-	-	175u3207	10	35
T6	45	10.8	14.2	13.5	21.000	-	-	-	175u3208	16	40
T6	55	8.8	11.6	11	26.000	-	-	-	175u3211	25	49
T6	75	6.6	8.4	7.0	30.000	-	-	-	175u3241	35	66

Table 7.15 T6, Vertical Braking 40% Duty Cycle

FC 302				Vertical braking 40% duty cycle							
Frequency converter data				Brake resistor data						Installation	
						Danfoss part number					
Mains type	P_m [kW]	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20	Cable cross section [mm²]	Thermo relay [A]
T7	1.1	620	830	630	0.360	-	175u3108	175u3109	-	1.5	0.8
T7	1.5	513	600	570	0.570	-	175u3110	175u3111	-	1.5	1
T7	2.2	340	403	415	0.790	-	175u3112	175u3113	-	1.5	1.3
T7	3	243	292	270	1.130	-	175u3118	175u3119	-	1.5	2
T7	4	180	216	200	1.700	-	175u3122	175u3123	-	1.5	2.8
T7	5.5	130	156	145	2.200	-	175u3106	175u3107	-	1.5	3.7
T7	7.5	94	113	105	3.200	-	175u3132	175u3133	-	1.5	5.2
T7	11	69.7	76.2	72	4.200	-	175u3142	175u3143	-	1.5	7.2
T7	15	46.8	55.5	52	6.000	-	-	-	175u3242	2.5	10.8
T7	18.5	36.0	44.7	42	8.000	-	-	-	175u3243	2.5	13.9
T7	22	29.0	37.5	31	10.000	-	-	-	175u3244	4	18
T7	30	22.5	29.1	27	14.000	-	-	-	175u3201	10	23
T7	37	18.0	23.5	22	17.000	-	-	-	175u3202	10	28
T7	45	13.5	19.3	15.5	21.000	-	-	-	175u3205	16	37
T7	55	13.5	15.7	13.5	26.000	-	-	-	175u3209	16	44
T7	75	8.8	11.5	11	36.000	-	-	-	175u3212	25	57

Table 7.16 T7, Vertical Braking 40% Duty Cycle

Horizontal braking: Duty cycle 10% and maximum 120 s repetition rates according the reference brake profile. Average power corresponds to 6%.
Vertical braking: Duty cycle 40% and maximum 120 s repetition rates according the reference brake profile. Average power corresponds to 27%.
Cable cross-section: Recommended min. value based upon PVC-insulated copper cable, 30 ℃ ambient temperature with normal heat dissipation.
All cabling must comply with national and local regulations on cable cross-sections and ambient temperature.
Thermal relay: Brake current setting of external thermal relay. All resistors have a built-in thermal relay switch N.C.
The IP54 is with 1,000 mm fixed unscreened cable. Vertical and horizontal mounting. Derating required by horizontal mounting.
IP21 & IP65 are with screw terminal for cable termination. Vertical and horizontal mounting. Derating required by horizontal mounting.
The IP20 is with bolt connection for cable termination. Floor mounting.

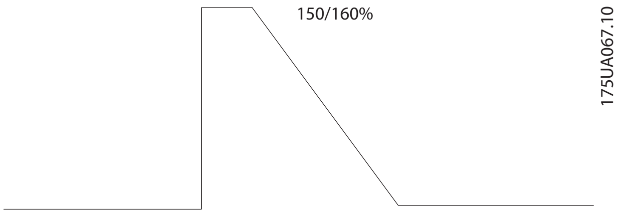

Illustration 7.2 Horizontal Loads

Illustration 7.3 Vertical Loads

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7.2.6 Other Flat Pack Brake Resistors

FC 301	P_m	R_{min}	$R_{br, nom}$	Flat pack IP65 for horizontal conveyors		
				R_{rec} per item	Duty cycle	Ordering no.
T2	[kW]	[Ω]	[Ω]	[Ω//W]	[%]	175Uxxxx
PK25	0.25	368	416	430/100	40	1002
PK37	0.37	248	281	330/100 or 310/200	27 or 55	1003 or 0984
PK55	0.55	166	189	220/100 or 210/200	20 or 37	1004 or 0987
PK75	0.75	121	138	150/100 or 150/200	14 or 27	1005 or 0989
P1K1	1.1	81.0	92	100/100 or 100/200	10 or 19	1006 or 0991
P1K5	1.5	58.5	66.5	72/200	14	0992
P2K2	2.2	40.2	44.6	50/200	10	0993
P3K0	3	29.1	32.3	35/200 or 72/200	7 14	0994 or 2 x 0992
P3K7	3.7	22.5	25.9	60/200	11	2 x 0996

Table 7.17 Other Flat Packs for Frequency Converters with Mains Supply FC 301 Mains: 200-240 V (T2)

FC 302	P_m	R_{min}	$R_{br. nom}$	Flat pack IP65 for horizontal conveyors		
				R_{rec} per item	Duty cycle	Ordering no.
T2	[kW]	[Ω]	[Ω]	[Ω/W]	[%]	175Uxxxx
PK25	0.25	380	475	430/100	40	1002
PK37	0.37	275	321	330/100 or 310/200	27 or 55	1003 or 0984
PK55	0.55	188	216	220/100 or 210/200	20 or 37	1004 or 0987
PK75	0.75	130	158	150/100 or 150/200	14 or 27	1005 or 0989
P1K1	1.1	81.0	105.1	100/100 or 100/200	10 or 19	1006 or 0991
P1K5	1.5	58.5	76.0	72/200	14	0992
P2K2	2.2	45.0	51.0	50/200	10	0993
P3K0	3	31.5	37.0	35/200 or 72/200	7 or 14	0994 or 2 x 0992
P3K7	3.7	22.5	29.7	60/200	11	2 x 0996

Table 7.18 Other Flat Packs for Frequency Converters with Mains Supply FC 302 Mains: 200-240 V (T2)

FC 301	P_m	R_{min}	$R_{br. nom}$	Flat pack IP65 for horizontal conveyors		
				R_{rec} per item	Duty cycle	Ordering no.
T4	[kW]	[Ω]	[Ω]	[Ω/W]	[%]	175Uxxxx
PK37	0.37	620	1121	830/100	30	1000
PK55	0.55	620	750	830/100	20	1000
PK75	0.75	485	548	620/100 or 620/200	14 or 27	1001 or 0982
P1K1	1.1	329	365	430/100 or 430/200	10 or 20	1002 or 0983
P1K5	1.5	240.0	263.0	310/200	14	0984
P2K2	2.2	161.0	176.5	210/200	10	0987
P3K0	3	117.0	127.9	150/200 or 300/200	7 or 14	0989 or 2 x 0985
P4K0	4	87	95	240/200	10	2 x 0986
P5K5	5.5	63	68	160/200	8	2 x 0988
P7K5	7.5	45	50	130/200	6	2 x 0990
P11K	11	34.9	38.0	80/240	5	2 x 0090
P15K	15	25.3	27.7	72/240	4	2 x 0091

Table 7.19 Other Flat Packs for Frequency Converters with Mains Supply FC 301 Mains: 380-480 V (T4)

FC 302	P_m	R_{min}	$R_{br. nom}$	Flat pack IP65 for horizontal conveyors		
				R_{rec} per item	Duty cycle	Ordering no.
T5	[kW]	[Ω]	[Ω]	[Ω/W]	[%]	175Uxxxx
PK37	0.37	620	1389	830/100	30	1000
PK55	0.55	620	929	830/100	20	1000
PK75	0.75	558	678	620/100 or 620/200	14 or 27	1001 or 0982
P1K1	1.1	382	453	430/100 or 430/200	10 or 20	1002 or 0983
P1K5	1.5	260.0	325.9	310/200	14	0984
P2K2	2.2	189.0	218.6	210/200	10	0987
P3K0	3	135.0	158.5	150/200 or 300/200	7 or 14	0989 or 2 x 0985
P4K0	4	99	117	240/200	10	2 x 0986
P5K5	5.5	72	84	160/200	8	2 x 0988
P7K5	7.5	50	61	130/200	6	2 x 0990
P11K	11	36.0	41.2	80/240	5	2 x 0090
P15K	15	27.0	30.0	72/240	4	2 x 0091

Table 7.20 Other Flat Packs for Frequency Converters with Mains Supply FC 302 Mains: 380-500 V (T5)

IP65 is a flat pack type with fixed cable.

7.2.7 Harmonic Filters

Harmonic filters are used to reduce mains harmonics.

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

Cooling and ventilation

IP20: Cooled by natural convection or with built-in fans. IP00: Additional forced cooling is required. Secure sufficient airflow through the filter during installation to prevent overheating of the filter. Airflow of minimum 2 m/s is required through the filter.

Power and current ratings		Typical motor	Filter current rating 50 Hz	Ordering no. AHF 005		Ordering no. AHF 010	
[kW]	[A]	[kW]	[A]	IP00	IP20	IP00	IP20
PK37-P4K0	1.2-9	3	10	130B1392	130B1229	130B1262	130B1027
P5K5-P7K5	14.4	7.5	14	130B1393	130B1231	130B1263	130B1058
P11K	22	11	22	130B1394	130B1232	130B1268	130B1059
P15K	29	15	29	130B1395	130B1233	130B1270	130B1089
P18K	34	18.5	34	130B1396	130B1238	130B1273	130B1094
P22K	40	22	40	130B1397	130B1239	130B1274	130B1111
P30K	55	30	55	130B1398	130B1240	130B1275	130B1176
P37K	66	37	66	130B1399	130B1241	130B1281	130B1180
P45K	82	45	82	130B1442	130B1247	130B1291	130B1201
P55K	96	55	96	130B1443	130B1248	130B1292	130B1204
P75K	133	75	133	130B1444	130B1249	130B1293	130B1207

Table 7.21 Harmonic Filters for 380-415 V, 50 Hz

Power and current ratings		Typical motor	Filter current rating 60 Hz	Ordering no. AHF 005		Ordering no. AHF 010	
[kW]	[A]	[kW]	[A]	IP00	IP20	IP00	IP20
PK37-P4K0	1.2-9	3	10	130B3095	130B2857	130B2874	130B2262
P5K5-P7K5	14.4	7.5	14	130B3096	130B2858	130B2875	130B2265
P11K	22	11	22	130B3097	130B2859	130B2876	130B2268
P15K	29	15	29	130B3098	130B2860	130B2877	130B2294
P18K	34	18.5	34	130B3099	130B2861	130B3000	130B2297
P22K	40	22	40	130B3124	130B2862	130B3083	130B2303
P30K	55	30	55	130B3125	130B2863	130B3084	130B2445
P37K	66	37	66	130B3026	130B2864	130B3085	130B2459
P45K	82	45	82	130B3127	130B2865	130B3086	130B2488
P55K	96	55	96	130B3128	130B2866	130B3087	130B2489
P75K	133	75	133	130B3129	130B2867	130B3088	130B2498

Table 7.22 Harmonic Filters for 380-415 V, 60 Hz

Power and current ratings		Typical motor	Filter current rating 60 Hz	Ordering no. AHF 005		Ordering no. AHF 010	
[kW]	[A]	[kW]	[A]	IP00	IP20	IP00	IP20
PK37-P4K0	1-7.4	3	10	130B1787	130B1752	130B1770	130B1482
P5K5-P7K5	9.9+13	7.5	14	130B1788	130B1753	130B1771	130B1483
P11K	19	11	19	130B1789	130B1754	130B1772	130B1484
P15K	25	15	25	130B1790	130B1755	130B1773	130B1485
P18K	31	18.5	31	130B1791	130B1756	130B1774	130B1486
P22K	36	22	36	130B1792	130B1757	130B1775	130B1487
P30K	47	30	48	130B1793	130B1758	130B1776	130B1488
P37K	59	37	60	130B1794	130B1759	130B1777	130B1491
P45K	73	45	73	130B1795	130B1760	130B1778	130B1492
P55K	95	55	95	130B1796	130B1761	130B1779	130B1493
P75K	118	75	118	130B1797	130B1762	130B1780	130B1494

Table 7.23 Harmonic Filters for 440-480 V, 60 Hz

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Power and current ratings		Typical motor	Filter current rating 60 Hz	Ordering no. AHF 005		Ordering no. AHF 010	
[kW]	[A]	[kW]	[A]	IP00	IP20	IP00	IP20
P11K	15	10	15	130B5261	130B5246	130B5229	130B5212
P15K	19	16.4	20	130B5262	130B5247	130B5230	130B5213
P18K	24	20	24	130B5263	130B5248	130B5231	130B5214
P22K	29	24	29	130B5263	130B5248	130B5231	130B5214
P30K	36	33	36	130B5265	130B5250	130B5233	130B5216
P37K	49	40	50	130B5266	130B5251	130B5234	130B5217
P45K	58	50	58	130B5267	130B5252	130B5235	130B5218
P55K	74	60	77	130B5268	130B5253	130B5236	130B5219
P75K	85	75	87	130B5269	130B5254	130B5237	130B5220

Table 7.24 Harmonic Filters for 600 V, 60 Hz

Power and current ratings 500-550 V		Typical motor	Power and Current Ratings 551-690 V		Typical motor	Filter current rating 50 Hz	Ordering no. AHF 005		Ordering no. AHF 010	
[kW]	[A]	[kW]	[kW]	[A]	[kW]	[A]	IP00	IP20	IP00	IP20
P11K	15	7.5	P15K	16	15	15	130B5000	130B5088	130B5297	130B5280
P15K	19.5	11	P18K	20	18.5	20	130B5017	130B5089	130B5298	130B5281
P18K	24	15	P22K	25	22	24	130B5018	130B5090	130B5299	130B5282
P22K	29	18.5	P30K	31	30	29	130B5019	130B5092	130B5302	130B5283
P30K	36	22	P37K	38	37	36	130B5021	130B5125	130B5404	130B5284
P37K	49	30	P45K	48	45	50	130B5022	130B5144	130B5310	130B5285
P45K	59	37	P55K	57	55	58	130B5023	130B5168	130B5324	130B5286
P55K	71	45	P75K	76	75	77	130B5024	130B5169	130B5325	130B5287
P75K	89	55				87	130B5025	130B5170	130B5326	130B5288

Table 7.25 Harmonic Filters for 500-690 V, 50 Hz

7.2.8 Sine-Wave Filters

Frequency converter power and current ratings						Filter current rating			Switching frequency	Ordering no.	
200-240 V		380-440 V		441-500 V		50 Hz	60 Hz	100 Hz		IP00	IP20/23[1)]
[kW]	[A]	[kW]	[A]	[kW]	[A]	[A]	[A]	[A]	[kHz]		
-	-	0.37	1.3	0.37	1.1	2.5	2.5	2	5	130B2404	130B2439
0.25	1.8	0.55	1.8	0.55	1.6						
0.37	2.4	0.75	2.4	0.75	2.1						
		1.1	3	1.1	3	4.5	4	3.5	5	130B2406	130B2441
0.55	3.5	1.5	4.1	1.5	3.4						
0.75	4.6	2.2	5.6	2.2	4.8	8	7.5	5.5	5	130B2408	130B2443
1.1	6.6	3	7.2	3	6.3						
1.5	7.5	-	-	-	-						
-	-	4	10	4	8.2	10	9.5	7.5	5	130B2409	130B2444
2.2	10.6	5.5	13	5.5	11	17	16	13	5	130B2411	130B2446
3	12.5	7.5	16	7.5	14.5						
3.7	16.7	-	-	-	-						
5.5	24.2	11	24	11	21	24	23	18	4	130B2412	130B2447
7.5	30.8	15	32	15	27	38	36	28.5	4	130B2413	130B2448
		18.5	37.5	18.5	34						
11	46.2	22	44	22	40	48	45.5	36	4	130B2281	130B2307
15	59.4	30	61	30	52	62	59	46.5	3	130B2282	130B2308
18.5	74.8	37	73	37	65	75	71	56	3	130B2283	130B2309
22	88	45	90	55	80	115	109	86	3	130B3179	130B3181*
30	115	55	106	75	105						
37	143	75	147	90	130	180	170	135	3	130B3182	130B3183*
45	170	90	177								

Table 7.26 Sine-Wave Filters for Frequency Converters with 380-500 V

*1) Ordering numbers marked with * are IP23.*

7

Frequency converter power and current ratings						Filter current rating			Switching frequency	Ordering no.	
525-600 V		690 V		525-550 V		50 Hz	60 Hz	100 Hz		IP00	IP20/23[1)]
[kW]	[A]	[kW]	[A]	[kW]	[A]	[A]	[A]	[A]	kHz		
0.75	1.7	1.1	1.6	-	-	4.5	4	3	4	130B7335	130B7356
1.1	2.4	1.5	2.2								
1.5	2.7	2.2	3.2								
2.2	3.9	3.0	4.5								
3	4.9	4.0	5.5	-	-	10	9	7	4	130B7289	130B7324
4	6.1	5.5	7.5								
5.5	9	7.5	10								
7.5	11	11	13	7.5	14	13	12	9	3	130B3195	130B3196
11	18	15	18	11	19	28	26	21	3	130B4112	130B4113
15	22	18.5	22	15	23						
18.5	27	22	27	18	28						
22	34	30	34	22	36	45	42	33	3	130B4114	130B4115
30	41	37	41	30	48						
37	52	45	52	37	54	76	72	57	3	130B4116	130B4117*
45	62	55	62	45	65						
55	83	75	83	55	87	115	109	86	3	130B4118	130B4119*
75	100	90	100	75	105						
90	131	-	-	90	137	165	156	124	2	130B4121	130B4124*

Table 7.27 Sine-Wave Filters for Frequency Converters with 525-690 V

*1) Ordering numbers marked with * are IP23.*

Parameter	Setting
14-00 Switching Pattern	[1] SFAVM
14-01 Switching Frequency	Set according the individual filter. Listed at filter product label and in output filter manual. Sine-wave filters are not allowing lower switching frequency than specified by the individual filter.
14-55 Output Filter	[2] Sine-Wave Filter Fixed
14-56 Capacitance Output Filter	Set according to the individual filter. Listed at filter product label and in output filter manual (only required for FLUX operation).
14-57 Inductance Output Filter	Set according to the individual filter. Listed at filter product label and in output filter manual (only required for FLUX operation).

Table 7.28 Parameter Settings for Sine-wave Filter Operation

7.2.9 dU/dt Filters

Frequency converter ratings [V]										Filter current rating [V]				Ordering no.		
200-240		380-440		441-500		525-550		551-690		380@60 Hz 200-400/ 440@50 Hz	460/480 @60 Hz 500/525 @50 Hz	575/600 @60 Hz	690 @50 Hz	IP00	IP20*	IP54
[kW]	[A]	[kW]	[A]	[kW]	[A]	[kW]	[A]	[kW]	[A]	[A]	[A]	[A]	[A]			
3	12.5	5.5	13	5.5	11	5.5	9.5	1.1	1.6	17	15	13	10	N/A	130B7367*	N/A
3.7	16	7.5	16	7.5	14.5	7.5	11.5	1.5	2.2							
-	-	-	-	-	-	-	-	2.2	3.2							
								3	4.5							
								4	5.5							
								5.5	7.5							
								7.5	10							
5.5	24.2	11	24	11	21	7,5	14	11	13	44	40	32	27	130B2835	130B2836	130B2837
7.5	30.8	15	32	15	27	11	19	15	18							
-	-	18.5	37.5	18.5	34	15	23	18.5	22							
-	-	22	44	22	40	18,5	28	22	27							
11	46.2	30	61	30	52	30	43	30	34	90	80	58	54	130B2838	130B2839	130B2840
15	59.4	37	73	37	65	37	54	37	41							
18.5	74.8	45	90	55	80	45	65	45	52							
22	88	-	-	-	-	-	-	-	-							
-	-	55	106	75	105	55	87	55	62	106	105	94	86	103B2841	103B2842	103B2843
-	-							75	83							
30	115	75	147	90	130	75	113	90	108	177	160	131	108	130B2844	130B2845	130B2846
37	143	90	177	-	-	90	137	-	-							
45	170	-	-	-	-	-	-	-	-							

* Dedicated A3 enclosure types supporting foot print mounting and book style mounting. Fixed screened cable connection to frequency converter.

Table 7.29 dU/dt Filters for 200-690 V

7

Parameter	Setting
14-01 Switching Frequency	Higher operating switching frequency than specified by the individual filter is not recommended.
14-55 Output Filter	[0] No Filter
14-56 Capacitance Output Filter	Not used
14-57 Inductance Output Filter	Not used

Table 7.30 Parameter Settings for dU/dt Filter Operation

8 Mechanical Installation

8.1 Safety

See *chapter 2 Safety* for general safety instructions.

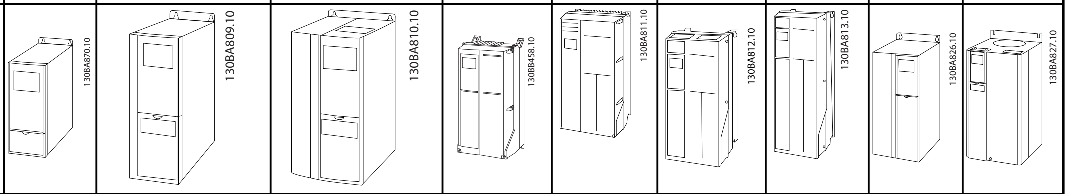
⚠WARNING

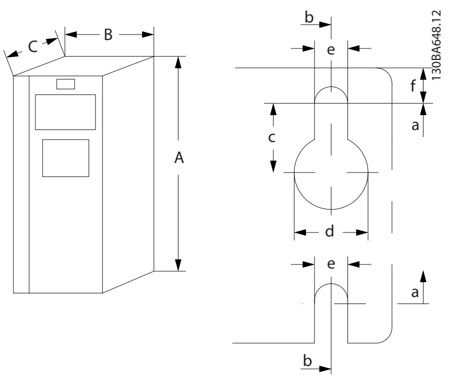
Pay attention to the requirements that apply to integration and field mounting kit. Observe the information in the list to avoid serious injury or equipment damage, especially when installing large units.

NOTICE

The frequency converter is cooled by means of air circulation.
To protect the unit from overheating, it must be ensured that the ambient temperature does NOT exceed the maximum temperature stated for the frequency converter and that the 24-hour average temperature is NOT exceeded. Locate the maximum temperature in *chapter 6.2.3 Ambient Conditions*. The 24-hour average temperature is 5 °C below the maximum temperature.

8.2 Mechanical Dimensions

Enclosure Type		A1	A2		A3		A4	A5	B1	B2	B3	B4
Power [kW]	200-240 V	0.25–1.5	0.25-2.2		3-3.7		0.25-2.2	0.25-3.7	5.5-7.5	11	5.5-7.5	11-15
	380-480/500 V	0.37-1.5	0.37-4.0		5.5-7.5		0.37-4	0.37-7.5	11-15	18.5-22	11-15	18.5-30
	525-600 V				0.75-7.5			0.75-7.5	11-15	18.5-22	11-15	18.5-30
	525-690 V				1.1-7.5					11-22		11-30
Illustrations												
IP		20	20	21	20	21	55/66	55/66	21/55/66	21/55/66	20	20
NEMA		Chassis	Chassis	Type 1	Chassis	Type 1	Type 12/4X	Type 12/4X	Type 1/12/4X	Type 1/12/4X	Chassis	Chassis
Height [mm]												
Height of back plate	A	200	268	375	268	375	390	420	480	650	399	520
Height with de-coupling plate for Fieldbus cables	A	316	374	-	374	-	-	-	-	-	420	595
Distance between mounting holes	a	190	257	350	257	350	401	402	454	624	380	495
Width [mm]												
Width of back plate	B	75	90	90	130	130	200	242	242	242	165	230
Width of back plate with one C option	B	-	130	130	170	170	-	242	242	242	205	230
Width of back plate with 2 C options	B	-	150	150	190	190	-	242	242	242	225	230
Distance between mounting holes	b	60	70	70	110	110	171	215	210	210	140	200
Depth [mm]												
Depth without option A/B	C	207	205	207	205	207	175	200	260	260	249	242
With option A/B	C	222	220	222	220	222	175	200	260	260	262	242
Screw holes [mm]												
	c	6.0	8.0	8.0	8.0	8.0	8.25	8.25	12	12	8	-
	d	ø8	ø11	ø11	ø11	ø11	ø12	ø12	ø19	ø19	12	-
	e	ø5	ø5.5	ø5.5	ø5.5	ø5.5	ø6.5	ø6.5	ø9	ø9	6.8	8.5
	f	5	9	9	6.5	6.5	6	9	9	9	7.9	15
Max weight [kg]		2.7	4.9	5.3	6.6	7.0	9.7	13.5/14.2	23	27	12	23.5
Front cover tightening torque [Nm]												
Plastic cover (low IP)		Click	Click		Click		-	-	Click	Click	Click	Click
Metal cover (IP55/66)		-	-		-		1.5	1.5	2.2	2.2	-	-



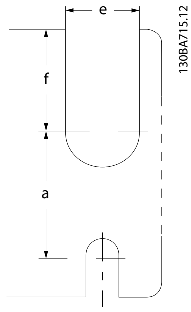
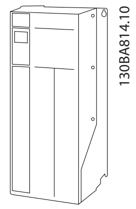
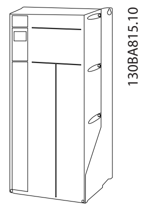
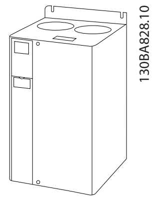
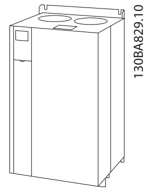
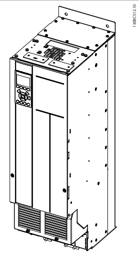
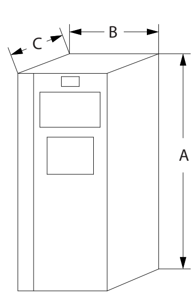
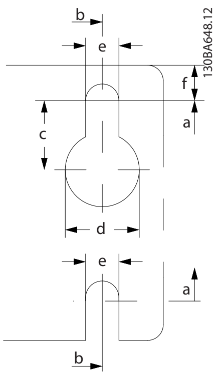


Illustration 8.1 Top and Bottom Mounting Holes (B4, C3 and C4 only)

Table 8.1 Mechanical Dimensions, Enclosure Types A and B

Enclosure Type		C1	C2	C3	C4	D3h
Power [kW]	**200-240 V**	**15-22**	**30-37**	**18.5-22**	**30-37**	-
	380-480/500 V	**30-45**	**55-75**	**37-45**	**55-75**	-
	525-600 V	**30-45**	**55-90**	**37-45**	**55-90**	-
	525-690 V		**30-75**	**37-45**		**55-75**
Illustrations						
IP		21/55/66	21/55/66	20	20	20
NEMA		Type 1/12/4X	Type 1/12/4X	Chassis	Chassis	Chassis
Height [mm]						
Height of back plate	A	680	770	550	660	909
Height with de-coupling plate for Fieldbus cables	A	-	-	630	800	-
Distance between mounting holes	a	648	739	521	631	-
Width [mm]						
Width of back plate	B	308	370	308	370	250
Width of back plate with one C option	B	308	370	308	370	-
Width of back plate with 2 C options	B	308	370	308	370	-
Distance between mounting holes	b	272	334	270	330	-
Depth [mm]						
Depth without option A/B	C	310	335	333	333	275
With option A/B	C	310	335	333	333	275
Screw holes [mm]						
	c	12.5	12.5	-	-	-
	d	ø19	ø19	-	-	-
	e	ø9	ø9	8.5	8.5	-
	f	9.8	9.8	17	17	-
Max weight [kg]		45	65	35	50	62
Front cover tightening torque [Nm]						
Plastic cover (low IP)		Click	Click	2.0	2.0	-
Metal cover (IP55/66)		2.2	2.2	2.0	2.0	-





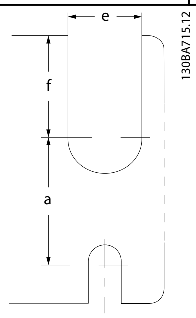


Illustration 8.1 Top and Bottom Mounting Holes (B4, C3 and C4 only)

Table 8.2 Mechanical Dimensions, Enclosure Types C and D

NOTICE

Accessory bags containing necessary brackets, screws and connectors are shipped with the frequency converters upon delivery.

8

8.2.1 Mechanical Mounting

8.2.1.1 Clearance

All enclosure types allow side-by-side installation except when an IP21/IP4X/TYPE 1 enclosure kit is used (see *chapter 11 Options and Accessories*).

Side-by-side mounting
IP20 A and B enclosure types can be arranged side-by-side with no clearance required between them, but the mounting order is important. *Illustration 8.1* shows how to mount the frames correctly.

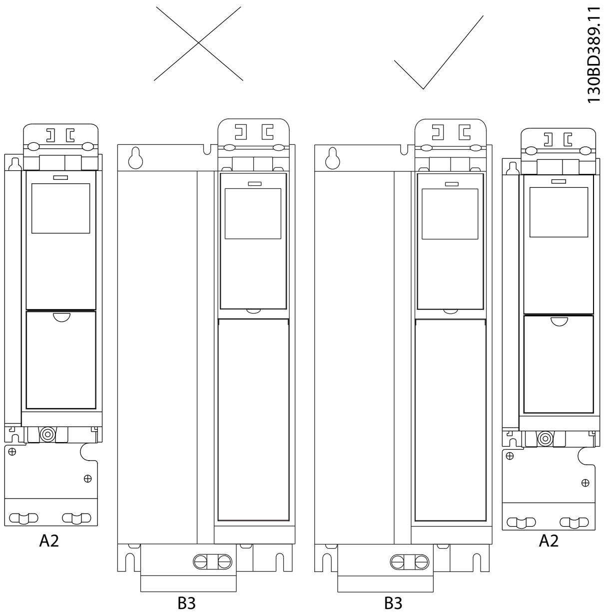


Illustration 8.1 Correct Side-by-side Mounting

If the IP21 enclosure kit is used on enclosure types A1, A2 or A3, there must be a clearance between the frequency converters of min. 50 mm.

For optimal cooling conditions, allow a free air passage above and below the frequency converter. See *Table 8.3*.

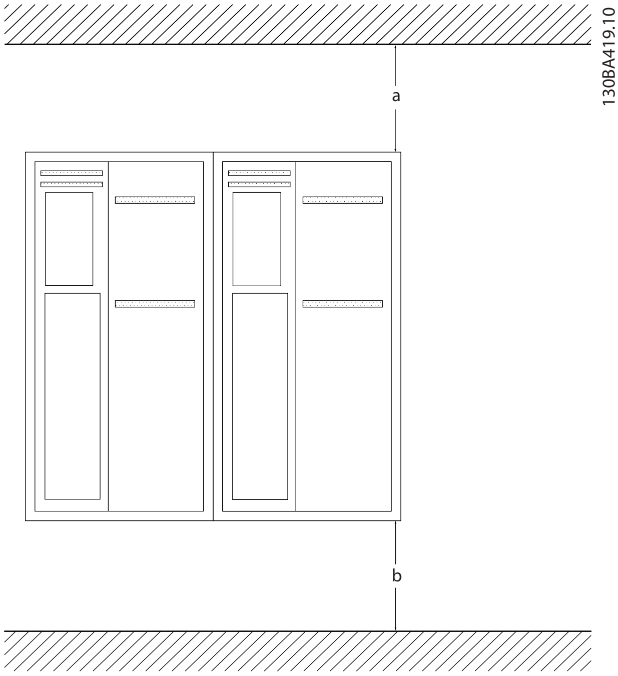


Illustration 8.2 Clearance

Enclosure Type	A1*/A2/A3/A4/ A5/B1	B2/B3/B4/ C1/C3	C2/C4
a [mm]	100	200	225
b [mm]	100	200	225

Table 8.3 Air Passage for Different Enclosure Types

8.2.1.2 Wall Mounting

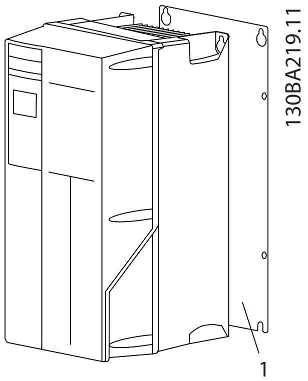
When mounting on a solid back wall the installation is straight forward.

1. Drill holes in accordance with the measurements given.
2. Provide screws suitable for the surface for mounting the frequency converter. Retighten all 4 screws.

If the frequency converter is to be mounted on a non-solid back wall, provide the frequency converter with a back plate, "1", due to insufficient cooling air over the heat sink.

NOTICE

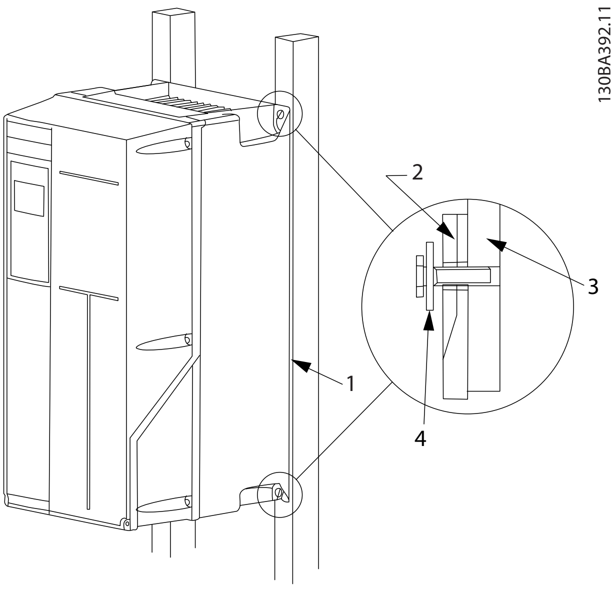
The back plate is relevant for A4, A5, B1, B2, C1 and C2 only.



1	Back plate

Illustration 8.3 Mounting on a non-solid Back-wall requires a Back Plate

For frequency converters with IP66 take extra care to maintain the corrosive-resistant surface. A fibre washer or a nylon washer may be used to protect the epoxy coating.



1	Back plate
2	IP66 frequency converter
3	Base plate
4	Fibre washer

Illustration 8.4 Mounting on a Non-solid Back Wall

9 Electrical Installation

9.1 Safety

See *chapter 2 Safety* for general safety instructions.

WARNING

INDUCED VOLTAGE

Induced voltage from output motor cables that run together can charge equipment capacitors even with the equipment turned off and locked out. Failure to run output motor cables separately or use screened cables could result in death or serious injury.

- **run output motor cables separately, or**
- **use screened cables**

CAUTION

SHOCK HAZARD

The frequency converter can cause a DC current in the PE conductor.

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

Failure to follow the recommendation means the RCD may not provide the intended protection.

WARNING

LEAKAGE CURRENT HAZARD

Leakage currents exceed 3.5 mA. Failure to ground the frequency converter properly could result in death or serious injury.

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

For electrical safety

- Ground the frequency converter in accordance with applicable standards and directives.
- Use a dedicated ground wire for input power, motor power and control wiring.
- Do not ground one frequency converter to another in a “daisy chain” fashion.
- Keep the ground wire connections as short as possible.
- Follow motor manufacturer wiring requirements.
- Minimum cable cross-section: 10 mm^2 (or 2 rated ground wires terminated separately).

For EMC-compliant installation

- Establish electrical contact between cable screen and frequency converter enclosure by using metal cable glands or by using the clamps provided on the equipment (see *chapter 9.4 Motor Connection*).
- Use high-strand wire to reduce electrical interference.
- Do not use pigtails.

NOTICE

POTENTIAL EQUALISATION

Risk of electrical interference, when the ground potential between the frequency converter and the system is different. Install equalising cables between the system components. Recommended cable cross-section: 16 mm^2.

9

WARNING

LEAKAGE CURRENT HAZARD

Leakage currents exceed 3.5 mA. Failure to ground the frequency converter properly could result in death or serious injury.

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

Aluminium Conductors

Terminals can accept aluminium conductors, but the conductor surface has to be clean and the oxidation must be removed and sealed by neutral acid-free Vaseline grease before the conductor is connected.
Furthermore, the terminal screw must be retightened after 2 days due to softness of the aluminium. It is crucial to keep the connection a gas tight joint, otherwise the aluminium surface oxidises again.

9.2 Cables

NOTICE

Cables General

All cabling must comply with national and local regulations on cable cross-sections and ambient temperature. Copper (75 °C) conductors are recommended.

9.2.1 Tightening Torque

Enclosure Type	200-240 V [kW]	380-500 V [kW]	525-690 V [kW]	Cable for	Tightening-up torque [Nm]
A1	0.25-1.5	0.37-1.5	-	Mains, Brake resistor, load sharing, Motor cables	0.5-0.6
A2	0.25-2.2	0.37-4	-		
A3	3-3.7	5.5-7.5	1.1-7.5		
A4	0.25-2.2	0.37-4			
A5	3-3.7	5.5-7.5	-		
B1	5.5-7.5	11-15	-	Mains, Brake resistor, load sharing, Motor cables	1.8
				Relay	0.5-0.6
				Ground	2-3
B2	11	18.5-22	11-22	Mains, Brake resistor, load sharing cables	4.5
				Motor cables	4.5
				Relay	0.5-0.6
				Ground	2-3
B3	5.5-7.5	11-15	-	Mains, Brake resistor, load sharing, Motor cables	1.8
				Relay	0.5-0.6
				Ground	2-3
B4	11-15	18.5-30	11-30	Mains, Brake resistor, load sharing, Motor cables	4.5
				Relay	0.5-0.6
				Ground	2-3
C1	15-22	30-45	-	Mains, Brake resistor, load sharing cables	10
				Motor cables	10
				Relay	0.5-0.6
				Ground	2-3
C2	30-37	55-75	30-75	Mains, motor cables	14 (up to 9 5mm^2) 24 (over 95 mm^2)
				Load Sharing, brake cables	14
				Relay	0.5-0.6
				Ground	2-3
C3	18.5-22	30-37	37-45	Mains, Brake resistor, load sharing, Motor cables	10
				Relay	0.5-0.6
				Ground	2-3
C4	37-45	55-75	-	Mains, motor cables	14 (up to 95 mm^2) 24 (over 95 mm^2)
				Load Sharing, brake cables	14
				Relay	0.5-0.6
				Ground	2-3

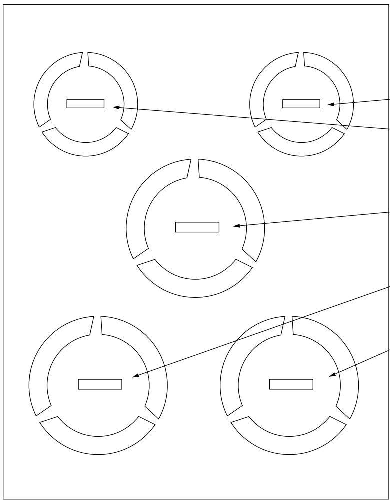
Table 9.1 Tightening Torque for Cables

9

9.2.2 Entry Holes

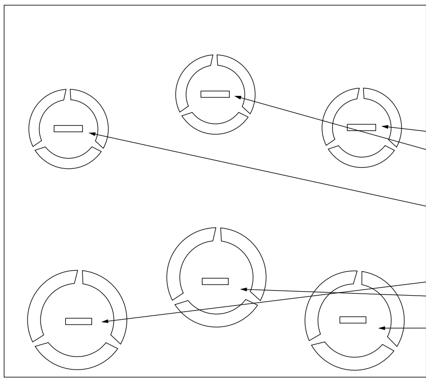
1. Remove cable entry from the frequency converter (Avoiding foreign parts falling into the frequency converter when removing knockouts).
2. Cable entry has to be supported around the knockout to be removed.
3. The knockout can now be removed with a strong mandrel and a hammer.
4. Remove burrs from the hole.
5. Mount cable entry on frequency converter.

The suggested use of the holes are recommendations, but other solutions are possible. Unused cable entry holes can be sealed with rubber grommets (for IP21).



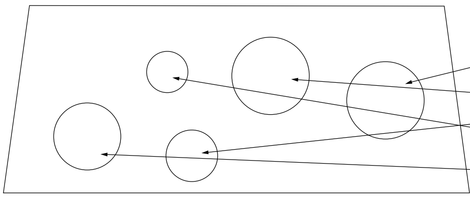
Hole number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Mains	3/4	28.4	M25
2) Motor	3/4	28.4	M25
3) Brake/load sharing	3/4	28.4	M25
4) Control cable	1/2	22.5	M20
5) Control cable	1/2	22.5	M20
1) Tolerance ± 0.2 mm			

Illustration 9.1 A2 - IP21



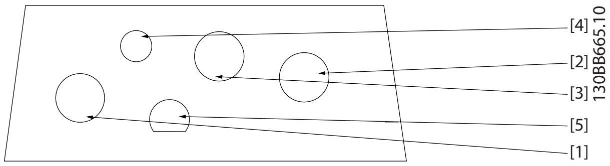
Hole number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Mains	3/4	28.4	M25
2) Motor	3/4	28.4	M25
3) Brake/load sharing	3/4	28.4	M25
4) Control cable	1/2	22.5	M20
5) Control cable	1/2	22.5	M20
6) Control cable	1/2	22.5	M20
1) Tolerance ± 0.2 mm			

Illustration 9.2 A3 - IP21



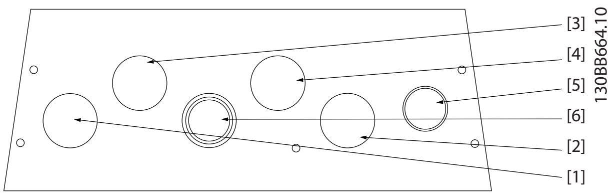
Hole number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Mains	3/4	28.4	M25
2) Motor	3/4	28.4	M25
3) Brake/load sharing	3/4	28.4	M25
4) Control cable	1/2	22.5	M20
5) Removed	-	-	-
1) Tolerance ± 0.2 mm			

Illustration 9.3 A4 - IP55



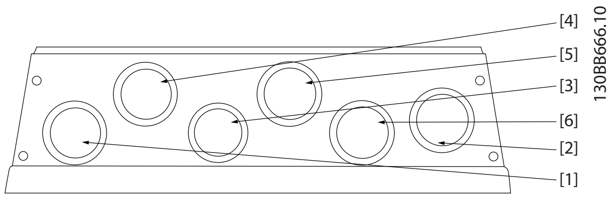
Hole number and recommended use	Nearest metric
1) Mains	M25
2) Motor	M25
3) Brake/load sharing	M25
4) Control cable	M16
5) Control cable	M20

Illustration 9.4 A4 - IP55 Threaded Gland Holes



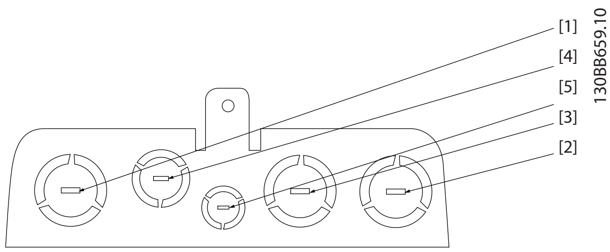
Hole number and recommended use	Dimensions 1)		Nearest metric
	UL [in]	[mm]	
1) Mains	3/4	28.4	M25
2) Motor	3/4	28.4	M25
3) Brake/load sharing	3/4	28.4	M25
4) Control cable	3/4	28.4	M25
5) Control cable 2)	3/4	28.4	M25
6) Control cable 2)	3/4	28.4	M25
1) Tolerance ± 0.2 mm 2) Knock-out hole			

Illustration 9.5 A5 - IP55



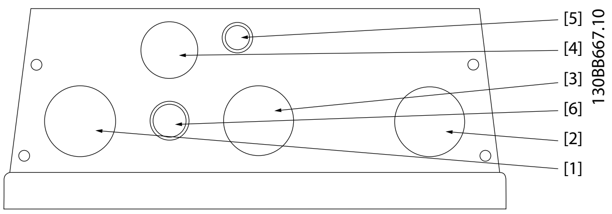
Hole number and recommended use	Nearest metric
1) Mains	M25
2) Motor	M25
3) Brake/load sharing	28.4 mm 1)
4) Control cable	M25
5) Control cable	M25
6) Control cable	M25
1) Knock-out hole	

Illustration 9.6 A5- IP55 Threaded Gland Holes



Hole number and recommended use	Dimensions 1)		Nearest metric
	UL [in]	[mm]	
1) Mains	1	34.7	M32
2) Motor	1	34.7	M32
3) Brake/load sharing	1	34.7	M32
4) Control cable	1	34.7	M32
5) Control cable	1/2	22.5	M20
1) Tolerance ± 0.2 mm			

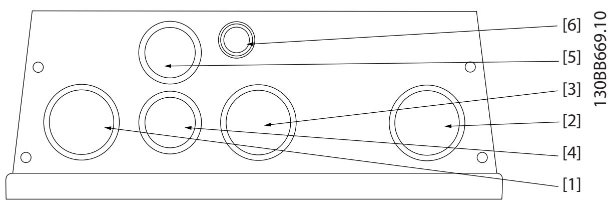
Illustration 9.7 B1 - IP21



Hole number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Mains	1	34.7	M32
2) Motor	1	34.7	M32
3) Brake/load sharing	1	34.7	M32
4) Control cable	3/4	28.4	M25
5) Control cable	1/2	22.5	M20
5) Control cable[2]	1/2	22.5	M20
1) Tolerance ± 0.2 mm 2) Knock-out hole			

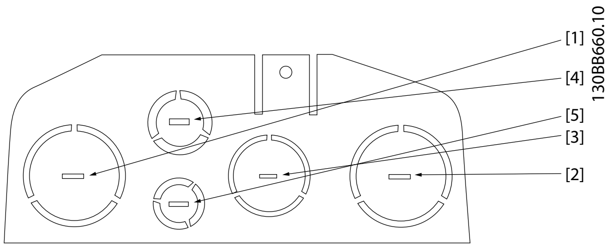
Illustration 9.8 B1 - IP55

9



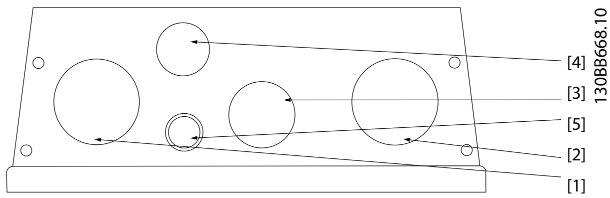
Hole number and recommended use	Nearest metric
1) Mains	M32
2) Motor	M32
3) Brake/load sharing	M32
4) Control cable	M25
5) Control cable	M25
6) Control cable	22.5 mm [1]
1) Knock-out hole	

Illustration 9.9 B1 - IP55 Threaded Gland Holes



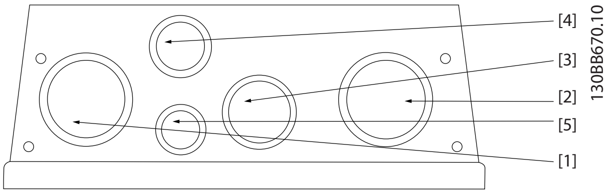
Hole number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Mains	1 1/4	44.2	M40
2) Motor	1 1/4	44.2	M40
3) Brake/load sharing	1	34.7	M32
4) Control cable	3/4	28.4	M25
5) Control cable	1/2	22.5	M20
1) Tolerance ± 0.2 mm			

Illustration 9.10 B2 - IP21



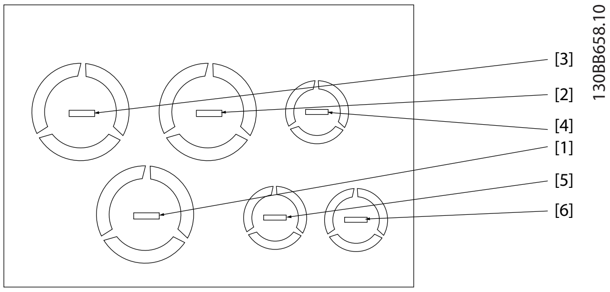
Hole number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Mains	1 1/4	44.2	M40
2) Motor	1 1/4	44.2	M40
3) Brake/load sharing	1	34.7	M32
4) Control cable	3/4	28.4	M25
5) Control cable[2]	1/2	22.5	M20
1) Tolerance ± 0.2 mm 2) Knock-out hole			

Illustration 9.11 B2 - IP55



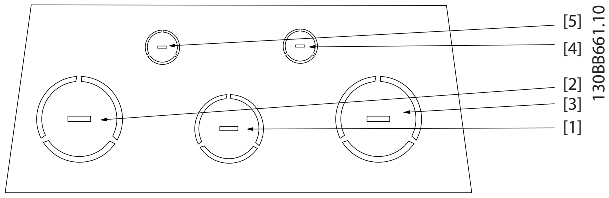
Hole number and recommended use	Nearest metric
1) Mains	M40
2) Motor	M40
3) Brake/load sharing	M32
4) Control cable	M25
5) Control cable	M20

Illustration 9.12 B2 - IP55 Threaded Gland Holes



Hole number and recommended use	Dimensions1)		Nearest metric
	UL [in]	[mm]	
1) Mains	1	34.7	M32
2) Motor	1	34.7	M32
3) Brake/load sharing	1	34.7	M32
4) Control cable	1/2	22.5	M20
5) Control cable	1/2	22.5	M20
6) Control cable	1/2	22.5	M20
1) Tolerance ± 0.2 mm			

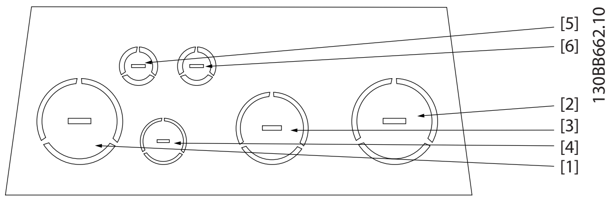
Illustration 9.13 B3 - IP21



Hole number and recommended use	Dimensions1)		Nearest metric
	UL [in]	[mm]	
1) Mains	2	63.3	M63
2) Motor	2	63.3	M63
3) Brake/load sharing	1 1/2	50.2	M50
4) Control cable	3/4	28.4	M25
5) Control cable	1/2	22.5	M20
1) Tolerance ± 0.2 mm			

Illustration 9.14 C1 - IP21

9



Hole number and recommended use	Dimensions1)		Nearest metric
	UL [in]	[mm]	
1) Mains	2	63.3	M63
2) Motor	2	63.3	M63
3) Brake/load sharing	1 1/2	50.2	M50
4) Control cable	3/4	28.4	M25
5) Control cable	1/2	22.5	M20
6) Control cable	1/2	22.5	M20
1) Tolerance ±0.2 mm			

Illustration 9.15 C2 - IP21

9.2.3 Tightening of the Cover after Connections are Made

Enclosure Type	IP20	IP21	IP55	IP66
A1	*	-	-	-
A2	*	*	-	-
A3	*	*	-	-
A4/A5	-	-	2	2
B1	-	*	2.2	2.2
B2	-	*	2.2	2.2
B3	*	-	-	-
B4	*	-	-	-
C1	-	*	2.2	2.2
C2	-	*	2.2	2.2
C3	2	-	-	-
C4	2	-	-	-
* = No screws to tighten - = Does not exist				

Table 9.2 Tightening of the Cover (Nm)

9.3 Mains Connection

It is mandatory to ground the mains connection properly using terminal 95 of the frequency converter, see *chapter 9.1.1 Grounding*.

The ground connection cable cross section must be at least 10 mm^2 or 2 x rated mains wires terminated separately according to EN 50178.
Use unscreened cable.

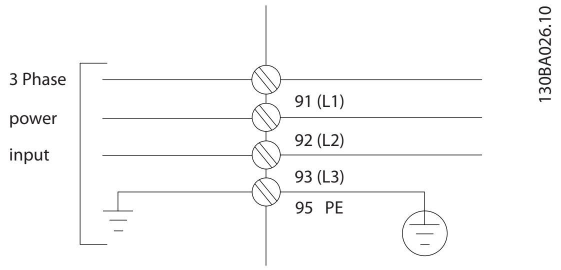


Illustration 9.16 Mains Connection

NOTICE

Using fuses and/or circuit breakers on the supply side is mandatory to ensure compliance with IEC 60364 for CE or NEC 2009 for UL, see *chapter 9.3.1.4 UL Compliance*.

NOTICE

Exceeding 480 V RMS

RISK OF DAMAGE TO THE FREQUENCY CONVERTER WITH RFI FILTER INSTALLED

When installed on a delta-grounded grid or an IT grid (including ground fault condition), mains input voltage in the range of 380-500 V (T4,T5) must not exceed 480 V RMS between mains and ground.

For some enclosures, the mounting is different if the frequency converter is configured from factory with a mains switch. The various scenarios are illustrated in the following.

Mains connection for enclosures A1, A2 and A3:

NOTICE

The power plug connector can be used on frequency converters up to 7.5 kW.

1. Fit the 2 screws in the de-coupling plate, slide it into place and tighten the screws.
2. Make sure the frequency converter is properly grounded. Connect to ground connection (terminal 95). Use screw from the accessory bag.
3. Place plug connector 91 (L1), 92 (L2), 93 (L3) from the accessory bag onto the terminals labelled MAINS at the bottom of the frequency converter.
4. Attach mains wires to the mains plug connector.
5. Support the cable with the supporting enclosed brackets.

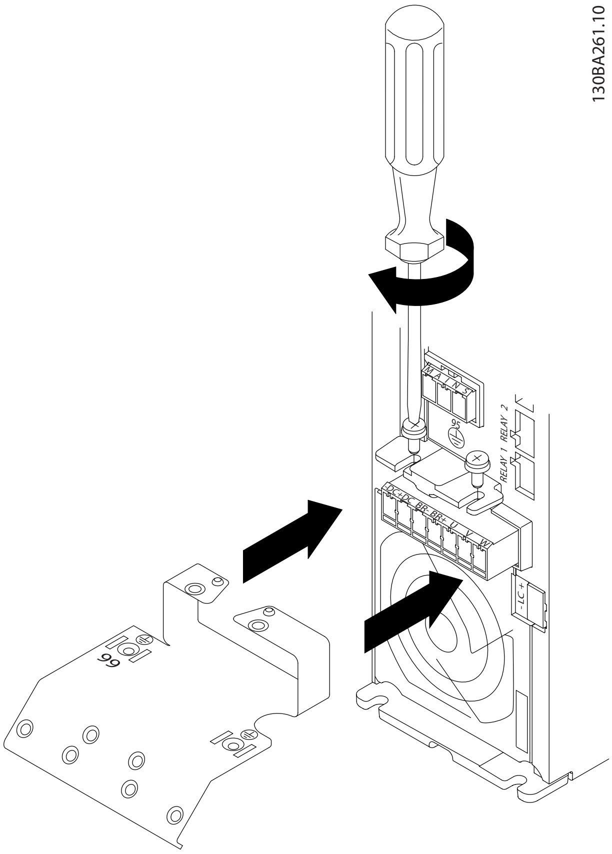


Illustration 9.17 Support Plate

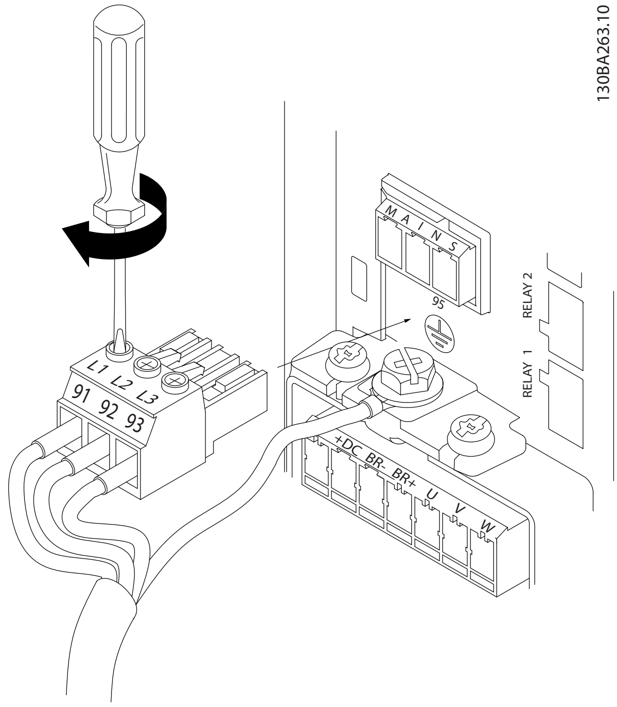


Illustration 9.19 Mounting Mains Plug and Tightening Wires

9

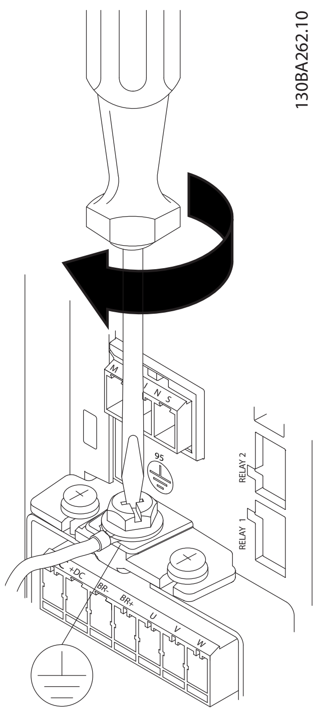


Illustration 9.18 Tightening the Ground Cable

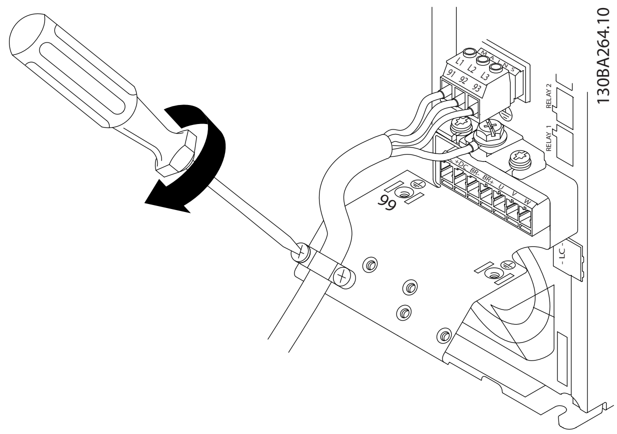


Illustration 9.20 Tighten Support Bracket

Mains connector enclosures A4/A5

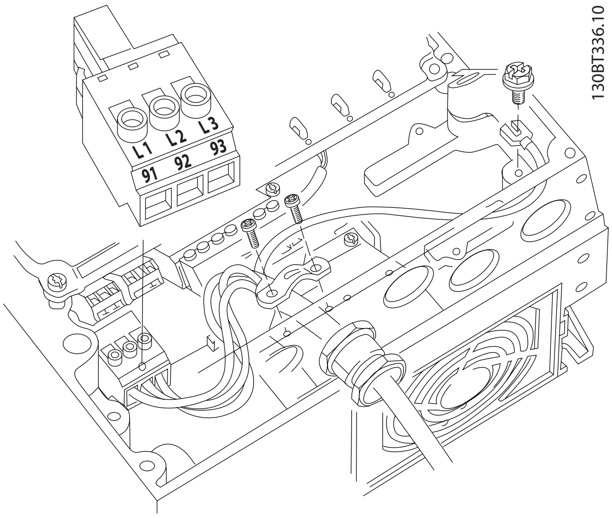


Illustration 9.21 Connecting to Mains and Grounding without Disconnector

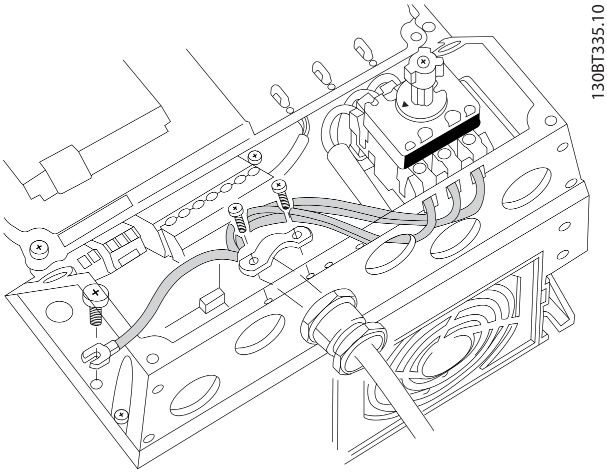


Illustration 9.22 Connecting to Mains and Grounding with Disconnector

When disconnector is used (enclosures A4/A5), mount the PE on the left side of the frequency converter.

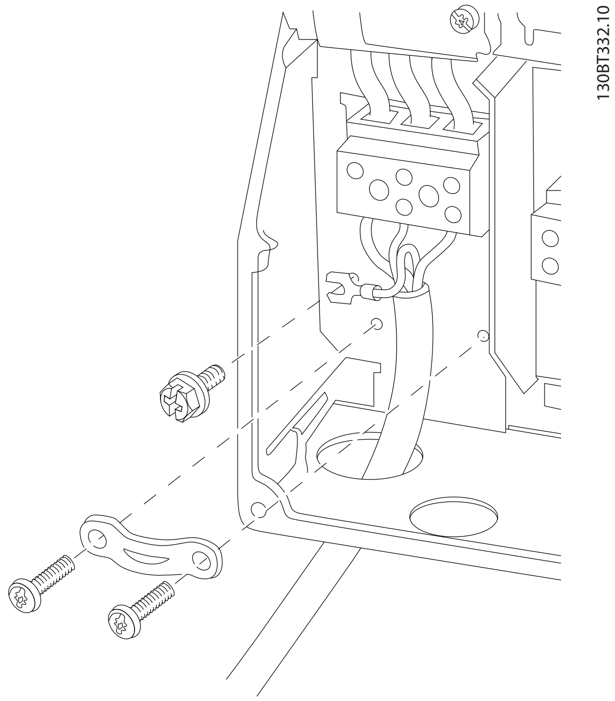


Illustration 9.23 Mains Connection Enclosures B1 and B2

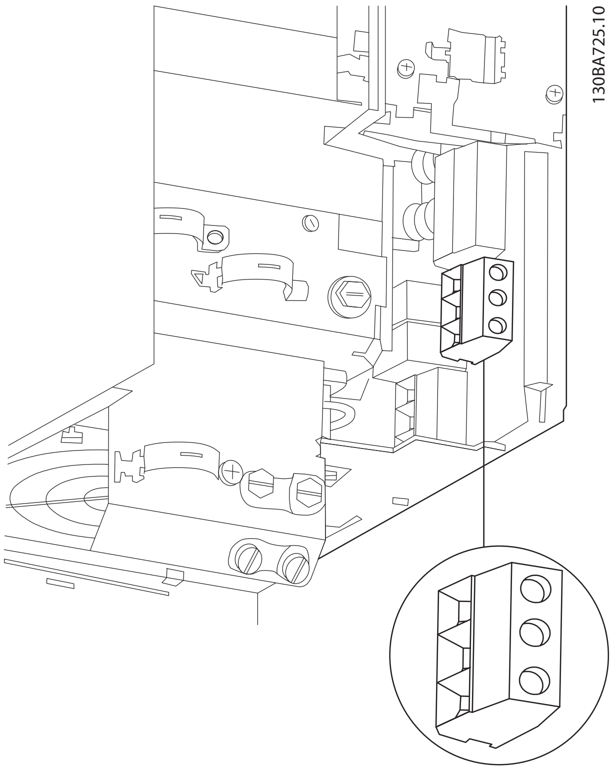


Illustration 9.24 Mains Connection Enclosure B3

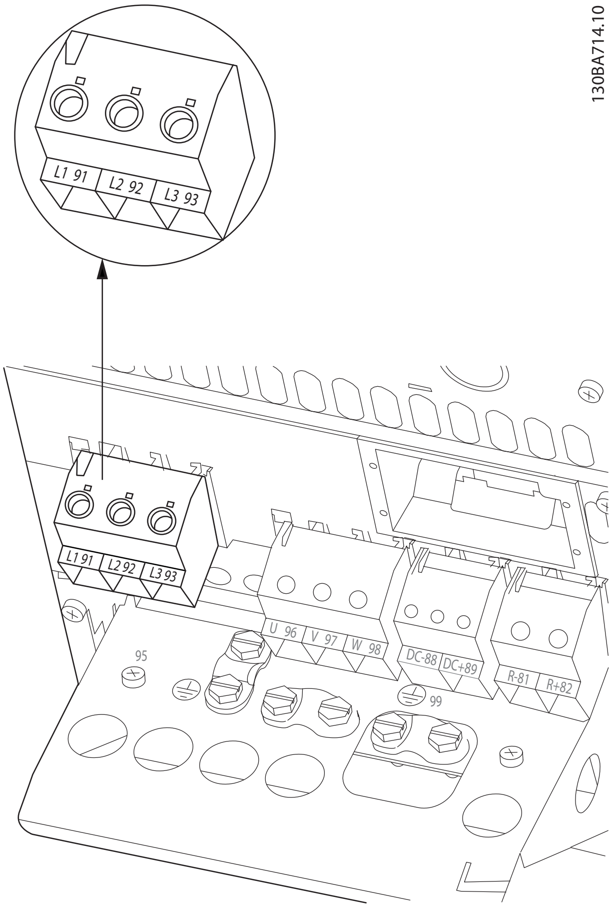


Illustration 9.25 Mains Connection Enclosure B4

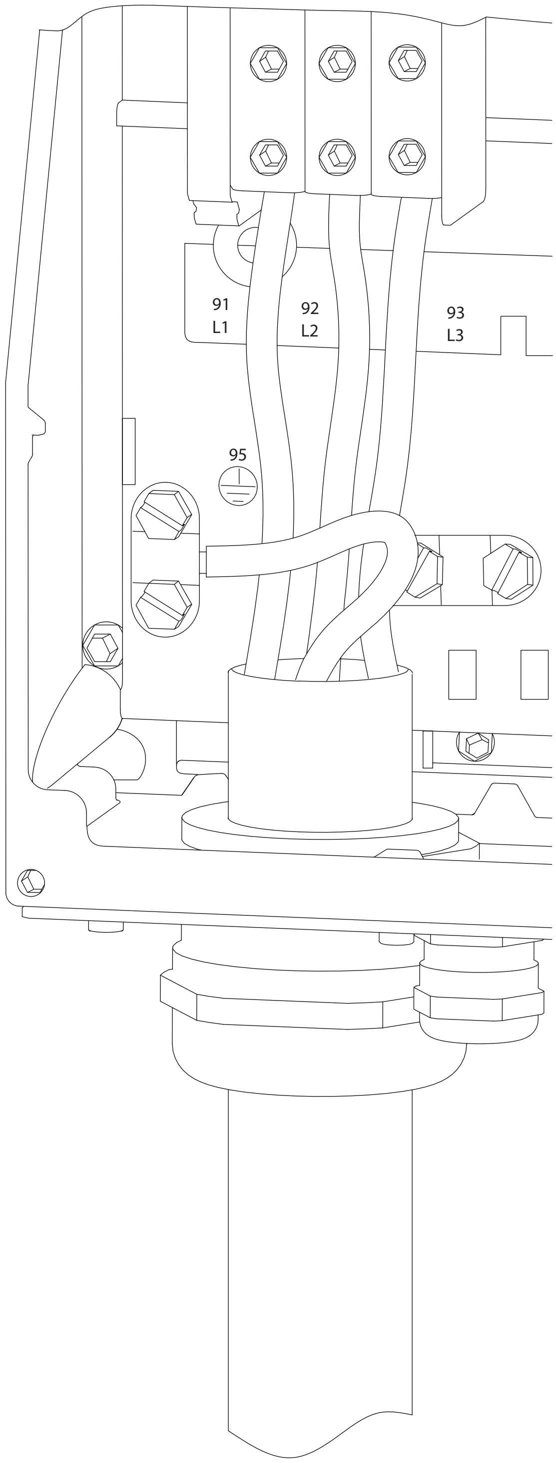


Illustration 9.26 Mains Connection Enclosures C1 and C2 (IP21/ NEMA Type 1 and IP55/66/NEMA Type 12).

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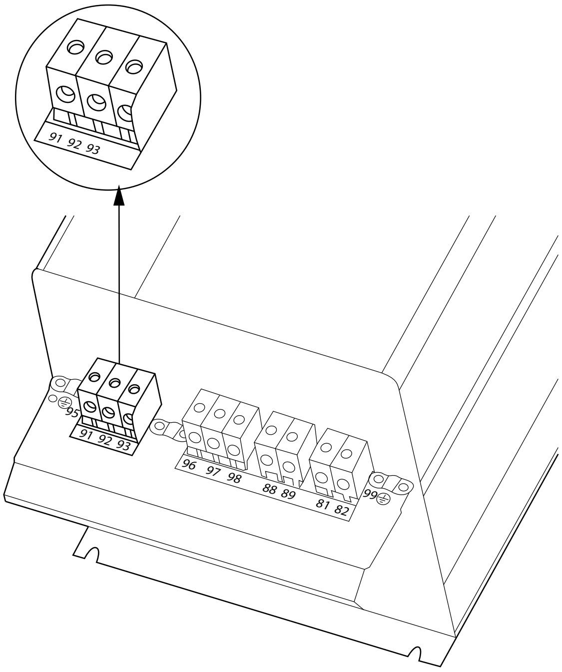

Illustration 9.27 Mains Connection Enclosures C3 (IP20).

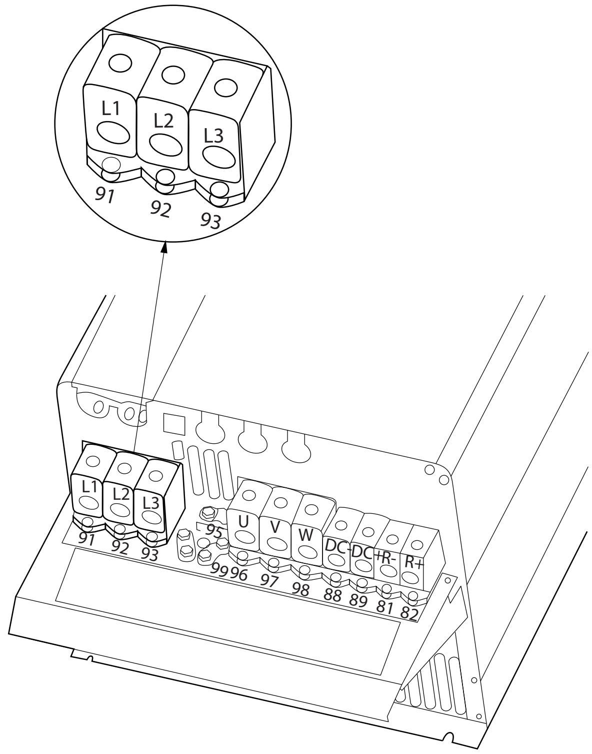

Illustration 9.28 Mains Connection Enclosures C4 (IP20).

9

9.3.1 Fuses and Circuit Breakers

9.3.1.1 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).

NOTICE

Using fuses and/or circuit breakers on the supply side is mandatory to ensure compliance with IEC 60364 for CE or NEC 2009 for UL.

Branch Circuit Protection
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.

NOTICE

The recommendations given do not cover branch circuit protection for UL.

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

9.3.1.2 Recommendations

The tables in *chapter 9.3.1 Fuses and Circuit Breakers* list the recommended rated current. Recommended fuses are of the type gG for small to medium power sizes. For larger power sizes, aR fuses are recommended. For circuit breakers, Moeller types are recommended. 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.

If fuses/circuit breakers according to recommendations are selected, possible damage on the frequency converter is mainly limited to damages inside the unit.

For further information see *Application Note Fuses and Circuit Breakers, MN90T*.

The fuses below are suitable for use on a circuit capable of delivering 100,000 A_{rms} (symmetrical), 240 V, 500 V, 600 V, or 690 V depending on the frequency converter voltage rating. With the proper fusing the frequency converter short circuit current rating (SCCR) is 100,000 A_{rms}.

The following UL listed fuses are suitable:

- UL248-4 class CC fuses
- UL248-8 class J fuses
- UL248-12 class R fuses (RK1)
- UL248-15 class T fuses

The following max. fuse size and type have been tested:

9.3.1.3 CE Compliance

Fuses or circuit breakers are mandatory to comply with IEC 60364. Danfoss recommend using a selection of the following.

Enclosure	Power [kW]	Recommended fuse size	Recommended max. fuse	Recommended circuit breaker Moeller	Max trip level [A]
A1	0.25-1.5	gG-10	gG-25	PKZM0-10	10
A2	0.25-2.2	gG-10 (0.25-1.5) gG-16 (2.2)	gG-25	PKZM0-16	16
A3	3.0-3.7	gG-16 (3) gG-20 (3.7)	gG-32	PKZM0-25	25
A4	0.25-2.2	gG-10 (0.25-1.5) gG-16 (2.2)	gG-32	PKZM0-25	25
A5	0.25-3.7	gG-10 (0.25-1.5) gG-16 (2.2-3) gG-20 (3.7)	gG-32	PKZM0-25	25
B1	5.5-7.5	gG-25 (5.5) gG-32 (7.5)	gG-80	PKZM4-63	63
B2	11	gG-50	gG-100	NZMB1-A100	100
B3	5.5	gG-25	gG-63	PKZM4-50	50
B4	7.5-15	gG-32 (7.5) gG-50 (11) gG-63 (15)	gG-125	NZMB1-A100	100
C1	15-22	gG-63 (15) gG-80 (18.5) gG-100 (22)	gG-160 (15-18.5) aR-160 (22)	NZMB2-A200	160
C2	30-37	aR-160 (30) aR-200 (37)	aR-200 (30) aR-250 (37)	NZMB2-A250	250
C3	18.5-22	gG-80 (18.5) aR-125 (22)	gG-150 (18.5) aR-160 (22)	NZMB2-A200	150
C4	30-37	aR-160 (30) aR-200 (37)	aR-200 (30) aR-250 (37)	NZMB2-A250	250

Table 9.3 200-240 V, Enclosure Types A, B and C

Enclosure	Power [kW]	Recommended fuse size	Recommended max. fuse	Recommended circuit breaker Moeller	Max trip level [A]
A1	0.37-1.5	gG-10	gG-25	PKZM0-10	10
A2	0.37-4.0	gG-10 (0.37-3) gG-16 (4)	gG-25	PKZM0-16	16
A3	5.5-7.5	gG-16	gG-32	PKZM0-25	25
A4	0.37-4	gG-10 (0.37-3) gG-16 (4)	gG-32	PKZM0-25	25
A5	0.37-7.5	gG-10 (0.37-3) gG-16 (4-7.5)	gG-32	PKZM0-25	25
B1	11-15	gG-40	gG-80	PKZM4-63	63
B2	18.5-22	gG-50 (18.5) gG-63 (22)	gG-100	NZMB1-A100	100
B3	11-15	gG-40	gG-63	PKZM4-50	50
B4	18.5-30	gG-50 (18.5) gG-63 (22) gG-80 (30)	gG-125	NZMB1-A100	100
C1	30-45	gG-80 (30) gG-100 (37) gG-160 (45)	gG-160	NZMB2-A200	160
C2	55-75	aR-200 (55) aR-250 (75)	aR-250	NZMB2-A250	250
C3	37-45	gG-100 (37) gG-160 (45)	gG-150 (37) gG-160 (45)	NZMB2-A200	150
C4	55-75	aR-200 (55) aR-250 (75)	aR-250	NZMB2-A250	250

Table 9.4 380-500 V, Enclosure Types A, B and C

Enclosure	Power [kW]	Recommended fuse size	Recommended max. fuse	Recommended circuit breaker Moeller	Max trip level [A]
A2	0-75-4.0	gG-10	gG-25	PKZM0-16	16
A3	5.5-7.5	gG-10 (5.5) gG-16 (7.5)	gG-32	PKZM0-25	25
A5	0.75-7.5	gG-10 (0.75-5.5) gG-16 (7.5)	gG-32	PKZM0-25	25
B1	11-18	gG-25 (11) gG-32 (15) gG-40 (18.5)	gG-80	PKZM4-63	63
B2	22-30	gG-50 (22) gG-63 (30)	gG-100	NZMB1-A100	100
B3	11-15	gG-25 (11) gG-32 (15)	gG-63	PKZM4-50	50
B4	18.5-30	gG-40 (18.5) gG-50 (22) gG-63 (30)	gG-125	NZMB1-A100	100
C1	37-55	gG-63 (37) gG-100 (45) aR-160 (55)	gG-160 (37-45) aR-250 (55)	NZMB2-A200	160
C2	75	aR-200 (75)	aR-250	NZMB2-A250	250
C3	37-45	gG-63 (37) gG-100 (45)	gG-150	NZMB2-A200	150
C4	55-75	aR-160 (55) aR-200 (75)	aR-250	NZMB2-A250	250

Table 9.5 525-600 V, Enclosure Types A, B and C

Enclosure	Power [kW]	Recommended fuse size	Recommended max. fuse	Recommended circuit breaker Moeller	Max trip level [A]
A3	1.1 1.5 2.2 3 4 5.5 7.5	gG-6 gG-6 gG-6 gG-10 gG-10 gG-16 gG-16	gG-25 gG-25 gG-25 gG-25 gG-25 gG-25 gG-25	PKZM0-16	16
B2/B4	11 15 18 22	gG-25 (11) gG-32 (15) gG-32 (18) gG-40 (22)	gG-63	-	-
B4/C2	30	gG-63 (30)	gG-80 (30)	-	-
C2/C3	37 45	gG-63 (37) gG-80 (45)	gG-100 (37) gG-125 (45)		
C2	55 75	gG-100 (55) gG-125 (75)	gG-160 (55-75)		

Table 9.6 525-690 V, Enclosure Types A, B and C

9.3.1.4 UL Compliance

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

Fuses or circuit breakers are mandatory to comply with NEC 2009. Danfoss recommends using a selection of the following:

	Recommended max. fuse					
Power [kW]	**Bussmann Type RK1 1)**	**Bussmann Type J**	**Bussmann Type T**	**Bussmann Type CC**	**Bussmann Type CC**	**Bussmann Type CC**
0.25-0.37	KTN-R-05	JKS-05	JJN-05	FNQ-R-5	KTK-R-5	LP-CC-5
0.55-1.1	KTN-R-10	JKS-10	JJN-10	FNQ-R-10	KTK-R-10	LP-CC-10
1.5	KTN-R-15	JKS-15	JJN-15	FNQ-R-15	KTK-R-15	LP-CC-15
2.2	KTN-R-20	JKS-20	JJN-20	FNQ-R-20	KTK-R-20	LP-CC-20
3.0	KTN-R-25	JKS-25	JJN-25	FNQ-R-25	KTK-R-25	LP-CC-25
3.7	KTN-R-30	JKS-30	JJN-30	FNQ-R-30	KTK-R-30	LP-CC-30
5.5	KTN-R-50	KS-50	JJN-50	-	-	-
7.5	KTN-R-60	JKS-60	JJN-60	-	-	-
11	KTN-R-80	JKS-80	JJN-80	-	-	-
15-18.5	KTN-R-125	JKS-125	JJN-125	-	-	-
22	KTN-R-150	JKS-150	JJN-150	-	-	-
30	KTN-R-200	JKS-200	JJN-200	-	-	-
37	KTN-R-250	JKS-250	JJN-250	-	-	-

Table 9.7 200-240 V, Enclosure Types A, B and C

	Recommended max. fuse			
Power [kW]	**SIBA Type RK1**	**Littel fuse Type RK1**	**Ferraz-Shawmut Type CC**	**Ferraz-Shawmut Type RK1 3)**
0.25-0.37	5017906-005	KLN-R-05	ATM-R-05	A2K-05-R
0.55-1.1	5017906-010	KLN-R-10	ATM-R-10	A2K-10-R
1.5	5017906-016	KLN-R-15	ATM-R-15	A2K-15-R
2.2	5017906-020	KLN-R-20	ATM-R-20	A2K-20-R
3.0	5017906-025	KLN-R-25	ATM-R-25	A2K-25-R
3.7	5012406-032	KLN-R-30	ATM-R-30	A2K-30-R
5.5	5014006-050	KLN-R-50	-	A2K-50-R
7.5	5014006-063	KLN-R-60	-	A2K-60-R
11	5014006-080	KLN-R-80	-	A2K-80-R
15-18.5	2028220-125	KLN-R-125	-	A2K-125-R
22	2028220-150	KLN-R-150	-	A2K-150-R
30	2028220-200	KLN-R-200	-	A2K-200-R
37	2028220-250	KLN-R-250	-	A2K-250-R

Table 9.8 200-240 V, Enclosure Types A, B and C

	Recommended max. fuse			
Power [kW]	Bussmann Type JFHR2[2)]	Littel fuse JFHR2	Ferraz-Shawmut JFHR2[4)]	Ferraz-Shawmut J
0.25-0.37	FWX-5	-	-	HSJ-6
0.55-1.1	FWX-10	-	-	HSJ-10
1.5	FWX-15	-	-	HSJ-15
2.2	FWX-20	-	-	HSJ-20
3.0	FWX-25	-	-	HSJ-25
3.7	FWX-30	-	-	HSJ-30
5.5	FWX-50	-	-	HSJ-50
7.5	FWX-60	-	-	HSJ-60
11	FWX-80	-	-	HSJ-80
15-18.5	FWX-125	-	-	HSJ-125
22	FWX-150	L25S-150	A25X-150	HSJ-150
30	FWX-200	L25S-200	A25X-200	HSJ-200
37	FWX-250	L25S-250	A25X-250	HSJ-250

Table 9.9 200-240 V, Enclosure Types A, B and C

[1)] KTS-fuses from Bussmann may substitute KTN for 240 V frequency converters.

[2)] FWH-fuses from Bussmann may substitute FWX for 240 V frequency converters.

[3)] A6KR fuses from FERRAZ SHAWMUT may substitute A2KR for 240 V frequency converters.

[4)] A50X fuses from FERRAZ SHAWMUT may substitute A25X for 240 V frequency converters.

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	Recommended max. fuse					
Power [kW]	Bussmann Type RK1	Bussmann Type J	Bussmann Type T	Bussmann Type CC	Bussmann Type CC	Bussmann Type CC
0.37-1.1	KTS-R-6	JKS-6	JJS-6	FNQ-R-6	KTK-R-6	LP-CC-6
1.5-2.2	KTS-R-10	JKS-10	JJS-10	FNQ-R-10	KTK-R-10	LP-CC-10
3	KTS-R-15	JKS-15	JJS-15	FNQ-R-15	KTK-R-15	LP-CC-15
4	KTS-R-20	JKS-20	JJS-20	FNQ-R-20	KTK-R-20	LP-CC-20
5.5	KTS-R-25	JKS-25	JJS-25	FNQ-R-25	KTK-R-25	LP-CC-25
7.5	KTS-R-30	JKS-30	JJS-30	FNQ-R-30	KTK-R-30	LP-CC-30
11	KTS-R-40	JKS-40	JJS-40	-	-	-
15	KTS-R-50	JKS-50	JJS-50	-	-	-
18	KTS-R-60	JKS-60	JJS-60	-	-	-
22	KTS-R-80	JKS-80	JJS-80	-	-	-
30	KTS-R-100	JKS-100	JJS-100	-	-	-
37	KTS-R-125	JKS-125	JJS-125	-	-	-
45	KTS-R-150	JKS-150	JJS-150	-	-	-
55	KTS-R-200	JKS-200	JJS-200	-	-	-
75	KTS-R-250	JKS-250	JJS-250	-	-	-

Table 9.10 380-500 V, Enclosure Types A, B and C

	Recommended max. fuse			
Power [kW]	SIBA Type RK1	Littel fuse Type RK1	Ferraz-Shawmut Type CC	Ferraz-Shawmut Type RK1
0.37-1.1	5017906-006	KLS-R-6	ATM-R-6	A6K-6-R
1.5-2.2	5017906-010	KLS-R-10	ATM-R-10	A6K-10-R
3	5017906-016	KLS-R-15	ATM-R-15	A6K-15-R
4	5017906-020	KLS-R-20	ATM-R-20	A6K-20-R
5.5	5017906-025	KLS-R-25	ATM-R-25	A6K-25-R
7.5	5012406-032	KLS-R-30	ATM-R-30	A6K-30-R
11	5014006-040	KLS-R-40	-	A6K-40-R
15	5014006-050	KLS-R-50	-	A6K-50-R
18	5014006-063	KLS-R-60	-	A6K-60-R
22	2028220-100	KLS-R-80	-	A6K-80-R
30	2028220-125	KLS-R-100	-	A6K-100-R
37	2028220-125	KLS-R-125	-	A6K-125-R
45	2028220-160	KLS-R-150	-	A6K-150-R
55	2028220-200	KLS-R-200	-	A6K-200-R
75	2028220-250	KLS-R-250	-	A6K-250-R

Table 9.11 380-500 V, Enclosure Types A, B and C

	Recommended max. fuse			
Power [kW]	Bussmann JFHR2	Ferraz- Shawmut J	Ferraz- Shawmut JFHR2[1)]	Littel fuse JFHR2
0.37-1.1	FWH-6	HSJ-6	-	-
1.5-2.2	FWH-10	HSJ-10	-	-
3	FWH-15	HSJ-15	-	-
4	FWH-20	HSJ-20	-	-
5.5	FWH-25	HSJ-25	-	-
7.5	FWH-30	HSJ-30	-	-
11	FWH-40	HSJ-40	-	-
15	FWH-50	HSJ-50	-	-
18	FWH-60	HSJ-60	-	-
22	FWH-80	HSJ-80	-	-
30	FWH-100	HSJ-100	-	-
37	FWH-125	HSJ-125	-	-
45	FWH-150	HSJ-150	-	-
55	FWH-200	HSJ-200	A50-P-225	L50-S-225
75	FWH-250	HSJ-250	A50-P-250	L50-S-250

Table 9.12 380-500 V, Enclosure Types A, B and C

[1)] *Ferraz-Shawmut A50QS fuses may substitute for A50P fuses.*

9

	Recommended max. fuse					
Power [kW]	Bussmann Type RK1	Bussmann Type J	Bussmann Type T	Bussmann Type CC	Bussmann Type CC	Bussmann Type CC
0.75-1.1	KTS-R-5	JKS-5	JJS-6	FNQ-R-5	KTK-R-5	LP-CC-5
1.5-2.2	KTS-R-10	JKS-10	JJS-10	FNQ-R-10	KTK-R-10	LP-CC-10
3	KTS-R15	JKS-15	JJS-15	FNQ-R-15	KTK-R-15	LP-CC-15
4	KTS-R20	JKS-20	JJS-20	FNQ-R-20	KTK-R-20	LP-CC-20
5.5	KTS-R-25	JKS-25	JJS-25	FNQ-R-25	KTK-R-25	LP-CC-25
7.5	KTS-R-30	JKS-30	JJS-30	FNQ-R-30	KTK-R-30	LP-CC-30
11	KTS-R-35	JKS-35	JJS-35	-	-	-
15	KTS-R-45	JKS-45	JJS-45	-	-	-
18	KTS-R-50	JKS-50	JJS-50	-	-	-
22	KTS-R-60	JKS-60	JJS-60	-	-	-
30	KTS-R-80	JKS-80	JJS-80	-	-	-
37	KTS-R-100	JKS-100	JJS-100	-	-	-
45	KTS-R-125	JKS-125	JJS-125	-	-	-
55	KTS-R-150	JKS-150	JJS-150	-	-	-
75	KTS-R-175	JKS-175	JJS-175	-	-	-

Table 9.13 525-600 V, Enclosure Types A, B and C

	Recommended max. fuse			
Power [kW]	SIBA Type RK1	Littel fuse Type RK1	Ferraz-Shawmut Type RK1	Ferraz-Shawmut J
0.75-1.1	5017906-005	KLS-R-005	A6K-5-R	HSJ-6
1.5-2.2	5017906-010	KLS-R-010	A6K-10-R	HSJ-10
3	5017906-016	KLS-R-015	A6K-15-R	HSJ-15
4	5017906-020	KLS-R-020	A6K-20-R	HSJ-20
5.5	5017906-025	KLS-R-025	A6K-25-R	HSJ-25
7.5	5017906-030	KLS-R-030	A6K-30-R	HSJ-30
11	5014006-040	KLS-R-035	A6K-35-R	HSJ-35
15	5014006-050	KLS-R-045	A6K-45-R	HSJ-45
18	5014006-050	KLS-R-050	A6K-50-R	HSJ-50
22	5014006-063	KLS-R-060	A6K-60-R	HSJ-60
30	5014006-080	KLS-R-075	A6K-80-R	HSJ-80
37	5014006-100	KLS-R-100	A6K-100-R	HSJ-100
45	2028220-125	KLS-R-125	A6K-125-R	HSJ-125
55	2028220-150	KLS-R-150	A6K-150-R	HSJ-150
75	2028220-200	KLS-R-175	A6K-175-R	HSJ-175

Table 9.14 525-600 V, Enclosure Types A, B and C

9

	Recommended max. fuse					
Power [kW]	Bussmann Type RK1	Bussmann Type J	Bussmann Type T	Bussmann Type CC	Bussmann Type CC	Bussmann Type CC
[kW]						
1.1	KTS-R-5	JKS-5	JJS-6	FNQ-R-5	KTK-R-5	LP-CC-5
1.5-2.2	KTS-R-10	JKS-10	JJS-10	FNQ-R-10	KTK-R-10	LP-CC-10
3	KTS-R15	JKS-15	JJS-15	FNQ-R-15	KTK-R-15	LP-CC-15
4	KTS-R20	JKS-20	JJS-20	FNQ-R-20	KTK-R-20	LP-CC-20
5.5	KTS-R-25	JKS-25	JJS-25	FNQ-R-25	KTK-R-25	LP-CC-25
7.5	KTS-R-30	JKS-30	JJS-30	FNQ-R-30	KTK-R-30	LP-CC-30
11	KTS-R-35	JKS-35	JJS-35	-	-	-
15	KTS-R-45	JKS-45	JJS-45	-	-	-
18	KTS-R-50	JKS-50	JJS-50	-	-	-
22	KTS-R-60	JKS-60	JJS-60	-	-	-
30	KTS-R-80	JKS-80	JJS-80	-	-	-
37	KTS-R-100	JKS-100	JJS-100	-	-	-
45	KTS-R-125	JKS-125	JJS-125	-	-	-
55	KTS-R-150	JKS-150	JJS-150	-	-	-
75	KTS-R-175	JKS-175	JJS-175	-	-	-

Table 9.15 525-690 V, Enclosure Types A, B and C

	Recommended max. fuse							
Power [kW]	Max. prefuse	Bussmann E52273 RK1/JDDZ	Bussmann E4273 J/JDDZ	Bussmann E4273 T/JDDZ	SIBA E180276 RK1/JDDZ	LittelFuse E81895 RK1/JDDZ	Ferraz-Shawmut E163267/E2137 RK1/JDDZ	Ferraz-Shawmut E2137 J/HSJ
11	30 A	KTS-R-30	JKS-30	JKJS-30	5017906-030	KLS-R-030	A6K-30-R	HST-30
15-18.5	45 A	KTS-R-45	JKS-45	JJS-45	5014006-050	KLS-R-045	A6K-45-R	HST-45
22	60 A	KTS-R-60	JKS-60	JJS-60	5014006-063	KLS-R-060	A6K-60-R	HST-60
30	80 A	KTS-R-80	JKS-80	JJS-80	5014006-080	KLS-R-075	A6K-80-R	HST-80
37	90 A	KTS-R-90	JKS-90	JJS-90	5014006-100	KLS-R-090	A6K-90-R	HST-90
45	100 A	KTS-R-100	JKS-100	JJS-100	5014006-100	KLS-R-100	A6K-100-R	HST-100
55	125 A	KTS-R-125	JKS-125	JJS-125	2028220-125	KLS-150	A6K-125-R	HST-125
75	150 A	KTS-R-150	JKS-150	JJS-150	2028220-150	KLS-175	A6K-150-R	HST-150

Table 9.16 525-690 V,Enclosure Types B and C

9.4 Motor Connection

WARNING

INDUCED VOLTAGE

Induced voltage from output motor cables that run together can charge equipment capacitors even with the equipment turned off and locked out. Failure to run output motor cables separately or use screened cables could result in death or serious injury.

- **run output motor cables separately, or**
- **use screened cables**

Motor Connection

NOTICE

To comply with EMC emission specifications, screened/armoured cables are required. For more information, see *chapter 5.2.1 EMC Test Results* and *Illustration 3.3*.

See *chapter 6.2 General Specifications* for correct dimensioning of motor cable cross-section and length.

9

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 intercon-nected separately.

Table 9.17 Terminal Descriptions

[1] *Protected Ground Connection*

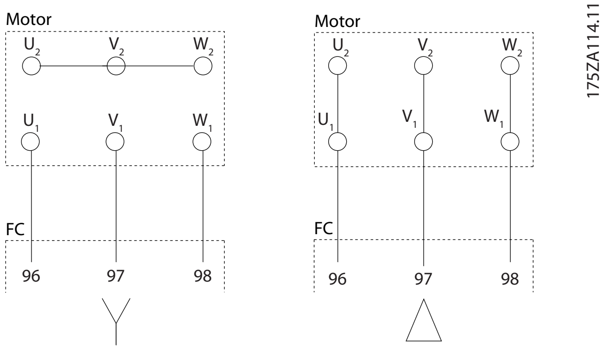


Illustration 9.29 Star and Delta Connections

NOTICE

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.

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.

NOTICE

Strip a piece of the motor cable to expose the screen behind the cable clamp, AND connect the ground connection to terminal 99.

Connect the motor cable screen to both the decoupling 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 in the frequency converter.
If it is necessary to split the screen to install a motor isolator or motor relay, the screen must be continued with the lowest possible HF impedance.

Cable-length and cross-section

The frequency converter has been tested with a given length of cable and a given cross-section of that cable. If the cross-section is increased, the cable capacitance - and thus the leakage current - may increase, and the cable length must be reduced correspondingly. Keep the motor cable as short as possible to reduce the noise level and leakage currents.

Switching frequency

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

1. Fasten decoupling plate to the bottom of the frequency converter with screws and washers from the accessory bag.
2. Attach motor cable to terminals 96 (U), 97 (V), 98 (W).
3. Connect to ground connection (terminal 99) on decoupling plate with screws from the accessory bag.
4. Insert plug connectors 96 (U), 97 (V), 98 (W) (up to 7.5 kW) and motor cable to terminals labelled MOTOR.
5. Fasten screened cable to decoupling plate with screws and washers from the accessory bag.

All types of 3-phase asynchronous standard motors can be connected to the frequency converter. Normally, small motors are star-connected (230/400 V, Y). Large motors are normally delta-connected (400/690 V, Δ). Refer to the motor name plate for correct connection mode and voltage.

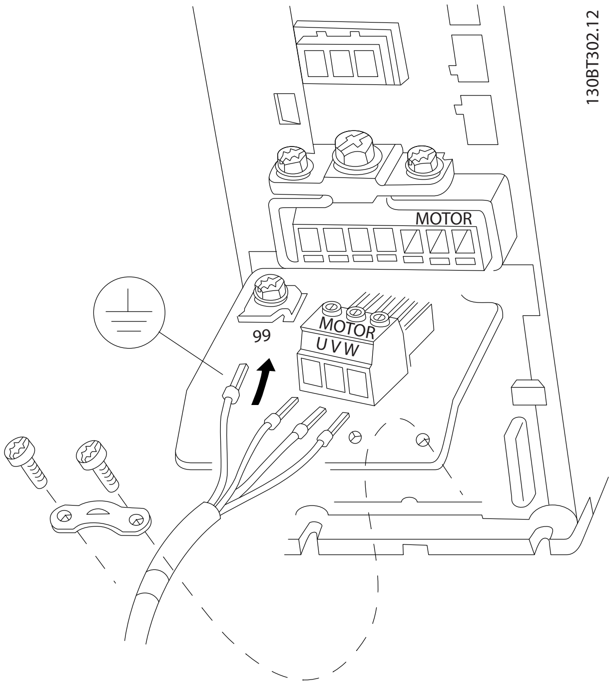


Illustration 9.30 Motor Connection for Enclosures A1, A2 and A3

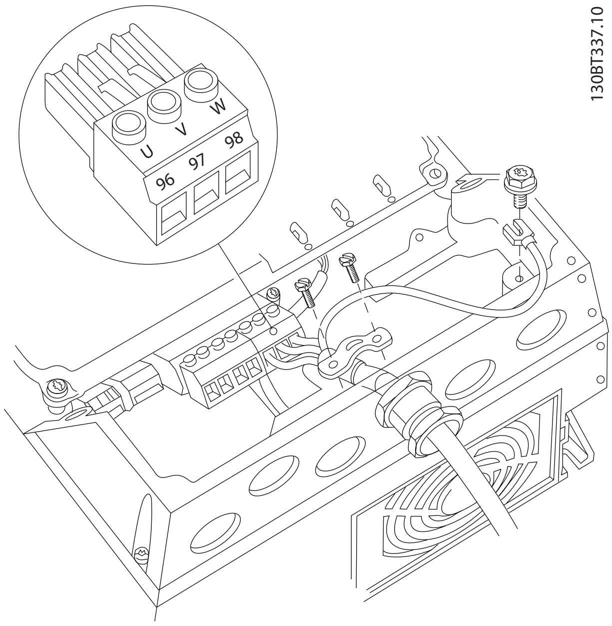


Illustration 9.31 Motor Connection for Enclosures A4/A5

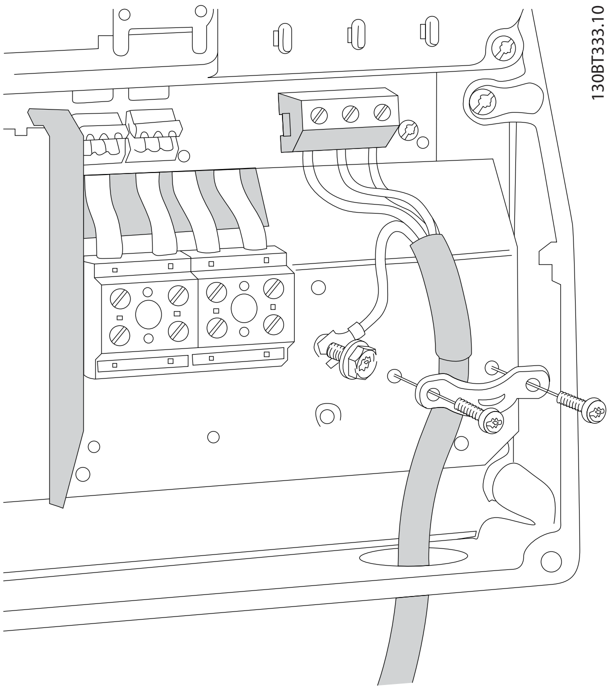


Illustration 9.32 Motor Connection for Enclosures B1 and B2

9

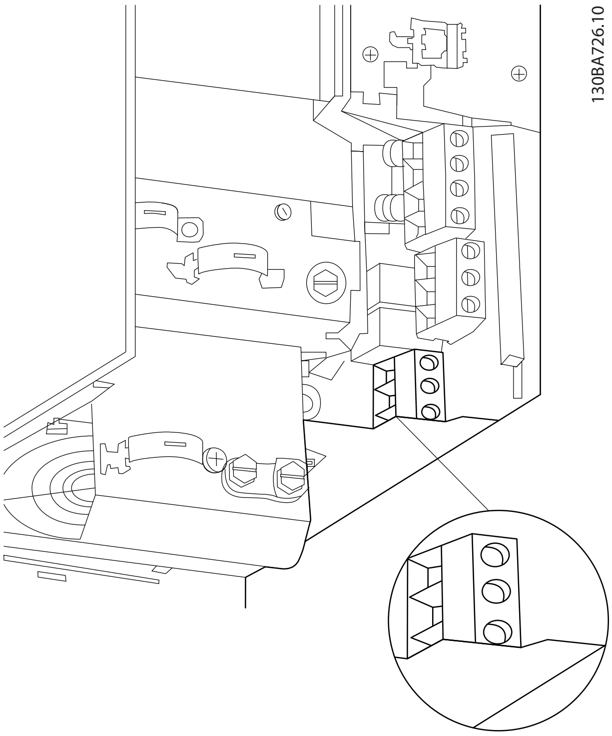


Illustration 9.33 Motor Connection for Enclosure B3

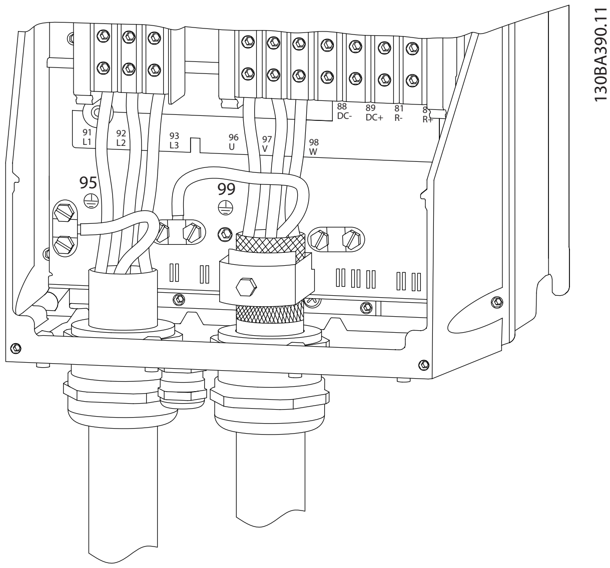


Illustration 9.35 Motor Connection Enclosures C1 and C2 (IP21/ NEMA Type 1 and IP55/66/NEMA Type 12)

9

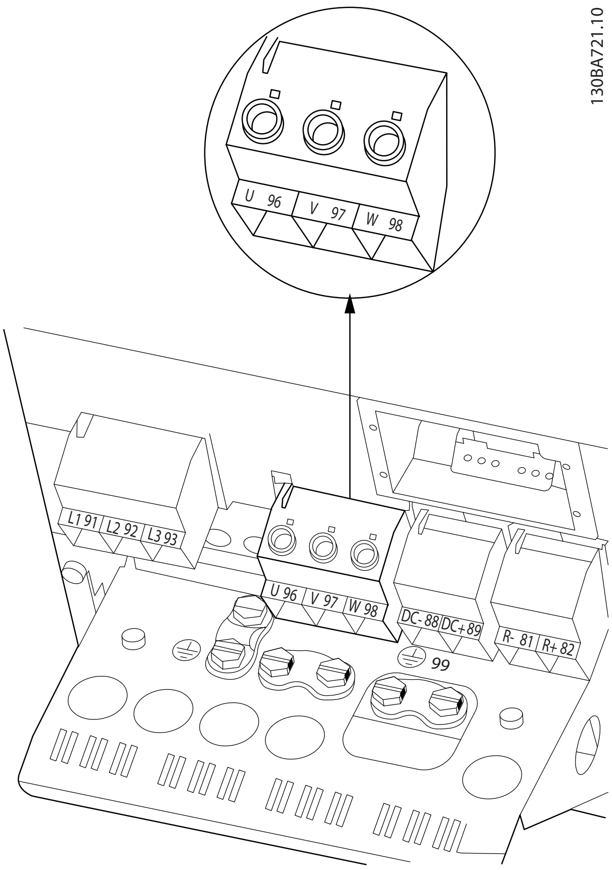


Illustration 9.34 Motor Connection for Enclosure B4

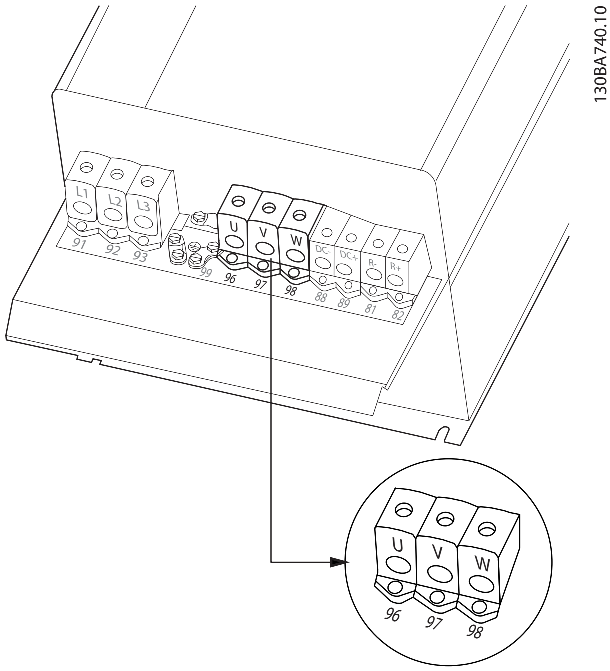


Illustration 9.36 Motor Connection for Enclosures C3 and C4

9.5 Earth Leakage Current Protection

Follow national and local codes regarding protective earthing of equipment with a leakage current > 3,5 mA. The protective earth connection must have a cross section of minimum 10 mm² or consist of 2 separate wires each with the same cross section as the phase wires. Frequency converter technology implies high frequency switching at high power. This generates a leakage current in the earth connection.

The earth leakage current is made up of several contributions and depends on various system configurations including RFI filtering, motor cable length, motor cable screening, and frequency converter power.

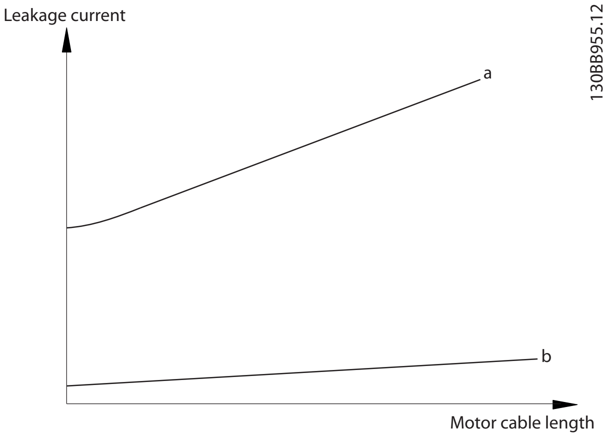


Illustration 9.37 Motor Cable Length and Power Size Influence on Leakage Current. Powersize a > Powersize b

The leakage current also depends on the line distortion.

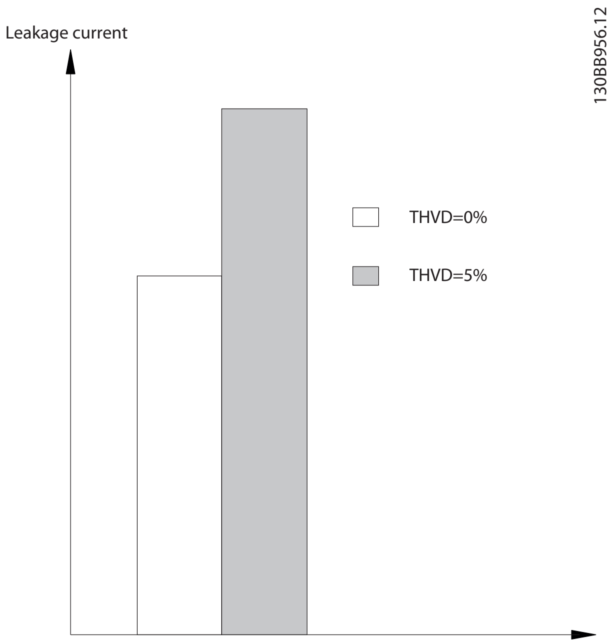


Illustration 9.38 Line Distortion Influences Leakage Current

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

- Ground wire (terminal 95) of at least 10 mm^2
- 2 separate 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 as they are capable of detecting AC and DC currents
- Use RCDs with a delay to prevent faults due to transient earth currents
- Dimension RCDs according to the system configuration and environmental considerations

The leakage current includes several frequencies originating from both the mains frequency and the switching frequency. Whether the switching frequency is detected depends on the type of RCD used.

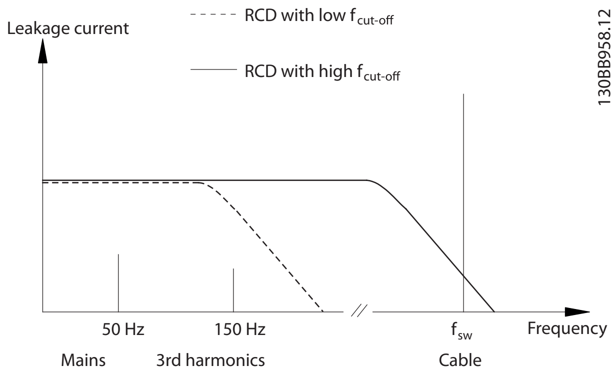


Illustration 9.39 Main Contributions to Leakage Current

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

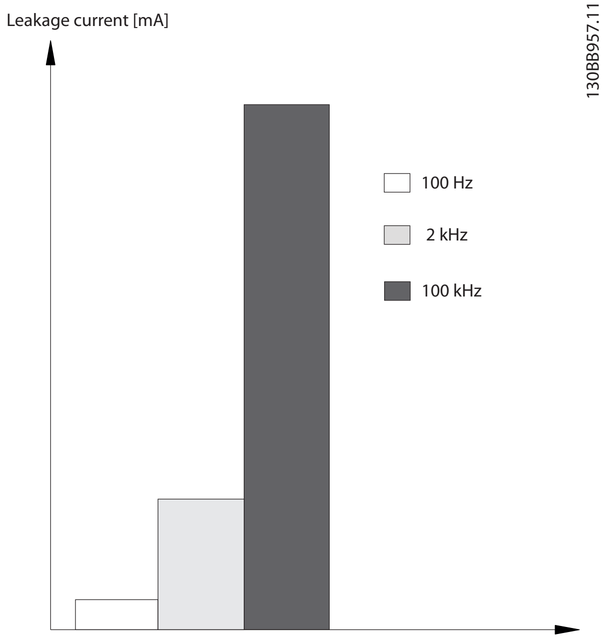


Illustration 9.40 The Influence of the Cut-off Frequency of the RCD on what Is Responded to/measured

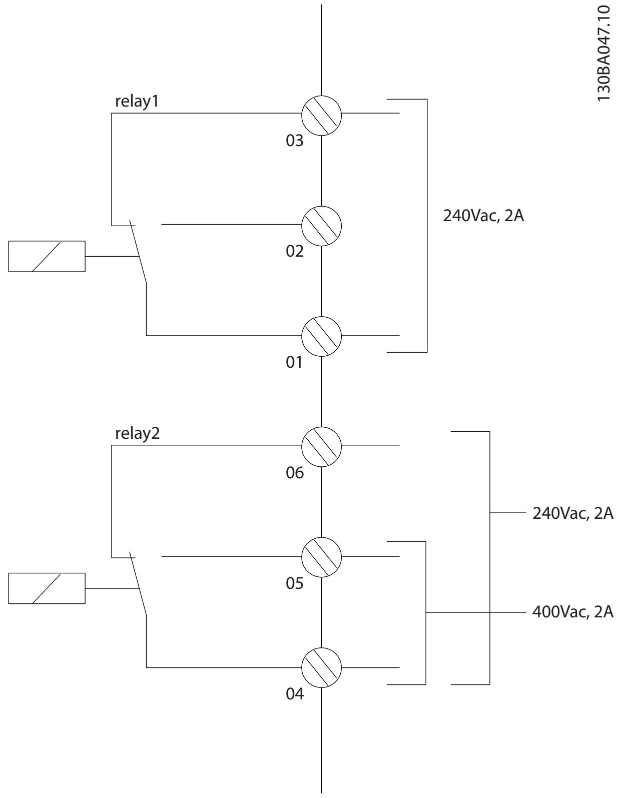


Illustration 9.41 Relay Outputs 1 and 2

9.6 Additional Connections

9.6.1 Relay

Relay 1

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

Relay 2 (Not FC 301)

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

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 Relay Option Module MCB 105.

To set relay output, see parameter group *5-4* Relays*.

No.	01-02	make (normally open)
	01-03	break (normally closed)
	04-05	make (normally open)
	04-06	break (normally closed)

Table 9.18 Description of Relays

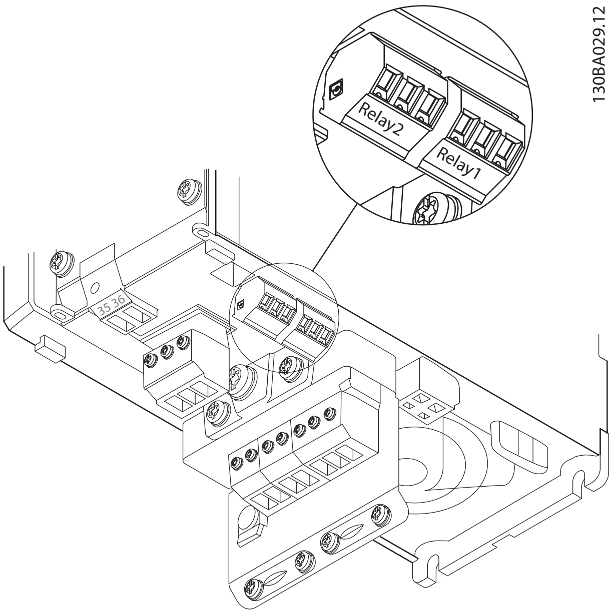


Illustration 9.42 Terminals for Relay Connection (Enclosure Types A1, A2 and A3).

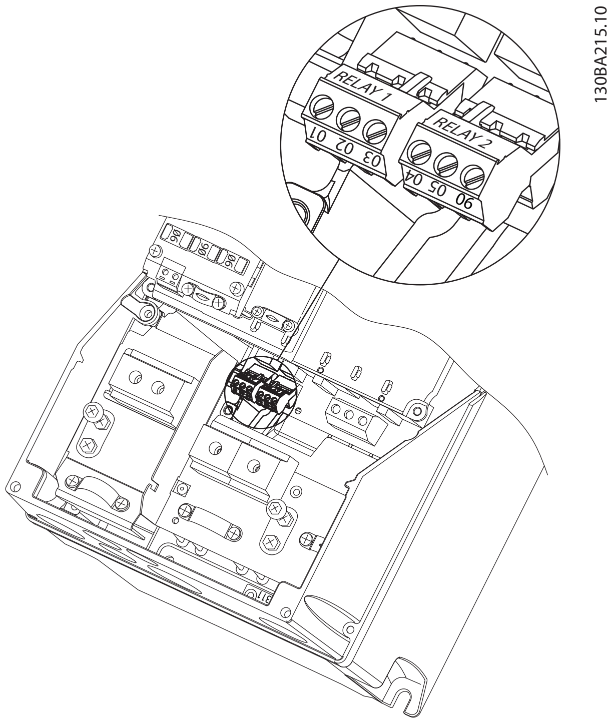


Illustration 9.44 Terminals for Relay Connection (Enclosure Types A5, B1 and B2).

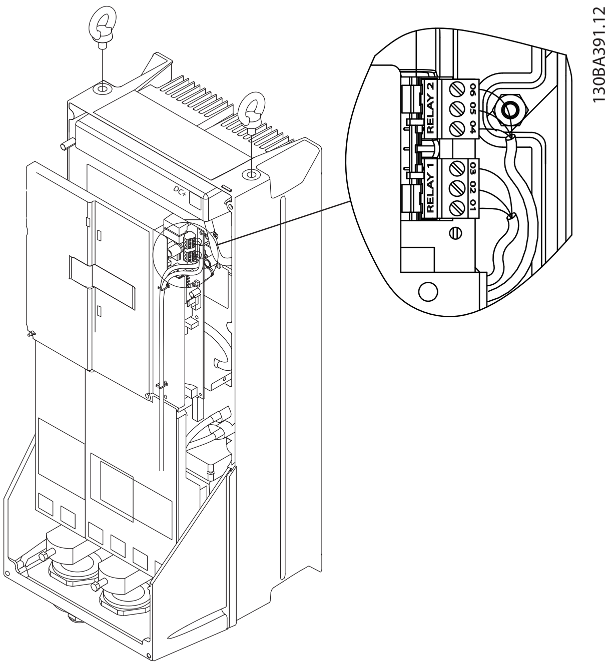


Illustration 9.43 Terminals for Relay Connection (Enclosure Types C1 and C2).

9.6.2 Disconnectors and Contactors

Assembling of IP55/NEMA Type 12 (enclosure type A5) with mains disconnector.

Mains switch is placed on left side on enclosure types B1, B2, C1 and C2. Mains switch on A5 enclosures is placed on right side.

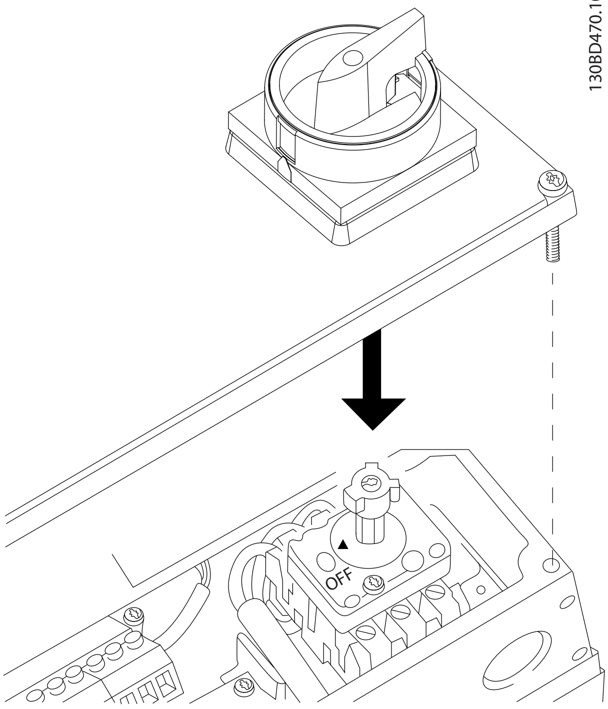
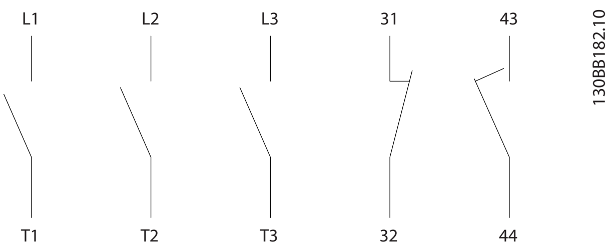
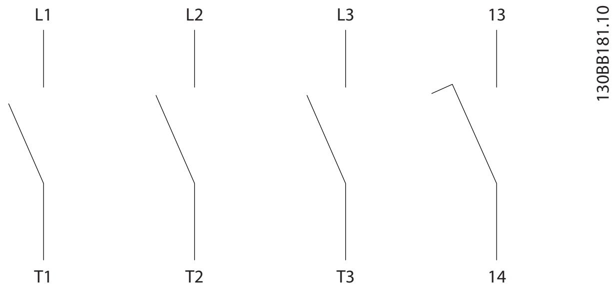


Illustration 9.45 Location of Mains Switch



Enclosure type	Type
A4/A5	Kraus&Naimer KG20A T303
B1	Kraus&Naimer KG64 T303
B2	Kraus&Naimer KG64 T303

Illustration 9.46 Terminal Connections for A4, A5, B1, B2



Enclosure type	Type
C1	Kraus&Naimer KG100 T303
C1	Kraus&Naimer KG105 T303
C2	Kraus&Naimer KG160 T303

Illustration 9.47 Terminal Connections for C1, C2

9.6.3 Load Sharing

The DC bus terminal is used for DC back-up, with the intermediate circuit being supplied from an external source. It uses terminals 88 and 89.

The connection cable must be screened and the max. 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.

⚠CAUTION

Note that voltages up to 1099 V DC may occur on the terminals.
Load Sharing calls for extra equipment and safety considerations.

⚠CAUTION

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

9.6.4 Brake Resistor

The connection cable to the brake resistor must be screened and the max. length from the frequency converter to the DC bar is limited to 25 m (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.

Terminals 81 and 82 are brake resistor terminals.

NOTICE

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

⚠CAUTION

Note that voltages up to 1099 V DC, depending on the supply voltage, may occur on the terminals.

9.6.5 PC Software

The PC is connected via a standard (host/device) USB cable, or via the RS-485 interface.

USB is a serial bus utilising 4 shielded wires with ground pin 4 connected to the shield in the PC USB port. By 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 ground potential difference caused by not following the recommendations described in *AC Mains Connection* in the *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 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 ground potential difference, but does not eliminate all potential differences due to the ground and shield connected in the PC USB port.

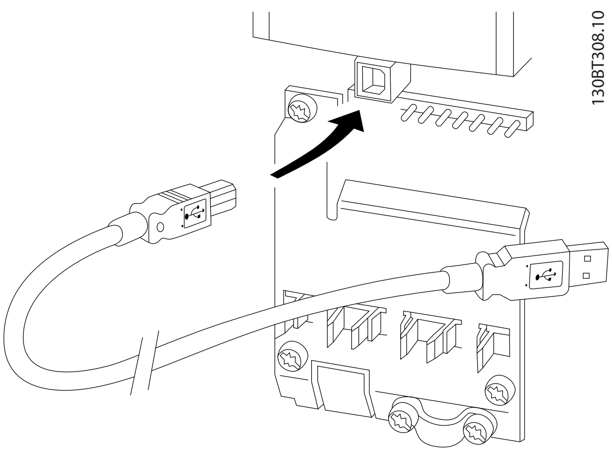


Illustration 9.48 USB Connection

9.6.5.1 MCT 10

To control the frequency converter from a PC, install the MCT 10 Set-up 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. Select *copy*.
5. Select the *project* section.
6. Select *paste*.
7. Select *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. Select *Open* – stored files are shown.
4. Open the appropriate file.
5. Select *Write to drive*.

All parameters are now transferred to the frequency converter.

9.6.5.2 MCT 31

The MCT 31 harmonic calculation PC tool enables easy estimation of the harmonic distortion in a given application. Both the harmonic distortion of Danfoss frequency converters as well as non-Danfoss frequency converters with additional harmonic reduction devices, such as Danfoss AHF filters and 12-18-pulse rectifiers, can be calculated.

9.6.5.3 Harmonic Calculation Software (HCS)

HCS is an advanced version of the harmonic calculation tool. The calculated results are compared to relevant norms and can be printed afterwards.

9.7 Additional Motor Information

9.7.1 Motor Cable

All types of 3-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.

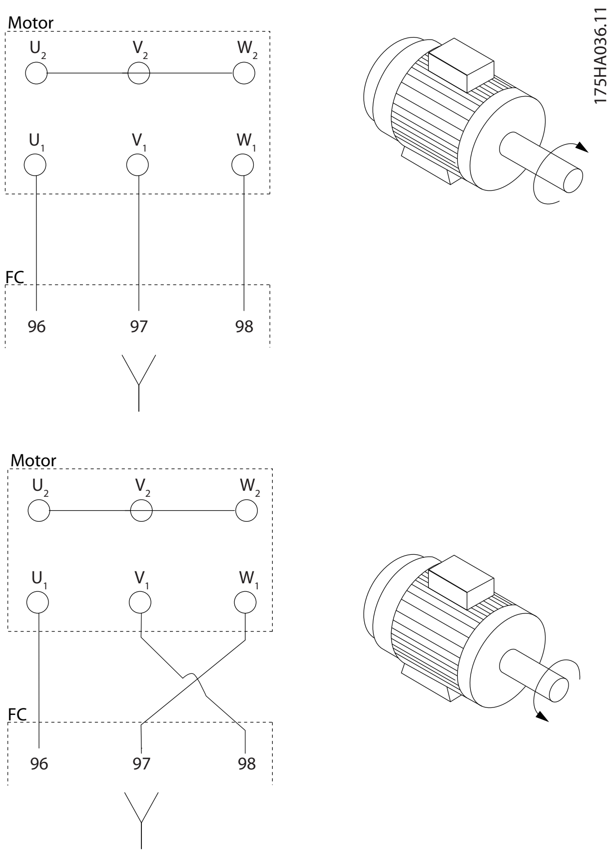


Illustration 9.49 Terminal Connection for Clockwise and Counter-clockwise Rotation

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

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

9.7.2 Connection of Multiple Motors

NOTICE

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 frequency converter can control several parallel-connected motors. When using parallel motor connection observe the following:

- VCC+ 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.
- Do not use common joint connection for long cable lengths, see *Illustration 9.51*.
- The total motor cable length specified in *Table 5.2*, is valid as long as the parallel cables are kept short (less than 10 m each), see *Illustration 9.53* and *Illustration 9.54*.
- Consider voltage drop across the motor cable, see *Illustration 9.54*.
- For long parallel cables, use LC filter, see *Illustration 9.54*.
- For long cables without parallel connection, see *Illustration 9.55*.

NOTICE

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 *[0] U/f*.

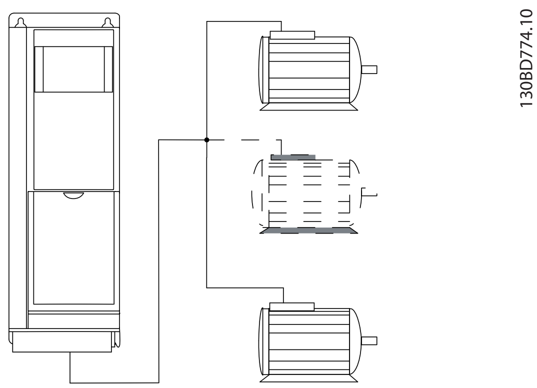


Illustration 9.50 Common Joint Connection for Short Cable Lengths

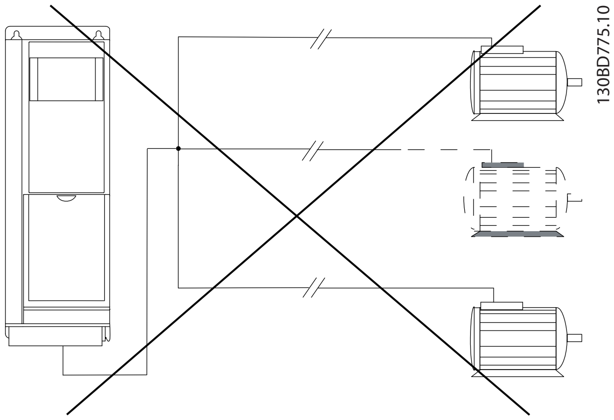


Illustration 9.51 Common Joint Connection for Long Cable Lengths

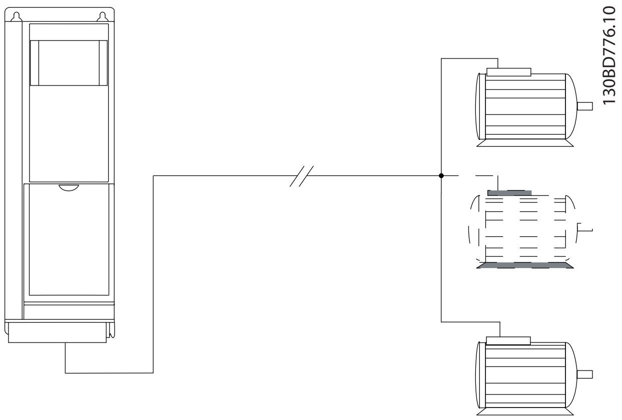


Illustration 9.52 Parallel Cables without Load

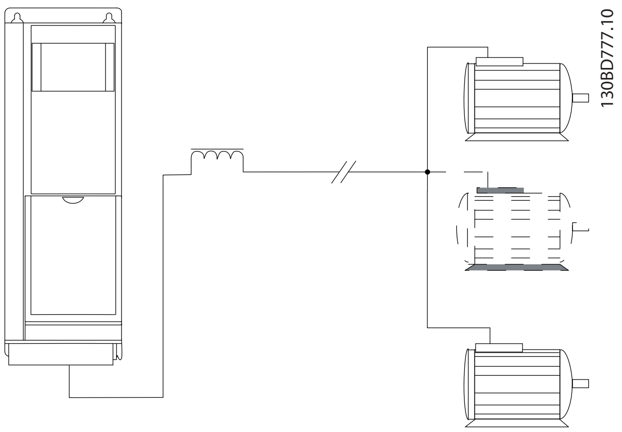


Illustration 9.53 Parallel Cables with Load

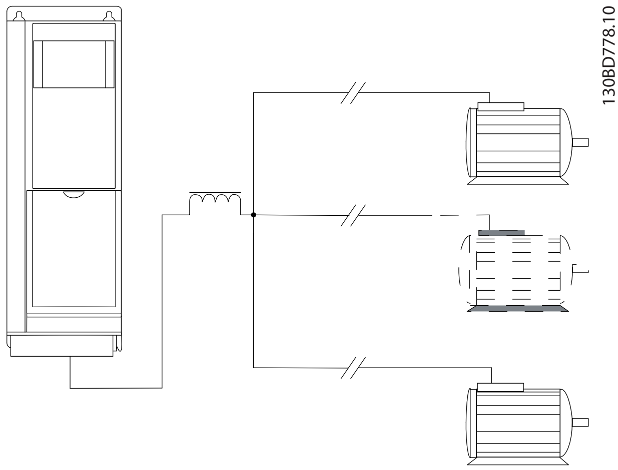


Illustration 9.54 LC Filter for Long Parallel Cables

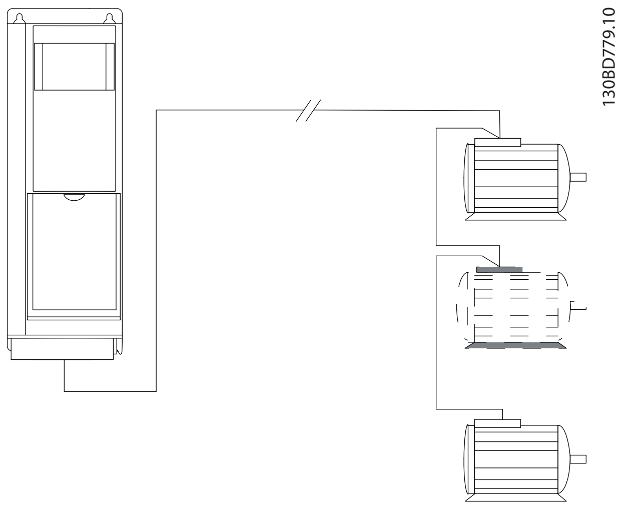


Illustration 9.55 Long Cables in Series Connection

9

Enclosure types	Power Size [kW]	Voltage [V]	1 cable [m]	2 cables [m]	3 cables [m]	4 cables [m]
A1, A2, A4, A5	0.37-0.75	400	150	45	8	6
		500	150	7	4	3
A2, A4, A5	1.1-1.5	400	150	45	20	8
		500	150	45	5	4
A2, A4, A5	2.2-4	400	150	45	20	11
		500	150	45	20	6
A3, A4, A5	5.5-7.5	400	150	45	20	11
		500	150	45	20	11
B1, B2, B3, B4, C1, C2, C3, C4	11-75	400	150	75	50	37
		500	150	75	50	37
A3	1.1-7.5	525-690	100	50	33	25
B4	11-30	525-690	150	75	50	37
C3	37-45	525-690	150	75	50	37

Table 9.19 Max. Cable Length for Each Parallel Cable

9.8 Safety

9.8.1 High Voltage Test

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

WARNING

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

9.8.2 EMC Grounding

Proper EMC grounding practice

- Respect safety grounding.
- Keeping the ground connection as short as possible results in the best EMC performance.
- Wires with greater square have a lower impedance and better EMC grounding.
- In case where more devices with metal cabinets are used, mount them on common metal mounting plate to improve EMC performance.

NOTICE

If necessary, use washers for fastening bolts, e.g. in case of painted parts.

CAUTION

POTENTIAL HAZARD IN THE EVENT OF INTERNAL FAILURE

Risk of personal injury when the frequency converter is not properly closed.

- **Before applying power, ensure all safety covers are in place and securely fastened.**

9.8.3 ADN-compliant Installation

Units with ingress protection rating IP55 (NEMA 12) or higher prevent spark formation, and are classified as limited explosion risk electrical apparatus in accordance with the European Agreement concerning International Carriage of Dangerous Goods by Inland Waterways (ADN).

For units with ingress protection rating IP20/Chassis, IP21/NEMA 1, or IP54, prevent risk of spark formation as follows:

- Do not install a mains switch
- Ensure that *14-50 RFI Filter* is set to *[1] On*.
- Remove all relay plugs marked “RELAY”. See *Illustration 9.56*.
- Check which relay options are installed, if any. The only permitted relay option is Extended Relay Card MCB 113.

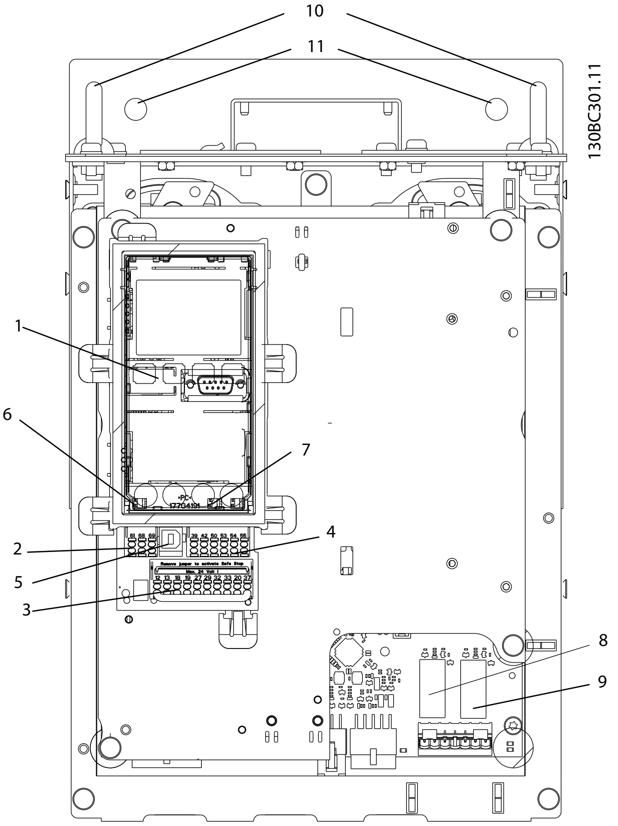


Illustration 9.56 Location of Relay Plugs, Pos. 8 and 9

Manufacturer declaration is available upon request.

10 Application Examples

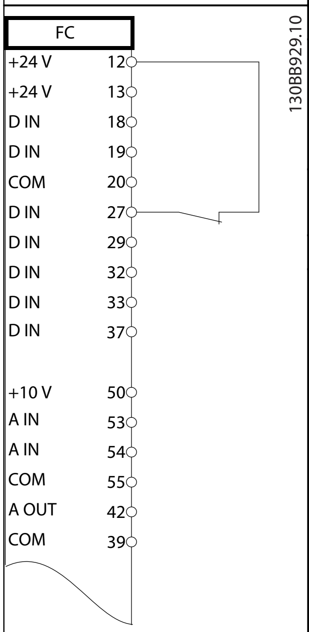
10.1 Commonly Used Applications

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 analog terminals A53 or A54 are required, these are also shown

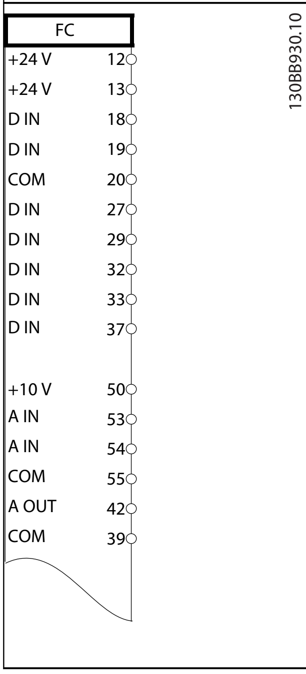
CAUTION

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



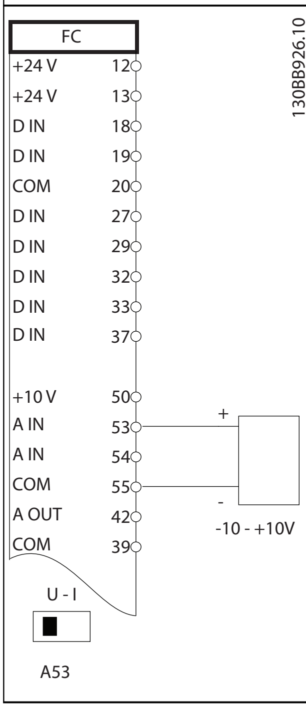
Parameters	
Function	**Setting**
1-29 Automatic Motor Adaptation (AMA)	[1] Enable complete AMA
5-12 Terminal 27 Digital Input	[2]* Coast inverse
*=Default Value	
Notes/comments: Parameter group *1–2* Motor Data* must be set according to motor	

Table 10.1 AMA with T27 Connected



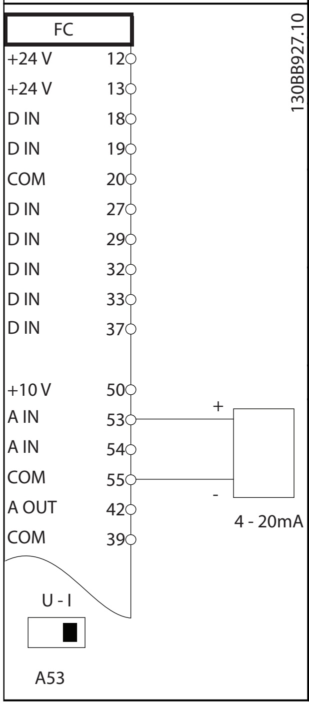
Parameters	
Function	**Setting**
1-29 Automatic Motor Adaptation (AMA)	[1] Enable complete AMA
5-12 Terminal 27 Digital Input	[0] No operation
*=Default Value	
Notes/comments: Parameter group *1–2* Motor Data* must be set according to motor	

Table 10.2 AMA without T27 Connected



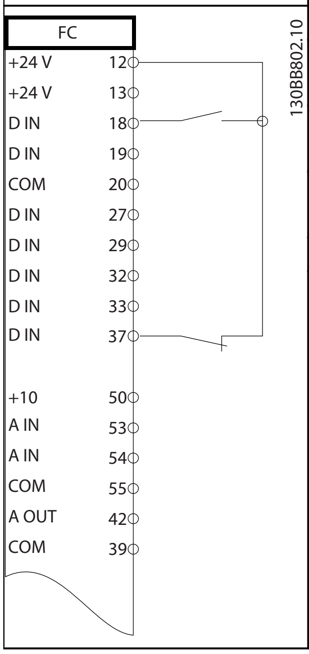
Parameters	
Function	**Setting**
6-10 Terminal 53 Low Voltage	0.07 V*
6-11 Terminal 53 High Voltage	10 V*
6-14 Terminal 53 Low Ref./Feedb. Value	0 RPM
6-15 Terminal 53 High Ref./Feedb. Value	1,500 RPM
*=Default Value	
Notes/comments:	

Table 10.3 Analog Speed Reference (Voltage)



Parameters	
Function	**Setting**
6-12 Terminal 53 Low Current	4 mA*
6-13 Terminal 53 High Current	20 mA*
6-14 Terminal 53 Low Ref./Feedb. Value	0 RPM
6-15 Terminal 53 High Ref./Feedb. Value	1,500 RPM
*=Default Value	
Notes/comments:	

Table 10.4 Analog 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 10.5 Start/Stop Command with Safe Torque Off

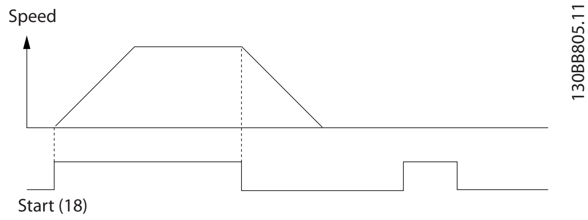
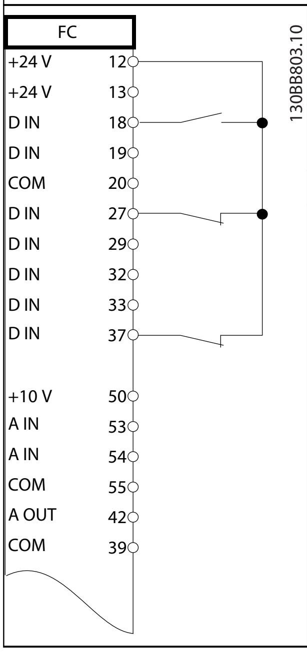


Illustration 10.1 Start/Stop with Safe Torque Off



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 10.6 Pulse Start/Stop

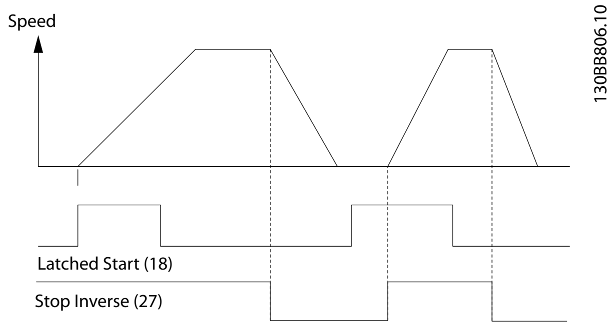


Illustration 10.2 Latched Start/Stop Inverse

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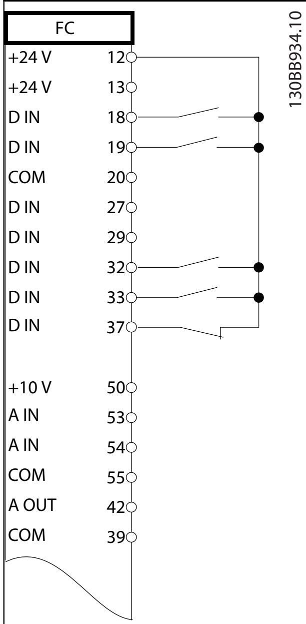
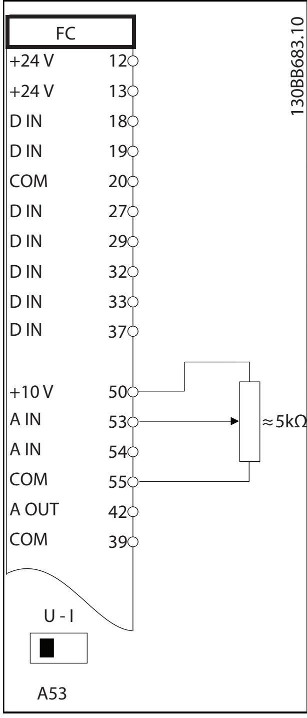


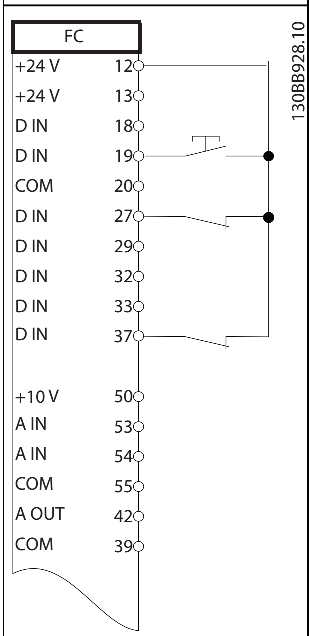
Parameters	
Function	**Setting**
5-10 Terminal 18 Digital Input	[8] Start
5-11 Terminal 19 Digital Input	[10] Reversing*
5-12 Terminal 27 Digital Input	[0] No operation
5-14 Terminal 32 Digital Input	[16] Preset ref bit 0
5-15 Terminal 33 Digital Input	[17] Preset ref bit 1
3-10 Preset Reference	
Preset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

Table 10.7 Start/Stop with Reversing and 4 Preset Speeds



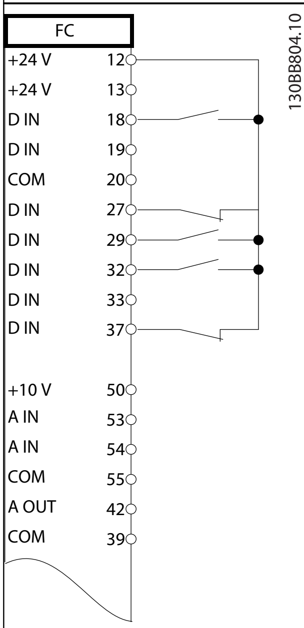
Parameters	
Function	**Setting**
6-10 Terminal 53 Low Voltage	0.07 V*
6-11 Terminal 53 High Voltage	10 V*
6-14 Terminal 53 Low Ref./Feedb. Value	0 RPM
6-15 Terminal 53 High Ref./Feedb. Value	1,500 RPM
*=Default Value	
Notes/comments:	

Table 10.9 Speed Reference (using a Manual Potentiometer)



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

Table 10.8 External Alarm Reset



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

Table 10.10 Speed Up/Down

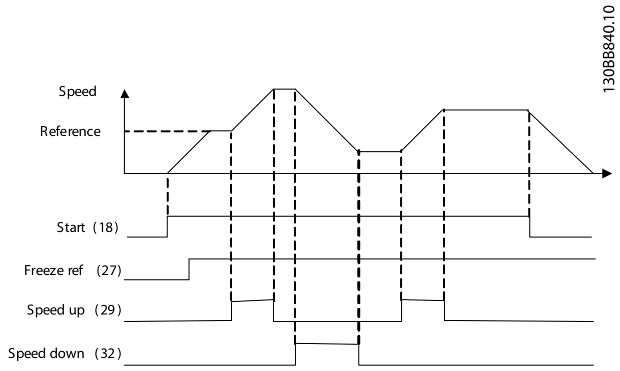
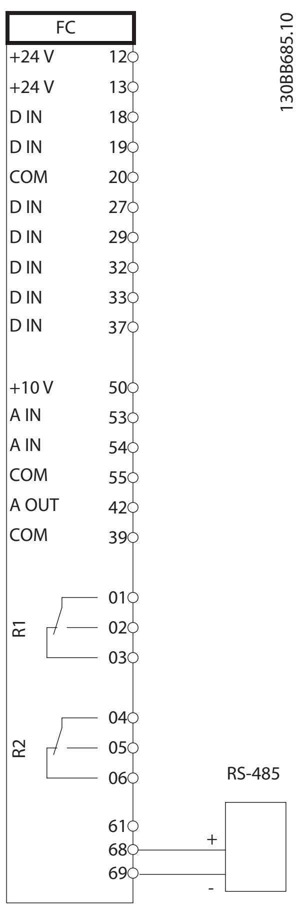


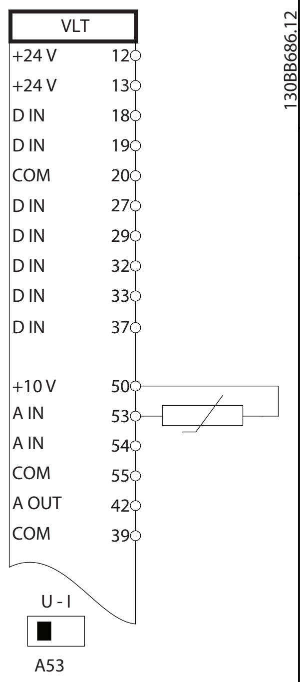
Illustration 10.3 Speed Up/Down



Parameters	
Function	**Setting**
8-30 Protocol	FC*
8-31 Address	1*
8-32 Baud Rate	9,600*
*=Default Value	

Notes/comments:
Select protocol, address, and Baud rate in the above mentioned parameters.

Table 10.11 RS-485 Network Connection



Parameters	
Function	**Setting**
1-90 Motor Thermal Protection	[2] Thermistor trip
1-93 Thermistor Source	[1] Analog input 53
*=Default Value	

Notes/comments:
If only a warning is desired, set *1-90 Motor Thermal Protection* to *[1] Thermistor warning.*

Table 10.12 Motor Thermistor

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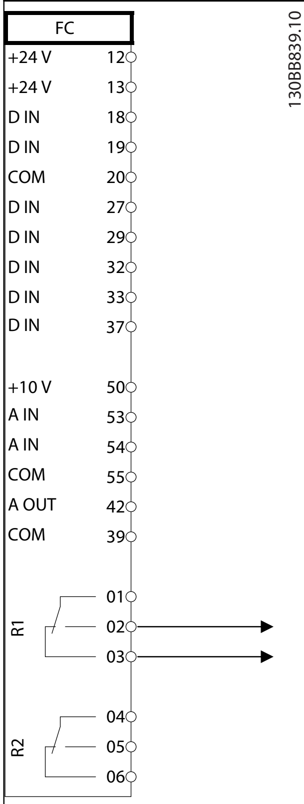
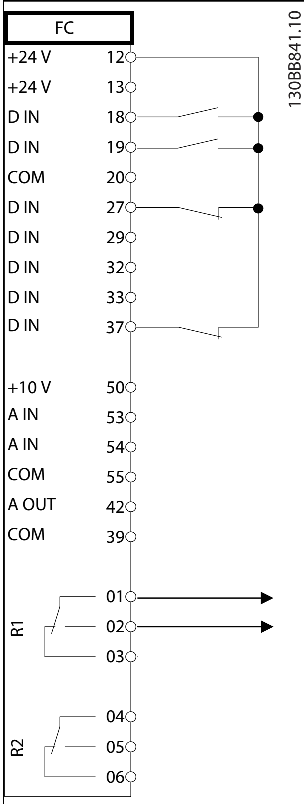


Parameters	
Function	Setting
4-30 Motor Feedback Loss Function	[1] Warning
4-31 Motor Feedback Speed Error	100 RPM
4-32 Motor Feedback Loss Timeout	5 s
7-00 Speed PID Feedback Source	[2] MCB 102
17-11 Resolution (PPR)	1024*
13-00 SL Controller Mode	[1] On
13-01 Start Event	[19] Warning
13-02 Stop Event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

Notes/comments:
If the limit in the feedback monitor is exceeded, Warning 90 is issued. The SLC monitors Warning 90 and in the case that Warning 90 becomes TRUE then relay 1 is triggered. External equipment may indicate that service is required. If the feedback error goes below the limit again within 5 s, the frequency converter continues and the warning disappears. But relay 1 is still triggered until [Reset] on the LCP.

Table 10.13 Using SLC to Set a Relay



Parameters	
Function	Setting
1-00 Configu- ration Mode	[0] Speed open loop
1-01 Motor Control Principle	[1] VVC+
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	$I_{m,n}$
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 10.14 Mechanical Brake Control (Open Loop)

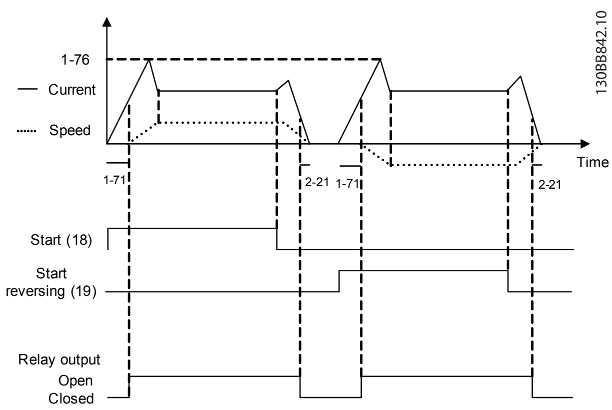


Illustration 10.4 Mechanical Brake Control (Open Loop)

10.1.1 Closed Loop Drive System

A frequency converter system consist usually of more elements such as

- Motor
- Gearbox
- Mechanical Brake
- Frequency converter
- Encoder as feed-back system
- Brake resistor for dynamic braking
- Transmission
- Load

Applications demanding mechanical brake control usually need a brake resistor.

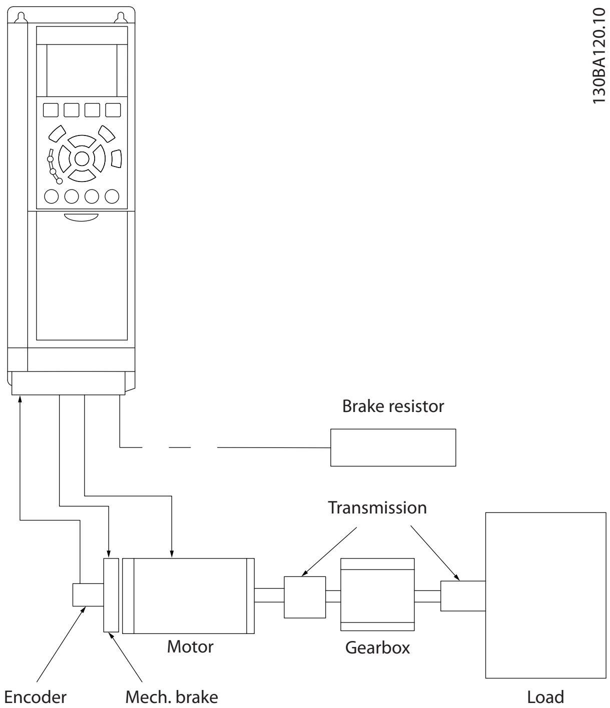


Illustration 10.5 Example of FC 302 Closed Loop Speed Control

10.1.2 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. Program terminal 27 to *[2] Coast, inverse* or *[3] Coast and Reset, inverse*, and program terminal 29 to *[1] Terminal mode 29 Output* and *[27] Torque limit & stop*.

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 *[27] Torque limit and stop*) is activated. The signal to terminal 27 changes from 'logic 1' to 'logic 0', and the motor starts to coast, thereby ensuring that the hoist stops even if the frequency converter itself cannot handle the required torque (i.e. due to excessive overload).

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

10

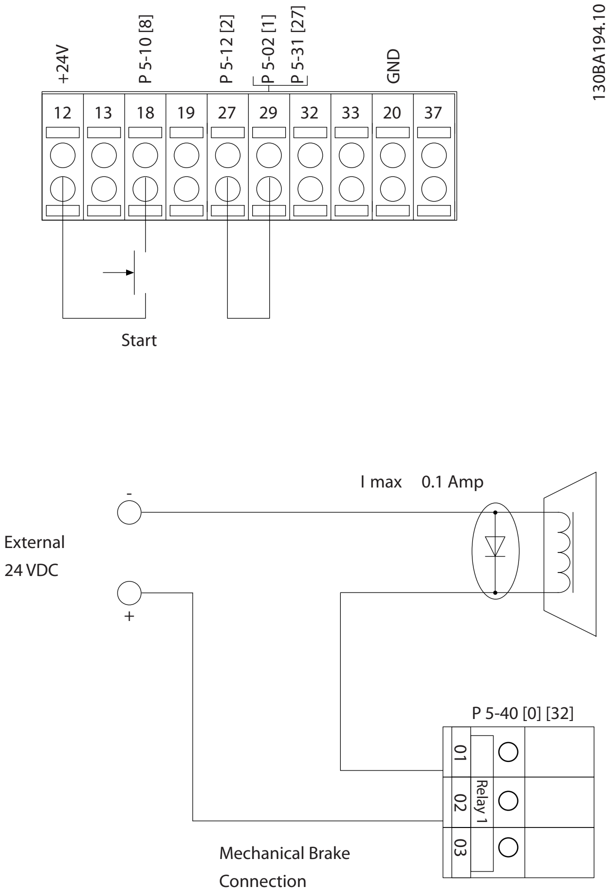


Illustration 10.6 External Electro-mechanical Brake

10.1.3 Programming of Speed Control

The required motor speed is set via a potentiometer connected to terminal 53. The speed range is 0 to 1500 RPM corresponding to 0 to 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.

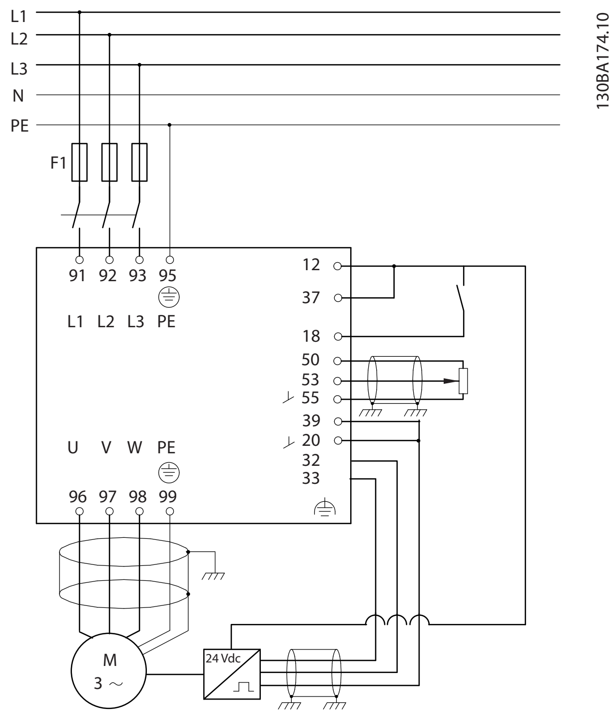


Illustration 10.7 Example - Speed Control Connections

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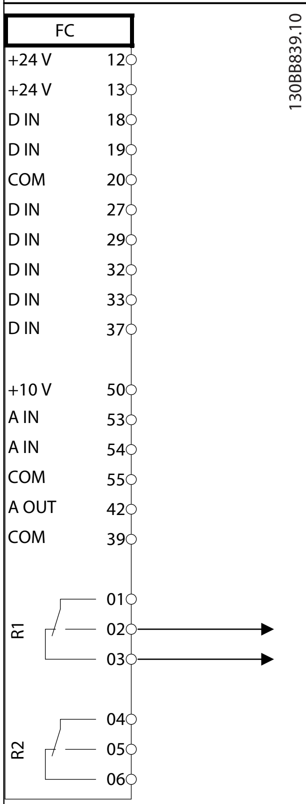
Application Example



Parameters	
Function	**Setting**
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:
Warning 90 will be issued when the feedback signal from the encoder does not correspond to the reference. 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.

Table 10.15 Using SLC to Set a Relay

10

11 Options and Accessories

11.1 Communication Options

- VLT® PROFIBUS DP V1 MCA 101
- VLT® DeviceNet MCA 104
- VLT® CAN Open MCA 105
- VLT® EtherCAT MCA 124
- VLT® PROFIBUS Converter MCA 114
- VLT® PROFINET MCA 120
- VLT® EtherNet/IP MCA 121
- VLT® Modbus TCP MCA 122
- VLT® POWERLINK MCA 122
- VLT® DeviceNet Converter MCA 194

11.2 I/O, Feed-back and Safety Options

11.2.1 VLT® General Purpose I/O Module MCB 101

MCB 101 is used for extension of digital and analog inputs and outputs of FC 301 and FC 302.

Fit MCB 101 into slot B in the VLT® AutomationDrive.

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Contents:

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

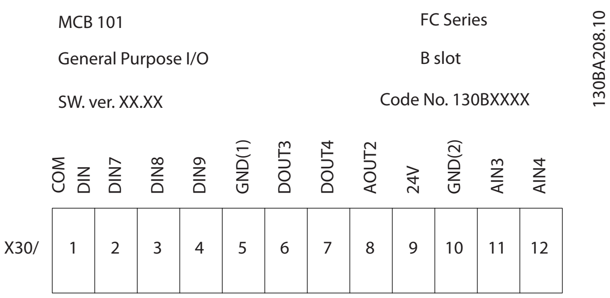

Illustration 11.1 MCB 101 Option

11.2.1.1 Galvanic Isolation in MCB 101

Digital/analog inputs are galvanically isolated from other inputs/outputs on the MCB 101 and in the control card of the frequency converter. Digital/analog outputs in the MCB 101 are galvanically isolated from other inputs/outputs on the MCB 101, but not from these 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), establish connection between terminals 1 and 5, see *Illustration 11.2*.

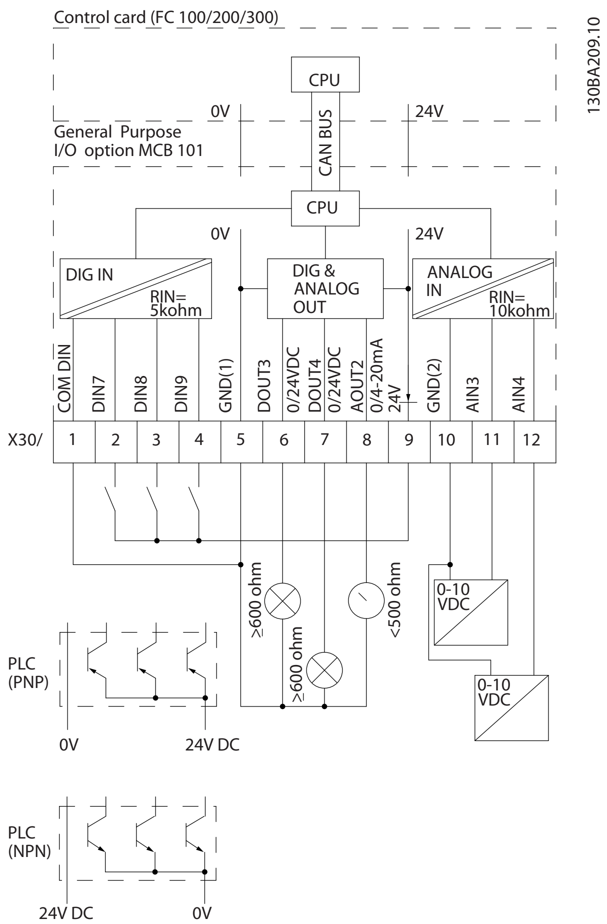

Illustration 11.2 Principle Diagram

Digital input - terminal X30/1-4	
Number of digital inputs	3
Terminal number	X30.2, X30.3, X30.4
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

Analog input - terminal X30/11, 12	
Number of analog inputs	2
Terminal number	X30.11, X30.12
Modes	Voltage
Voltage level	0-10 V
Input impedance	> 10 kΩ
Max. voltage	20 V
Resolution for analog inputs	10 bit (+ sign)
Accuracy of analog inputs	Max. error 0.5% of full scale
Bandwidth	FC 301: 20 Hz/ FC 302: 100 Hz

Digital outputs - terminal X30/6, 7	
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

Analog output - terminal X30/8	
Number of analog outputs	1
Terminal number	X30.8
Current range at analog output	0-20 mA
Max. load GND - analog output	500 Ω
Accuracy on analog output	Max. error: 0.5 % of full scale
Resolution on analog output	12 bit

11.2.2 VLT® Encoder Option MCB 102

The encoder module can be used as 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 encoder option in parameter group *17-** Feedback Option*.

Used for

- VVC+ closed loop
- Flux Vector Speed control
- Flux Vector Torque control
- Permanent magnet motor

Supported encoder types:
Incremental encoder: 5 V TTL type, RS-422, max. frequency: 410 kHz
Incremental encoder: 1 Vpp, sine-cosine
Hiperface® Encoder: Absolute and Sine-Cosine (Stegmann/SICK)
EnDat encoder: Absolute and Sine-Cosine (Heidenhain) Supports version 2.1
SSI encoder: Absolute

NOTICE

Incremental encoders are not recommended for use with PM motors due to risk of wrong polarity.

NOTICE

It is strongly recommended to always supply the encoder through the MCB 102. It shall be avoided to use external power supply for the encoder.

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.

NOTICE

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

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Connector Designation X31	Incremental Encoder (refer to *Illustration 11.3*)	SinCos Encoder Hiperface® (refer to *Illustration 11.4*)	EnDat Encoder	SSI Encoder	Description
1	NC			24 V*	24 V Output (21-25 V, I_{max}:125 mA)
2	NC	8 VCC			8V Output (7-12V, I_{max}: 200mA)
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 11.1 Encoder Connections

** Supply for encoder: see data on encoder*

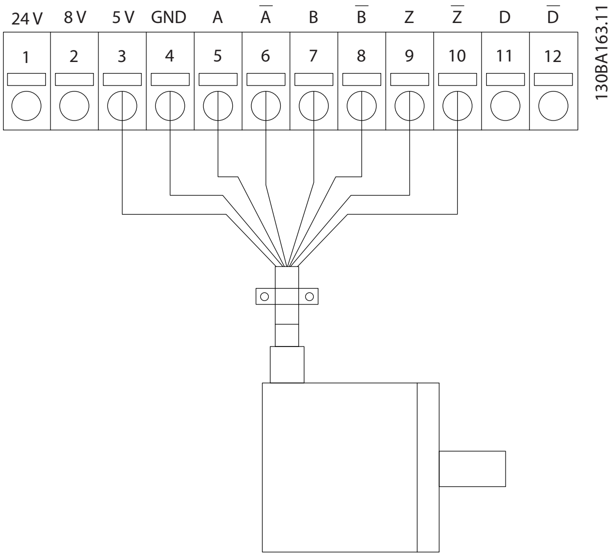

Illustration 11.3 Incremental Encoder

NOTICE

Max. cable length 150 m.

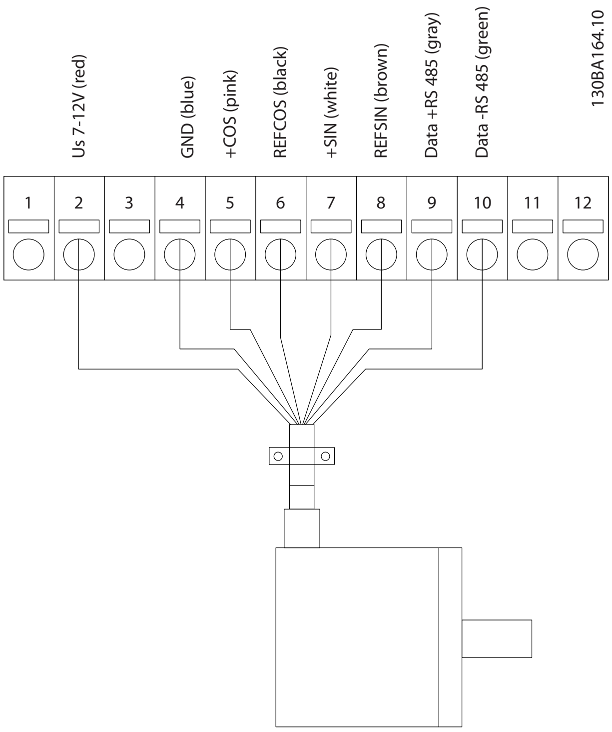

Illustration 11.4 SinCos Encoder Hiperface

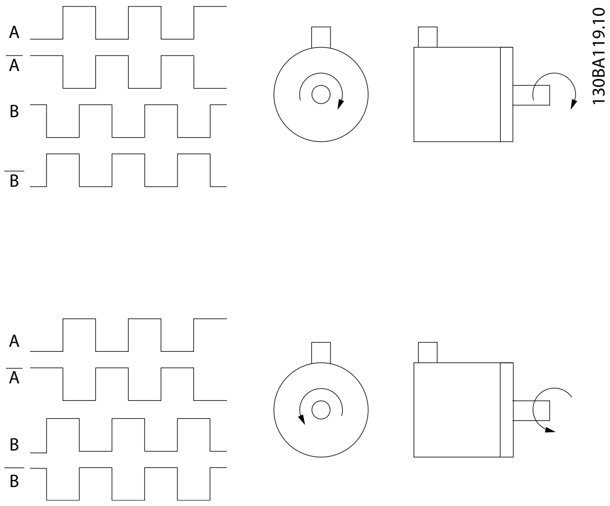

Illustration 11.5 Rotation Direction

11.2.3 VLT® Resolver Option MCB 103

Resolver Option MCB 103 is used for interfacing resolver motor feedback to VLT® AutomationDrive. Resolvers are used basically as motor feedback device 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*.

Resolver Option MCB 103 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 V_{rms} *7.0 V_{rms}
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 11.2 Resolver Specifications

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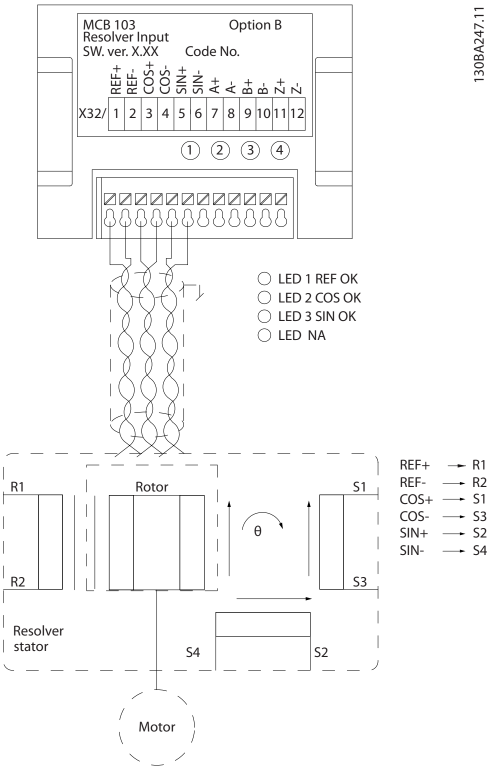


Illustration 11.6 MCB 103 Resolver Input

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 *[1] Warning* or *[2] Trip*.

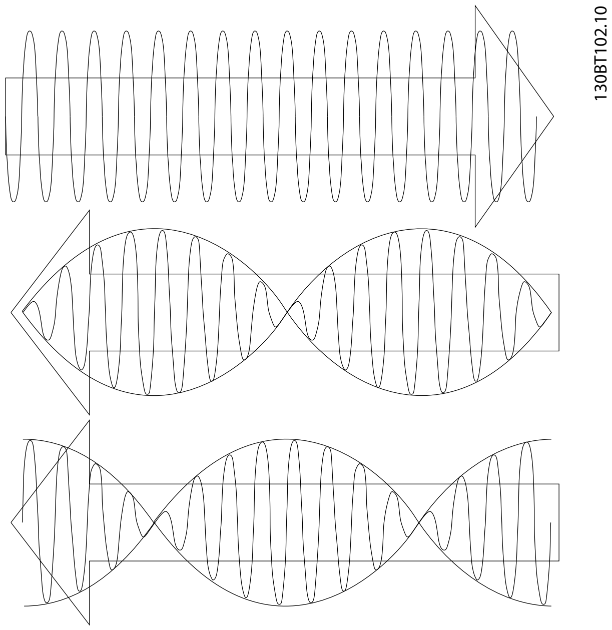


Illustration 11.7 Permanent Magnet (PM) Motor with Resolver as Speed Feedback

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.

NOTICE

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

NOTICE

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

NOTICE

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 11.3 Parameters to Adjust

11.2.4 VLT® Relay Card MCB 105

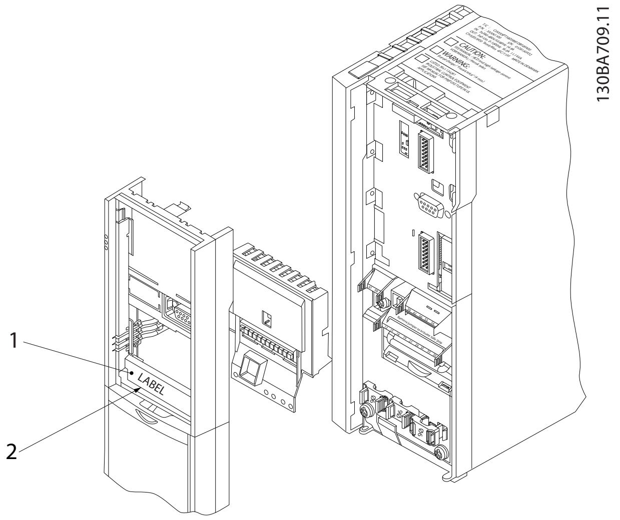
The Relay Option MCB 105 includes 3 pieces of SPDT contacts and must be fitted into option slot B.

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 s^{-1}

1) IEC 947 part 4 and 5

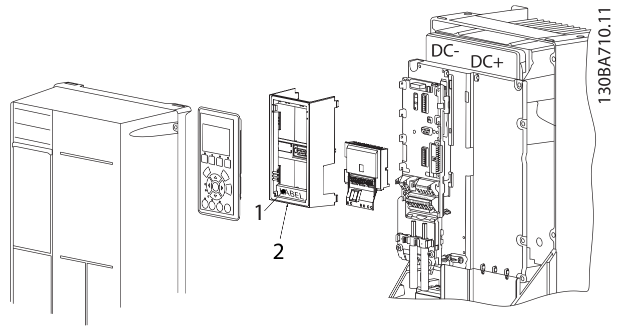
When the relay option kit is ordered separately the kit includes

- Relay Module MCB 105
- Enlarged LCP fixture and enlarged terminal cover
- Label for covering access to switches S201, S202 and S801
- Cable strips for fastening cables to relay module



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

Illustration 11.8 Enclosure Types A2-A3-B3



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

Illustration 11.9 Enclosure Types A5-B1-B2-B4-C1-C2-C3-C4

⚠WARNING

Warning Dual supply

How to add the Relay Card MCB 105 Option:

1. Disconnect power to the frequency converter.
2. Disconnect power to the live part connections on relay terminals.
3. Remove the LCP, the terminal cover and the LCP fixture from the frequency converter.
4. Fit the MCB 105 option in slot B.
5. Connect the control cables and fasten the cables with the enclosed cable strips.
6. Make sure the length of the stripped wire is correct (see *Illustration 11.11*).
7. Do not mix live parts (high voltage) with control signals (PELV).
8. Fit the enlarged LCP fixture and enlarged terminal cover.
9. Replace the LCP.
10. Connect power to the frequency converter.
11. Select the relay functions in *5-40 Function Relay* [6-8], *5-41 On Delay, Relay* [6-8] and *5-42 Off Delay, Relay* [6-8].

NOTICE

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

NOTICE

To access RS-485 termination switch S801 or current/voltage switches S201/S202, dismount the relay card (see *Illustration 11.8* and *Illustration 11.9*, position 2).

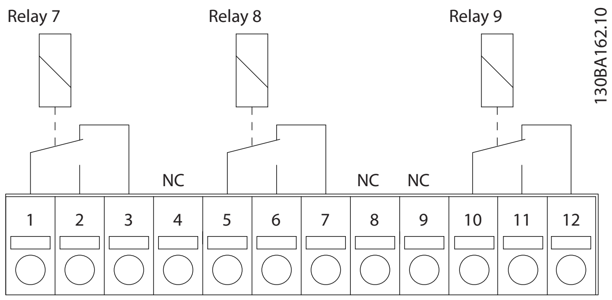


Illustration 11.10 Relays

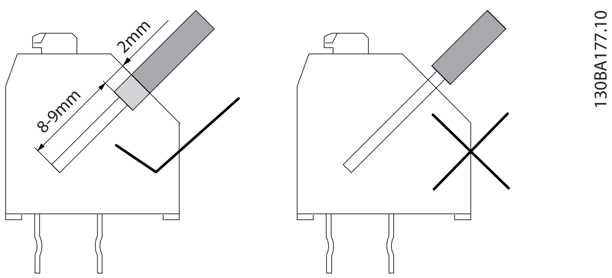
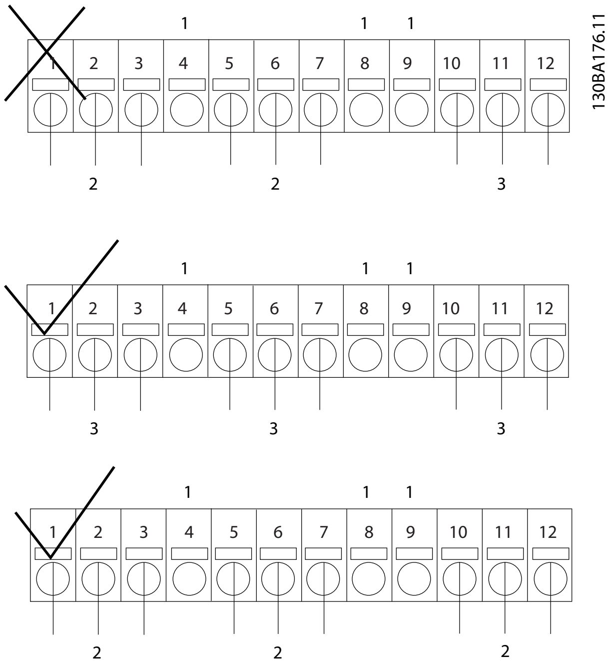


Illustration 11.11 Correct Wire Inserting



1	NC
2	Live part
3	PELV

Illustration 11.12 Correct Relay Wiring

NOTICE

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

11.2.5 VLT® Safe PLC Interface Option MCB 108

The Safe PLC Interface Option MCB 108 is designed to be built-in between the Safe dual pole (plus/minus) on the Safe PLC and the Safe Stop input on FC 302. The Safe PLC interface allows the safe output on the Safe PLC to maintain the test pulses on the plus and minus output without impacting the sensor signal to safe stop T37.
It can be used in combination with safety devices to satisfy the requirement of IEC61800-5-2 SIL 2, ISO13849-1 cat. 3 for Safe Torque Off (STO).

The option module MCB 108 is galvanically isolated via an internal DC/DC converter and it can be fitted into option slot B.

Input voltage (DC)	18-28 V DC
Typical current input (DC)	60 mA
Max. current input (DC)	110 mA DC
Max. current inrush (DC)	500 mA DC
Output voltage (DC)	20 V DC@Vin = 24 V
Turn on delay	1 ms
Turn off delay	3 ms

Observe the following precautions

- The FC 302 with MCB 108 (including the connections between X31/9 and Terminal 37) must be placed inside an IP54 enclosure.
- Safe Stop activation (i.e. removal of 24 V DC voltage supply to terminal 37 by removing voltage to dual pole input of MCB 108) does not provide electrical safety.
- The safety device connected to the dual pole input of the MCB 108 must fulfill the requirements of cat. 3 / PL d according to ISO 13849-1 for interrupting the voltage/current to the MCB 108. This also applies for the connections between the MCB 108 and the safety device.
- Read and follow the instructions for the safety device to connect it properly to MCB 108.

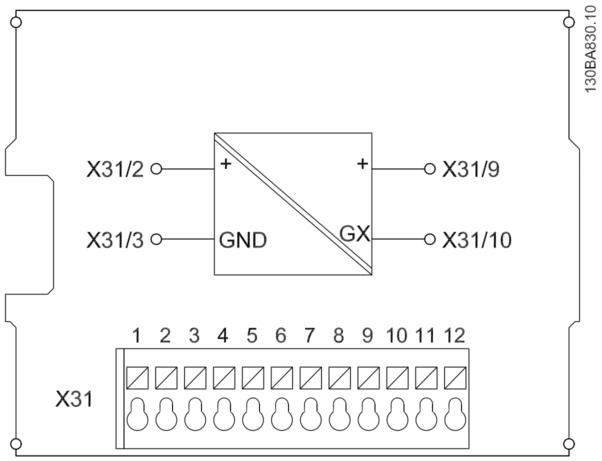


Illustration 11.13 Option Module Safe PLC Interface MCB 108

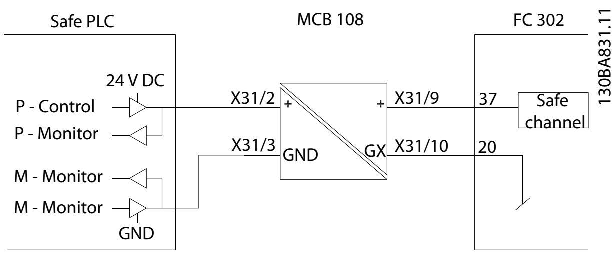


Illustration 11.14 Safe PLC Interface MCB 108 Connection

11.2.6 VLT® PTC Thermistor Card MCB 112

The MCB 112 option makes it possible to monitor the temperature of an electrical motor through a galvanically isolated PTC thermistor input. It is a B option for frequency converter with Safe Torque Off.

For different application possibilities, see *chapter 10 Application Examples*.

X44/1 and X44/2 are the thermistor inputs. X44/12 enables Safe Torque Off of the frequency converter (T-37), if the thermistor values make it necessary, and X44/10 informs the frequency converter that a request for safe torque off came from the MCB 112 to ensure a suitable alarm handling. One of the digital inputs parameters (or a digital input of a mounted option) must be set to *[80] PTC Card 1* to use the information from X44/10. Configure *5-19 Terminal 37 Safe Stop* to the desired Safe Torque Off functionality (default is Safe Stop Alarm).

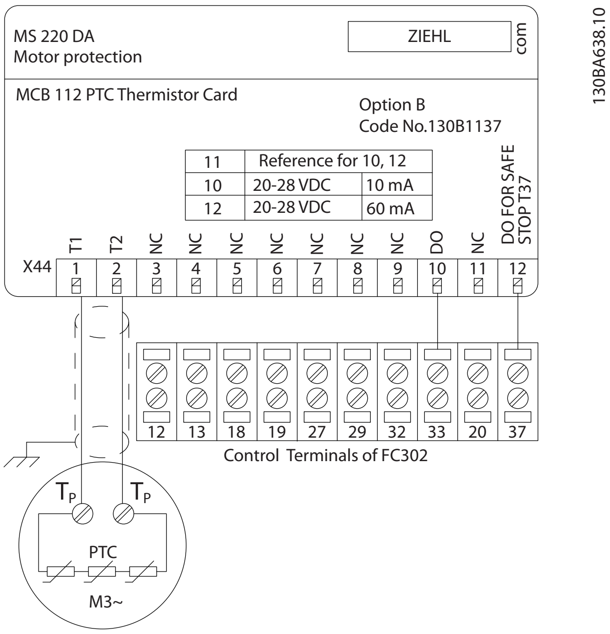


Illustration 11.15 Installation of MCB 112

ATEX Certification with FC 102, FC 202 and FC 302

The MCB 112 has been certified for ATEX, which means that the frequency converter with the MCB 112 can be used with motors in potentially explosive atmospheres. See the *VLT® PTC Thermistor Card MCB 112 Operating Instructions* for more information.

Illustration 11.16 ATmosphère EXplosive (ATEX)

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 to +60 °C
	EN 60068-2-1 Dry heat
Moisture	5-95%, no condensation permissible
Vibration resistance	10 to 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	

11.2.7 VLT® Extended Relay Card MCB 113

The MCB 113 adds 7 digital inputs, 2 analog 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 VLT® AutomationDrive and is automatically detected after mounting.

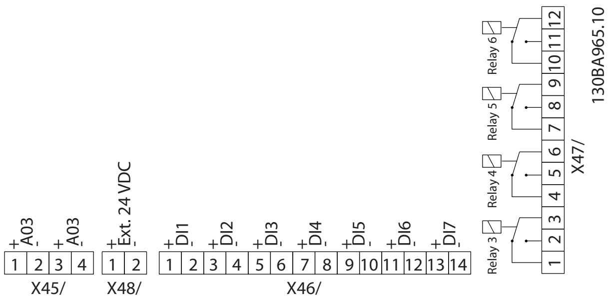


Illustration 11.17 Electrical Connections of MCB 113

MCB 113 can be connected to an external 24 V on X58/ to ensure galvanical isolation between the VLT® AutomationDrive and the option card. If galvanical isolation is not needed, the option card can be supplied through internal 24 V from the frequency converter.

NOTICE

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

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

NOTICE

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

Electrical Data

Relays	
Numbers	4 SPDT
Load at 250 V AC/30 V DC	8 A
Load at 250 V AC/30 V DC with 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 thru-put delay	10 ms

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

11.2.8 VLT® Sensor Input Option MCB 114

The sensor input option card MCB 114 can be used in the following cases:

- Sensor input for temperature transmitters PT100 and PT1000 for monitoring bearing temperatures
- As general extension of analog inputs with one additional input for multi-zone control or differential pressure measurements
- Support extended PID controllers with I/Os for set point, transmitter/sensor inputs

Typical motors, designed with temperature sensors to protect bearings from being overloaded, are fitted with 3 PT100/1000 temperature sensors; one in front, one in the back end bearing, and one in the motor windings. The Danfoss option MCB 114 supports 2- or 3-wire sensors with individual temperature limits for under/over temperature. An auto detection of sensor type, PT100 or PT1000 takes place at power up.

The option can generate an alarm if the measured temperature is either below the low limit or above the high limit specified by the user. The individual measured temperature on each sensor input can be read out in the display or by readout parameters. If an alarm occurs, the relays or digital outputs can be programmed to be active high by selecting *[21] Thermal Warning* in parameter group *5-** Digital In/Out*.

A fault condition has a common warning/alarm number associated with it, which is Alarm/Warning 20, Temp. input error. Any present output can be programmed to be active in case the warning or alarm appears.

11.2.8.1 Electrical and Mechanical Specifications

Analogue Input	
Number of analogue inputs	1
Format	0–20 mA or 4–20 mA
Wires	2
Input impedance	<200 Ω
Sample rate	1 kHz
3rd order filter	100 Hz at 3 dB

The option is able to supply the analogue sensor with 24 V DC (terminal 1).

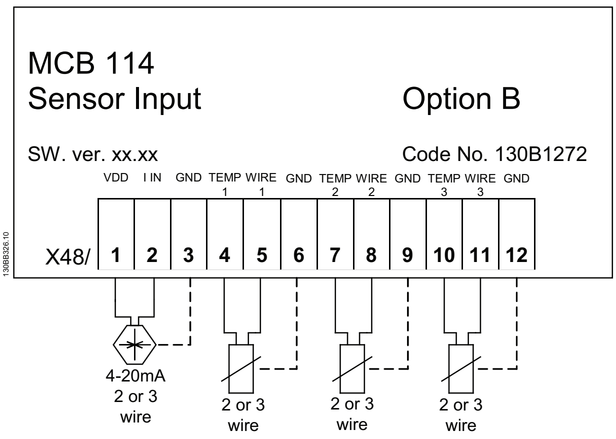
Temperature Sensor Input	
Number of analogue inputs supporting PT100/1000	3
Signal type	PT100/1000
Connection	PT 100 2 or 3 wire/PT1000 2 or 3 wire
Frequency PT100 and PT1000 input	1 Hz for each channel
Resolution	10 bit
Temperature range	-50–204 °C -58–399 °F

Galvanic Isolation	
The sensors to be connected are expected to be galvanically isolated from the mains voltage level	IEC 61800-5-1 and UL508C

Cabling	
Maximum signal cable length	500 m

11.2.8.2 Electrical Wiring

11



Terminal	Name	Function
1	VDD	24 V DC to supply 4-20 mA sensor
2	I in	4-20 mA input
3	GND	Analog input GND
4, 7, 10	Temp 1, 2, 3	Temperature input
5, 8, 11	Wire 1, 2, 3	3rd wire input if 3 wire sensors are used
6, 9, 12	GND	Temp. input GND

Illustration 11.18 MCB 114

11.2.9 VLT® Safe Option MCB 15x

NOTICE

For more information on MCB 15x see the *MCB 15x Safe Option Operating Instructions*.

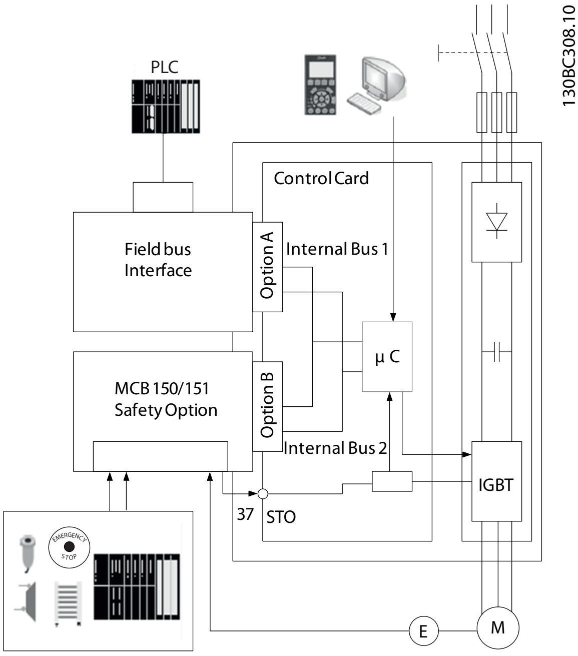


Illustration 11.19 Safe Drive System

The MCB 15x performs safety functions in accordance with EN IEC 61800-5-2. It monitors safe motion sequences on frequency converters, which are safely brought to a stop and shut down in the event of an error.
The MCB 15x is built into a VLT® AutomationDrive FC 302 and requires a signal from a sensor unit. A safe drive system from Danfoss consists of the following

- Frequency converter, VLT® AutomationDrive FC 302
- MCB 15x built into the frequency converter

The MCB 15x

- activates safety functions
- monitors safe motion sequences
- signals the status of safety functions to the safety control system via possible connected Profibus fieldbus
- activates the selected failure reaction Safe Torque Off or Safe Stop 1, in the event of an error

There are 2 variants of the MCB 15x, one with HTL encoder interface (MCB 151) and one with TTL encoder interface (MCB 150).

The MCB 15x Safe Option is constructed as a standard option for the VLT® AutomationDrive FC 302 and is automatically detected after mounting.

The MCB 15x can be used to monitor the stopping, starting or speed of a rotating or laterally moving device. As speed monitor, the option is often used in combination with hard guarding, access doors, and safety gates with solenoid-lock or -unlock safety switches. When the speed of the monitored device drops below the set switch point (where its speed is no longer considered dangerous), the MCB 15x sets S37 output low. This allows the operator to open the safety gate. In speed monitor applications, the safety output S37 is high for operation (when the motor speed of the monitored device is below the set switch point). When the speed exceeds the set value, indicating a too-high (dangerous) speed, the safety output is low.

The frequency converter

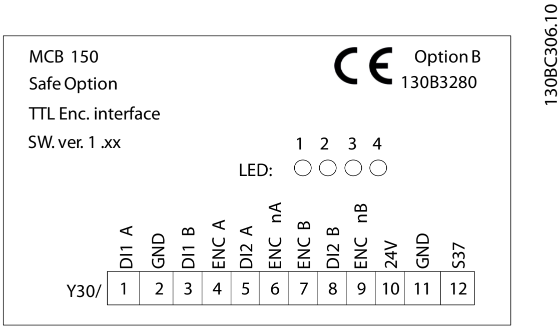
- removes the power to the motor,
- switches the motor to torque-free, if Safe Torque Off is activated

The safety control system

- activates the safety functions via inputs on the MCB 15x
- evaluates signals from safety devices, such as
  - E-STOP push buttons
  - Non Contact Magnetic switch
  - Interlocking switch
  - Light curtain devices
- processes the MCB 15x status function
- provides safe connection between MCB 15x and safety control system
- provides fault detection at activation of safety functions (shorts across contacts, short circuit) on signal between the safety control system and MCB 15x

11

Front View



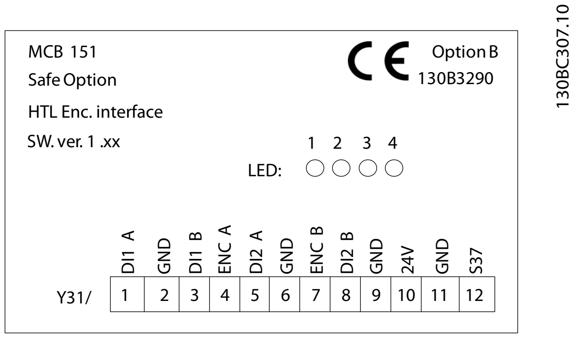


Illustration 11.21 MCB 151

Illustration 11.20 MCB 150

Technical Specifications

MCB 150/MCB 151

Power consumption	2 W (equivalent power consumption related to VDD)
Current consumption VCC (5 V)	< 200 mA
Current consumption VDD (24 V)	< 30 mA (< 25 mA for MCB 150)

Digital inputs

Number of digital inputs	4 (2 x 2-channel Digital Safety Input)
Input voltage range	0 to 24 V DC
Input voltage, logic '0'	< 5 V DC
Input voltage, logic '1'	> 12 V DC
Input voltage (max)	28 V DC
Input current (min)	6 mA @Vin=24 V (inrush current 12 mA peak)
Input resistance	approx. 4 kΩ
Galvanic isolation	No
Short circuit-proof	Yes
Input pulse recognition time (min)	3 ms
Discrepancy time (min)	9 ms
Cable length	< 30 m (screened or unscreened cable) > 30 m (screened cable)

Digital output (Safe output)

Number of outputs	1
Output voltage low	< 2 V DC
Output voltage high	> 19.5 V DC
Output voltage (max)	24.5 V DC
Nominal output current (@24 V)	< 100 mA
Nominal output current (@0 V)	< 0.5 mA
Galvanic Isolation	No
Diagnostic test pulse	300 us
Short circuit-proof	Yes
Cable length	< 30 m (screened cable)

TTL encoder input (MCB 150)

Number of encoder inputs	4 (2 x differential inputs A/A, B/B)
Encoder types	TTL, RS-422/RS-485 incremental encoders
Input differential voltage range	-7 to +12 V DC
Input common mode voltage	-12 to +12 V DC
Input voltage, logic '0' (diff)	< -200 mV DC
Input voltage, logic '1' (diff)	> +200 mV DC
Input resistance	approx. 120 Ω

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Maximum frequency	410 KHz
Short circuit-proof	Yes
Cable length	< 150 m (Tested with screened cable - Heidenhain AWM Style 20963 80°C 30V E63216, 100 m screened motor cable, no load on motor)

HTL encoder input (MCB 151)	
Number of encoder inputs	2 (2 x single ended inputs A; B)
Encoder types	HTL incremental encoders; HTL Proximity sensor
Logic input	PNP
Input voltage range	0 to 24 V DC
Input voltage, logic '0'	< 5 V DC
Input voltage, logic '1'	> 12 V DC
Input voltage (max)	28 V DC
Input resistance	approx. 4 Ω
Maximum frequency	110 kHz
Short circuit-proof	Yes
Cable length	< 100 m (Tested with screened cable - Heidenhain AWM Style 20963 80 °C 30V E63216, 100 m screened motor cable, no load on motor)

24 V supply output	
Supply voltage	24 V DC (Voltage tolerance: +0.5 V DC to -4.5 V DC)
Maximum output current	150 mA
Short circuit-proof	Yes
Cable length	< 30 m (screened or unscreened cable) > 30 m (screened cable)

Ground I/O section	
Cable length	< 30 m (screened or unscreened cable) > 30 m (screened cable)

Cable cross sections	
Digital inputs/output supply voltage	0.75 mm^2/AWG 18, AEH without plastic collar in accordance with DIN 46228/1

Reset characteristics	
Manual reset time	≤ 5 ms (MCB 15x) ≤ 5 ms (frequency converter) ≤ 10 ms (fieldbus)
Manual reset pulse time	10 μs (MCB 15x and frequency converter)
Automatic reset time	≤ 4 ms
Start-up reset time	≤ 5 s (*42-90 Restart Safe Option*)

Response time	
Input to output response time	≤ 2 ms
Emergency stop until beginning of SS1/SLS	≤ 7 ms
Cross fault detection time	≤ 3 ms (@activated output)

11

11.2.10 VLT® C Option Adapter MCF 106

The C Option Adapter MCF 106 makes it possible to add an additional B option to the frequency converter. One A and one B option can be installed in the standard A and B slots of the control card and up to 2 B options can be installed in the C Option Adapter.

For further information, see the *VLT® AutomationDrive FC 300, C Option Adapter MCF 106 Installation Instructions*.

11.3 Motion Control Options

Ordering

Motion Control Options (MCO) are supplied either as option cards for field installation or as built-in options. For retrofit, purchase a mounting kit. Each enclosure has its own mounting kit. MCO 3xx is to be used in slot C0, but can be combined with another option in slot C1.

Mounting kit depending on enclosure type	Order no.
Bookstyle	
A2 and A3 (40 mm for one C option)	130B7530
A2 and A3 (60 mm for C0 + C1 option)	130B7531
B3 (40 mm for one C option)	130B1413
B3 (60 mm for C0 + C1 option)	130B1414
Compact	
A5	130B7532
B, C, D, E and F (except B3)	130B7533

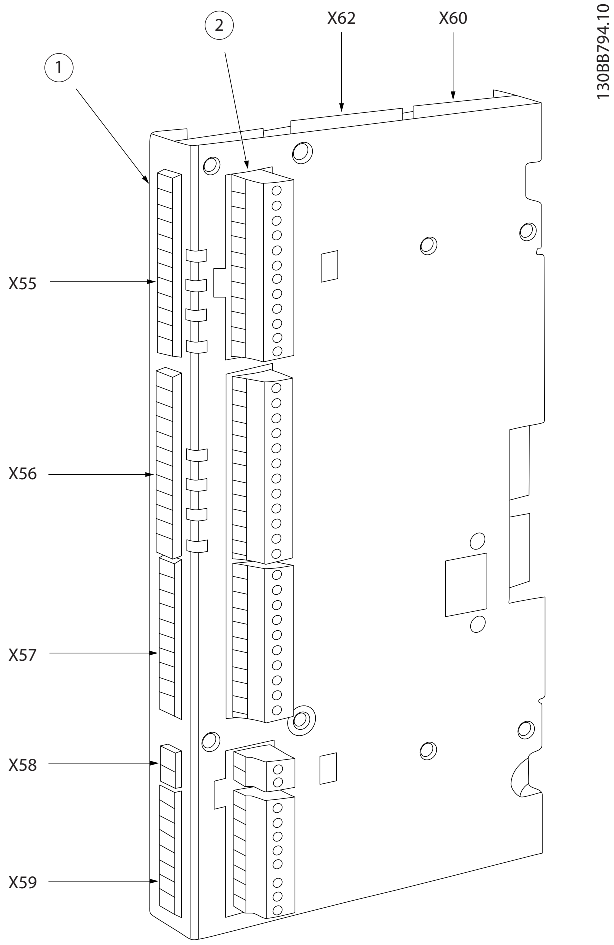
Table 11.4 Mounting Kit Ordering Numbers

11

Technical specifications

For enclosures A5, B1 and B2 all MCO 3xx terminals are located next to the control card. Remove the front cover to get access.

MCO control terminals are plug connectors with screw terminals. Terminals X55, X56, X57, X58 and X59 are duplicated to be used for both bookstyle and compact enclosures.



1	Terminal block for bookstyle
2	Terminal block for compact
X55	Encoder 2
X56	Encoder 1
X57	Digital inputs
X58	24 V DC supply
X59	Digital outputs
X62	MCO CAN Bus
X60	Debug connections (RS-485)

Illustration 11.22 Location of Terminal Blocks

Terminal Overview

Terminal number	Descriptive Name Encoder 2 (Feedback)
1	+24 V Supply
2	+8 V Supply
3	+5 V Supply
4	GND
5	A
6	A not
7	B
8	B not
9	Z/Clock
10	Z not/Clock not
11	DATA
12	DATA not

Table 11.5 Terminal Block X55

Terminal number	Descriptive Name Encoder 1 (Master)
1	+24 V Supply
2	N/A
3	+5V Supply
4	GND
5	A
6	A not
7	B
8	B not
9	Z/Clock
10	Z not/Clock not
11	DATA
12	DATA not

Table 11.6 Terminal Block X56

Terminal number	Descriptive Name Digital inputs
1	Digital Input
2	Digital Input
3	Digital Input
4	Digital Input
5	Digital Input
6	Digital Input
7	Digital Input
8	Digital Input
9	Digital Input
10	Digital Input

Table 11.7 Terminal Block X57

Terminal number	Descriptive Name Supply
1	+24 V Supply
2	GND

Table 11.8 Terminal Block X58

Terminal number	Descriptive Name Digital outputs
1	Digital Output/Input
2	Digital Output/Input
3	Digital Output
4	Digital Output
5	Digital Output
6	Digital Output
7	Digital Output
8	Digital Output

Table 11.9 Terminal Block X59

Terminal number	MCO Debug (RS-485)
[1]CS	Control Select
62	RxD/TxD - P
63	RxD/TxD - N
66	0 V
67	+5 V

Table 11.10 Terminal Block X60

Terminal number	MCO CAN Bus
1	N/A
2	CAN - L
3	DRAIN
4	CAN - H
5	N/A

Table 11.11 Terminal Block X62

11.3.1 VLT® Motion Control Option MCO 305

The MCO 305 is an integrated free programmable motion controller for FC 301 and FC 302, for more information, see *chapter 11.3.1 Motion Control Options.*

11.3.2 VLT® Synchronising Controller MCO 350

NOTICE

Terminal block X59 has fixed functionality for MCO 350.

NOTICE

Terminal block X62 is not supported for MCO 350.

NOTICE

Terminal block X60 is not used for MCO 350.

For more information, see *chapter 11.3.1 Motion Control Options.*

11.3.3 VLT® Positioning Controller MCO 351

NOTICE

Terminal block X59 has fixed functionality for MCO 351.

NOTICE

Terminal block X62 is not supported for MCO 351.

NOTICE

Terminal block X60 is not used for MCO 351.

For more information, see *chapter 11.3.1 Motion Control Options*.

11.4 Accessories

11.4.1 Brake Resistors

In applications where the motor is used as a brake, energy is generated in the motor and sent back into the frequency converter. If the energy cannot be transported back to the motor, it increases the voltage in the frequency converter DC-line. In applications with frequent braking and/or high inertia loads, this increase may lead to an overvoltage trip in the frequency 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 *chapter 5.5.3 Control with Brake Function* for dimensioning of brake resistors. Code numbers can be found in *chapter 7 How to Order*.

11.4.2 Sine-wave Filters

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

For the FC 300, Danfoss supplies 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 also causes some noise. Solve the problem by integrating the filter in a cabinet or similar.

11.4.3 dU/dt Filters

dU/dt filters are differential-mode low-pass filters which reduce motor terminal phase-to-phase peak voltages and reduce the rise time to a level that lowers the stress on the insulation at the motor windings. This is especially an issue at short motor cables.

Compared to sinewave filters (see *chapter 11.4.2 Sine-wave Filters*), the dU/dt filters have a cut-off frequency above the switching frequency.

11.4.4 Common Mode Filters

High frequency common mode cores reduce electromagnetic interference and eliminate bearing damage by electrical discharge. They are special nanocrystalline magnetic cores which have superior filtering performance compared to regular ferrite cores. They act like a common-mode inductor (between phases and ground).

Installed around the three motor phases (U, V, W), the common mode filters reduce high-frequency common-mode currents. As a result, high-frequency electromagnetic interference from the motor cable is reduced.

11.4.5 Harmonic Filters

The Danfoss AHF 005 and AHF 010 are advanced harmonic filters not to be compared with traditional harmonic trap filters. The Danfoss harmonic filters have been specially designed to match the Danfoss frequency converters.

By connecting the Danfoss harmonic filters AHF 005 or AHF 010 in front of a Danfoss frequency converter the total harmonic current distortion generated back to the mains is reduced to 5% and 10% respectively.

11.4.6 IP21/Type 1 Enclosure Kit

IP20/IP4X top/TYPE 1 is an optional enclosure element available for IP20 compact units.
If the enclosure kit is used, an IP20 unit is upgraded to comply with enclosure IP21/4X top/TYPE 1.

The IP4X top can be applied to all standard IP20 FC 30X variants.

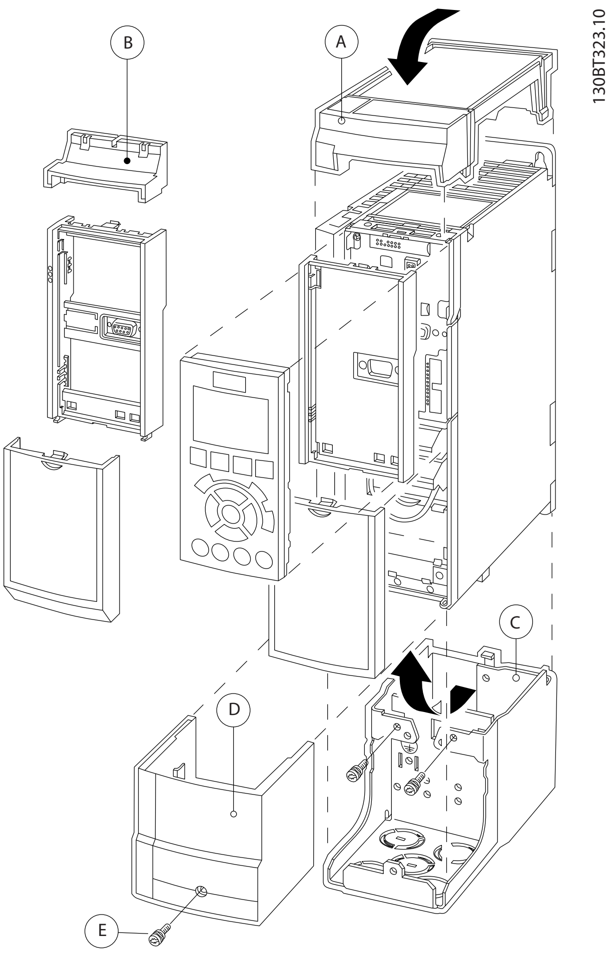


Illustration 11.23 Enclosure Type A2

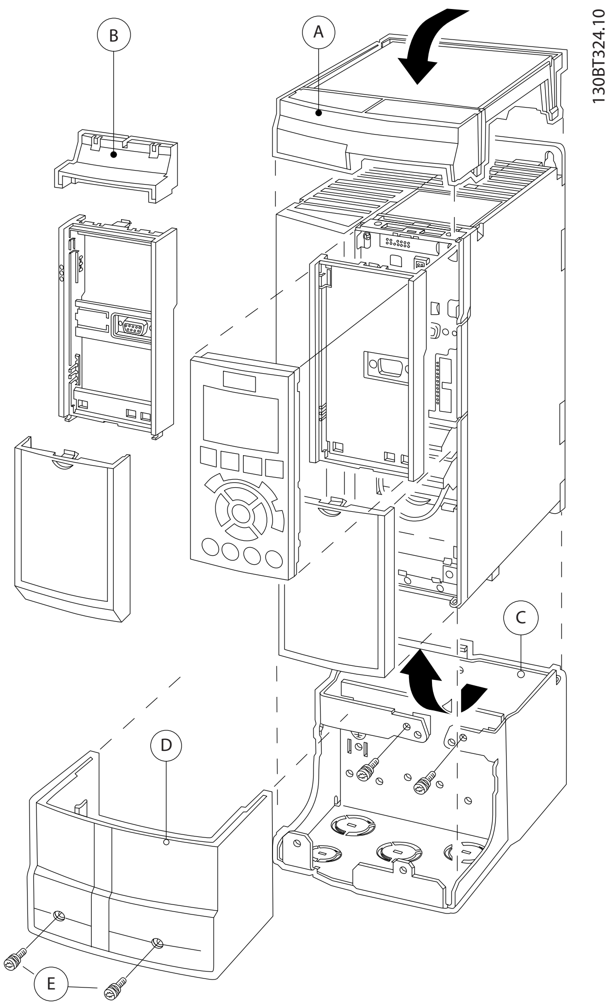


Illustration 11.24 Enclosure Type A3

A	Top cover
B	Brim
C	Base part
D	Base cover
E	Screw(s)

Table 11.12 Legend to *Illustration 11.23* and *Illustration 11.24*

Place the top cover as shown. If an A or B option is used the brim must be fitted to cover the top inlet. Place the base part C at the bottom of the frequency converter and use the clamps from the accessory bag to correctly fasten the cables

Holes for cable glands:

- Size A2: 2x M25 and 3xM32
- Size A3: 3xM25 and 3xM32

Enclosure type	Height A [mm]	Width B [mm]	Depth C* [mm]
A2	372	90	205
A3	372	130	205
B3	475	165	249
B4	670	255	246
C3	755	329	337
C4	950	391	337

Table 11.13 Dimensions

** If option A/B is used, the depth increases (see chapter 8.2.1 Mechanical Dimensions for details)*

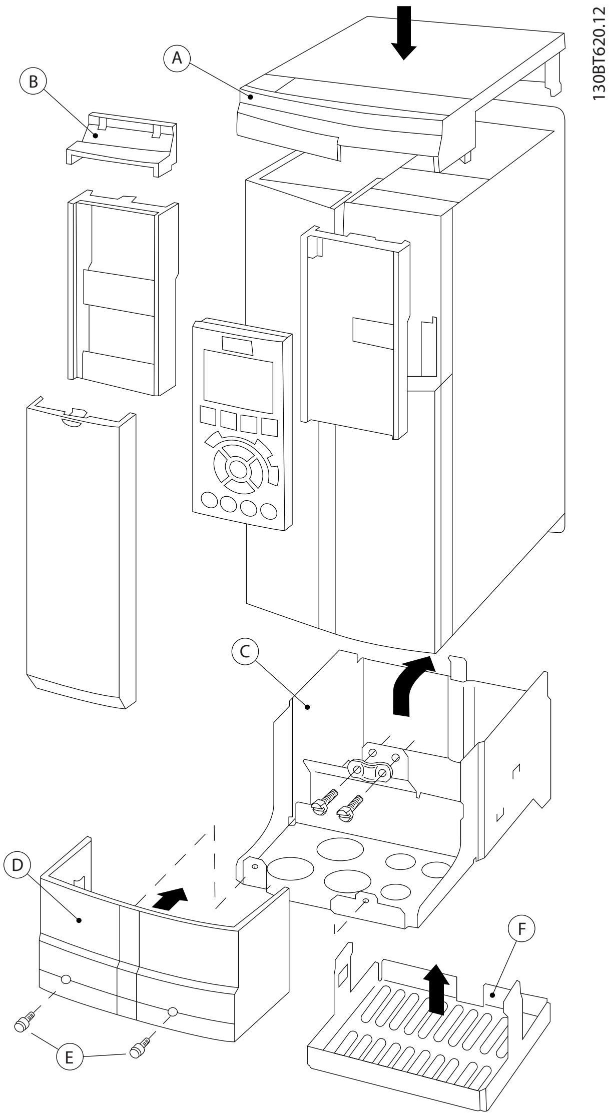


Illustration 11.25 Enclosure Type B3

Illustration 11.26 Enclosure Types B4 - C3 - C4

A	Top cover
B	Brim
C	Base part
D	Base cover
E	Screw(s)
F	Fan cover
G	Top clip

Table 11.14 Legend to *Illustration 11.25* and *Illustration 11.25*

11

When option module A and/or option module B is/are used, the brim (B) must be fitted to the top cover (A).

NOTICE

Side-by-side installation is not possible when using the *IP21/IP4X/TYPE 1 Enclosure Kit*

11.4.7 Remote Mounting Kit for LCP

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. 1 Nm.

The LCP enclosure is rated IP66

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

Table 11.15 Technical Data

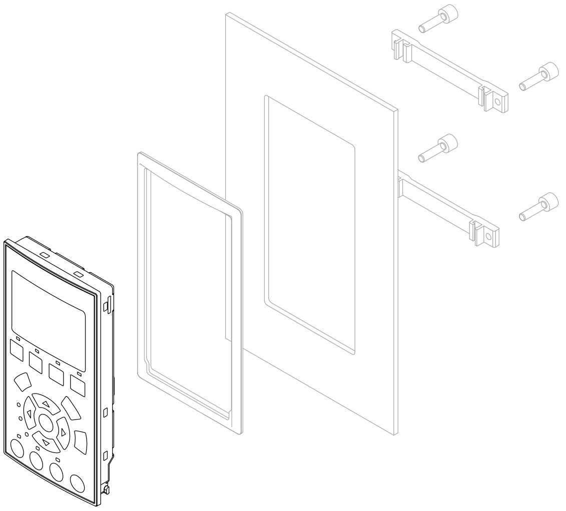


Illustration 11.27 LCP Kit with Graphical LCP, Fasteners, 3 m Cable and Gasket
Ordering No. 130B1113

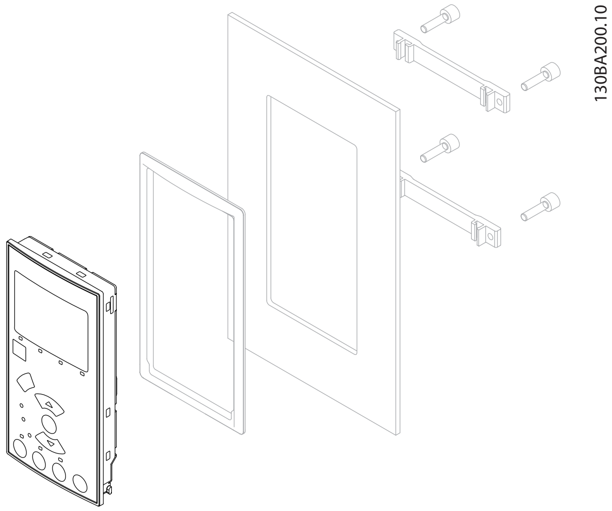


Illustration 11.28 LCP Kit with Numerical LCP, Fasteners and Gasket
Ordering no. 130B1114

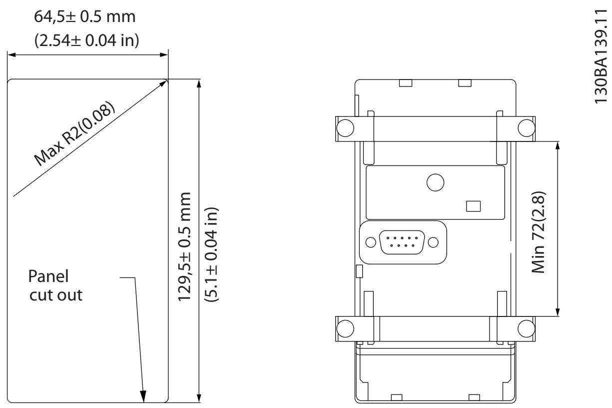


Illustration 11.29 Dimensions

11

11.4.8 Mounting Bracket for Enclosure Types A5, B1, B2, C1 and C2

Step 1

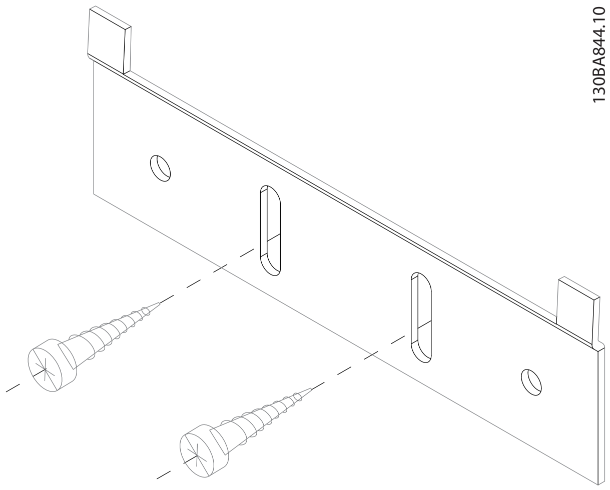


Illustration 11.30 Lower Bracket

Position the lower bracket and mount it with screws. Do not tighten the screws completely since this will make it difficult to mount the frequency converter.

Step 2

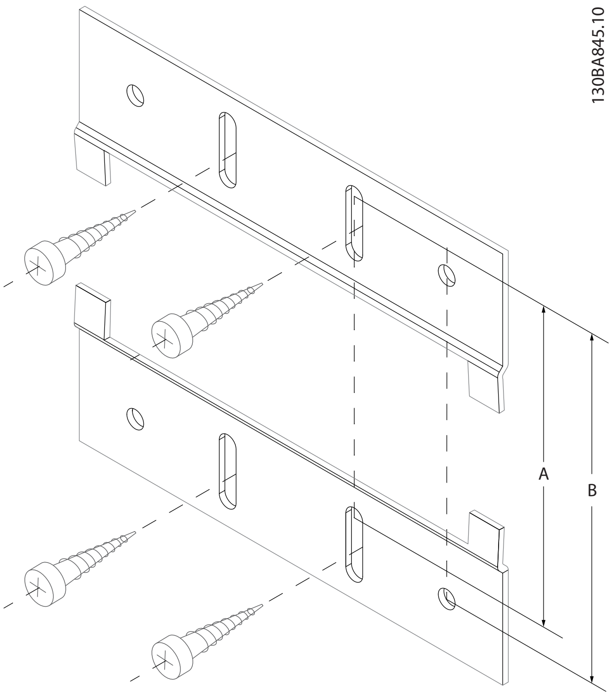


Illustration 11.31 Upper Bracket

Measure distance A or B, and position the upper bracket, but do not tighten it. See dimensions in *Table 11.16*.

Enclosure	IP	A [mm]	B [mm]	Ordering number
A5	55/66	480	495	130B1080
B1	21/55/66	535	550	130B1081
B2	21/55/66	705	720	130B1082
B3	21/55/66	730	745	130B1083
B4	21/55/66	820	835	130B1084

Table 11.16 Details

Step 3

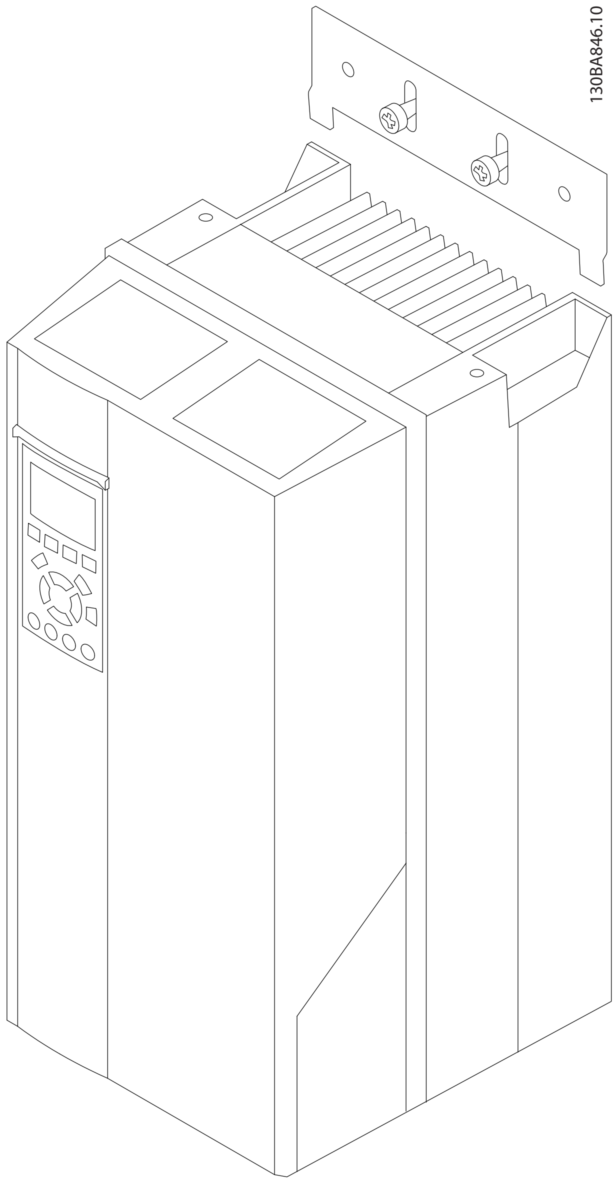


Illustration 11.32 Positioning

www.famcocorp.com
E-mail: info@famcocorp.com
@famco_group
Tel:۰۲۱-۴۸۰۰۰۰۴۹
Fax:۰۲۱ - ۴۴۹۹۴۶۴۲
تهران، کیلومتر۲۱ بزرگراه لشگری (جاده مخصوص کرج)
روبروی پالایشگاه نفت پارس، پلاک ۱۲

Place the frequency converter in the lower bracket, lift the upper one. When the frequency converter is in place, lower the upper bracket.

Step 4

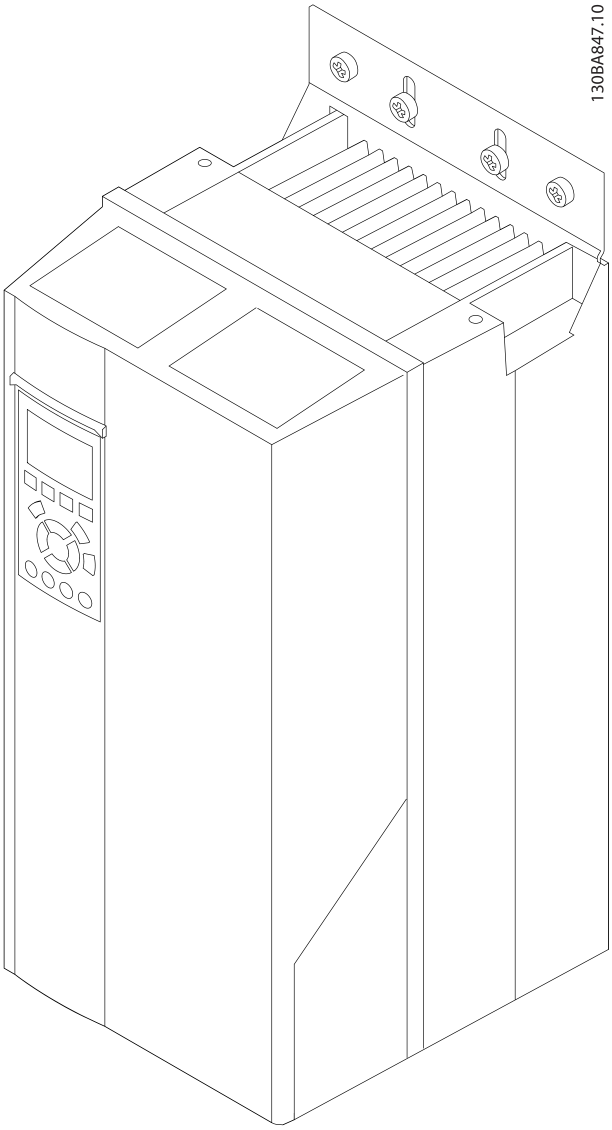


Illustration 11.33 Tightening of Screws

Now tighten the screws. For extra security, drill and mount screws in all holes.

12 RS-485 Installation and Set-up

12.1 Installation and Set-up

12.1.1 Overview

RS-485 is a 2-wire bus interface compatible with multi-drop network topology, that is, 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, see *Illustration 12.1*.

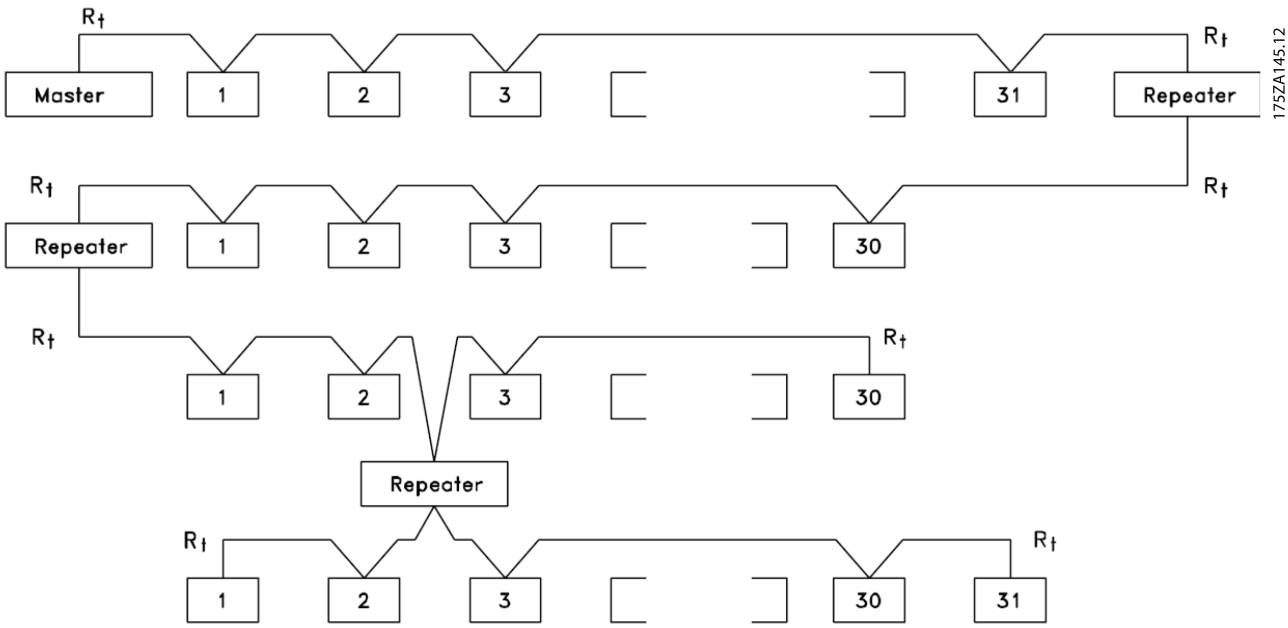


Illustration 12.1 RS-485 Bus Interface

NOTICE

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

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

Low-impedance ground connection of the screen at every node is important, including at high frequencies. Thus, connect a large surface of the screen to ground, for example with a cable clamp or a conductive cable gland. It may be necessary to apply potential-equalising 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 [Ω]	120
Cable length [m]	Max. 1200 (including drop lines) Max. 500 station-to-station

Table 12.1 Cable Specifications

12.2 Network Connection

One or more frequency converters can be connected to a control (or master) using the RS-485 standardised interface. Terminal 68 is connected to the P signal (TX+, RX+), while terminal 69 is connected to the N signal (TX-,RX-). See drawings in *chapter 3.5 Wiring Schematic*.

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

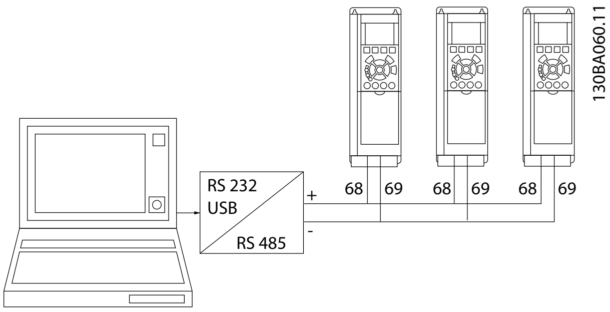


Illustration 12.2 Parallel Connections

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

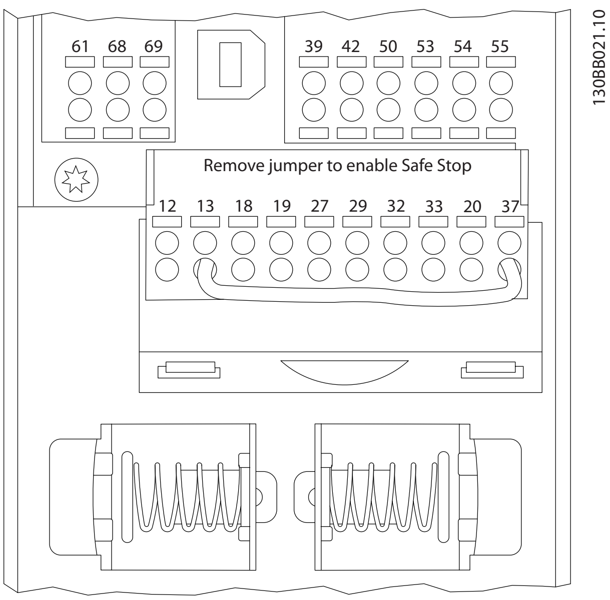


Illustration 12.3 Control Card Terminals

12.3 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 for "ON".

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

12.4 RS-485 Installation and Set-up

12.4.1 EMC Precautions

The following EMC precautions are recommended to achieve interference-free operation of the RS-485 network.

Observe relevant national and local regulations, for example regarding protective earth connection. Keep the RS-485 communication cable 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 inches) 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°.

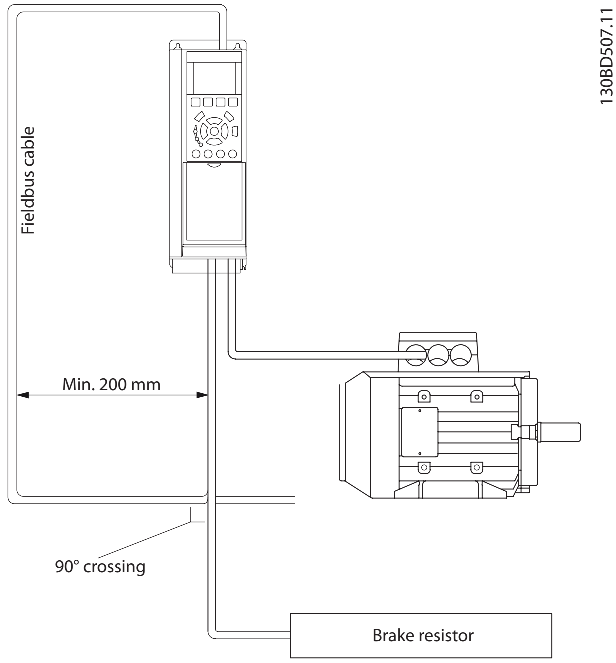


Illustration 12.4 Cable Routing

12.5 FC Protocol Overview

The FC protocol, also referred to as FC bus or Standard bus, is the Danfoss standard fieldbus. It defines an access technique according to the master-follower principle for communications via a serial bus.
One master and a maximum of 126 followers can be connected to the bus. The master selects the individual followers via an address character in the telegram. A follower itself can never transmit without first being requested to do so, and direct message transfer between the individual followers is not possible. Communications occur in the half-duplex mode.

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

The physical layer is RS-485, thus utilising the RS-485 port built into the frequency converter. The FC protocol supports different telegram formats:

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

12.6 Network Configuration

12.6.1 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 12.2 FC Protocol Parameters

12.7 FC Protocol Message Framing Structure

12.7.1 Content of a Character (byte)

12

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

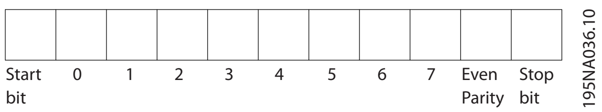

Illustration 12.5 Content of a Character

12.7.2 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.

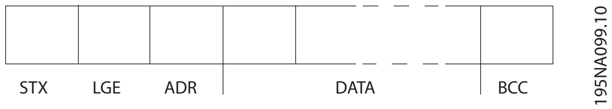

Illustration 12.6 Telegram Structure

12.7.3 Telegram Length (LGE)

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

4 data bytes	LGE=4+1+1=6 bytes
12 data bytes	LGE=12+1+1=14 bytes
Telegramscontaining texts	10[1)]+n bytes

Table 12.3 Length of Telegrams

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

12.7.4 Frequency Converter Address (ADR)

2 different address formats are used.
The address range of the frequency converter is either 1-31 or 1-126.

1. Address format 1-31:

Bit 7 = 0 (address format 1-31 active)

Bit 6 is not used

Bit 5 = 1: Broadcast, address bits (0-4) are not used

Bit 5 = 0: No Broadcast

Bit 0-4 = frequency converter address 1-31

2. Address format 1-126:

Bit 7 = 1 (address format 1-126 active)

Bit 0-6 = frequency converter address 1-126

Bit 0-6 = 0 Broadcast

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

12.7.5 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.

12.7.6 The Data Field

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

The 3 types of telegram are:

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

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

Illustration 12.7 Process Block

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

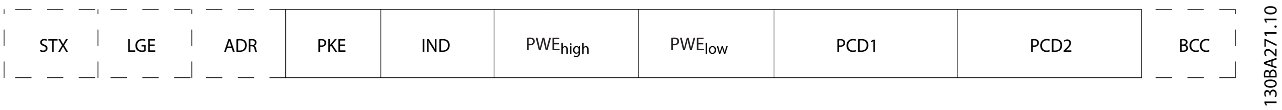

Illustration 12.8 Parameter Block

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

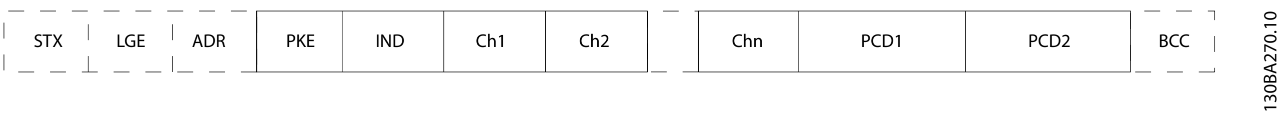

Illustration 12.9 Text Block

12

12

12.7.7 The PKE Field

The PKE field contains 2 sub-fields: Parameter command and response AK, and Parameter number PNU:

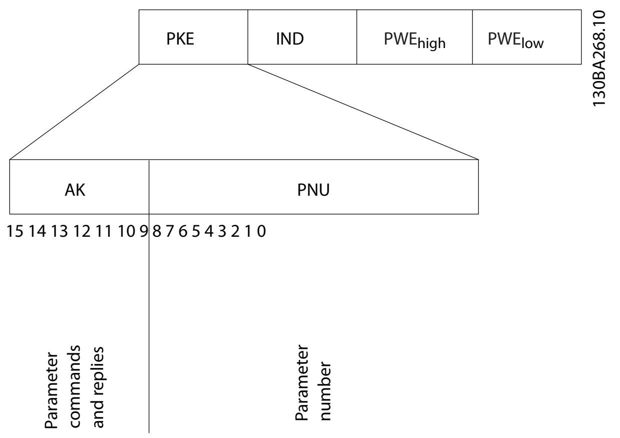

Illustration 12.10 PKE Field

Bits no. 12-15 transfer parameter commands from master to follower and return processed follower responses to the master.

Bit no.				Parameter command
15	14	13	12	
0	0	0	0	No command
0	0	0	1	Read parameter value
0	0	1	0	Write parameter value in RAM (word)
0	0	1	1	Write parameter value in RAM (double word)
1	1	0	1	Write parameter value in RAM and EEprom (double word)
1	1	1	0	Write parameter value in RAM and EEprom (word)
1	1	1	1	Read/write text

Table 12.4 Parameter Commands Master ⇒ Follower

Bit no.				Response
15	14	13	12	
0	0	0	0	No response
0	0	0	1	Parameter value transferred (word)
0	0	1	0	Parameter value transferred (double word)
0	1	1	1	Command cannot be performed
1	1	1	1	text transferred

Table 12.5 Response Follower⇒ Master

If the command cannot be performed, the follower sends this response:
0111 Command cannot be performed

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

PWE low (Hex)	Fault Report
0	The parameter number used does not exit
1	There is no write access to the defined parameter
2	Data value exceeds the parameter's limits
3	The sub index used does not exit
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 frequency converter's present mode. Certain parameters can only be changed when the motor is turned off
82	There is no bus access to the defined parameter
83	Data change is not possible because factory set-up is selected

Table 12.6 Parameter Value Fault Report

12.7.8 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*.

12.7.9 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.

12.7.10 Parameter Value (PWE)

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

When a follower responds to a parameter request (read command), the present parameter value in the PWE block is transferred and returned to the master. If a parameter contains not a numerical value, but several data options, e.g. *0-01 Language* where [0] is English, and [4] is 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 to 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”.

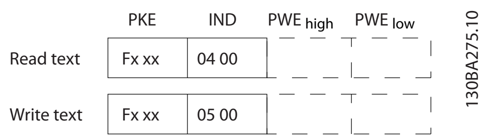

Illustration 12.11 Text via PWE Block

12.7.11 Supported Data Types

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 12.7 Supported Data Types

12.7.12 Conversion

The various attributes of each parameter are displayed in factory setting. 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 therefore read as 10.0.

Examples:
0 s ⇒ conversion index 0
0.00 s ⇒ conversion index -2
0 ms ⇒ conversion index -3
0.00 ms ⇒ conversion index -5

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

Table 12.8 Conversion Table

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12.7.13 Process Words (PCD)

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

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

Table 12.9 Process Words (PCD)

12.8 Examples

12.8.1 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
PWEHIGH = 0000 Hex

PWELOW = 03E8 Hex - Data value 1000, corresponding to 100 Hz, see *chapter 12.7.12 Conversion*.

The telegram looks like this:

E19E H	0000 H	0000 H	03E8 H
PKE	IND	PWE high	PWE low

130BA092.10

Illustration 12.12 Write Data in EEPROM

NOTICE

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

The response from the follower to the master is:

119E H	0000 H	0000 H	03E8 H
PKE	IND	PWE high	PWE low

130BA093.10

Illustration 12.13 Response from Follower

12.8.2 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
PWEHIGH = 0000 Hex
PWELOW = 0000 Hex

1155 H	0000 H	0000 H	0000 H
PKE	IND	PWE high	PWE low

130BA094.10

Illustration 12.14 Parameter Value

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

1155 H	0000 H	0000 H	03E8 H
PKE	IND	PWE high	PWE low

130BA267.10

Illustration 12.15 Response from Follower

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*.

12.9 Modbus RTU Overview

12.9.1 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.

12.9.2 What the User Should Already Know

The built-in 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.

12.9.3 Modbus RTU Overview

Regardless of the type of physical communication networks, the Modbus RTU Overview describes the process a controller uses to request access to another device. This process includes how the Modbus RTU responds to requests from another device, and how errors are detected and reported. It also establishes a common format for the layout and contents of message fields.
During communications over a Modbus RTU network, the protocol determines:

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

If a reply is required, the controller constructs the reply message and sends it.
Controllers communicate using a master-follower technique in which only the master can initiate transactions (called queries). Followers respond by supplying the requested data to the master, or by taking the action requested in the query.
The master can address individual followers, or initiate a broadcast message to all followers. Followers return a response to queries that are addressed to them individually. No responses are returned to broadcast queries from the master. The Modbus RTU protocol establishes the format for the master's query by providing the device (or broadcast) address, a function code defining the requested action, any data to be sent, and an error-checking field. The follower's response message is also constructed using Modbus protocol. It contains fields confirming the action taken, any data to be returned, and an error-checking field. If an error occurs in receipt of the message, or if the follower is unable to perform the

requested action, the follower constructs an error message, and send it in response, or a time-out occurs.

12.9.4 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 a variety of preset speeds
- Run in reverse
- Change the active set-up
- Control the frequency converter's built-in relay

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.

12.10 Network Configuration

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 12.10 Modbus RTU Parameters

12.11 Modbus RTU Message Framing Structure

12.11.1 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 12.11*.

Start bit	Data byte								Stop/ parity	Stop

Table 12.11 Format for Each Byte

Coding System	8-bit binary, hexadecimal 0-9, A-F. 2 hexadecimal characters contained in each 8-bit field of the message
Bits Per Byte	1 start bit 8 data bits, least significant bit sent first 1 bit for even/odd parity; no bit for no parity 1 stop bit if parity is used; 2 bits if no parity
Error Check Field	Cyclical Redundancy Check (CRC)

12.11.2 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 12.12*.

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 12.12 Typical Modbus RTU Message Structure

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12.11.3 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 field to be transmitted is the device address. Following the last transmitted character, a similar period of at least 3.5 character intervals marks the end of the message. A new message can begin after this period. The entire message frame must be transmitted as a continuous stream. If a silent period of more than 1.5 character intervals occurs before completion of the frame, the receiving device flushes the incomplete message and assumes that the next byte is the address field of a new message. Similarly, if a new message begins before 3.5 character intervals after a previous message, the receiving device considers it a continuation of the previous message. This causes a time-out (no response from the follower), since the value in the final CRC field is not valid for the combined messages.

12.11.4 Address Field

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

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12.11.5 Function Field

The function field of a message frame contains 8 bits. Valid codes are in the range of 1-FF. Function fields are used to send messages between master and follower. When a message is sent from a master to a follower device, the function code field tells the follower what kind of action to perform. When the follower responds to the master, it uses the function code field to indicate either a normal (error-free) response, or that some kind of error occurred (called an exception response). For a normal response, the follower simply echoes the original function code. For an exception response, the follower returns a code that is equivalent to the original function code with its most significant bit set to logic 1. In addition, the follower places a unique code into the data field of the response message. This tells the master what kind of error occurred, or the reason for the exception. Also refer to *chapter 12.11.10 Function Codes Supported by Modbus RTU* and *chapter 12.11.11 Modbus Exception Codes*

12.11.6 Data Field

The data field is constructed using sets of 2 hexadecimal digits, in the range of 00 to FF hexadecimal. These are made up of one RTU character. The data field of messages sent from a master to follower device contains additional information which the follower must use to take the action defined by the function code. This can include items such as coil or register addresses, the quantity of items to be handled, and the count of actual data bytes in the field.

12.11.7 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 2 values are unequal, a bus time-out results. The error-checking field contains a 16-bit binary value implemented as 2 8-bit bytes. When this is done, 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.

12.11.8 Coil Register Addressing

In Modbus, all data are organised in coils and holding registers. Coils hold a single bit, whereas holding registers hold a 2-byte word (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	Master to follower
17-32	Frequency converter speed or set-point reference Range 0x0 – 0xFFFF (-200% ... ~200%)	Master to follower
33-48	Frequency converter status word (see *Table 12.15*)	Follower to master
49-64	Open loop mode: Frequency converter output frequency Closed loop mode: Frequency converter feedback signal	Follower to master
65	Parameter write control (master to follower) 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.	Master to follower
66-65536	Reserved	

Table 12.13 Coil Descriptions

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 12.14 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 12.15 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 12.16 Holding Registers

** Used to specify the index number to be used when accessing an indexed parameter.*

12

12.11.9 How to Control the Frequency Converter

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

12.11.10 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 (hex)
Read coils	1
Read holding registers	3
Write single coil	5
Write single register	6
Write multiple coils	F
Write multiple registers	10
Get comm. event counter	B
Report follower ID	11

Table 12.17 Function Codes

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

Table 12.18 Function Codes

12.11.11 Modbus Exception Codes

For a full explanation of the structure of an exception code response, refer to *chapter 12.11.5 Function Field.*

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

Table 12.19 Modbus Exception Codes

12.12 How to Access Parameters

12.12.1 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 (10 x parameter number) DECIMAL. Example: Reading *3-12 Catch up/slow Down Value* (16bit): The holding register 3120 holds the parameters value. A value of 1352 (Decimal), means that the parameter is set to 12.52%

Reading *3-14 Preset Relative Reference* (32bit): The holding registers 3410 & 3411 holds the parameters value. A value of 11300 (Decimal), means that the parameter is set to 1113.00.

For information on the parameters, size and converting index, consult the product relevant programming guide.

12.12.2 Storage of Data

The coil 65 decimal determines whether data written to the frequency converter are stored in EEPROM and RAM (coil 65=1) or only in RAM (coil 65= 0).

12.12.3 IND (Index)

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

12.12.4 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.

12.12.5 Conversion Factor

The different attributes for each parameter can be seen in the section on factory settings. Since a parameter value can only be transferred as a whole number, a conversion factor must be used to transfer decimals.

12.12.6 Parameter Values

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

Non-standard data types
Non-standard data types are text strings and are stored as 4x registers (40001–4FFFF). The parameters are read using function 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).

12.13 Danfoss FC Control Profile

12.13.1 Control Word According to FC Profile (*8-10 Control Profile* = FC profile)

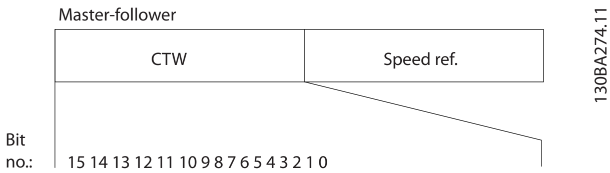

Illustration 12.16 Control Word

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 12.20 Control Word Bits

12

Explanation of the Control Bits

Bits 00/01
Bits 00 and 01 are used to select between the 4 reference values, which are pre-programmed in *3-10 Preset Reference* according to *Table 12.21*.

Programmed ref. value	Parameter	Bit 01	Bit 00
1	*3-10 Preset Reference* [0]	0	0
2	*3-10 Preset Reference* [1]	0	1
3	*3-10 Preset Reference* [2]	1	0
4	*3-10 Preset Reference* [3]	1	1

Table 12.21 Reference Values

NOTICE

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

Bit 02, DC brake
Bit 02 = ’0’ leads to DC braking and stop. Set braking current and duration in *2-01 DC Brake Current* and *2-02 DC Braking Time*.
Bit 02 = ’1’ leads to ramping.

Bit 03, Coasting
Bit 03 = ’0’: The frequency converter immediately "lets go" of the motor, (the output transistors are "shut off") and it coasts to a standstill.
Bit 03 = ’1’: The frequency converter starts the motor, if the other starting conditions are met.

Make a selection in *8-50 Coasting Select* to define how Bit 03 gates with the corresponding function on a digital input.

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

Bit 05, Hold output frequency
Bit 05 = ’0’: The present output frequency (in Hz) freezes. Change the frozen output frequency only with the digital inputs (*5-10 Terminal 18 Digital Input* to *5-15 Terminal 33 Digital Input*) programmed to *Speed up* and *Slow down*.

NOTICE

If Freeze output is active, the frequency converter can only be stopped by the following:

- **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*.**

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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 signal’s leading edge, 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
Tells 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. Turn off the control word, if it should not be used when updating or reading parameters.

Bit 11, Relay 01
Bit 11 = "0": Relay not activated.
Bit 11 = "1": Relay 01 activated provided that *Control word bit 11* is selected in *5-40 Function Relay*.

Bit 12, Relay 04
Bit 12 = "0": Relay 04 is not activated.
Bit 12 = "1": Relay 04 is activated provided that *Control word bit 12* is selected in *5-40 Function Relay*.

Bit 13/14, Selection of set-up
Use bits 13 and 14 to select from the 4 menu set-ups according to *Table 12.22*.

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

Table 12.22 4 Menu Set-ups

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 or Logic and is selected.

12.13.2 Status Word According to FC Profile (STW) (*8-10 Control Profile* = FC profile)

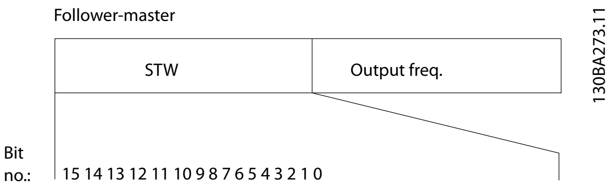

Illustration 12.17 Status Word

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 12.23 Status Word Bits

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 might 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 activated on the control unit or *Local control* in *3-13 Reference Site* is selected. Control via serial communication is not possible.
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 overtemperature on the inverter.
Bit 12 = ’1’: The inverter stops because of overtemperature, but the unit does not trip and resumes operation once the overtemperature stops.

Bit 13, Voltage OK/limit exceeded
Bit 13 = ’0’: There are no voltage warnings.
Bit 13 = ’1’: The DC-voltage in the frequency converter’s 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.

12.13.3 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 by means of 2’s complement. The actual output frequency (MAV) is scaled in the same way as the bus reference.

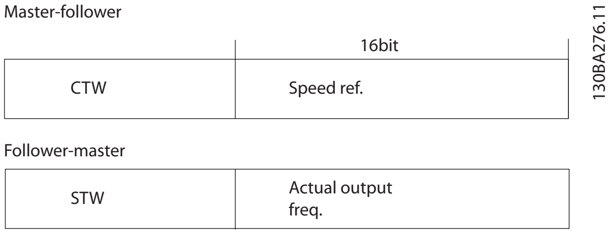

Illustration 12.18 Actual Output Frequency (MAV)

The reference and MAV are scaled as follows:

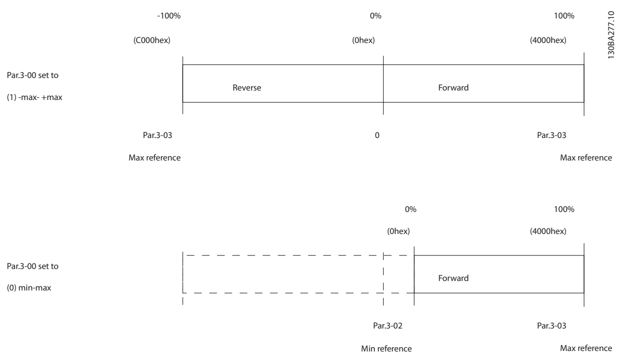

Illustration 12.19 Reference and MAV

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12.13.4 Control Word according to PROFIdrive Profile (CTW)

The control word is used to send commands from a master (for example, a PC) to a follower.

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

Table 12.24 Control Word Bits

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 0="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*.

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

Bit 03, Coasting/No coasting
Coasting stop Bit 03="0" leads to a stop.
When bit 03="1", the frequency converter can start if the other start conditions are satisfied.

NOTICE

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

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

NOTICE

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

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

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

NOTICE

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

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

Bit 08, Jog 1 OFF/ON
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, that is, it is possible to turn off the control word, if it should not be used for 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, that is, the speed reference value is reduced.

Bits 13/14, Set-up selection
Bits 13 and 14 are used to select between the 4 parameter set-ups according to *Table 12.25*:

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

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

Table 12.25 Set-up Selection

Bit 15, No function/Reverse
Bit 15="0" causes no reversing.
Bit 15="1" causes reversing.
Note: In the factory setting reversing is set to *digital* in *8-54 Reversing Select*.

NOTICE

Bit 15 causes reversing only when *Ser. communication, Logic or* or *Logic and* is selected.

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12.13.5 Status Word according to PROFIdrive Profile (STW)

The status word is used to notify a master (for example, a PC) about the status of a follower.

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

Table 12.26 Status Word Bits

Explanation of the status bits

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

Bit 01, VLT not ready/ready
Same significance as bit 00, however, there is a supply of the power unit. The frequency converter is ready when it receives the necessary start signals.

Bit 02, Coasting/Enable
When bit 02="0", bit 00, 01 or 02 of the control word is "0" (OFF 1, OFF 2 or OFF 3 or coasting) - or the frequency converter is switched off (trip).
When bit 02="1", bit 00, 01 or 02 of the control word is "1"; the frequency converter has not tripped.

Bit 03, No error/Trip
When bit 03="0", no error condition of the frequency converter exists.
When bit 03="1", the frequency converter has tripped and requires a reset signal before it can start.

Bit 04, ON 2/OFF 2
When bit 01 of the control word is "0", then bit 04="0".
When bit 01 of the control word is "1", then bit 04="1".

Bit 05, ON 3/OFF 3
When bit 02 of the control word is "0", then bit 05="0".
When bit 02 of the control word is "1", then bit 05="1".

Bit 06, Start possible/Start not possible
If PROFIdrive has been selected in *8-10 Control Word Profile*, bit 06 is "1" after a switch-off acknowledgment, after activation of OFF2 or OFF3, and after switching on the mains voltage. Start not possible is reset, with bit 00 of the control word being set to "0" and bit 01, 02 and 10 being set to "1".

Bit 07, No warning/Warning
Bit 07="0" means that there are no warnings.
Bit 07="1" means that a warning has occurred.

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

Bit 09, Local operation/Bus control
Bit 09="0" indicates that the frequency converter has been stopped with [Stop] 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 starts 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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Design Guide
VLT® Micro Drive FC 51

Contents

1 Introduction

1.1 Available Literature

This design guide contains the basic information necessary for installing and running the frequency converter.

Danfoss technical literature is available in print from local Danfoss Sales Offices.

- *VLT® Micro Drive FC 51 Quick Guide*
- *VLT® Micro Drive FC 51 Programming Guide*
- *VLT® Micro Drive FC 51 LCP Mounting Instruction*
- *VLT® Micro Drive FC 51 De-coupling Plate Mounting Instruction*
- *VLT® Micro Drive FC 51 Remote Mounting Kit Mounting Instruction*
- *VLT® Micro Drive FC 51 DIN Rail Kit Mounting Instruction*
- *VLT® Micro Drive FC 51 IP21 Kit Mounting Instruction*
- *VLT® Micro Drive FC 51 Nema1 Kit Mounting Instruction*
- *VLT® Micro Drive FC 51 Line Filter MCC 107 Installation Instruction*

1.2 Manual and Software Version

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

Edition	Remarks	Software version
MG02K4XX	Miscellaneous minor updates.	3.1X

Table 1.1 Manual and Software Version

1.3 Abbreviations

°C	Degrees celsius
A	Ampere/AMP
AC	Alternating current
AMT	Automatic motor tuning
AWG	American wire gauge
DC	Direct current
EMC	Electro magnetic compatibility
ETR	Electronic thermal relay
FC	Frequency converter
$f_{M,N}$	Nominal motor frequency
g	Gram
Hz	Hertz
I_{INV}	Rated inverter output current
I_{LIM}	Current limit
$I_{M,N}$	Nominal motor current
$I_{VLT,MAX}$	The maximum output current
$I_{VLT,N}$	The rated output current supplied by the frequency converter
kHz	Kilohertz
LCP	Local control panel
m	Meter
mA	Milliampere
MCT	Motion control tool
mH	Millihenry inductance
min	Minute
ms	Millisecond
nF	Nanofarad
Nm	Newton meters
n_s	Synchronous motor speed
$P_{M,N}$	Nominal motor power
PCB	Printed circuit board
PELV	Protective extra low voltage
RPM	Revolutions per minute
Regen	Regenerative terminals
s	Second
T_{LIM}	Torque limit
$U_{M,N}$	Nominal motor voltage
V	Volt

Table 1.2 Abbreviations

1.4 Definitions

1.4.1 Frequency Converter

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

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

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

1.4.2 Input

Control command
The connected motor can be started and stopped with LCP and the digital inputs.
Functions are divided into 2 groups.
Functions in group 1 have higher priority than functions in group 2.

Group 1	Reset, coast stop, reset and coast stop, quick stop, DC brake, stop, and the [Off] key.
Group 2	Start, pulse start, reversing, start reversing, jog, and freeze output.

Table 1.3 Function Groups

1.4.3 Motor

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

f_M
The motor frequency.

f_{MAX}
The maximum motor frequency.

f_{MIN}
The minimum motor frequency.

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

I_M
The motor current.

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

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

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

U_M
The instant motor voltage.

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

Break-away torque

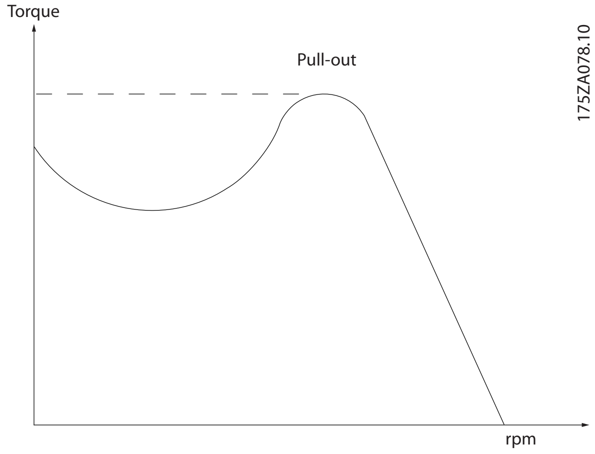


Illustration 1.1 Break-away Torque

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

Start-disable command
A stop command belonging to the group 1 control commands, see *Table 1.3*.

Stop command
See *Table 1.3*.

1.4.4 References

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

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

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

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 *parameter 3-03 Maximum Reference*.

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

1.4.5 Miscellaneous

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

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

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

Automatic Motor Tuning, AMT
AMT algorithm determines the electrical parameters for the connected motor at standstill.

Brake resistor
The brake resistor is a module capable of absorbing the brake power generated in regenerative braking. This regenerative brake power increases the DC-link voltage, and a brake chopper ensures that the power is transmitted to the brake resistor.

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

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

Relay outputs
The frequency converter features 2 programmable relay outputs.

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

Initializing
If initializing is carried out (*parameter 14-22 Operation Mode*), the programmable parameters of the frequency converter return to their default settings.
Initializing *parameter 14-22 Operation Mode* does not initialize communication parameters.

Intermittent duty cycle
An intermittent duty rating refers to a sequence of duty cycles. Each cycle consists of an on-load and an off-load period. The operation can be either periodic duty or none-periodic duty.

LCP
The local control panel 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 m from the frequency converter, that is, in a front panel with the installation kit option.

lsb
Least significant bit.

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

msb
Most significant bit.

On-line/Off-line parameters
Changes to on-line parameters are activated immediately after the data value is changed. To activate changes to off-line parameters, press [OK].

PI controller
The PI controller maintains the speed, pressure, temperature, and so on, by adjusting the output frequency to match the varying load.

RCD
Residual current device.

Set-up
Save parameter settings in 2 set-ups. Change between the 2 parameter set-ups and edit 1 set-up, while another set-up is active.

Slip compensation
The frequency converter compensates for the motor slip by giving the frequency a supplement that follows the measured motor load keeping the motor speed almost constant.

Smart logic control (SLC)
The SLC is a sequence of user-defined actions executed when the associated user-defined events are evaluated as true by the SLC.

Thermistor
A temperature-dependent resistor.

STW
Status word.

FC standard bus
Includes RS485 bus with FC protocol.

Trip
A state entered in fault situations, for example, if the frequency converter is subject to an overtemperature 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 canceled by activating reset or, sometimes, by being programmed to reset automatically. Do not use trip for personal safety.

Trip lock
A state entered in fault situations when the frequency converter is protecting itself and requiring physical intervention, for example, if the frequency converter is subject to a short circuit on the output. A trip lock can only be canceled by cutting off mains, removing the cause of the fault, and reconnecting the frequency converter. Restart is prevented until the trip state is canceled by activating reset or, sometimes, by being programmed to reset automatically. Trip lock may not be used for personal safety.

1

VT characteristics
Variable torque characteristics used for pumps and fans.

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

1.5 Power Factor

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

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

The power factor for 3-phase control:

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

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

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

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

2

2 Safety and Conformity

2.1 Safety

The following symbols are used in this manual:

⚠WARNING

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

⚠CAUTION

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

NOTICE

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

2.1.1 Safety Precautions

⚠WARNING

HIGH VOLTAGE

Frequency converters contain high voltage when connected to AC mains input, DC supply, or load sharing. Failure to perform installation, start-up, and maintenance by qualified personnel can result in death or serious injury.

- **Only qualified personnel must perform installation, start-up, and maintenance.**

⚠WARNING

UNINTENDED START

When the frequency converter is connected to AC mains, DC supply, or load sharing, the motor may start at any time. Unintended start during programming, service, or repair work can result in death, serious injury, or property damage. The motor can start with an external switch, a fieldbus command, an input reference signal from the LCP or LOP, via remote operation using MCT 10 Set-up Software, or after a cleared fault condition.

To prevent unintended motor start:

- **Press [Off/Reset] on the LCP before programming parameters.**
- **Disconnect the frequency converter from the mains.**
- **Completely wire and assemble the frequency converter, motor, and any driven equipment before connecting the frequency converter to AC mains, DC supply, or load sharing.**

⚠WARNING

DISCHARGE TIME

The frequency converter contains DC-link capacitors, which can remain charged even when the frequency converter is not powered. High voltage can be present even when the warning LED indicator lights are off. Failure to wait the specified time after power has been removed before performing service or repair work can result in death or serious injury.

- **Stop the motor.**
- **Disconnect AC mains and remote DC-link power supplies, including battery back-ups, UPS, and DC-link connections to other frequency converters.**
- **Disconnect or lock PM motor.**
- **Wait for the capacitors to discharge fully. The minimum duration of waiting time is specified in *Table 2.1*.**
- **Before performing any service or repair work, use an appropriate voltage measuring device to make sure that the capacitors are fully discharged.**

Size	Minimum waiting time (minutes)
M1, M2, and M3	4
M4 and M5	15

Table 2.1 Discharge Time

⚠WARNING

LEAKAGE CURRENT HAZARD

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

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

⚠WARNING

EQUIPMENT HAZARD

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

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

⚠WARNING

UNINTENDED MOTOR ROTATION WINDMILLING

Unintended rotation of permanent magnet motors creates voltage and can charge the unit, resulting in death, serious injury, or equipment damage.

- **Ensure that permanent magnet motors are blocked to prevent unintended rotation.**

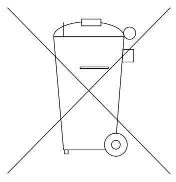
⚠CAUTION

INTERNAL FAILURE HAZARD

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

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

2.2 Disposal Instruction



Equipment containing electrical components cannot be disposed of together with domestic waste.
It must be separately collected with electrical and electronic waste according to local and currently valid legislation.

2.3 Approvals

The frequency converter complies with UL 508C thermal memory retention requirements. For more information refer to *chapter 3.5.1 Motor Thermal Protection*.

2.4 CE Labeling

2.4.1 CE Conformity and Labeling

What is CE conformity and labeling?
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 3 EU directives:

The Machinery Directive (98/37/EEC)
All machines with critical moving parts are covered by the machinery directive of January 1, 1995. Since a frequency converter is largely electrical, it does 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. Danfoss does this with a manufacturer's declaration.

The Low Voltage Directive (73/23/EEC)
Frequency converters must be CE labeled 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 on 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 after request. To carry out EMC-correct installation, see the instructions in this design guide. In addition, Danfoss specifies which standards our products comply with. Danfoss offers 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. Note that the responsibility for the final EMC properties of the appliance, system or installation rests with the installer.

2

2.4.2 What is Covered

The EU *Guidelines on the Application of Council Directive 89/336/EEC* outline 3 typical situations of using a frequency converter. See *chapter 2.4.3 Danfoss Frequency Converter and CE Labelling* for EMC coverage and CE labelling.

- The frequency converter is sold directly to the end-consumer. The frequency converter is for example sold to a DIY market. The end-consumer is a layman. The end-consumer installs the frequency converter himself for use with a hobby machine, a kitchen appliance, and so on. For such applications, the frequency converter must be CE labeled in accordance with the EMC directive.
- The frequency converter is sold for installation in a plant. The plant is built up by professionals of the trade. It could be a production plant or a heating/ventilation plant designed and installed by professionals of the trade. Neither the frequency converter nor the finished plant has to be CE labeled under the EMC directive. However, the unit must comply with the basic EMC requirements of the directive. This is ensured by using components, appliances, and systems that are CE labeled under the EMC directive.
- The frequency converter is sold as part of a complete system. The system is being marketed as complete and could for example, be an air-conditioning system. The complete system must be CE labeled in accordance with the EMC directive. The manufacturer can ensure CE labelling under the EMC directive either by using CE labeled components or by testing the EMC of the system. It is not necessary to test the entire system if only CE labeled components are selected.

2.4.3 Danfoss Frequency Converter and CE Labelling

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

However, CE labelling may cover many different specifications. Check what a given CE label specifically covers.

The covered specifications can be different and a CE label may therefore give the installer a false feeling of security when using a frequency converter as a component in a system or an appliance.

Danfoss CE labels the frequency converters in accordance with the Low Voltage Directive. This means 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.

The design guide offers detailed instructions for installation to ensure EMC-correct installation. Furthermore, Danfoss specifies which our different products comply with.

Danfoss provides other types of assistance that can help to obtain the best EMC result.

2.4.4 Compliance with EMC Directive 2004/108/EC

As mentioned, the frequency converter is mostly used by professionals of the trade as a complex component forming part of a larger appliance, system, or installation. Note 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. If the EMC-correct instructions for installation are followed, the standards and test levels stated for power drive systems are complied with.

2.5 Air Humidity

The frequency converter has been designed to meet the IEC/EN 60068-2-3 standard, EN 50178 9.4.2.2 at 50 °C (122 °F).

2.6 Aggressive Environments

A frequency converter contains many mechanical and electronic components. All are to some extent vulnerable to environmental effects.

CAUTION

Do not install the frequency converter in environments with airborne liquids, particles, or gases that may affect or damage the electronic components. Failure to take necessary protective measures increases the risk of stoppages, potentially causing equipment damage and personnel injury.

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

IP54. As an extra protection, coated printed circuit boards can be ordered as an option (standard on some power sizes).

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 dusty environments, use equipment with enclosure rating IP54 or a cabinet for IP20/TYPE 1 equipment.

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

Such chemical reactions rapidly affect and damage the electronic components. In such environments, mount the equipment in a cabinet with fresh air ventilation, keeping aggressive gases away from the frequency converter.
An extra protection in such areas is a coating of the printed circuit boards, which can be ordered as an option.

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.

2.7 Vibration and Shock

The frequency converter has been tested according to the procedure based on the shown standards, *Table 2.2*.

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

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

Table 2.2 Standards

2.8 Advantages

2.8.1 Why use a Frequency Converter for Controlling Fans and Pumps?

A frequency converter takes advantage of the fact that centrifugal fans and pumps follow the laws of proportionality for such fans and pumps. For further information, see *chapter 2.8.3 Example of Energy Savings*.

2.8.2 The Clear Advantage - Energy Savings

The clear advantage of using a frequency converter for controlling the speed of fans or pumps lies in the electricity savings.
When comparing with alternative control systems and technologies, a frequency converter is the optimum energy control system for controlling fan and pump systems.

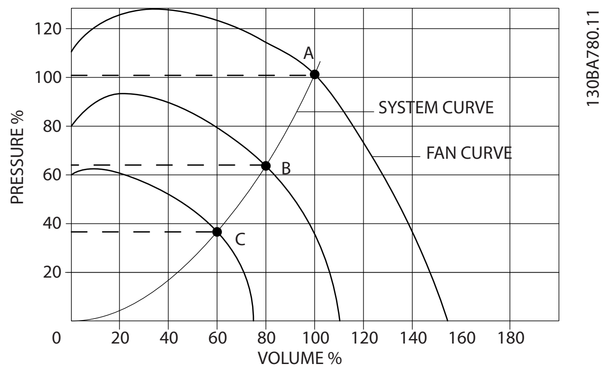


Illustration 2.1 Fan Curves (A, B, and C) for Reduced Fan Volumes

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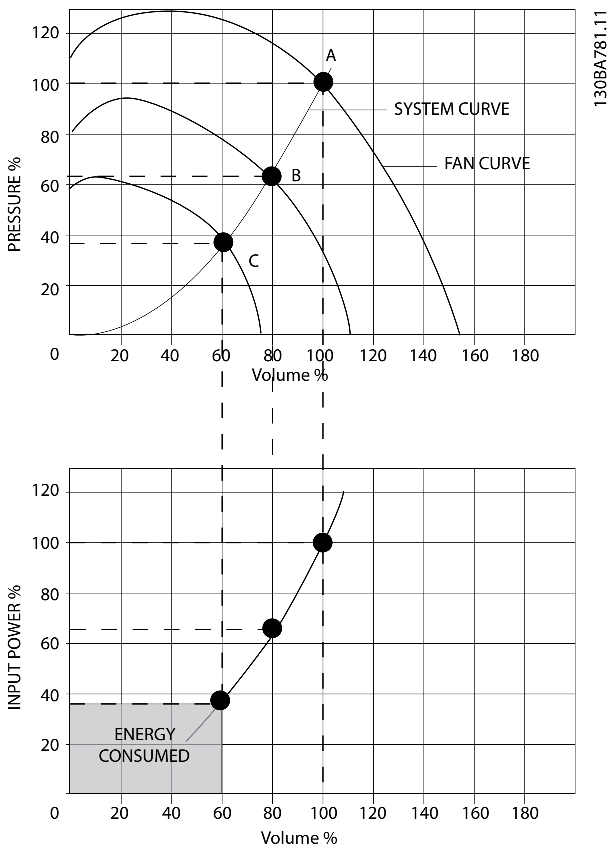


Illustration 2.2 Energy Savings with Frequency Converter Solution

When using a frequency converter to reduce fan capacity to 60% - more than 50% energy savings may be obtained in typical applications.

2.8.3 Example of Energy Savings

As shown in *Illustration 2.3*, the flow is controlled by changing the RPM. By reducing the speed by only 20% from the rated speed, the flow is also reduced by 20%. This is because the flow is directly proportional to the RPM. The consumption of electricity, however, is reduced by 50%.
If the system in question only needs to be able to supply a flow that corresponds to 100% a few days in a year, while the average is below 80% of the rated flow for the remainder of the year, the amount of energy saved is even more than 50%.

Illustration 2.3 describes the dependence of flow, pressure, and power consumption on RPM.

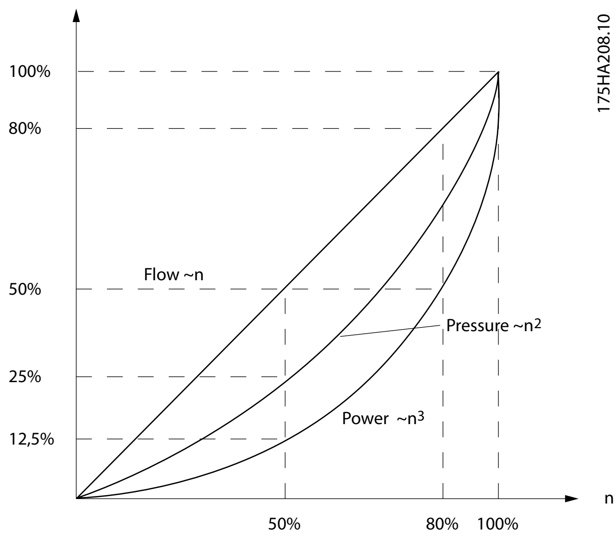


Illustration 2.3 Laws of Proportionally

$$Flow: \frac{Q_1}{Q_2} = \frac{n_1}{n_2}$$

$$Pressure: \frac{H_1}{H_2} = \left(\frac{n_1}{n_2}\right)^2$$

$$Power: \frac{P_1}{P_2} = \left(\frac{n_1}{n_2}\right)^3$$

Q=Flow	P=Power
Q_1=Rated flow	P_1=Rated power
Q_2=Reduced flow	P_2=Reduced power
H=Pressure	n=Speed control
H_1=Rated pressure	n_1=Rated speed
H_2=Reduced pressure	n_2=Reduced speed

Table 2.3 The Laws of Proportionality

2.8.4 Comparison of Energy Savings

The Danfoss frequency converter solution offers major savings compared with traditional energy saving solutions such as discharge damper solution and inlet guide vanes (IGV) solution. This is because the frequency converter is able to control fan speed according to thermal load on the system, and the frequency converter has a built-in facility that enables the frequency converter to function as a building management system, BMS.

Illustration 2.3 shows typical energy savings obtainable with 3 well-known solutions when fan volume is reduced to 60%.
As the graph shows, more than 50% energy savings can be achieved in typical applications.

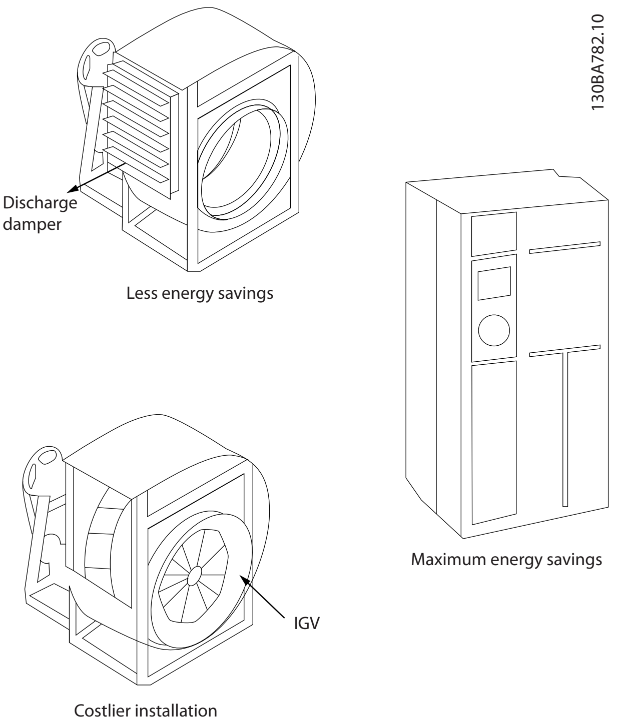


Illustration 2.4 The 3 Common Energy Saving Systems

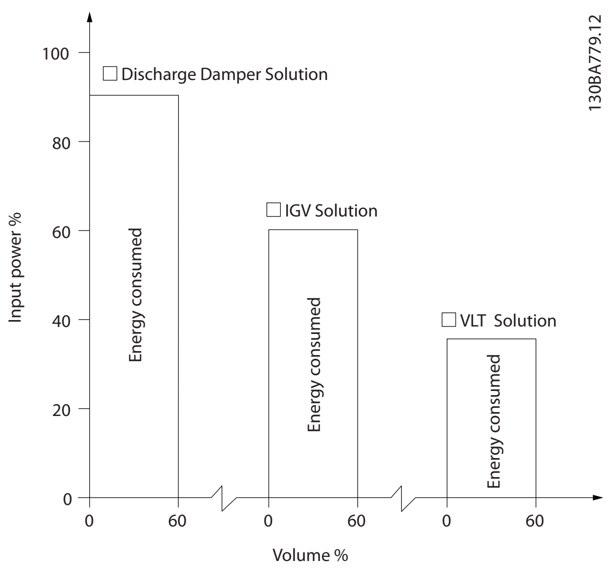


Illustration 2.5 Energy Savings

Discharge dampers reduce power consumption. Inlet guide vanes offer a 40% reduction, but are expensive to install. The Danfoss frequency converter solution reduces energy consumption with more than 50% and is easy to install. It also reduces noise, mechanical stress and wear-and-tear, and extends the life span of the entire application.

2.8.5 Example with Varying Flow over 1 Year

This example is calculated based on pump characteristics obtained from a pump datasheet.
The result obtained shows energy savings more than 50% at the given flow distribution over a year. The payback period depends on the price per kWh and the price of frequency converter. In this example, it is less than a year when compared with valves and constant speed.

Energy savings

$P_{shaft}=P_{shaft\ output}$

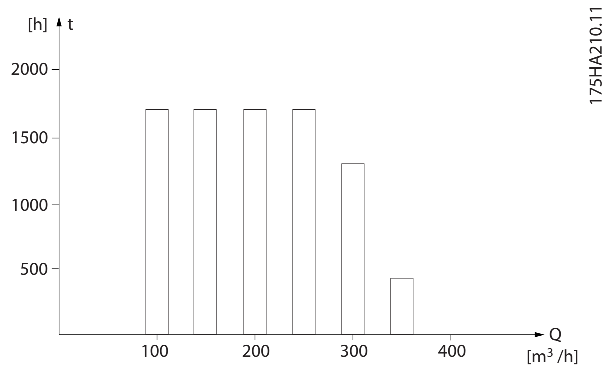


Illustration 2.6 Flow Distribution over 1 Year

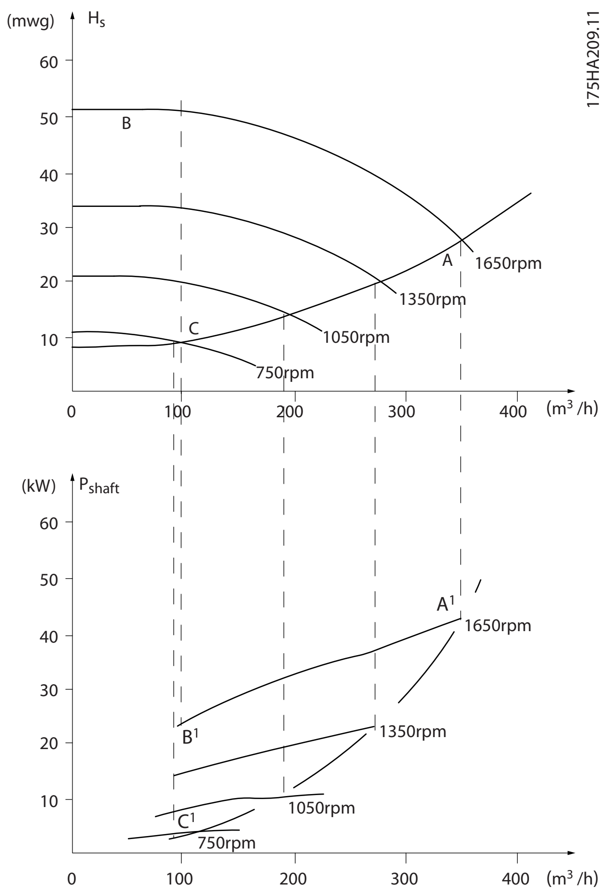


Illustration 2.7 Energy

m³/ h	Distri-bution		Valve regulation		Frequency converter control	
	%	Hours	Power	Consump-tion	Power	Consump-tion
			A_1 - B_1	kWh	A_1 - C_1	kWh
350	5	438	42.5	18.615	42.5	18.615
300	15	1314	38.5	50.589	29.0	38.106
250	20	1752	35.0	61.320	18.5	32.412
200	20	1752	31.5	55.188	11.5	20.148
150	20	1752	28.0	49.056	6.5	11.388
100	20	1752	23.0	40.296	3.5	6.132
Σ	100	8760		275.064		26.801

Table 2.4 Result

2.8.6 Better Control

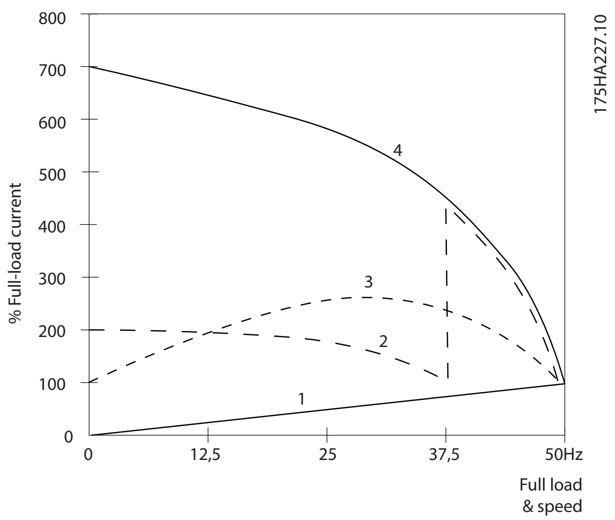
If a frequency converter is used for controlling the flow or pressure of a system, improved control is obtained.
A frequency converter can vary the speed of the fan or pump, obtaining variable control of flow and pressure.
Furthermore, a frequency converter can quickly adapt the speed of the fan or pump to new flow or pressure conditions in the system.

Simple control of process (flow, level, or pressure) utilizing the built-in PI control.

2.8.7 Star/Delta Starter or Soft Starter not Required

When larger motors are started, it is necessary in many countries to use equipment that limits the start-up current. In more traditional systems, a star/delta starter or soft starter is widely used. Such motor starters are not required if a frequency converter is used.

As illustrated in *Illustration 2.8*, a frequency converter does not consume more than rated current.



1	VLT® Micro Drive
2	Star/delta starter
3	Soft starter
4	Start directly on mains

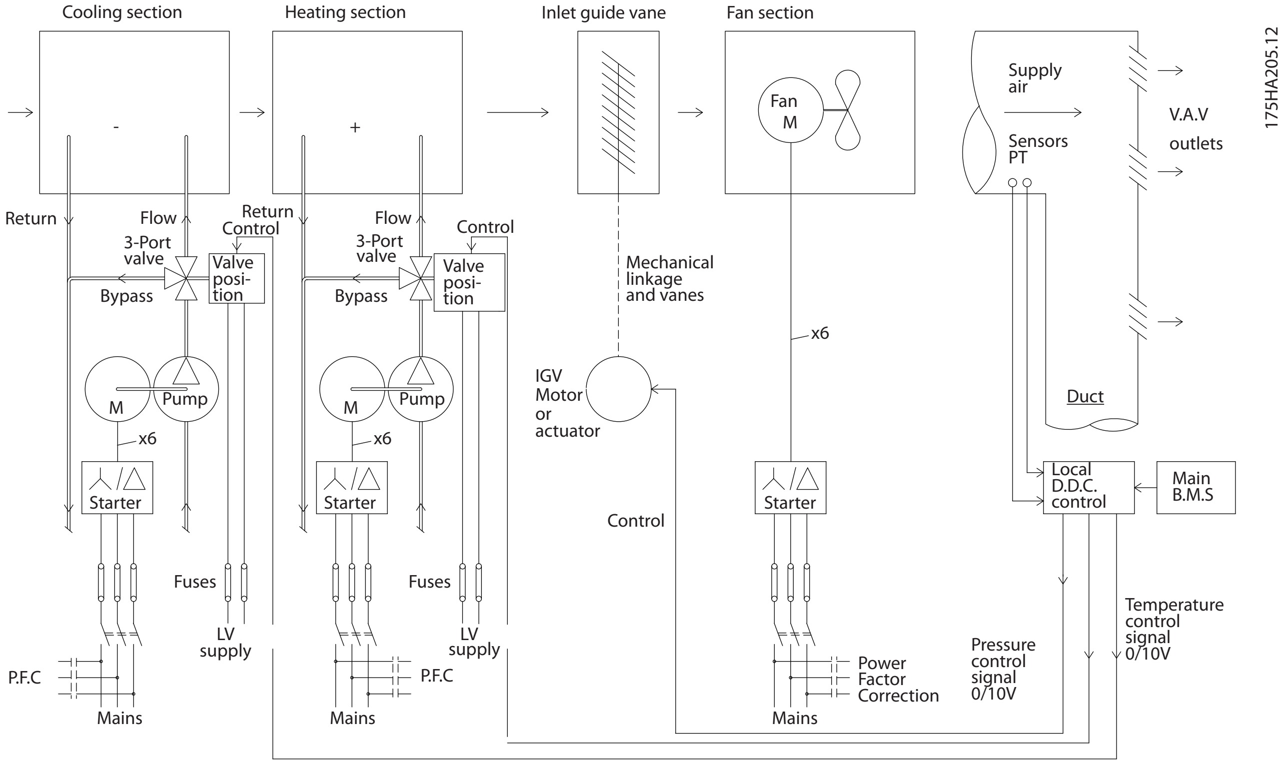
Illustration 2.8 Current

2.8.8 Using a Frequency Converter Saves Money

The example in *chapter 2.8.9 Without a Frequency Converter* shows that a frequency converter replaces other equipment. It is possible to calculate the cost of installing the 2 different systems. In the example, the 2 systems can be established at roughly the same price.

Use the VLT® Energy Box software that is introduced in *chapter 1.1 Available Literature* to calculate the cost savings that can be achieved by using a frequency converter.

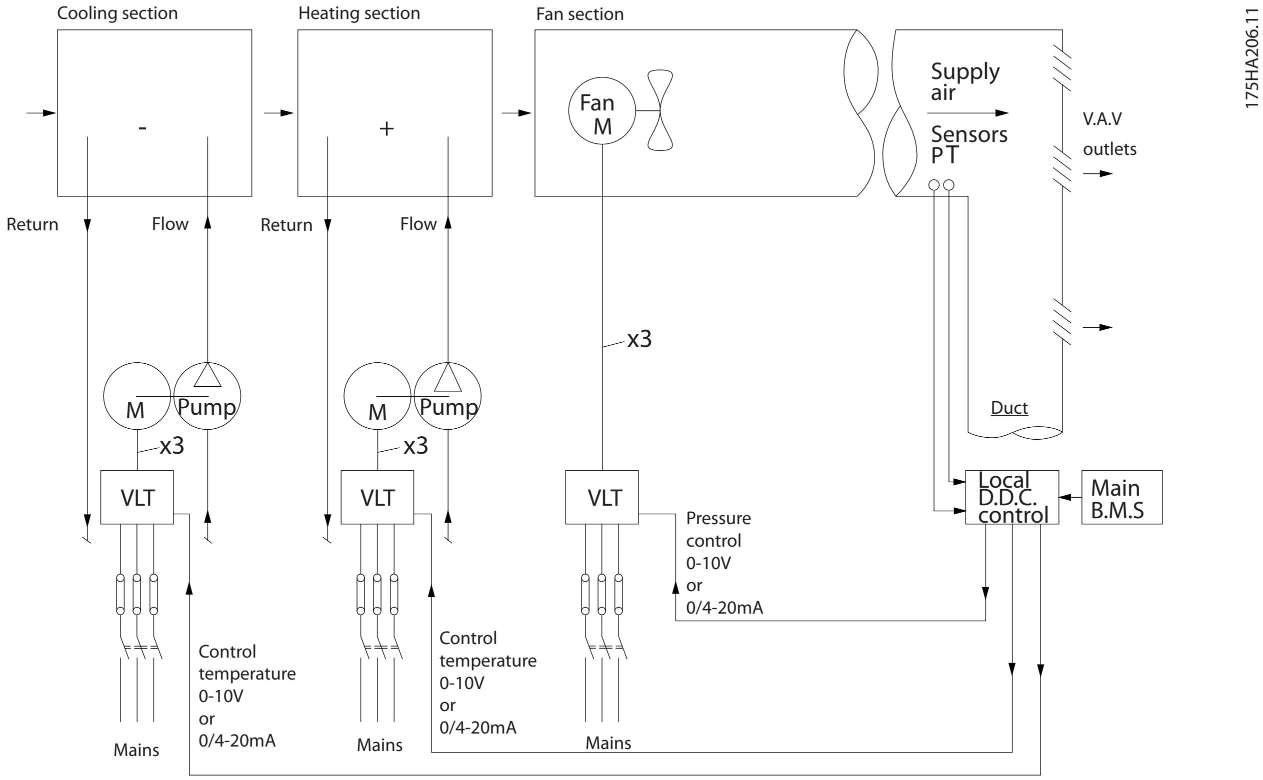
2.8.9 Without a Frequency Converter



D.D.C.	Direct digital control
E.M.S.	Energy management system
V.A.V.	Variable air volume
Sensor P	Pressure
Sensor T	Temperature

Illustration 2.9 Traditional Fan System

2.8.10 With a Frequency Converter



D.D.C.	Direct digital control
E.M.S.	Energy management system
V.A.V.	Variable air volume
Sensor P	Pressure
Sensor T	Temperature

Illustration 2.10 Fan System Controlled by Frequency Converters

3 Product Overview

3.1 Control Structures

3

Select the configuration mode in *parameter 1-00 Configuration Mode*.

3.1.1 Control Structure Open Loop

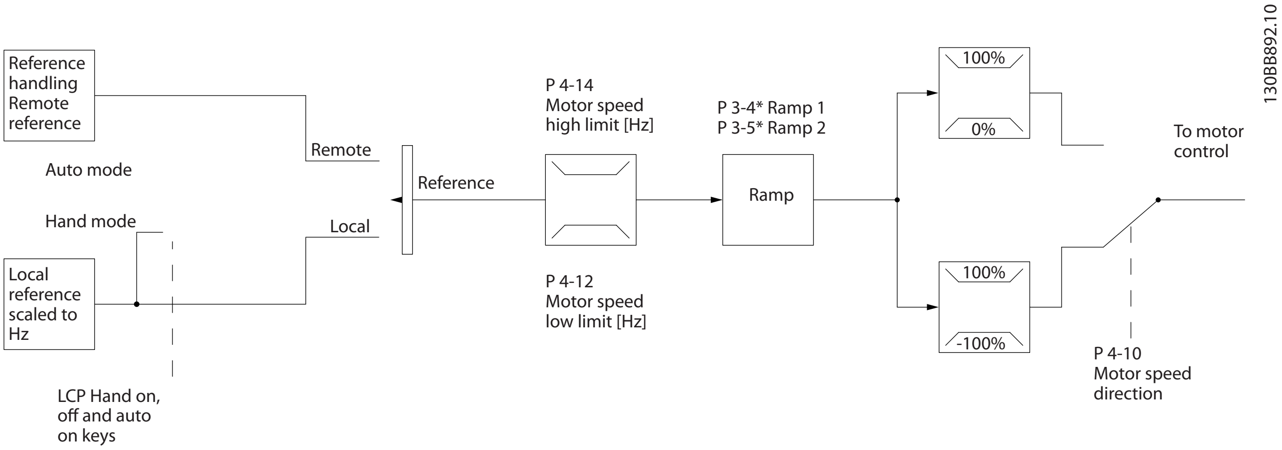


Illustration 3.1 Open-loop Structure

In the configuration shown in *Illustration 3.1*, *parameter 1-00 Configuration Mode* is set to *[0] Open loop*. The resulting reference from the reference handling system or the local reference is received and fed through the ramp limitation and speed limitation before being sent to the motor control. The output from the motor control is then limited by the maximum frequency limit.

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

The frequency converter can be operated manually via the local control panel (LCP) or remotely via analog/digital inputs or fieldbus. If allowed in *parameter 0-40 [Hand on] Key on LCP*, *parameter 0-44 [Off/Reset] Key on LCP*, and *parameter 0-42 [Auto on] Key on LCP*, it is possible to start and stop the frequency converter by pressing the [Hand On] and [Off/Reset] keys. Alarms can be reset via the [Off/Reset] key. After pressing the [Hand On] key, the frequency converter goes into hand mode and follows (by default) the local reference set using the LCP potentiometer (LCP 12) or [▲]/[▼] (LCP 11). The potentiometer can be disabled using parameter *6-80 LCP Potmeter Enable*. If the potentiometer is disabled, use the navigation keys for adjusting reference.

After pressing the [Auto On] key, the frequency converter goes into auto mode and follows (by default) the remote reference. In this mode, it is possible to control the frequency converter via the digital inputs and RS485. See more about starting, stopping, changing ramps and parameter set-ups, and so on, in parameter group *5-1* Digital Inputs* or parameter group *8-5* Serial Communication*.

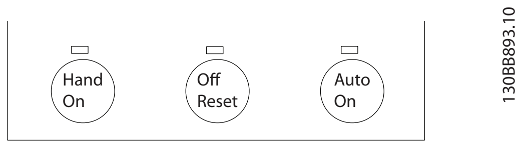


Illustration 3.2 LCP Control Keys

Local reference forces the configuration mode to open loop, independent on the setting of *1-00 Configuration Mode*.

Local reference is restored at power-down.

3.1.3 Control Structure Closed Loop

The internal controller allows the frequency converter to become a part of the controlled system. The frequency converter receives a feedback signal from a sensor in the system. It then compares this feedback to a setpoint reference value and determines the error, if any, between these 2 signals. It then adjusts the speed of the motor to correct this error.

For example, consider a pump application where the speed of a pump is to be controlled so that the static pressure in a pipe is constant. The static pressure value is supplied to the frequency converter as the setpoint reference. A static pressure sensor measures the actual static pressure in the pipe and supplies this data to the frequency converter as a feedback signal. If the feedback signal is greater than the setpoint reference, the frequency converter slows the pump down to reduce the pressure. In a similar way, if the pipe pressure is lower than the setpoint reference, the frequency converter automatically speeds the pump up to increase the pressure provided by the pump.

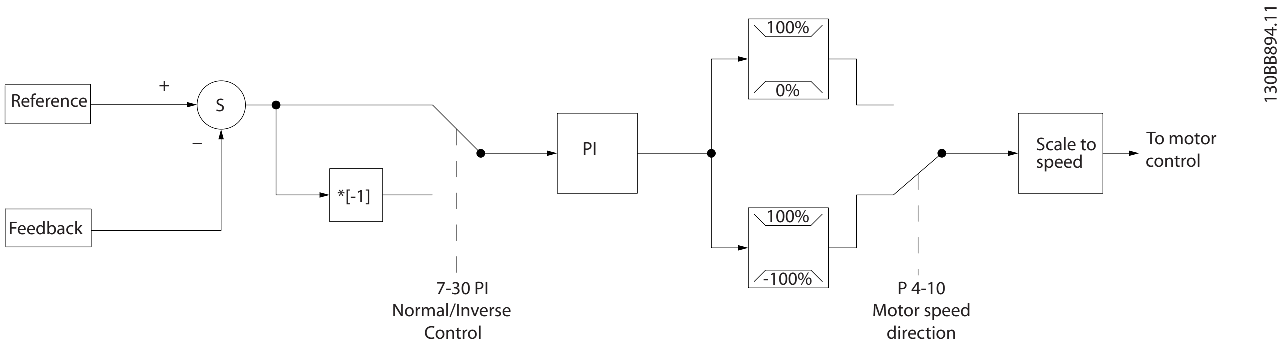


Illustration 3.3 Control Structure Closed Loop

While the default values for the closed-loop controller of the frequency converter often provide satisfactory performance, the control of the system can often be optimized by adjusting parameters.

3

3.1.4 Reference Handling

Details for open-loop and closed-loop operation.

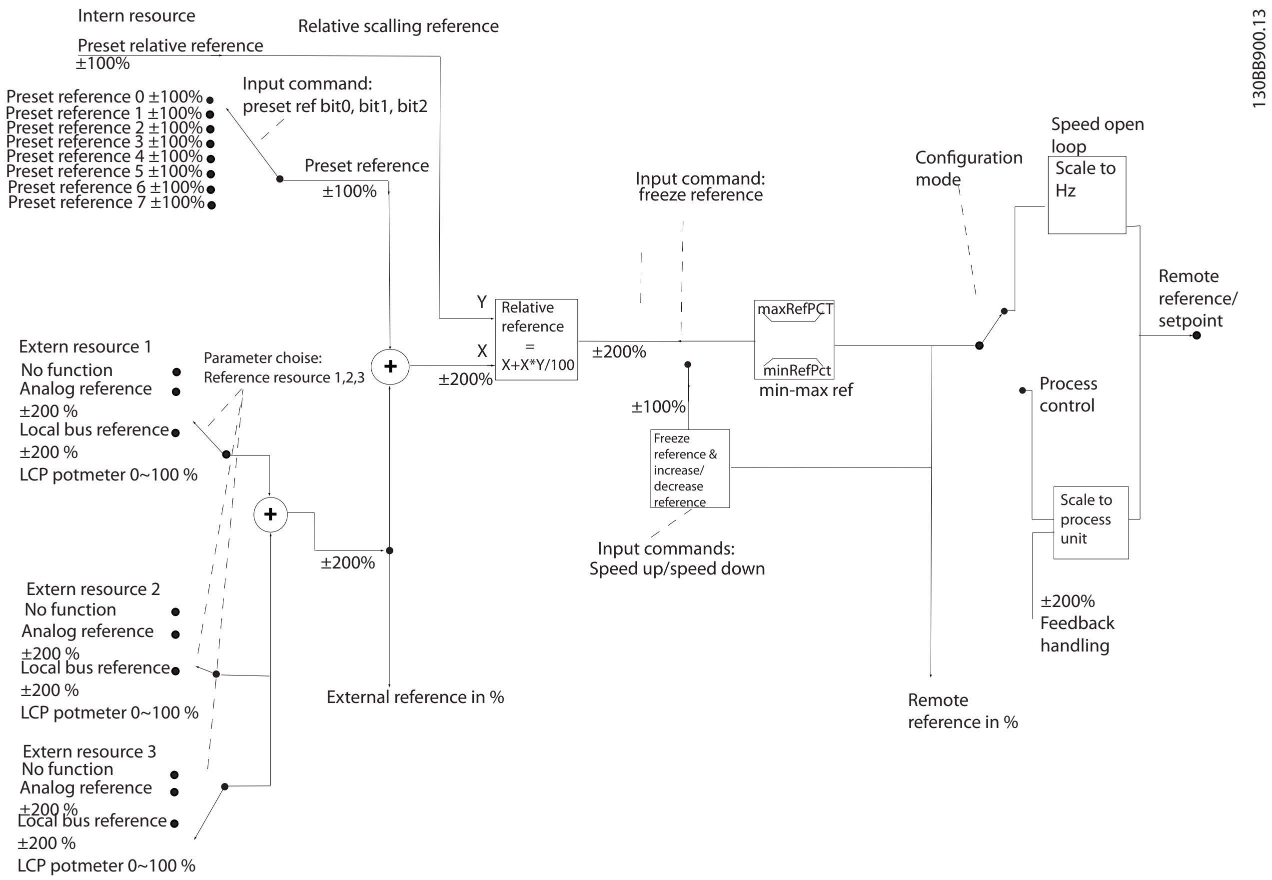


Illustration 3.4 Block Diagram Showing Remote Reference

The remote reference consists of:

- Preset references.
- External references (analog inputs and serial communication bus references).
- The preset relative reference.
- Feedback-controlled setpoint.

Up to 8 preset references can be programmed in the frequency converter. The active preset reference can be selected using digital inputs or the serial communications bus. The reference can also be supplied externally, most commonly from an analog input. This external source is selected by 1 of the 3 reference source parameters (*parameter 3-15 Reference 1 Source*, *parameter 3-16 Reference 2 Source*, and *parameter 3-17 Reference 3 Source*). All reference resources and the bus reference are added to produce the total external reference. The external reference, the preset reference, or the sum of the 2 can be selected to be the active reference. Finally, this reference can by be scaled using *parameter 3-14 Preset Relative Reference*.

The scaled reference is calculated as follows:

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

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

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

3.2 General Aspects of EMC

3.2.1 General Aspects of EMC Emissions

Frequency converters (and other electrical devices) generate electronic or magnetic fields that may interfere with their environment. The electromagnetic compatibility (EMC) of these effects depends on the power and the harmonic characteristics of the devices.

Uncontrolled interaction between electrical devices in a system can degrade compatibility and impair reliable operation. Interference may take the form of mains harmonics distortion, electrostatic discharges, rapid voltage fluctuations, or high frequency interference. Electrical devices generate interference along with being affected by interference from other generated sources.

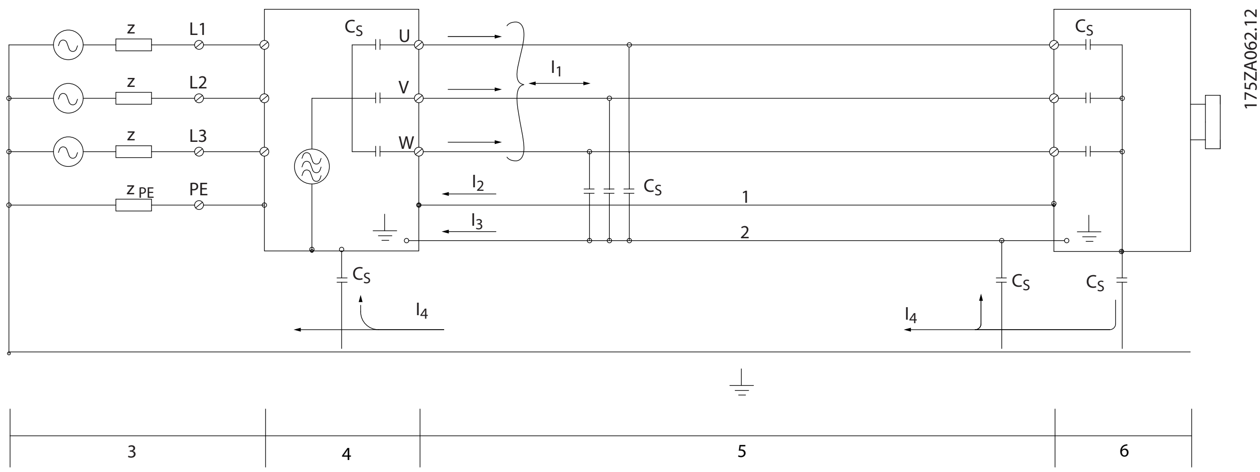
Electrical interference usually occurs at frequencies in the range 150 kHz to 30 MHz. Airborne interference from the frequency converter system in the range 30 MHz to 1 GHz is generated from the inverter, motor cable, and the motor. Capacitive currents in the motor cable coupled with a high dU/dt from the motor voltage generate leakage currents, as shown in *Illustration 3.5*.
The use of a shielded motor cable increases the leakage current (see *Illustration 3.5*) because shielded cables have higher capacitance to ground than unshielded cables. If the leakage current is not filtered, it causes greater interference on the mains in the radio frequency range below approximately 5 MHz. Since the leakage current (I_1) is carried back to the unit through the shield (I_3), there is, in principle, only a small electro-magnetic field (I_4) from the shielded motor cable according to *Illustration 3.5*.

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

When placing the shield on a mounting plate for the frequency converter, ensure that the mounting plate is made of metal, to convey the shield currents back to the unit. Ensure good electrical contact from the mounting plate through the mounting screws to the frequency converter chassis.

When using unshielded cables, some emission requirements are not complied with, although most immunity requirements are observed.

To reduce the interference level from the entire system (unit+installation), make motor and brake cables as short as possible. Avoid placing cables with a sensitive signal level alongside motor cables and brake cables. The control electronics generate radio interference at frequencies higher than 50 MHz (airborne).



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

Illustration 3.5 Generation of Leakage Currents

3

3.2.2 Emission Requirements

The EMC product standard for frequency converters defines 4 categories (C1, C2, C3, and C4) with specified requirements for emission and immunity. *Table 3.1* states the definition of the 4 categories and the equivalent classification from EN 55011.

Category	Definition	Equivalent emission class 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, which are not plug-in and not movable, and must be installed and commissioned by a professional.	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 3.1 Correlation between IEC 61800-3 and EN 55011

When the generic (conducted) emission standards are used, the frequency converters are required to comply with the limits in *Table 3.2*.

Environment	Generic emission standard	Equivalent emission class 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 3.2 Correlation between Generic Emission Standards and EN 55011

3.2.3 EMC Test Results (Emission)

FC type	Conducted emission. Maximum shielded cable length [m]						Radiated emission			
	Industrial environment				Housing, trades, and light industries		Industrial environment			
	EN 55011 Class A2		EN 55011 Class A1		EN 55011 Class B		EN 55011 Class A2		EN 55011 Class A1	
	Without external filter	With external filter	Without external filter	With external filter	Without external filter	With external filter	Without external filter	With external filter	Without external filter	With external filter
≤2.2 kW. Single-phase, 230 V	25	–	15	50	5	15	Yes	–	No	Yes
≤7.5 kW. Up to 500 V AC, 3-phase	25	–	15	50	–	15	Yes	–	No	Yes
11–22 kW. Up to 500 V AC, 3-phase	25	–	15	50	–	15	Yes	–	No	Yes

Table 3.3 EMC Test Result

3.2.4 Harmonics Emission Requirements

Equipment connected to the public supply network

NOTICE

Without a power option, the frequency converter may not comply with harmonics emission requirements.

Options	Definition
1	IEC/EN 61000-3-2 Class A for 3-phase balanced equipment (for professional equipment only up to 1 kW total power).
2	IEC/EN 61000-3-12 Equipment 16 A-75 A and professional equipment as from 1 kW up to 16 A phase current.

Table 3.4 Harmonics Emission Requirements

3.2.5 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 therefore comply also with the lower requirements for home and office environment with a large safety margin.

3.3 Galvanic Isolation (PELV)

PELV offers protection through 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.

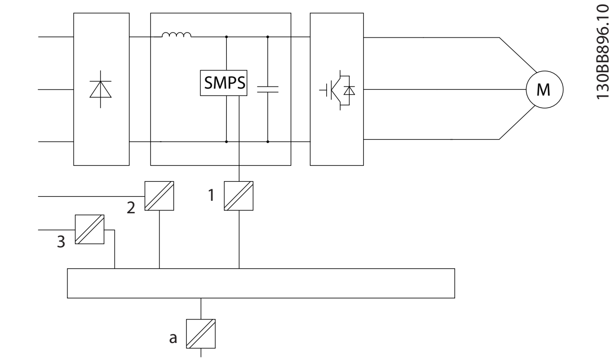
All control terminals and relay terminals 01-03/04-06 comply with PELV (protective extra low voltage) (does not apply to grounded delta leg above 440 V).

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, as described, 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 *Illustration 3.7*.

To maintain PELV, all connections made to the control terminals must be PELV, for example, thermistor must be reinforced/double insulated.

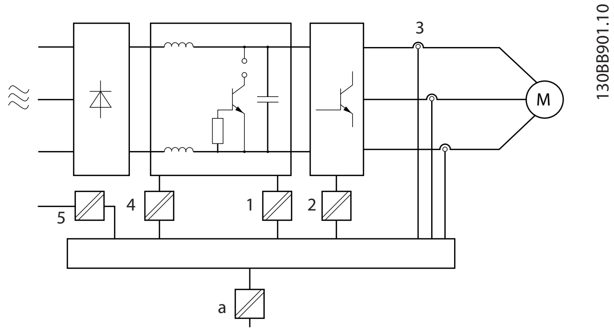
0.25–22 kW (0.34–30 hp)



1	Supply (SMPS)
2	Optocouplers, communication between AOC and BOC
3	Custom relays
a	Control card terminals

Illustration 3.6 Galvanic Isolation

30–90 kW (40–120 hp)



1	Supply (SMPS) including signal isolation of UDC, indicating the intermediate current voltage
2	Gate drive that runs the IGBTs (trigger transformers/opto-couplers)
3	Current transducers
4	Internal soft-charge, RFI, and temperature measurement circuits
5	Custom relays
a	Control card terminals

Illustration 3.7 Galvanic Isolation

The functional galvanic isolation (see *Illustration 3.6*) is for the RS485 standard bus interface.

3

⚠CAUTION

INSTALLATION AT HIGH ALTITUDE

At altitudes above 2000 m (6500 ft), contact Danfoss regarding PELV.

3.4 Ground Leakage Current

⚠WARNING

DISCHARGE TIME

Touching the electrical parts could be fatal - even after the equipment has been disconnected from mains.
Also make sure that other voltage inputs have been disconnected, such as load sharing (linkage of DC intermediate circuit), and the motor connection for kinetic back-up.
Before touching any electrical parts, wait at least the amount of time indicated in *Table 2.1*.
Shorter time is allowed only if indicated on the nameplate for the specific unit.

⚠WARNING

LEAKAGE CURRENT HAZARD

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

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

⚠WARNING

RESIDUAL CURRENT DEVICE PROTECTION

This product can cause a DC current in the protective conductor. Where a residual current device (RCD) is used for protection in case of direct or indirect contact, only an RCD of Type B is allowed on the supply side of this product. Otherwise, apply another protective measure, such as separation from the environment by double or reinforced insulation, or isolation from the supply system by a transformer. See also application note *Protection against Electrical Hazards*.
Protective grounding of the frequency converter and the use of RCDs must always follow national and local regulations.

3.5 Extreme Running Conditions

Short circuit (motor phase-phase)
Current measurement in each of the 3 motor phases or in the DC-link, protects the frequency converter against short circuits. A short circuit between 2 output phases causes an overcurrent in the inverter. The inverter is turned off individually when the short circuit current exceeds the allowed value (*Alarm 16 Trip Lock*).

For information about protecting the frequency converter against a short circuit at the load sharing and brake outputs, see *chapter 6.6 Fuses*.

Switching on the output
Switching on the output between the motor and the frequency converter is fully permitted. The frequency converter is not damaged in any way by switching on the output. However, fault messages may appear.

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

- The load drives the motor (at constant output frequency from the frequency converter), that is the load generates energy.
- During deceleration (ramp-down) if the inertia moment is high, the friction is low, and the ramp-down time is too short for the energy to be dissipated as a loss in the frequency converter, the motor, and the installation.
- Incorrect slip compensation setting (*parameter 1-62 Slip Compensation*) may cause higher DC-link voltage.

The control unit may attempt to correct the ramp if *parameter 2-17 Over-voltage Control* is enabled.
The frequency converter turns off to protect the transistors and the DC link capacitors when a certain voltage level is reached.

Mains drop-out
During a mains drop-out, the frequency converter keeps running until the DC-link 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 frequency converter to coast.

3.5.1 Motor Thermal Protection

Motor thermal protection can be provided in 2 ways.

Using a motor thermistor, via 1 of the following:

- Thermistor input on a standard AI.
- VLT® Sensor Input MCB 114.
- VLT® PTC Thermistor Card MCB 112.

The frequency converter monitors motor temperature as the speed and load vary to detect overheating conditions.

The other method calculates motor temperature by measuring current, frequency, and operating time. The frequency converter shows the thermal load on the motor in percentage and can issue a warning at a programmable

overload setpoint. Programmable options at the overload allow the frequency converter to stop the motor, reduce output, or ignore the condition. Even at low speeds, the frequency converter meets I2t Class 20 electronic motor overload standards.
This method is called electronic thermal relay (ETR).

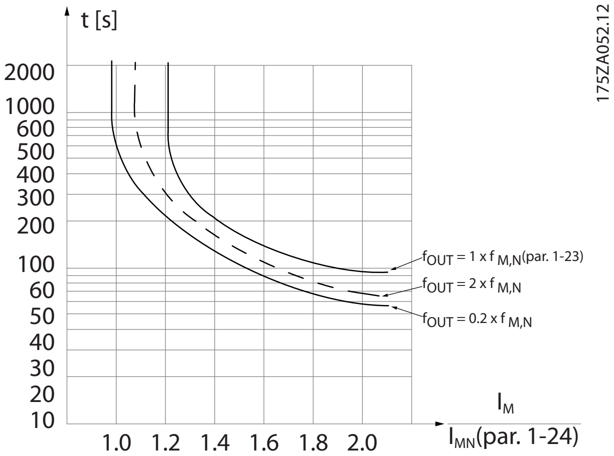


Illustration 3.8 ETR Characteristics

The X-axis shows the ratio between I_{motor} and I_{motor} nominal. The Y axis shows the time in s before the ETR cut of and trips the frequency converter. The curves show the characteristic nominal speed, at twice the nominal speed and at 0.2 x the nominal speed.
At lower speed, the ETR cuts off at lower heat due to less cooling of the motor. In that way, the motor is protected from being overheated even at low speed. The ETR feature is calculating the motor temperature based on actual current and speed. The calculated temperature is visible as a readout parameter in *parameter 16-18 Motor Thermal* in the product-specific *Programming Guide*.
A special version of the ETR is also available for EX-e motors in ATEX areas. This function makes it possible to enter a specific curve to protect the Ex-e motor. The *Programming Guide* takes the user through the set-up.

4 Selection

4.1 Options and Accessories

4.1.1 Local Control Panel (LCP)

For detailed information on programming, see *VLT® Micro Drive FC 51 Programming Guide*.

NOTICE

The frequency converter can also be programmed from a PC via RS485 port by installing the MCT 10 Set-up Software.

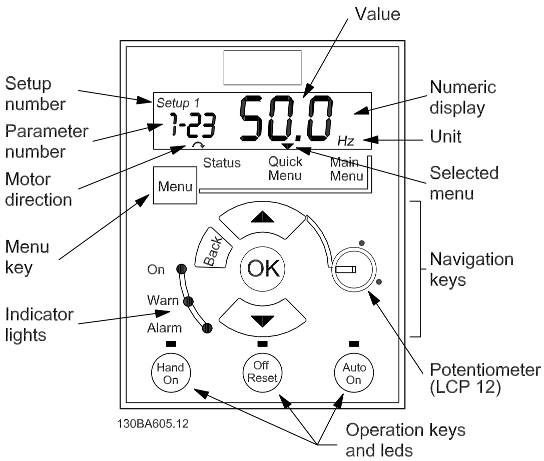


Illustration 4.1 Description of LCP Keys and Display

Press [Menu] to select one of the following menus:

Status
For readouts only.

Quick Menu
For access to Quick Menus 1 and 2.

Main Menu
For access to all parameters.

Navigation keys
[Back]: For moving to the previous step or layer in the navigation structure.
[▲] [▼]: For maneuvering between parameter groups, parameters and within parameters.
[OK]: For selecting a parameter and for accepting changes to parameter settings.

Operation keys
A yellow indicator light above the operation keys indicates the active key.
[Hand On]: Starts the motor and enables control of the frequency converter via the LCP.
[Off/Reset]: Stops the motor (off). If in alarm mode, the alarm is reset.
[Auto On]: The frequency converter is controlled either via control terminals or serial communication.
[Potentiometer] (LCP 12): The potentiometer works in 2 ways:
In *auto mode* the potentiometer acts as an extra programmable analog input.
In *hand-on mode*, the potentiometer controls local reference.

4.1.2 Remote Mounting Kit for LCP

The LCP can be moved to the front of a cabinet by using the remote built-in kit. The enclosure is IP55.

Enclosure	IP55 front
Maximum cable length between LCP and unit	3 m
Communication standard:	RS485
Ordering number	132B0102

Table 4.1 Technical Data

4.1.3 FC 51 Remote Mounting Kit Mounting Instruction

Step 1
Fit the gasket on the LCP in the frequency converter.

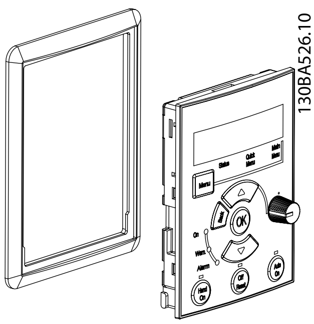


Illustration 4.2 Fit Gasket on LCP

Step 2
Place the LCP on the panel - see dimensions of the hole in *Illustration 4.3*.

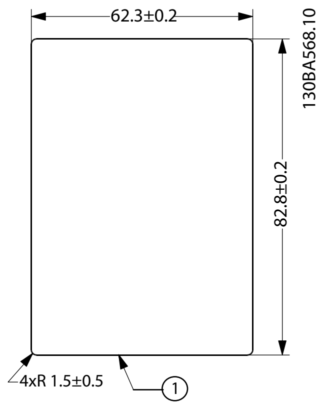


Illustration 4.3 Dimensions of Hole

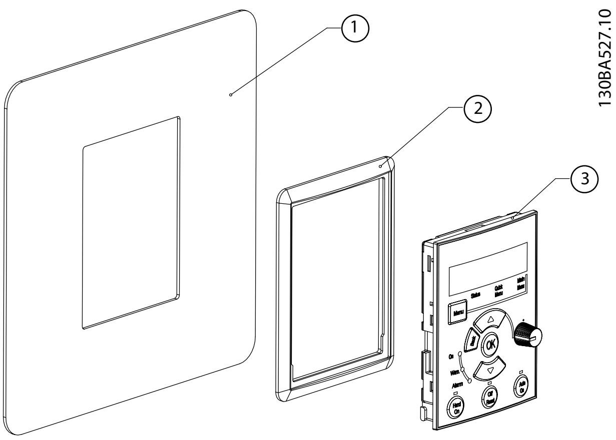


Illustration 4.4 Panel, Gasket, and LCP

Step 3
Place the bracket on the back of the LCP, then slide down. Tighten screws and connect the cable to the LCP.

NOTICE

Use the provided thread cutting screws to fasten the connector to the LCP. Tightening torque: 1.3 Nm (11.5 in-lb).

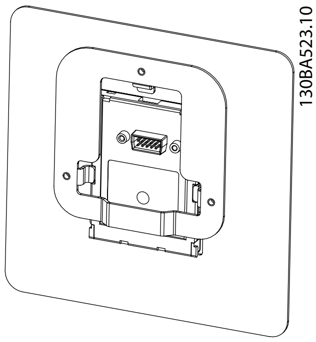


Illustration 4.5 Place the Bracket on LCP

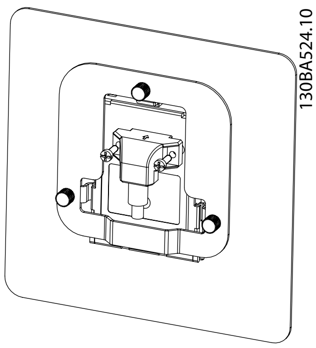


Illustration 4.6 Tighten Screws and Connect Cable to LCP

Step 4
Connect the cable to the frequency converter.

NOTICE

Use the provided thread cutting screws to fasten connector to the frequency converter. Tightening torque: 1.3 Nm (11.5 in-lb).

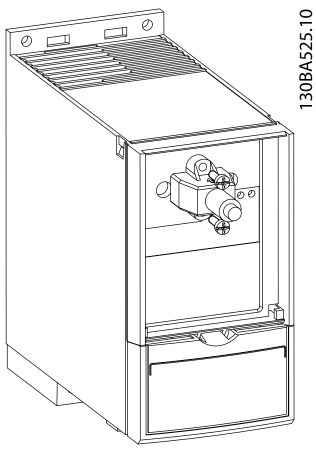


Illustration 4.7 Connect Cable to the Frequency Converter

4

4.1.4 IP21/TYPE 1 Enclosure Kit

Frame	IP class	Power [kW]			Height [mm] A	Width [mm] B	Depth [mm] C	Ordering number
		1x200–240 V	3x200–240 V	3x380–480 V				
M1	IP21	0.18–0.75	0.25–0.75	0.37–0.75	219.3	73	155.9	132B0108
M2	IP21	1.5	1.5	1.5–2.2	245.6	78	175.4	132B0109
M3	IP21	2.2	2.2–3.7	3.0–7.5	297.5	95	201.4	132B0110
M4	IP21	–	–	11–15	–	–	–	–
M5	IP21	–	–	18.5–22	–	–	–	–

Table 4.2 IP21/TYPE 1 Enclosure Kit

4.1.5 Type 1 (NEMA)

Frame	IP class	Power [kW]			Height [mm] A	Width [mm] B	Depth [mm] C	Ordering number
		1x200–240 V	3x200–240 V	3x380–480 V				
M1	IP20	0.18–0.75	0.25–0.75	0.37–0.75	194.3	70.0	155.9	132B0103
M2	IP20	1.5	1.5	1.5–2.2	220.6	75.0	175.4	132B0104
M3	IP20	2.2	2.2–3.7	3.0–7.5	282.5	90.0	201.3	132B0105
M4	IP20	–	–	11–15	345.6	125.0	248.5	132B0120
M5	IP20	–	–	18.5–22	385.5	165.0	248.2	132B0121

Table 4.3 Type 1 (NEMA)

4.1.6 Decoupling Plate

Frame	IP class	Power [kW]			Height [mm] A	Width [mm] B	Depth [mm] C	Ordering number
		1x200–240 V	3x200–240 V	3x380–480 V				
M1	IP20	0.18–0.75	0.25–0.75	0.37–0.75	204.2	70.0	155.9	132B0106
M2	IP20	1.5	1.5	1.5–2.2	230.0	75.0	175.4	132B0106
M3	IP20	2.2	2.2–3.7	3.0–7.5	218.5	90.0	201.3	132B0107
M4	IP20	–	–	11–15	347.5	125.0	248.5	132B0122
M5	IP20	–	–	18.5–22	387.5	165.0	248.2	132B0122

Table 4.4 Decoupling Plate

4.1.7 FC 51 Type 1 Kit Mounting Instruction for M1, M2 and M3

Step 1
Mount metal plate on frequency converter and tighten the screws. Tightening torque: 2 Nm (18 in-lb).

M1	4 x ½”
M2	5 x ½“
M3	2 x ½”
	3 x 3/4”

Table 4.5 Conduit Sizes

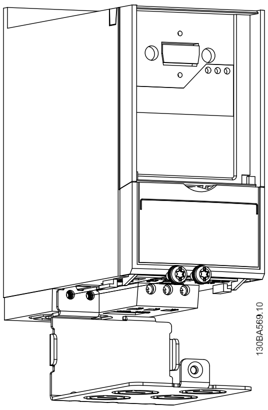


Illustration 4.8 Mount Metal Plate on Frequency Converter

Step 2
Fit base cover on frequency converter and tighten screw.

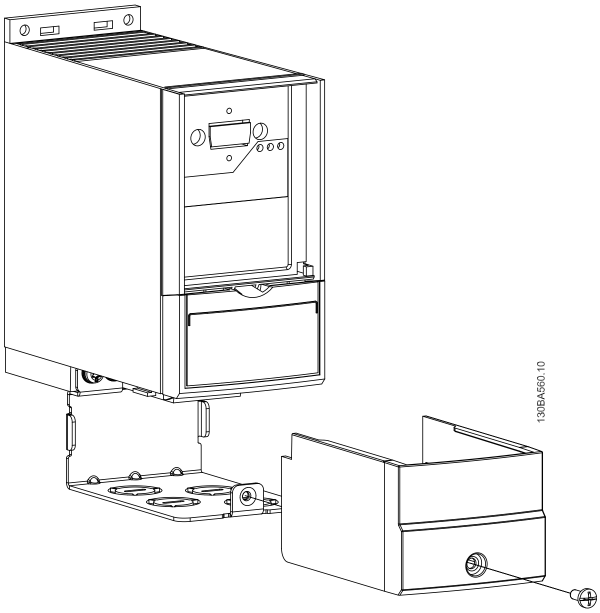


Illustration 4.9 Fit Base Cover on Frequency Converter

4.1.8 FC 51 Type 1 Kit Mounting Instruction for M4 and M5

Step 1
Mount metal plate on frequency converter and tighten the screws. Tightening torque: 2 Nm (18 in-lb).

M4	3x½”
M5	3x1“

Table 4.6 Conduit Sizes

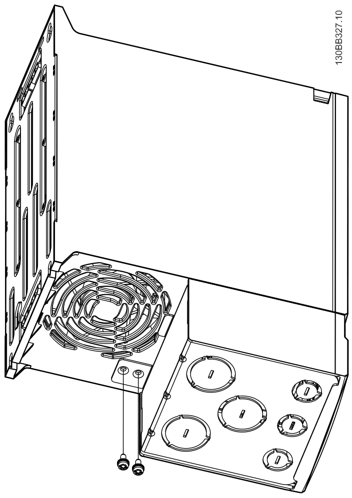


Illustration 4.10 Mount Metal Plate on Frequency Converter

Step 2
Fit base cover on frequency converter and tighten screw.

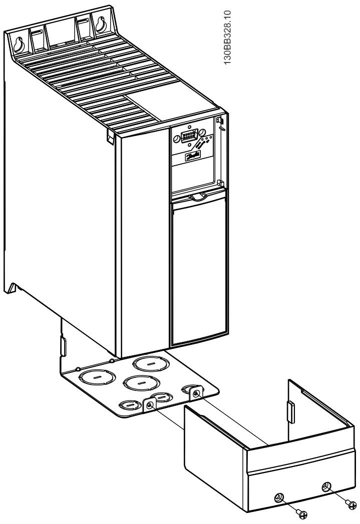


Illustration 4.11 Fit Base Cover on Frequency Converter

4

4

4.1.9 FC 51 IP21 Kit Mounting Instruction

Step 1

Fit top cover on frequency converter.

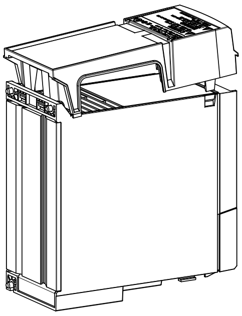


Illustration 4.12 Fit Top Cover on Frequency Converter

Step 2

Remove knockouts on metal plate and fit rubber grommets.

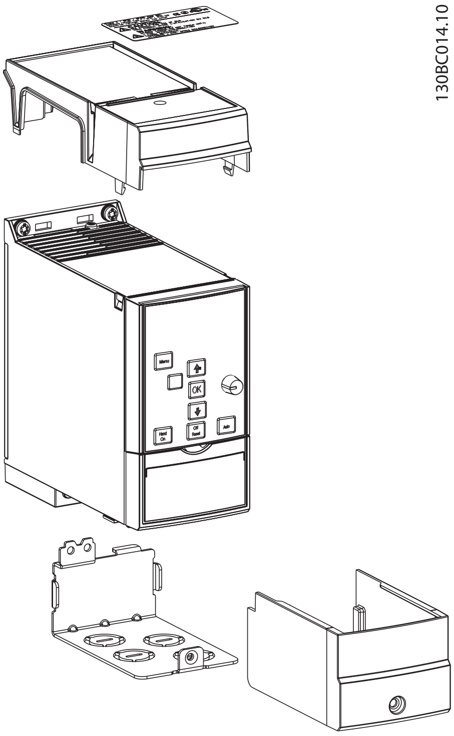


Illustration 4.13 Remove Knockouts and Fit Rubber Grommets

Step 3

Mount metal plate on frequency converter and tighten screws. Tightening torque: 2 Nm (18 in-lb).

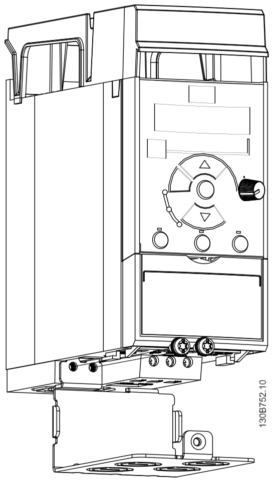


Illustration 4.14 Mount Metal Plate on Frequency Converter

Step 4

Fit base cover on frequency converter and tighten screw.

NOTICE

IP21 is only achieved with LCP 11 or LCP 12 mounted.

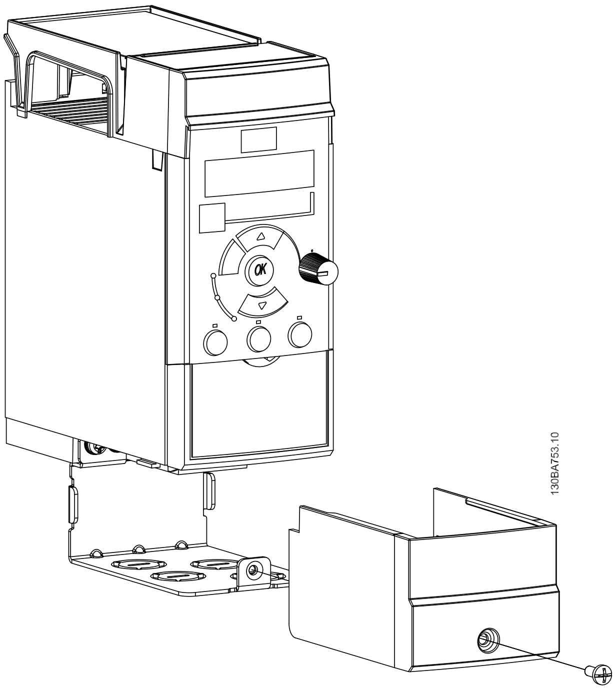


Illustration 4.15 Fit Base Cover on Frequency Converter

4.1.10 FC 51 Decoupling Plate Mounting Instruction for M1 and M2

Step 1

Mount metal plate on frequency converter and fasten with two screws. Tightening torque: 2 Nm (18 in-lb).

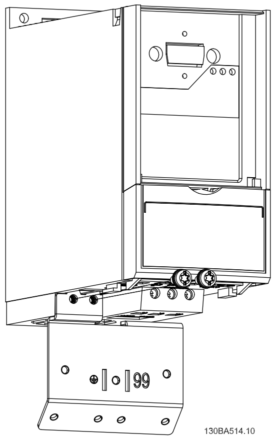


Illustration 4.16 Mount Metal Plate

Step 2

Mount bracket on decoupling plate.

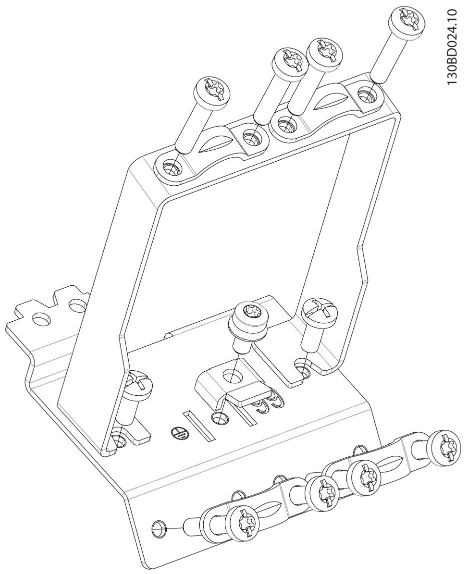


Illustration 4.17 Mount Bracket

Step 3

Decoupling plate mounted.

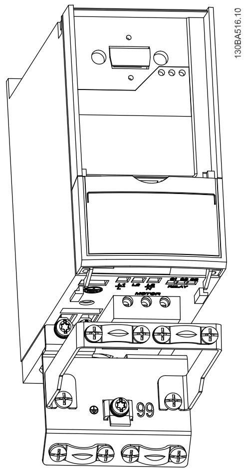


Illustration 4.18 Decoupling Plate Mounted

4.1.11 FC 51 Decoupling Plate Mounting Instruction for M3

Step 1

Mount decoupling plate on frequency converter and fasten with 2 screws. Tightening torque: 2 Nm (18 in-lb).

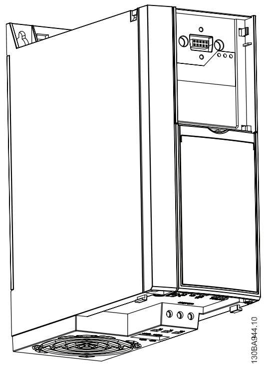


Illustration 4.19 Mount Decoupling Plate

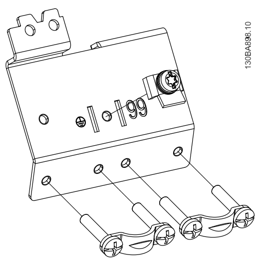


Illustration 4.20 Fasten with Screws

Step 2
Decoupling plate mounted.

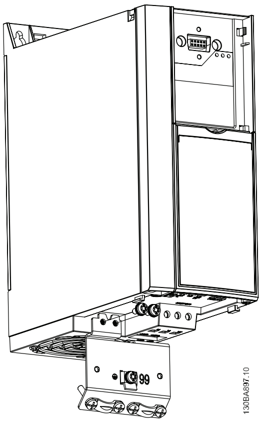


Illustration 4.21 Decoupling Plate Mounted

4.1.12 FC 51 Decoupling Plate Mounting Instruction for M4 and M5

Step 1
Mount metal plate on frequency converter and fasten with 2 screws. Tightening torque: 2 Nm (18 in-lb).

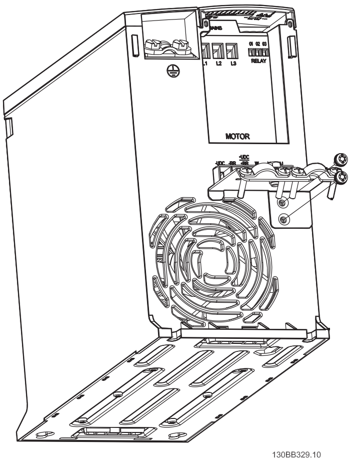


Illustration 4.22 Mount Metal Plate

Step 2
Decoupling plate mounted.

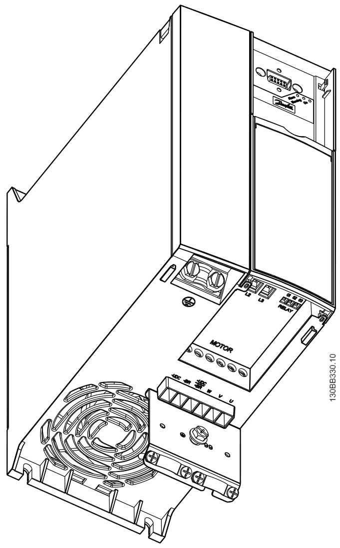


Illustration 4.23 Decoupling Plate Mounted

Step 3
Mount bracket on decoupling plate.

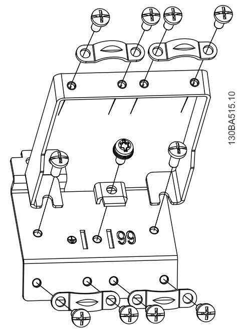


Illustration 4.24 Mount Bracket

4.1.13 FC 51 DIN Rail Kit Mounting Instruction

Step 1
Mount plastic part on frequency converter.

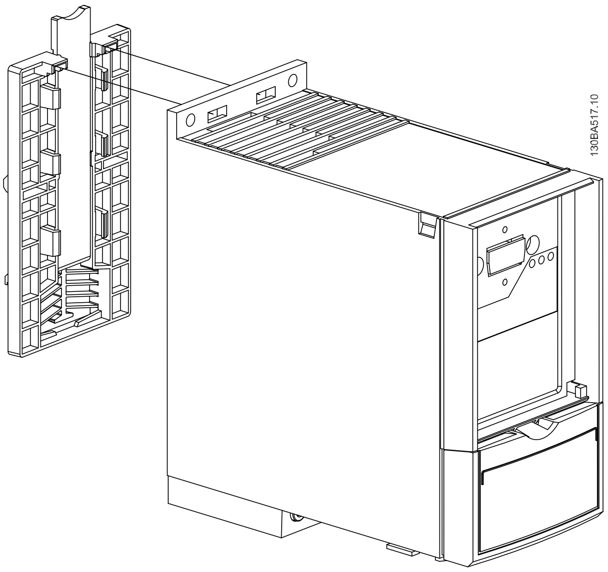


Illustration 4.25 Mount Plastic Part

Step 2
Fit frequency converter on DIN rail (DIN rail kit is only for M1 and M2).

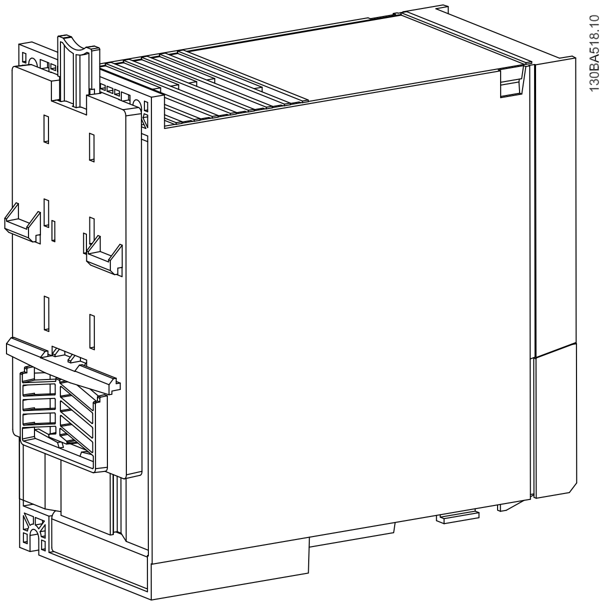
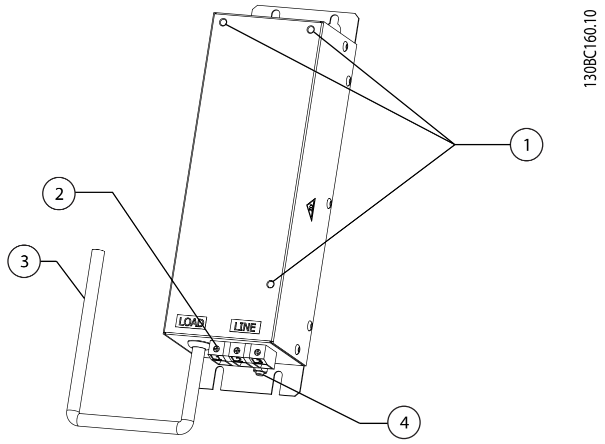


Illustration 4.26 Fit Frequency Converter on DIN Rail

4.1.14 Line Filter MCC 107 Installation Instructions

Line filters of the type MCC 107 combine a harmonic filter and an EMC filter. The line filters improve performance of the line current to the frequency converter. The 3 different line filter enclosure sizes correspond to the VLT® Micro Drive enclosure types M1, M2 and M3.



1	Mounting holes for frequency converter
2	Input terminal
3	Output line
4	Protective earth (PE)

Illustration 4.27 Line Filter MCC 107 with VLT® Micro Drive FC 51

CAUTION

HOT SURFACES

The surface of the line filter can get hot during operation.

- **Do not touch the line filter during operation or wear protective gloves.**

WARNING

HIGH VOLTAGE

Frequency converters contain high voltage when connected to AC mains input, DC supply, or load sharing. Failure to perform installation, start-up, and maintenance by qualified personnel can result in death or serious injury.

- **Only qualified personnel must perform installation, start-up, and maintenance.**

NOTICE

Always replace defective filters, never repair them.

4.1.15 Mounting

There are 2 options for mounting the line filter correctly:

Front mounting

- Mount the filter in a vertical position with the terminals at the bottom.
- Mount the frequency converter on the front of the line filter using 3 M4 bolts.

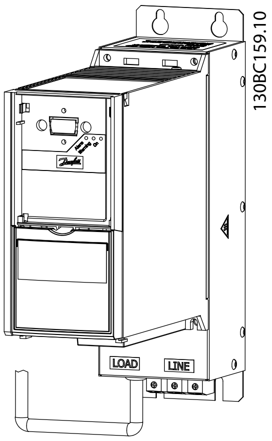


Illustration 4.28 Line Filter with Frequency Converter

- Ensure metal-to-metal contact between filter and frequency converter.

NOTICE

Metal-to-metal contact improves EMC performance and enables the base plate of the frequency converter to function as heat sink for the line filter.

Side mounting

- Mount the filter side-by-side with the frequency converter.
  There is no requirement for spacing between filter and frequency converter.
- Mount the back of the line filter to a cooling surface, such as a metal wall. Alternatively, derate the line filter by 1 size: For example, use a 0.75 kW (1 hp) line filter with a 0.37 kW (0.5 hp) frequency converter.

CAUTION

HIGH TEMPERATURES

Risk of fire or device damage.

- **Do not mount the line filter close to heat-sensitive material (such as wood).**

4.1.16 Wiring

WARNING

LEAKAGE CURRENT HAZARD

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

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

1. Connect line filter to protective earth (PE). Use a cabinet mounting panel or similar to achieve optimum grounding conditions.
2. Connect input terminal to mains power (cable not supplied).
3. Connect output cable to the input terminals of the frequency converter.
4. Ensure solid electrical contact between line filter and frequency converter (high frequency grounding).

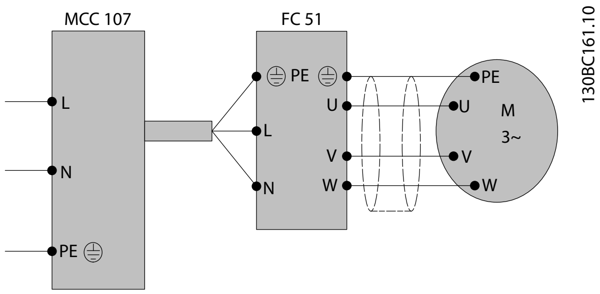


Illustration 4.29 Line 1

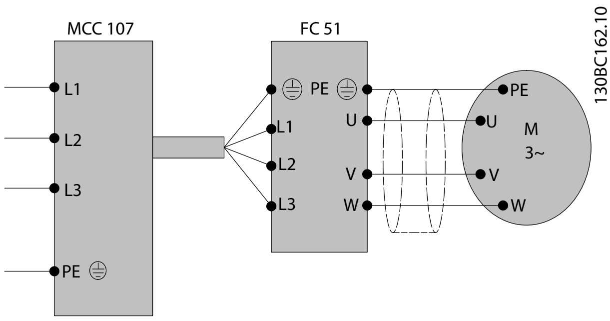


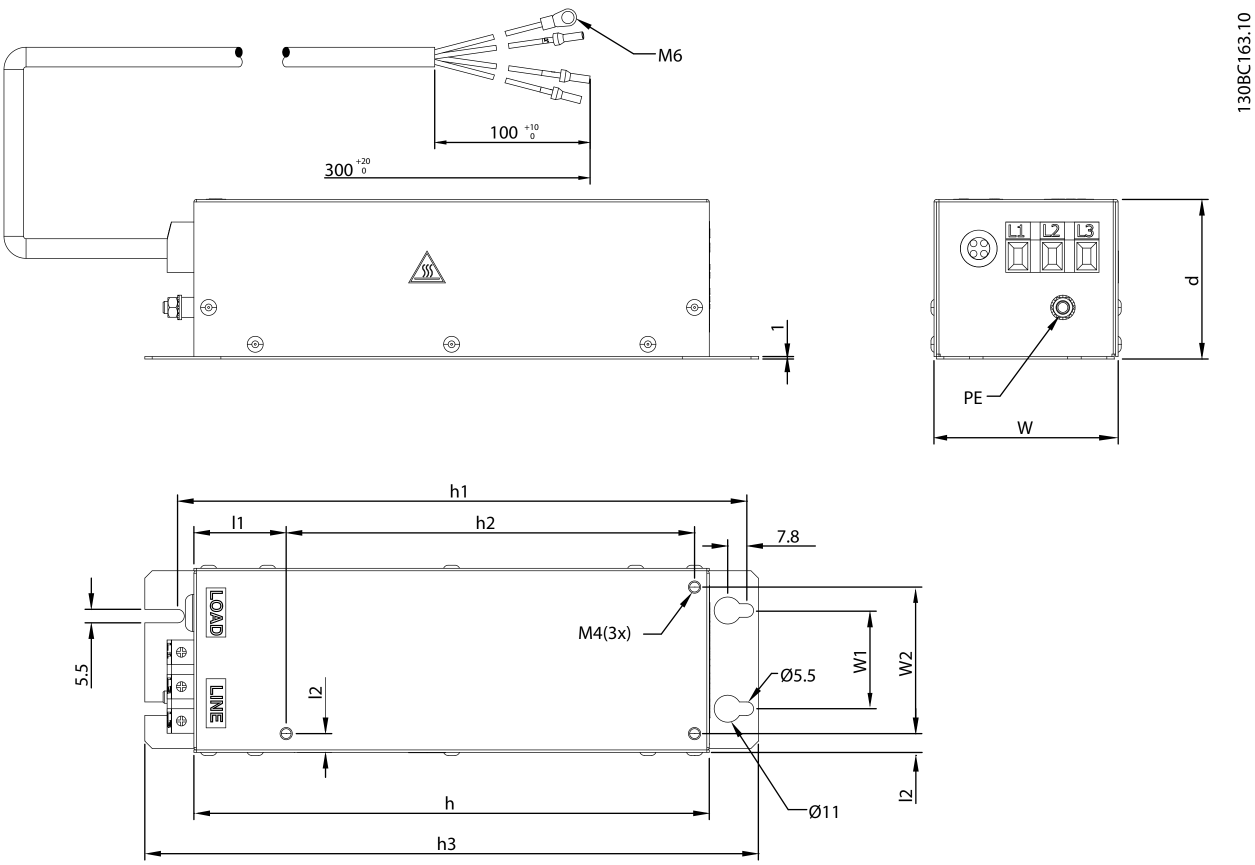
Illustration 4.30 Line 2

NOTICE

- **Reduce common mode interferences by establishing a low impedance current path to the frequency converter.**
- **To ensure optimum EMC performance, use a decoupling plate kit (ordering numbers 132B0106 or 132B0107)**

For voltage rating, wire size, and fuse selection, see the *VLT® Micro Drive FC 51 Quick Guide*.

4.1.17 Dimensions



Frame	M1	M2	M3
w [mm]	70	75	90
d [mm]	55	65	69
h [mm]	190	210	300
h3 [mm]	230	250	340
w1 [mm]	40	40	55.6
h1 [mm]	213	233	323
w2 [mm]	55	59	69
h2 [mm]	140	166.5	226
l1 [mm]	45	38.5	68
l2 [mm]	7.6	8	9.3
PE (metric)	M6	M6	M6
Weight [kg]	2	3	5

Illustration 4.31 Dimensions

4

4.2 Special Conditions

4.2.1 Purpose of Derating

Consider the purpose of derating when using the frequency converter at low air pressure (heights), at low speeds, with long motor cables, cables with a large cross-section, or at high ambient temperature. The required action is described in this section.

4.2.2 Derating for Ambient Temperature

Derating for ambient temperature and IGBT switching.

The ambient temperature measured over 24 hours should be at least 5 °C lower than the maximum ambient temperature. If the frequency converter is operated at high ambient temperature, decrease the constant output current. The frequency converter has been designed for operation at maximum 50 °C ambient temperature with 1 motor size smaller than nominal. Continuous operation at full load at 50 °C ambient temperature reduces the lifetime of the frequency converter.

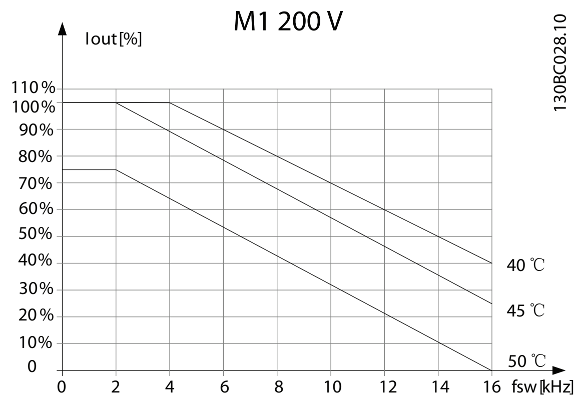


Illustration 4.32 M1 200 V

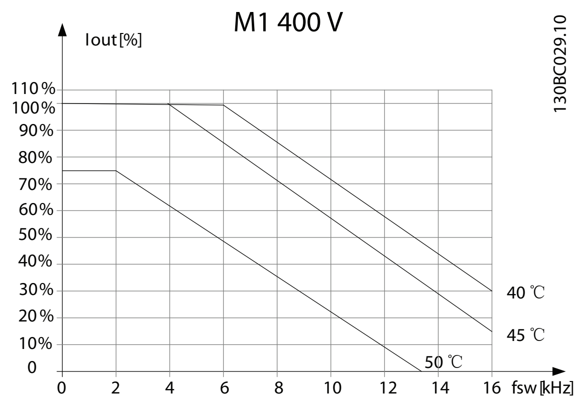


Illustration 4.33 M1 400 V

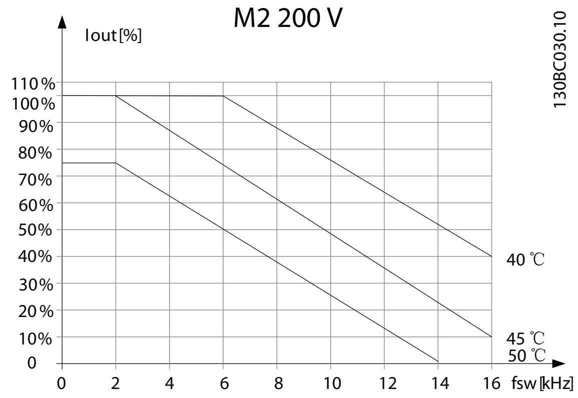


Illustration 4.34 M2 200 V

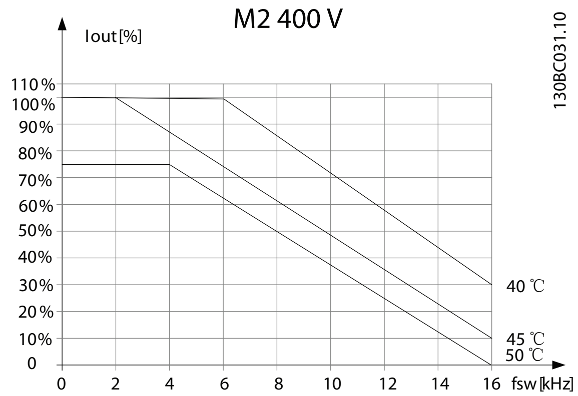


Illustration 4.35 M2 400 V

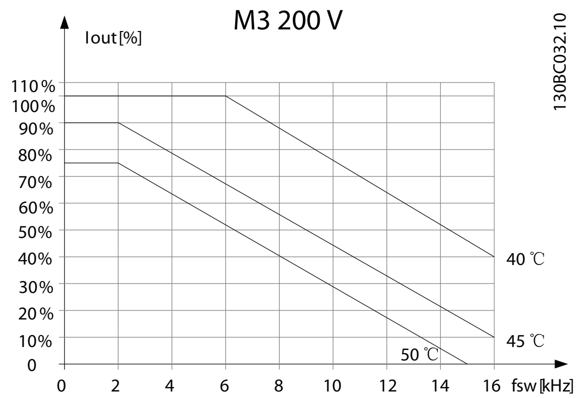


Illustration 4.36 M3 200 V

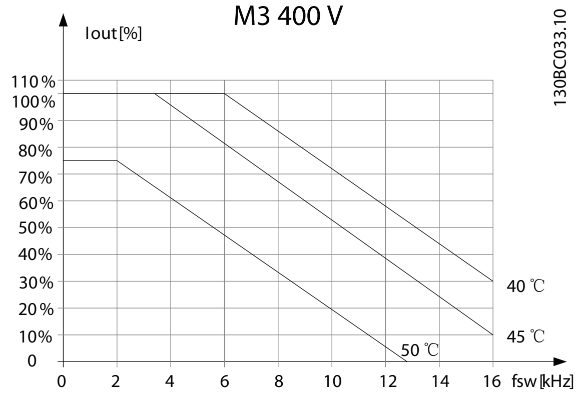


Illustration 4.37 M3 400 V

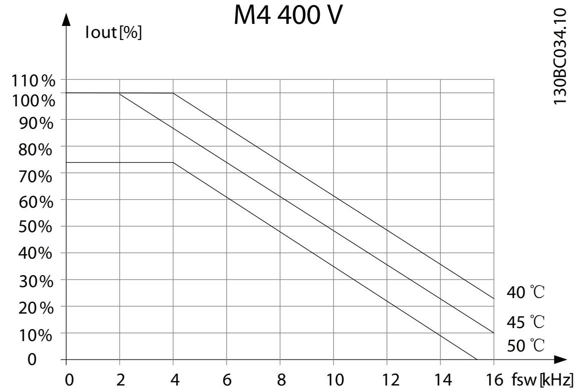


Illustration 4.38 M4 200 V

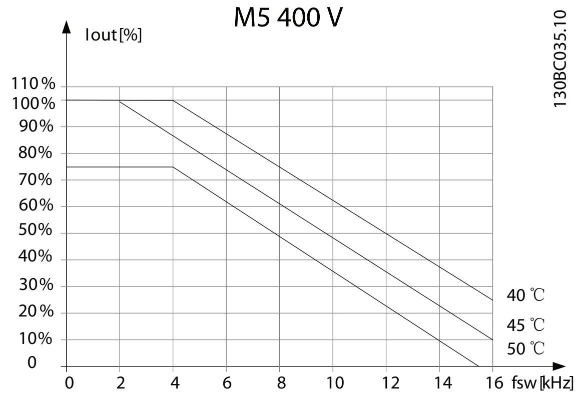


Illustration 4.39 M4 400 V

4.2.3 Derating for Low Air Pressure

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

CAUTION

INSTALLATION AT HIGH ALTITUDE

For altitudes above 2000 m (6560 ft), contact Danfoss regarding PELV.

Below 1000 m (3280 ft) altitude, no derating is necessary, but above 1000 m (3280 ft), decrease the ambient temperature or the maximum output current.
Decrease the output by 1% per 100 m (328 ft) altitude above 1000 m (3280 ft), or reduce the maximum ambient temperature by 1 °C per 200 m (656 ft).

4.2.4 Automatic Adaptations to Ensure Performance

The frequency converter constantly checks for critical levels of:

- Internal temperature.
- Load current.
- High voltage on the DC link.
- Low motor speeds.

As a response to a critical level, the frequency converter can adjust the switching frequency and/or change the switching pattern to ensure the performance of the frequency converter. The capability for automatic output current reduction extends the acceptable operating conditions even further.

4.2.5 Derating for Running at Low Speed

When a motor is connected to a frequency converter, it is necessary to check that the cooling of the motor is adequate. The level of heating depends on the load on the motor, as well as the operating speed and time.

Constant torque applications (CT mode)

A problem may occur at low RPM values in constant torque applications. In a constant torque application, a motor may overheat at low speeds due to less cooling air from the motor integral fan.

Therefore, if the motor runs continuously at an RPM value lower than half of the rated value, supply the motor with extra air-cooling (or use a motor designed for this type of operation).

An alternative is to reduce the load level of the motor by using a larger motor. However, the design of the frequency converter puts a limit to the motor size.

5 How to Order

5.1 Drive Configurator

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

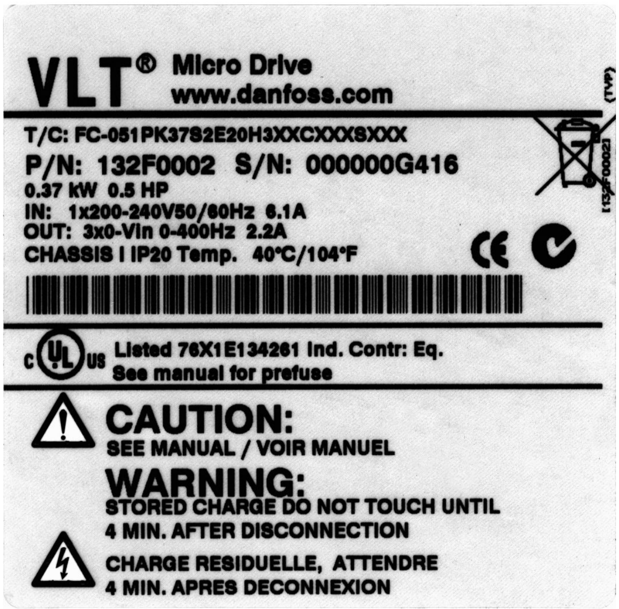
To order standard frequency converters and frequency converters with integral options, send a type code string describing the product to the Danfoss sales office. An example type code:

FC051PXXXXXXXXHXXXXXXXSXXX

Use the web-based Drive Configurator to configure the right frequency converter for the right application and generate the type code string. The Drive Configurator automatically generates an 8-digit sales number (either for 1 product or a project list with several products) to be delivered to your local sales office.

5.2 FC Identification

The nameplate sticker is located on the top of each frequency converter and shows the ratings, serial number, warnings catalog number, and other relevant data for each unit. See *Table 5.2* for details, how to read the type code string.



130BA505

Illustration 5.1 Nameplate Sticker

5.3 Type Code

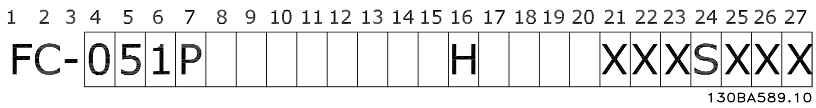


Table 5.1 Type Code

Description	Pos.	Possible option
Product group	1–3	Adjustable frequency converters
Series and product type	4–6	Micro Drive
Power size	7–10	0.18–22 kW (0.24–30 hp)
Mains voltage	11–12	S2: Single-phase 200-240 V AC T2: 3-phase 200–240 V AC T4: 3-phase 380–480 V AC
Enclosure	13–15	IP20/Chassis
RFI filter	16–17	H3: RFI filter A1/B (reduced cable length)
Brake	18	B: Brake chopper included (from 1.5 kW (2 hp) and up) X: No brake chopper included
Display	19	X: No local control panel N: Numerical local control panel (LCP) P: Numerical local control panel (LCP) with potentiometer
Coating PCB	20	C: Coated PCB X: No coated PCB
Mains option	21	X: No mains option
Adaptation A	22	X: No adaptation
Adaptation B	23	X: No adaptation
Software release	24–27	SXXX: Latest release - std. software

Table 5.2 Type Code Description

5

5.4 Ordering Numbers

	200–240 V			380–480 V	
Power [kW]	Current [I_{nom}]	Single-phase	3-phase	Current [I_{nom}]	3 ph.
0.18	1.2	132F0001			
0.25	1.5		132F0008		
0.37	2.2	132F0002	132F0009	1.2	132F0017
0.75	4.2	132F0003	132F0010	2.2	132F0018
1.5	6.8	132F0005	132F0012	3.7	132F0020
2.2	9.6	132F0007	132F0014	5.3	132F0022
3.0				7.2	132F0024
3.7	15.2		132F0016		
4.0	Frequency converters from 1.5 kW (2 hp) and up have built-in brake chopper.			9.0	132F0026
5.5				12.0	132F0028
7.5				15.5	132F0030
11.0				23.0	132F0058
15.0				31.0	132F0059
18.5				37.0	132F0060
22.0				43.0	132F0061

Table 5.3 Ordering Numbers

5.5 Options

Ordering number	Description
132B0100	VLT® Control Panel LCP 11 w/o potentiometer
132B0101	VLT® Control Panel LCP 12 with potentiometer
132B0102	Remote mounting kit for LCP incl. 3 m cable IP55 with LCP 11, IP21 with LCP 12
132B0103	Nema type 1 kit for M1 enclosure
132B0104	Type 1 kit for M2 enclosure
132B0105	Type 1 kit for M3 enclosure
132B0106	Decoupling plate kit for M1 and M2 enclosures
132B0107	Decoupling plate kit for M3 enclosure
132B0108	IP21 for M1 enclosure
132B0109	IP21 for M2 enclosure
132B0110	IP21 for M3 enclosure
132B0111	DIN rail mounting kit for M1 and M2 enclosure
132B0120	Type 1 kit for M4 enclosure
132B0121	Type 1 kit for M5 enclosure
132B0122	Decoupling plate kit for M4 and M5 enclosures
130B2522	Line Filter MCC 107 for 132F0001
130B2522	Line Filter MCC 107 for 132F0002
130B2533	Line Filter MCC 107 for 132F0003
130B2525	Line Filter MCC 107 for 132F0005
130B2530	Line Filter MCC 107 for 132F0007
130B2523	Line Filter MCC 107 for 132F0008
130B2523	Line Filter MCC 107 for 132F0009
130B2523	Line Filter MCC 107 for 132F0010
130B2526	Line Filter MCC 107 for 132F0012
130B2531	Line Filter MCC 107 for 132F0014
130B2527	Line Filter MCC 107 for 132F0016
130B2523	Line Filter MCC 107 for 132F0017
130B2523	Line Filter MCC 107 for 132F0018
130B2524	Line Filter MCC 107 for 132F0020

Ordering number	Description
130B2526	Line Filter MCC 107 for 132F0022
130B2529	Line Filter MCC 107 for 132F0024
130B2531	Line Filter MCC 107 for 132F0026
130B2528	Line Filter MCC 107 for 132F0028
130B2527	Line Filter MCC 107 for 132F0030

Table 5.4 Options for VLT® Micro Drive FC 51

NOTICE

Danfoss line filters and brake resistors are available upon request.

6 How to Install

6.1 Before Starting

6.1.1 Checklist

When unpacking the frequency converter, make sure that the unit is undamaged and complete. Check that the packaging contains the following:

- VLT® Micro Drive FC 51
- Quick Guide

Optional: LCP and/or decoupling plate.

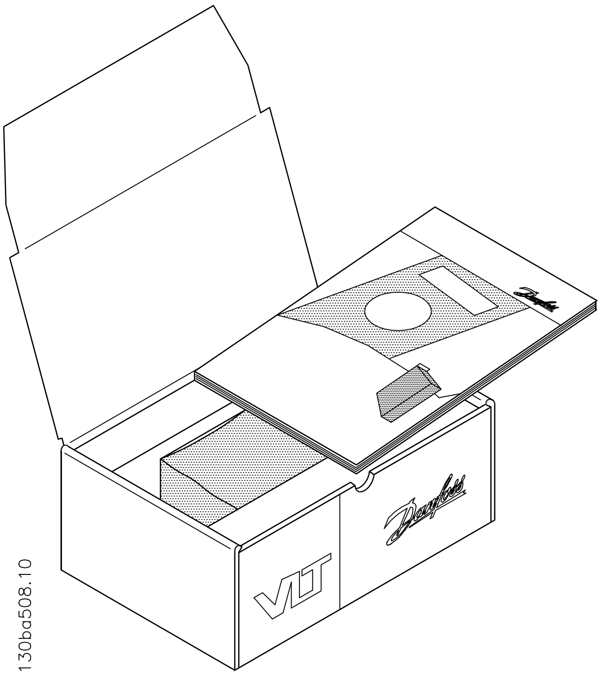


Illustration 6.1 Content of Box

6.2 Side-by-Side Installation

The frequency converter can be mounted side-by-side for IP20 rating units and requires 100 mm (3.94 in) clearance above and below for cooling. Regarding surroundings in general, see *chapter 9 Specifications*.

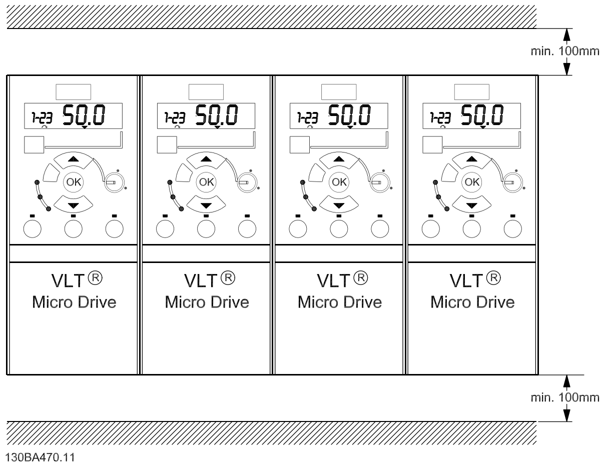


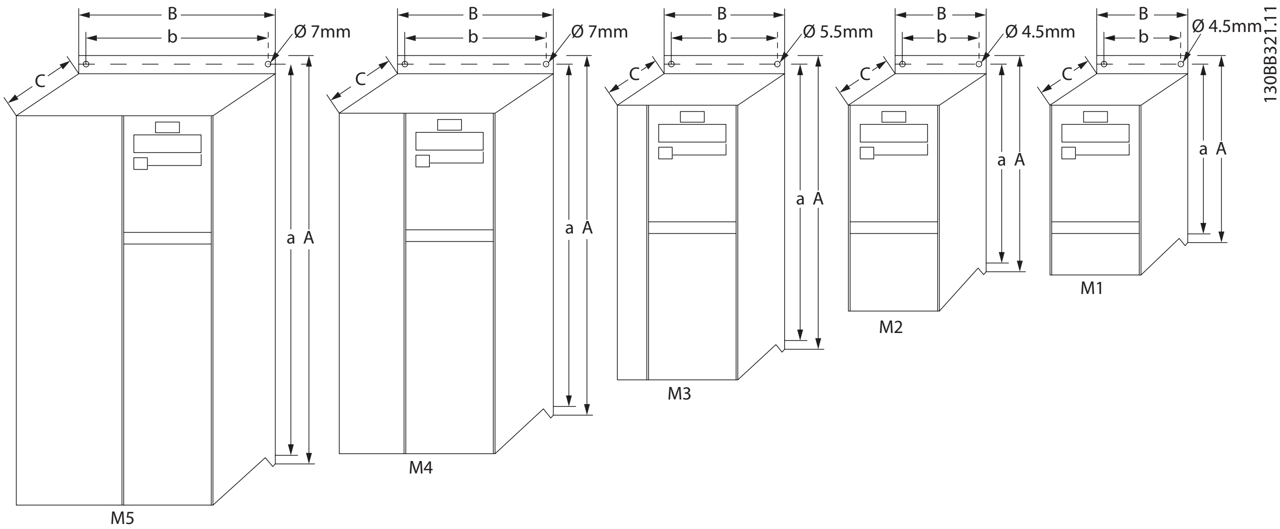
Illustration 6.2 Side-by-side Installation

6.3 Before Commencing Repair Work

1. Disconnect the FC 51 from mains (and external DC supply, if present).
2. Wait for 4 minutes (M1, M2, and M3) and 15 minutes (M4 and M5) for discharge of the DC-link. See *Table 2.1*.
3. Disconnect the DC bus terminals and the brake terminals (if present).
4. Remove the motor cable.

6.4 Mechanical Dimensions

A template for drilling is on the flap of the packaging.



	Power [kW]			Height [mm]			Width [mm]		Depth[1)] [mm]	Maximum weight
Enclosure	1X200–240 V	3X200–240 V	3X380–480 V	A	A (including decoupling plate)	a	B	b	C	[kg]
M1	0.18–0.75	0.25–0.75	0.37–0.75	150	205	140.4	70	55	148	1.1
M2	1.5	1.5	1.5–2.2	176	230	166.4	75	59	168	1.6
M3	2.2	2.2–3.7	3.0–7.5	239	294	226	90	69	194	3.0
M4	–	–	11.0–15.0	292	347.5	272.4	125	97	241	6.0
M5	–	–	18.5–22.0	335	387.5	315	165	140	248	9.5
1) For LCP with potentiometer, add 7.6 mm (0.3 in).										

Illustration 6.3 Mechanical Dimensions

6.5 Electrical Installation in General

NOTICE

All cabling must comply with national and local regulations on cable cross-sections and ambient temperature. Copper conductors required, (60–75 °C) recommended.

	Power [kW]			Torque [Nm]					
Enclosure	1x200–240 V	3x200–240 V	3x380–480 V	Line	Motor	DC connection/brake	Control terminals	Ground	Relay
M1	0.18–0.75	0.25–0.75	0.37–0.75	0.8	0.7	Spade[1)]	0.15	3	0.5
M2	1.5	1.5	1.5–2.2	0.8	0.7	Spade[1)]	0.15	3	0.5
M3	2.2	2.2–3.7	3.0–7.5	0.8	0.7	Spade[1)]	0.15	3	0.5
M4	–	–	11.0–15.0	1.3	1.3	1.3	0.15	3	0.5
M5	–	–	18.5–22.0	1.3	1.3	1.3	0.15	3	0.5
1) Spade connectors (6.3 mm (0.25 in) Faston plugs)									

Table 6.1 Tightening of Terminals

6

6.6 Fuses

Branch circuit protection
To protect the installation against electrical and fire hazards, protect all branch circuits in an installation, switch gear, machines, and so on, against short circuits and overcurrent according to national/international regulations.

Short-circuit protection
Use the fuses mentioned in *Table 6.2* to protect service personnel or other equipment if there is an internal failure in the unit or short circuit on DC-link. If there is a short circuit on the motor or brake output, the frequency converter provides full short-circuit protection.

Overcurrent protection
To avoid overheating of the cables in the installation, provide overload protection. Always carry out overcurrent protection according to national regulations. Fuses must be designed for protection in a circuit capable of supplying a maximum of 100000 A_{rms} (symmetrical), 480 V maximum.

Non-UL compliance
If UL/cUL is not to be complied with, use the fuses mentioned in *Table 6.2*, which ensure compliance with EN50178/IEC61800-5-1:
If there is a malfunction, not following the fuse recommendation may result in damage to the frequency converter and the installation.

FC 51	Maximum fuses UL						Maximum fuses non–UL
	Bussmann	Bussmann	Bussmann	Littelfuse	Ferraz Shawmut	Ferraz Shawmut	
1x200–240 V							
kW	Type RK1	Type J	Type T	Type RK1	Type CC	Type RK1	Type gG
0K18-0K37	KTN-R15	JKS-15	JJN-15	KLN-R15	ATM-R15	A2K-15R	16A
0K75	KTN-R25	JKS-25	JJN-25	KLN-R25	ATM-R25	A2K-25R	25A
1K5	KTN-R35	JKS-35	JJN-35	KLN-R35	–	A2K-35R	35A
2K2	KTN-R50	JKS-50	JJN-50	KLN-R50	–	A2K-50R	50A
3x200–240 V							
0K25	KTN-R10	JKS-10	JJN-10	KLN-R10	ATM-R10	A2K-10R	10A
0K37	KTN-R15	JKS-15	JJN-15	KLN-R15	ATM-R15	A2K-15R	16A
0K75	KTN-R20	JKS-20	JJN-20	KLN-R20	ATM-R20	A2K-20R	20A
1K5	KTN-R25	JKS-25	JJN-25	KLN-R25	ATM-R25	A2K-25R	25A
2K2	KTN-R40	JKS-40	JJN-40	KLN-R40	ATM-R40	A2K-40R	40A
3K7	KTN-R40	JKS-40	JJN-40	KLN-R40	–	A2K-40R	40A
3x380–480 V							
0K37-0K75	KTS-R10	JKS-10	JJS-10	KLS-R10	ATM-R10	A6K-10R	10A
1K5	KTS-R15	JKS-15	JJS-15	KLS-R15	ATM-R15	A2K-15R	16A
2K2	KTS-R20	JKS-20	JJS-20	KLS-R20	ATM-R20	A6K-20R	20A
3K0	KTS-R40	JKS-40	JJS-40	KLS-R40	ATM-R40	A6K-40R	40A
4K0	KTS-R40	JKS-40	JJS-40	KLS-R40	ATM-R40	A6K-40R	40A
5K5	KTS-R40	JKS-40	JJS-40	KLS-R40	–	A6K-40R	40A
7K5	KTS-R40	JKS-40	JJS-40	KLS-R40	–	A6K-40R	40A
11K0	KTS-R60	JKS-60	JJS-60	KLS-R60	–	A6K-60R	63A
15K0	KTS-R60	JKS-60	JJS-60	KLS-R60	–	A6K-60R	63A
18K5	KTS-R60	JKS-60	JJS-60	KLS-R60	–	A6K-60R	80A
22K0	KTS-R60	JKS-60	JJS-60	KLS-R60	–	A6K-60R	80A

Table 6.2 Fuses

6.7 Mains Connection

Step 1: Mount ground cable.

Step 2: Mount wires in terminals L1/L, L2, and L3/N and tighten.

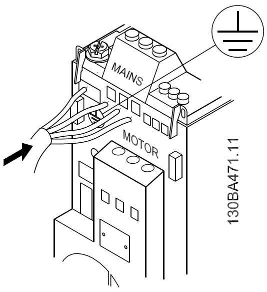


Illustration 6.4 Mounting of Ground Cable and Mains Wires

For 3-phase connection, connect wires to all 3 terminals. For single-phase connection, connect wires to terminals L1/L and L3/N.

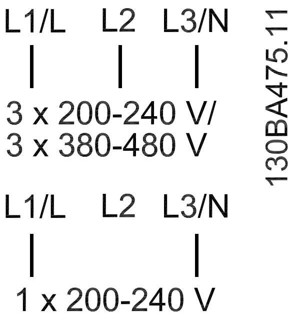


Illustration 6.5 3-phase and Single-phase Wire Connections

6.8 Motor Connection

6.8.1 How to Connect the Motor

See *chapter 9 Specifications* for correct dimensioning of motor cable cross-section and length.

- Use a shielded/armored motor cable to comply with EMC emission specifications, and connect this cable to both the decoupling plate and the motor metal.
- Keep the motor cable as short as possible to reduce the noise level and leakage currents.

For further details on mounting of the decoupling plate, see *VLT® Micro Drive FC 51 Decoupling Plate Mounting Instruction for M1 and M2*.

All types of 3-phased asynchronous standard motors can be connected to the frequency converter. Normally, small motors are star-connected (230/400 V, Δ/Y). Large motors are delta-connected (400/690 V, Δ/Y). Refer to the motor nameplate for correct connection and voltage.

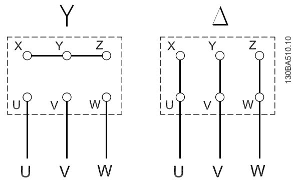


Illustration 6.6 Star and Delta Connections

Step 1: Mount the ground cable.

Step 2: Connect wires to terminals either in star or delta connection. See the motor nameplate for further information.

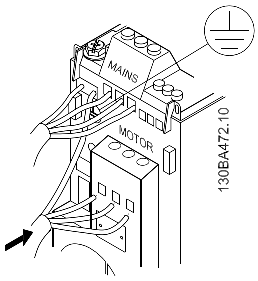


Illustration 6.7 Mounting of Ground Cable and Motor Wires

For EMC-correct installation, use optional decoupling plate, see *chapter 5.5 Options*.

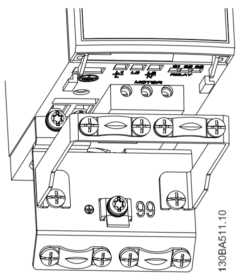


Illustration 6.8 Frequency Converter with Decoupling Plate

6.8.2 Motor Cables

See *chapter 9 Specifications* for maximum dimensioning of motor cable cross-section and length.

- Use a shielded/armored motor cable to comply with EMC emission specifications.
- Keep the motor cable as short as possible to reduce the noise level and leakage currents.
- Connect the motor cable shield to both the decoupling plate of the frequency converter and to the metal cabinet of the motor.
- Make the shield connections with the largest possible surface area (cable clamp). This is done by using the supplied installation devices in the frequency converter.
- Avoid mounting with twisted shield ends (pigtails), which spoils high frequency shielding effects.
- If it is necessary to split the shield to install a motor isolator or motor relay, the shield must be continued with the lowest possible HF impedance.

6.8.3 Electrical Installation of Motor Cables

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

Cable length and cross-section
The frequency converter has been tested with a given length of cable and a given cross-section of that cable. If the cross-section is increased, the cable capacitance, and thus the leakage current, may increase, and the cable length must be reduced correspondingly.

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 sine-wave filter instruction in *parameter 14-01 Switching Frequency*.

Aluminum conductors
Aluminum conductors are not recommended. When using aluminum conductors, ensure that the conductor surface is clean and the oxidation is removed and sealed by a neutral acid-free grease before connecting the conductor. Retighten the terminal screw after 2 days due to the softness of aluminum. It is crucial to keep the connection a gas-tight joint, otherwise the aluminum surface oxidizes again.

6.8.4 EMC-correct Electrical Installation

General points to be observed to ensure EMC-correct electrical installation.

- Use only shielded/armored motor cables and shielded/armored control cables.
- Connect the shield to ground at both ends.
- Avoid installation with twisted shield ends (pigtails), since this ruins the shielding effect at high frequencies. Use the cable clamps provided instead.
- It is important to ensure good electrical contact from the installation plate through the installation screws to the metal cabinet of the frequency converter.
- Use star washers and galvanically conductive installation plates.
- Do not use unshielded/unarmored motor cables in the installation cabinets.

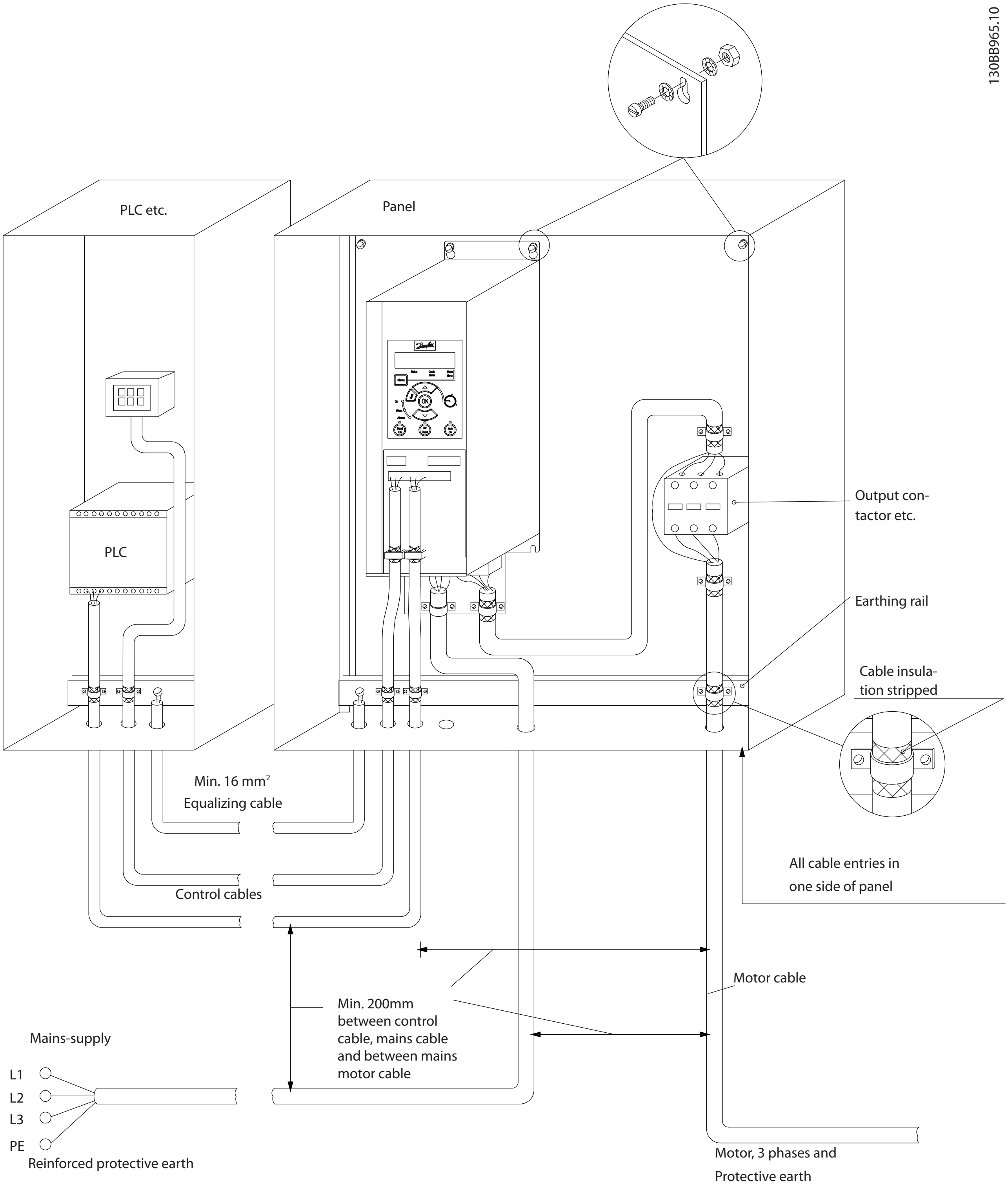


Illustration 6.9 EMC-correct Electrical Installation

NOTICE

For North America use metal conduits instead of shielded cables.

6.9 Use of EMC-Correct Cables

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

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

Transfer impedance (Z_T) is rarely stated by cable manufacturers, 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 shield material.
- The contact resistance between the individual shield conductors.
- The shield coverage, that is, the physical area of the cable covered by the shield - often stated as a percentage value.
- Shield type, that is, braided or twisted pattern.
    - Aluminum-clad with copper wire.
    - Twisted copper wire or armored steel wire cable.
    - Single-layer braided copper wire with varying percentage shield coverage. This is the typical Danfoss reference cable.
    - Double-layer braided copper wire.
    - Twin layer of braided copper wire with a magnetic, shielded/armored intermediate layer.
    - Cable that runs in copper tube or steel tube.
    - Lead cable with 1.1 mm (0.04 in) wall thickness.

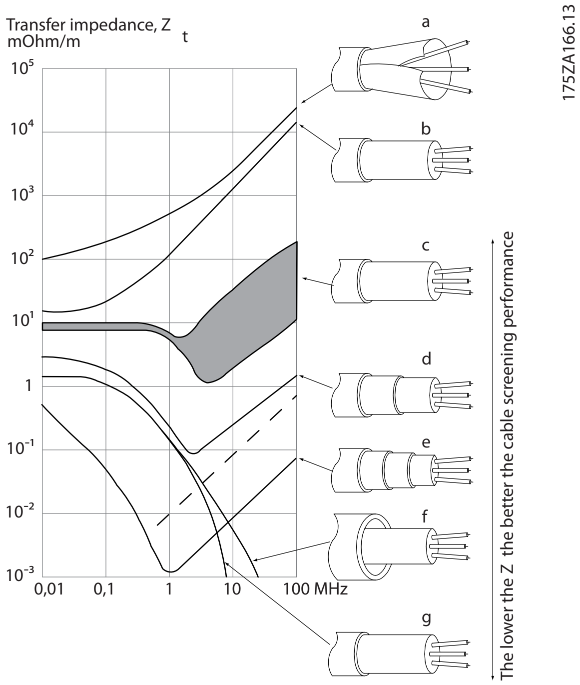
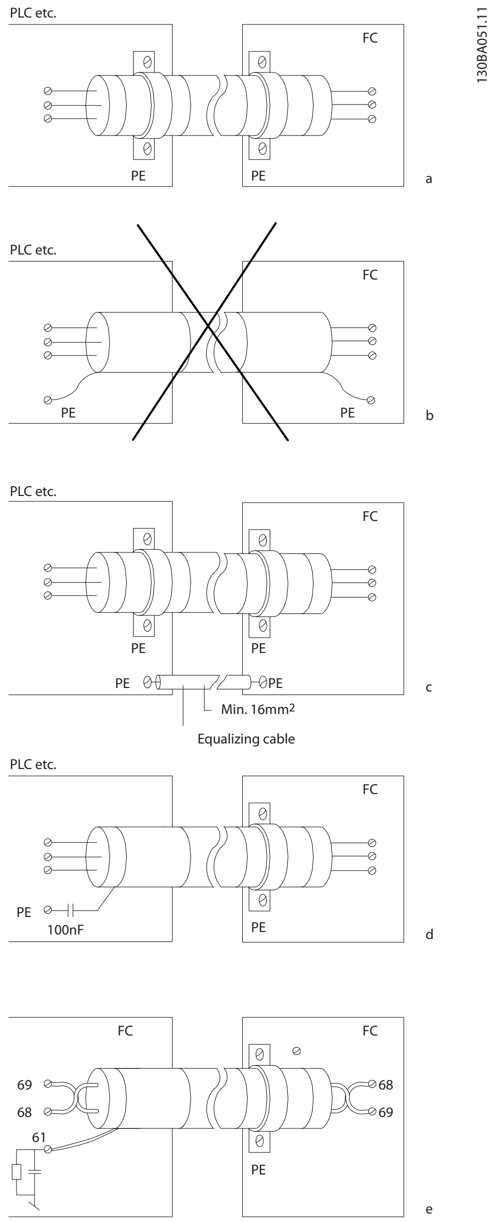


Illustration 6.10 Transfer Impedance of Different Wires

6.10 Grounding of Shielded/Armored Control Cables

Braid and shield/armor the control cables. Connect the shield to the metal cabinet of the unit with a cable clamp at both ends. *Illustration 6.11* shows correct grounding examples.



a	Correct grounding
b	Incorrect grounding
c	Protection from potential between PLC and frequency converter
d	50/60 Hz ground loops
e	Cables for serial communication

Illustration 6.11 Grounding Examples

a. **Correct grounding**
Control cables and cables for serial communication are fitted with cable clamps at both ends to ensure the best possible electrical contact.

b. **Incorrect grounding**
Do not use twisted cable ends (pigtails). They increase the shield impedance at high frequencies.

c. **Protection from potential between PLC and frequency converter**
If the ground potential between the frequency converter and the PLC is different, electric noise that disturbs the entire system is possible. Fit an equalizing cable, next to the control cable. Minimum cable cross-section: 16 mm^2 (4 AWG).

d. **For 50/60 Hz ground loops**
Long control cables sometimes causes 50/60 Hz ground loops. Connect 1 end of the shield to ground via a 100 nF capacitor (keeping leads short).

e. **Cables for serial communication**
Eliminate low-frequency noise currents between 2 frequency converters by connecting 1 end of the shield to terminal 61. This terminal is connected to ground via an internal RC link. Use twisted-pair cables to reduce the differential mode interference between the conductors.

6.11 Residual Current Device

If local safety regulations are complied with, use RCD relays, multiple protective grounding, or grounding as extra protection.
If an ground fault appears, a DC content may develop in the faulty current.
If RCD relays are used, observe local regulations. Relays must be suitable for protection of 3-phase equipment with a bridge rectifier and for a brief discharge on power-up, see *chapter 3.4 Ground Leakage Current* for further information.

6

6.12 Electrical Overview

6.12.1 Power Circuit - Overview

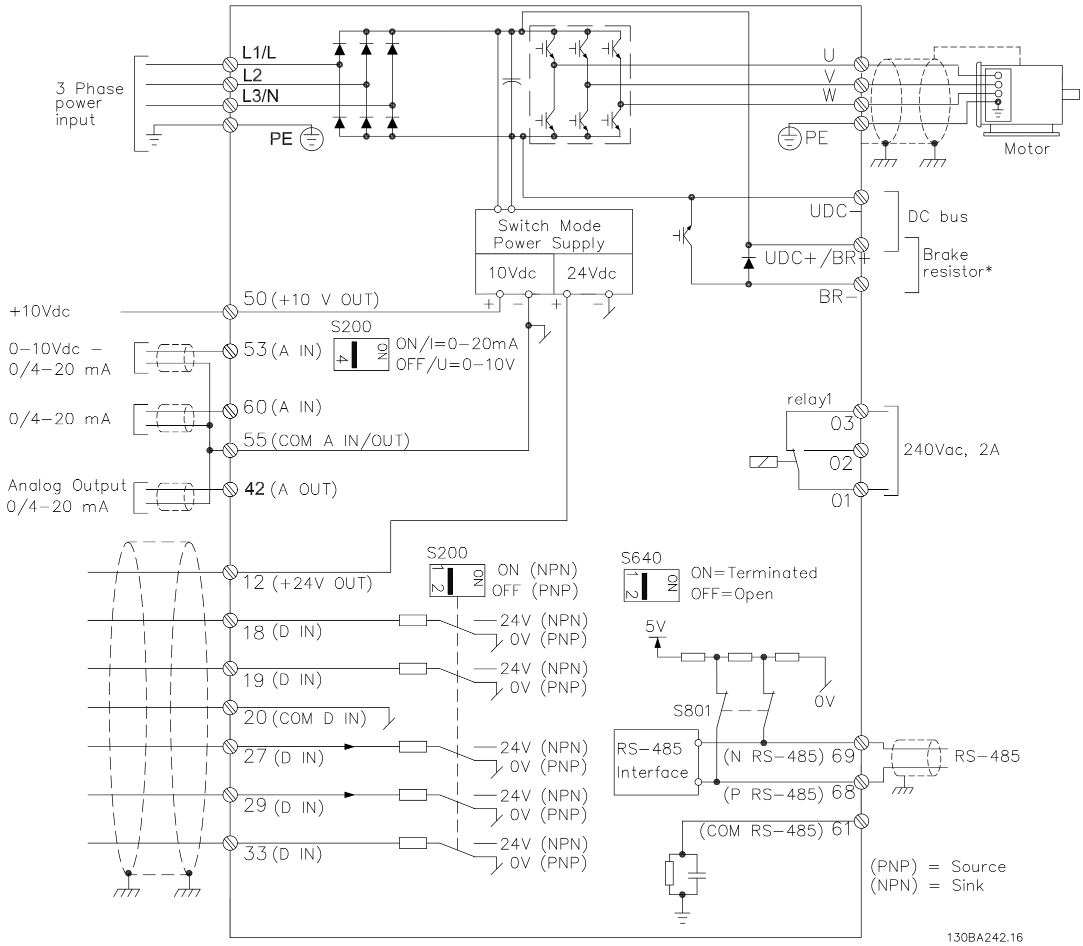


Illustration 6.12 Diagram Showing all Electrical Terminals

* Brakes (BR+ and BR-) are not applicable for enclosure size M1.

For information about brake resistors, see *VLT® Brake Resistor MCE 101 Design Guide*.
Improved power factor and EMC performance can be achieved by installing optional Danfoss line filters.
Danfoss power filters can also be used for load sharing. For more information about load sharing, see *VLT® FC 51 Micro Drive Load Sharing* application note.

6.13 Electrical Installation and Control Cables

Terminal number	Terminal description	Parameter number	Factory default
1+2+3	Relay1	5-40	No operation
12	DC 24 V supply	–	+24 V DC
18	Digital input	5-10	Start
19	Digital input	5-11	Reversing
20	Common digital ground	–	Common
27	Digital input	5-12	Reset
29	Digital input	5-13	Jog
33	Digital input	5-15	Preset ref bit 0
42	Analog output/digital output	6-9*	No operation
50	Supply for analog input	–	+10 V DC
53	Analog input (voltage or current)	3-15/6-1*	Reference
55	Common analog ground	–	Common
60	Current input	3-16/6-2*	Reference

Table 6.3 Terminal Connections

Long control cables and analog signals may, in rare cases and depending on installation, result in 50/60 Hz ground loops due to noise from mains supply cables.

If this occurs, break the shield or insert a 100 nF capacitor between shield and chassis.

NOTICE

To separate common terminals 20, 39, and 55, connect the common of digital/analog inputs and outputs. This avoids ground current interference among groups. For example, it avoids switching on digital inputs disturbing analog inputs.

NOTICE

Control cables must be shielded/armored.

6.14 Control Terminals

6.14.1 Access to Control Terminals

All control cable terminals are located underneath the terminal cover in front of the frequency converter. Remove the terminal cover using a screwdriver.

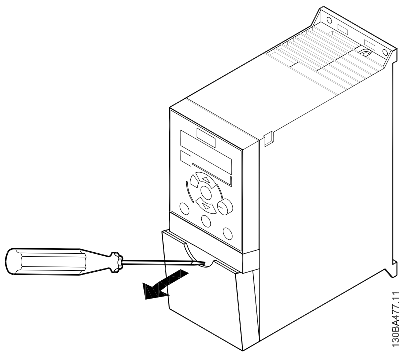


Illustration 6.13 Removing Terminal Cover

NOTICE

See back of terminal cover for outlines of control terminals and switches.

6.14.2 Connecting to Control Terminals

Illustration 6.14 shows all control terminals of the frequency converter. Applying start (terminal 18) and an analog reference (terminals 53 or 60) make the frequency converter run.

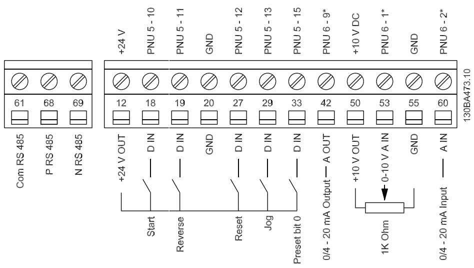


Illustration 6.14 Overview of Control Terminals in PNP-configuration and Factory Setting

6

6.15 Switches

NOTICE

Do not operate switches with power on the frequency converter.

Bus termination

Switch *BUS TER* position ON terminates the RS485 port, terminals 68, 69. See *Illustration 6.15*.

Default setting = Off

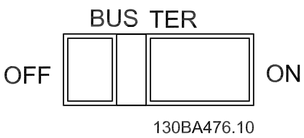
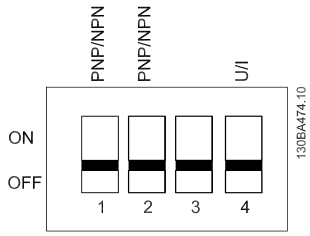


Illustration 6.15 S640 Bus Termination

S200 Switches 1-4



Switch 1	*Off=PNP terminals 29 On=NPN terminals 29
Switch 2	*Off=PNP terminal 18, 19, 27, and 33 On=NPN terminal 18, 19, 27, and 33
Switch 3	No function
Switch 4	*Off=Terminal 53 0–10 V On=Terminal 53 0/4–20 mA
*=default setting	

Illustration 6.16 S200 Switches 1–4

NOTICE

Set *parameter 6-19 Terminal 53 Mode* according to switch 4 position.

6.16 Final Set-Up and Test

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

Step 1. Locate the motor nameplate

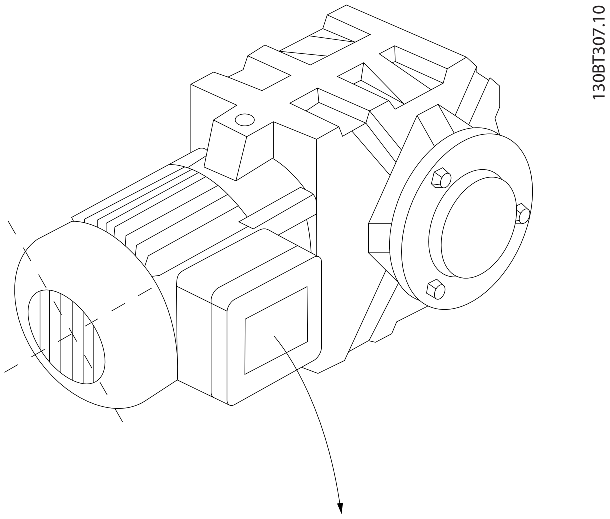
The motor is either star- (Y) or delta-connected (Δ). This information is on the motor nameplate data.

Step 2. Enter the motor nameplate data in this parameter list

To access this list, press the [Quick Menu] key and select *Q2 Quick Setup*.

	Motor Power [kW] or Motor Power [HP]	*Parameter 1-20 Motor Power [kW]* *Parameter 1-21 Motor Power [HP]*
1	Motor Voltage	*Parameter 1-22 Motor Voltage*
2	Motor Frequency	*Parameter 1-23 Motor Frequency*
3	Motor Current	*Parameter 1-24 Motor Current*
4	Motor Nominal Speed	*Parameter 1-25 Motor Nominal Speed*

Table 6.4 Parameters for Quick Set-up



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 6.17 Motor Nameplate Example

Step 3. Activate the automatic motor tuning (AMT)
Performing an AMT ensures optimum performance. The AMT measures the values from the motor model equivalent diagram.

1. Connect terminal 27 to terminal 12 or set *parameter 5-12 Terminal 27 Digital Input* to *[0] No function*.
2. Activate the AMT *1-29 Automatic Motor Tuning (AMT)*.
3. Select between complete or reduced AMT. If an LC filter is mounted, run only the reduced AMT, or remove the LC filter during the AMT procedure.
4. Press [OK]. The display shows *Press [Hand On] to start*.
5. Press [Hand On]. A progress bar indicates if the AMT is in progress.

Stop the AMT during operation

1. Press [Off] - the frequency converter enters into alarm mode and the display shows that the user terminated the AMT.

Successful AMT

1. The display shows *Press [OK] to finish AMT*.
2. Press [OK] to exit the AMT state.

Unsuccessful AMT

1. The frequency converter enters into alarm mode. A description of the alarm can be found in the *Troubleshooting* section in *VLT® Micro Drive FC 51 Programming Guide*.
2. Report value in the [Alarm Log] shows the last measuring sequence carried out by the AMT, before the frequency converter entered alarm mode. This number along with the description of the alarm helps with troubleshooting. Contact Danfoss Service and make sure to mention number and alarm description.

Unsuccessful AMT is often caused by incorrectly registered motor nameplate data or too big difference between the motor power size and the frequency converter power size.

Step 4. Set speed limit and ramp time
Set up the limits for speed and ramp time.

Minimum reference	*Parameter 3-02 Minimum Reference*
Maximum reference	*Parameter 3-03 Maximum Reference*

Table 6.5 Reference Limit Parameters

Motor speed low limit	*Parameter 4-11 Motor Speed Low Limit [RPM]* or *Parameter 4-12 Motor Speed Low Limit [Hz]*
Motor speed high limit	*Parameter 4-13 Motor Speed High Limit [RPM]* or *Parameter 4-14 Motor Speed High Limit [Hz]*

Table 6.6 Speed Limit Parameters

Ramp-up time 1 [s]	*Parameter 3-41 Ramp 1 Ramp Up Time*
Ramp-down time 1 [s]	*Parameter 3-42 Ramp 1 Ramp Down Time*

Table 6.7 Ramp Time Parameters

6

6.17 Parallel Connection of Motors

The frequency converter can control several motors connected in parallel. When using a parallel motor connection, consider the following points:

- When motors are connected in parallel, *parameter 1-29 Automatic Motor Tuning (AMT)* cannot be used.
- Run applications with motors connected in parallel in U/F mode (volts per hertz).
- The usage of VVC+ mode is limited to certain applications when the motors connected in parallel are of the same type and size.
- Total current consumption of motors must not exceed the rated output current I_{INV} of the frequency converter.
- Significant difference in motor sizes may cause problems at start and at low RPM. The relatively high ohmic resistance in the stator of a small motor demands higher voltage at start and at low RPM.
- Do not use the electronic thermal relay (ETR) of the frequency converter as motor protection. To provide extra motor protection, include thermistors in each motor winding or individual thermal relays.

During the installation of a parallel motor application, consider the following points:

- Connection A/B is only possible when the total motor cable is shorter than 50 m (164 ft).
- In connection C/D the total motor cable length specified in general specifications is valid as long as the parallel cables are less than 10 m (32.8 ft).

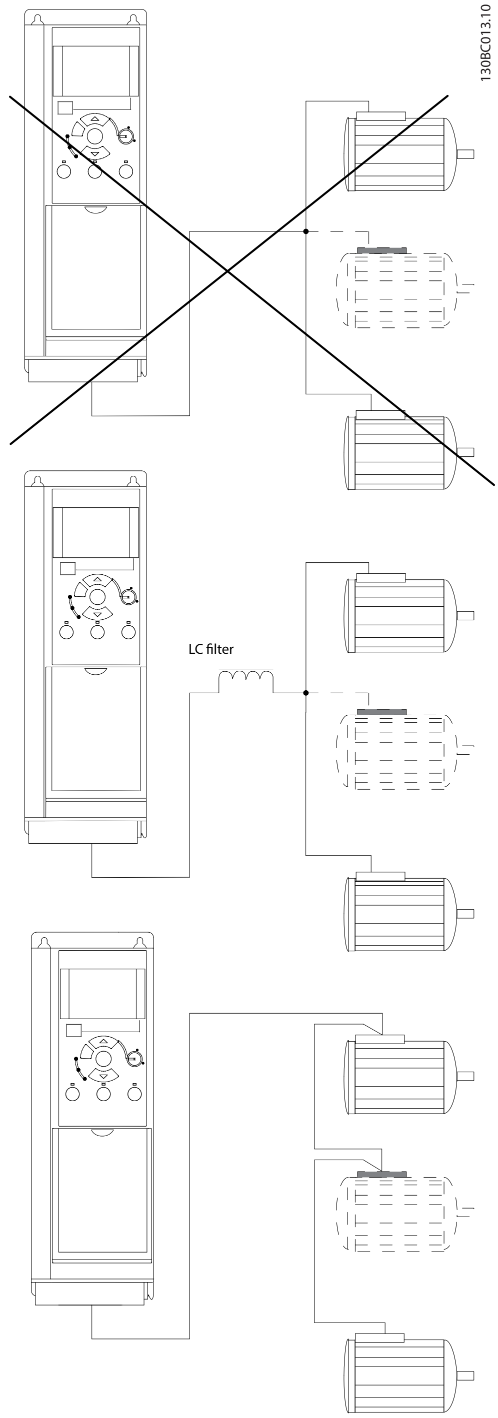


Illustration 6.18 Parallel Connection of Motors

6.18 Motor Installation

6.18.1 Motor Insulation

For motor cable lengths ≤ the maximum cable length listed in *chapter 9.1 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, 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 6.8 Motor Insulation Ratings

6.19 Installation of Misc. Connections

6.19.1 RS485 Bus Connection

1 or more frequency converters can be connected to a control (or master) using the RS485 interface. Terminal 68 is connected to the P signal (TX+, RX+), while terminal 69 is connected to the N signal (TX-, RX-).

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

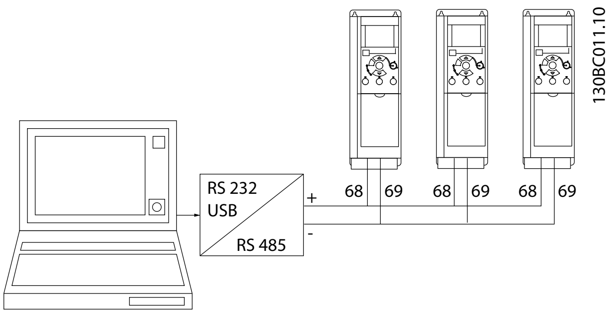


Illustration 6.19 RS485 Bus Connection

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

Bus termination
Terminate the RS485 bus with resistors at both ends. For this purpose, set switch S801 on the control card for ON.

Set the communication protocol to *parameter 8-30 Protocol*.

6.19.2 How to Connect a PC to the Frequency Converter

To control or program the frequency converter from a PC, install the PC-based configuration tool MCT 10 Set-up Software.

MCT 10 Set-up Software
MCT 10 Set-up Software has been designed as an easy-to-use interactive tool for setting parameters in our frequency converters.

The PC-based configuration tool MCT 10 Set-up Software is useful for:

- Planning a communication network off-line. MCT 10 Set-up Software contains a complete frequency converter database.
- Commissioning frequency converters online.
- Saving settings for all frequency converters.
- Replacing a frequency converter in a network.
- Expanding an existing network.

Save frequency converter settings

1. Connect a PC to the unit via USB port.
2. Open the MCT 10 Set-up Software.
3. Select *Read from drive*.
4. Select *Save as*.

All parameters are now stored in the PC.

Save frequency converter settings

1. Connect a PC to the unit via USB port.
2. Open the MCT 10 Set-up Software.
3. Select *Open*, the software shows the stored files.
4. Open the appropriate file.
5. Select *Write to drive*.

All parameter settings are now transferred to the frequency converter.

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

6

The MCT 10 Set-up Software modules
The following modules are included in the software package:

	MCT 10 Set-up Software Setting parameters. Copy to and from frequency converters. Documentation and print out of parameter settings including diagrams.
	External user interface Preventive maintenance schedule. Clock settings. Timed action programming. Smart logic controller set-up.

Table 6.9 MCT 10 Set-up Software

Ordering number
Order the CD containing the MCT 10 Set-up Software using code number 130B1000.

6.20 Safety

6.20.1 High-voltage Test

Carry out a high-voltage test by short-circuiting terminals U, V, W, L_1, L_2, and L_3. Energize maximum 2.15 kV DC for 380–500 V frequency converters and 2.525 kV DC for 525–690 V frequency converters for 1 s between this short circuit and the chassis.

⚠WARNING

LEAKAGE CURRENT HAZARD

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

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

6.20.2 Safety Ground Connection

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

⚠WARNING

LEAKAGE CURRENT HAZARD

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

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

7 Programming

7.1 How to Programme

7.1.1 Programming with MCT 10 Set-up Software

The frequency converter can be programmed from a PC via RS485 port using the MCT 10 Set-up Software.

Refer to *VLT® Motion Control Tools MCT 10 Set-up Software Operating Instructions*.

7.1.2 Programming with the LCP 11 or LCP 12

The LCP is divided into 4 functional groups:

1. Numeric display.
2. Menu key.
3. Navigation keys.
4. Operation keys and indicator lights.

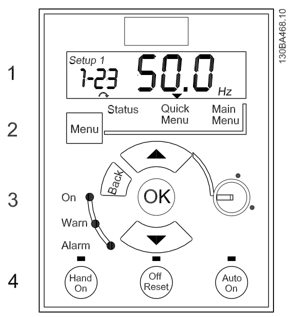


Illustration 7.1 LCP 12 with Potentiometer

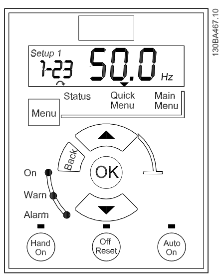


Illustration 7.2 LCP 11 without Potentiometer

The display

The display shows different information.

Set-up number shows the active set-up and the edit set-up. If the same set-up acts as both active and edit set-up, only that set-up number is shown (factory setting).
When active and edit set-up differ, the display shows both numbers (set-up 12). The flashing number indicates the edit set-up.

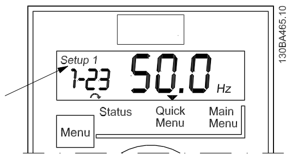


Illustration 7.3 Indicating Set-up

The small digits to the left are the selected parameter number.

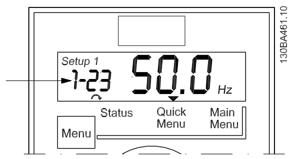


Illustration 7.4 Indicating Selected Parameter Number

The large digits in the middle of the display show the value of the selected parameter.

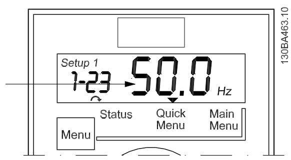


Illustration 7.5 Indicating Value of Selected Parameter

The right side of the display shows the unit of the selected parameter. This can be either Hz, A, V, kW, hp, %, s, or RPM.

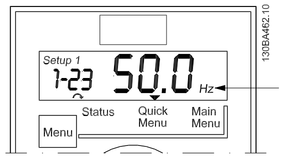


Illustration 7.6 Indicating Unit of Selected Parameter

Motor direction is shown to the bottom left of the display, indicated by a small arrow pointing either clockwise or counterclockwise.

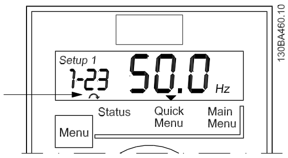


Illustration 7.7 Indicating Motor Direction

7

Press [Menu] to select 1 of the following menus

Status Menu
The status menu is either in readout mode or hand-on mode. In readout mode, the value of the currently selected readout parameter is shown in the display.

In hand-on mode, the local LCP reference is displayed.

Quick Menu
Displays Quick Menu parameters and their settings. Parameters in the Quick Menu can be accessed and edited from here. Most applications can be run by setting the parameters in Quick Menu.

Main Menu
Displays Main Menu parameters and their settings. All parameters can be accessed and edited here.

Indicator lights

- Green indicator light: The frequency converter is on.
- Yellow indicator light: Indicates a warning. See chapter *Troubleshooting* in the *VLT® Micro Drive FC 51 Programming Guide*.
- Flashing red LED: Indicates an alarm. See chapter *Troubleshooting* in *VLT® Micro Drive FC 51 Programming Guide*.

Navigation keys
[Back]: For moving to the previous step or layer in the navigation structure.
[▲] [▼]: For maneuvering between parameter groups, parameters, and within parameters.
[OK]: For selecting a parameter and for accepting changes to parameter settings.

Pressing [OK] for more than 1 s enters the adjust mode. In the adjust mode, it is possible to make fast adjustment by pressing [▲] [▼] combined with [OK].

Press [▲] [▼] to change value. Press [OK] to shift between digits quickly.

To exit the adjust mode, press [OK] more than 1 s again with changes saving or press [Back] without changes saving.

Operation keys
A yellow indicator light above the operation keys indicates the active key.
[Hand On]: Starts the motor and enables control of the frequency converter via the LCP.
[Off/Reset]: The motor stops except in alarm mode. In alarm mode, the motor is reset.
[Auto On]: The frequency converter is controlled either via control terminals or serial communication.
[Potentiometer] (LCP 12): The potentiometer works in 2 ways depending on the mode in which the frequency converter is running.
In auto mode, the potentiometer acts as an extra programmable analog input.
In hand-on mode, the potentiometer controls local reference.

7.2 Status Menu

After power-up, the Status Menu is active. Press [Menu] to toggle between Status, Quick Menu, and Main Menu.

[▲] and [▼] toggle between the options in each menu.

The display indicates the status mode with a small arrow above Status.

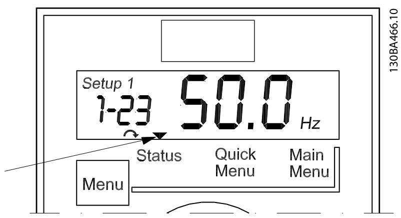


Illustration 7.8 Indicating Status Mode

7.3 Quick Menu

The Quick Menu gives easy access to the most frequently used parameters.

1. To enter Quick Menu, press [Menu] key until indicator in display is placed above Quick Menu.
2. Press [▲] [▼] to select either QM1 or QM2, then press [OK].
3. Press [▲] [▼] to browse through the parameters in the Quick Menu.
4. Press [OK] to select a parameter.
5. Press [▲] [▼] to change the value of a parameter setting.
6. Press [OK] to accept the change.
7. To exit, press either [Back] twice to enter Status, or press [Menu] once to enter Main Menu.

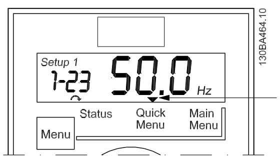


Illustration 7.9 Indicating Quick Menu Mode

7.4 Quick Menu Parameters

7.4.1 Quick Menu Parameters - Basic Settings QM1

This section describes the parameters in Quick Menu.

*=Factory setting.

1-20 Motor Power [kW]/[hp] ($P_{m.n}$)

Option:		Function:
		Enter motor power from nameplate data. Two sizes down, 1 size up from nominal VLT rating.
[1]	0.09 kW/0.12 hp	
[2]	0.12 kW/0.16 hp	
[3]	0.18kW/0.25 hp	
[4]	0.25 kW/0.33 hp	
[5]	0.37kW/0.50 hp	
[6]	0.55 kW/0.75 hp	
[7]	0.75 kW/1.00 hp	
[8]	1.10 kW/1.50 hp	
[9]	1.50 kW/2.00 hp	
[10]	2.20 kW/3.00 hp	
[11]	3.00 kW/4.00 hp	
[12]	3.70 kW/5.00 hp	
[13]	4.00 kW/5.40 hp	

1-20 Motor Power [kW]/[hp] ($P_{m.n}$)

Option:		Function:
[14]	5.50 kW/7.50 hp	
[15]	7.50 kW/10.0 hp	
[16]	11.00 kW/15.00 hp	
[17]	15.00 kW/20.00 hp	
[18]	18.50 kW/25.00 hp	
[19]	22.00 kW/29.50 hp	
[20]	30.00 kW/40.00 hp	

NOTICE

Changing this parameter affects parameters *1-22 Motor Voltage* to *1-25 Motor Nominal Speed*, *1-30 Stator Resistance (Rs)*, *1-33 Stator Leakage Reactance (X1)*, and *1-35 Main Reactance (Xh)*.

1-22 Motor Voltage ($U_{m.n}$)

Range:		Function:
230/400 V	[50–999 V]	Enter motor voltage from nameplate data.

1-23 Motor Frequency ($f_{m.n}$)

Range:		Function:
50 Hz*	[20–400 Hz]	Enter motor frequency from nameplate data.

1-24 Motor Current ($I_{m.n}$)

Range:		Function:
M-type dependent*	[0.01–100.00 A]	Enter motor current from nameplate data.

1-25 Motor Nominal Speed ($n_{m.n}$)

Range:		Function:
M-type Dependent*	[100–9999 RPM]	Enter motor nominal speed from nameplate data.

1-29 Automatic Motor Tuning (AMT)

Option:		Function:
		Use AMT to optimize motor performance. When *parameter 1-01 Motor Control Principle* is set to *[0] U/f*, AMT does not work. **NOTICE** **This parameter cannot be changed while the motor is running.** 1. Stop the frequency converter - make sure that the motor is at standstill. 2. Select *[2] Enable AMT*. 3. Apply start signal: - Via LCP: Press [Hand On]. - Or in remote on mode: Apply start signal on terminal 18.
[0] *	Off	AMT function is disabled.

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1-29 Automatic Motor Tuning (AMT)

Option:		Function:
[2]	Enable AMT	AMT function starts running. **NOTICE** **To gain optimum tuning of the frequency converter, run AMT on a cold motor.**
[3]	Complete AMT with Rotating motor	**NOTICE** **The motor rotates when this option is active.** With this option selected, the frequency converter optimizes the following parameters: *1-35 Main Reactance (X2)*, *1-30 Stator Resistance (Rs)*, and *1-33 Stator Leakage Reactance (X1)*.

3-02 Minimum Reference

Range:		Function:
0.00*	[-4999-4999]	Enter the value for minimum reference. The sum of all internal and external references are clamped (limited) to the minimum reference value, *parameter 3-02 Minimum Reference*.

3-03 Maximum Reference

Range:		Function:
		The range of this parameter is *parameter 3-02 Minimum Reference*–4999.
60.000 Hz or 50.000 Hz depending on the setting in par. 0-03.*	[-4999–4999]	Enter the value for maximum reference. The sum of all internal and external references are clamped (limited) to the maximum reference value, *parameter 3-03 Maximum Reference*.

3-41 Ramp1 Ramp-up Time

Range:		Function:
Size related*	[0.05-3600.00 s]	Enter ramp-up time from 0 Hz to rated motor frequency ($f_{M,N}$) set in *parameter 1-23 Motor Frequency*. Select a ramp-up time ensuring that torque limit is not exceeded, see *parameter 4-16 Torque Limit in Motor Mode*.

3-42 Ramp1 Ramp-down Time

Range:		Function:
Size related*	[0.05-3600.00 s]	Enter ramp-down time from rated motor frequency ($f_{M,N}$) in *parameter 1-23 Motor Frequency* to 0 Hz. Select a ramp-down time that does not cause overvoltage in the inverter due to regenerative operation of motor. Furthermore, regenerative torque must not exceed limit set in *parameter 4-17 Torque Limit in Generator Mode*.

7.4.2 Quick Menu Parameters - PI Basic Settings QM2

The following is a brief description of the parameters for the PI basic settings. For a more detailed description, see *VLT® Micro Drive FC 51 Programming Guide*.

1-00 Configuration Mode

Option:		Function:
		Use this parameter for selecting the application control principle to be used when a remote reference is active. **NOTICE** **Changing this parameter resets *parameter 3-00 Reference Range*, *parameter 3-02 Minimum Reference* and *parameter 3-03 Maximum Reference* to their default values.** **NOTICE** **This parameter cannot be adjusted while motor is running.**
[0] *	Speed Open Loop	For normal speed control (references).
[3]	Process	Enables process closed-loop control. See parameter group *7-3* Process PI Control* for further information on PI controller.

3-02 Minimum Reference

Range:		Function:
0.00*	[-4999-4999]	Enter the value for minimum reference. The sum of all internal and external references are clamped (limited) to the minimum reference value, *parameter 3-02 Minimum Reference*.

3-03 Maximum Reference

Range:		Function:
		The range of this parameter is *parameter 3-02 Minimum Reference*–4999.
60.000 Hz or 50.000 Hz depending on the setting in par. 0-03.*	[-4999–4999]	Enter the value for maximum reference. The sum of all internal and external references are clamped (limited) to the maximum reference value, *parameter 3-03 Maximum Reference*.

3-10 Preset Reference

Option:		Function:
		Each parameter set-up contains 8 preset references which are selectable via 3 digital inputs or fieldbus.
[0.00] *	-100.00–100.00%	Enter the different preset references using array programming. Normally, 100%=value set in *parameter 3-03 Maximum Reference*. However, there are exceptions if *parameter 3-00 Reference Range* is set to *[0] Min - Max*. Example 1: *Parameter 3-02 Minimum Reference* is set to 20, and *parameter 3-03 Maximum Reference* is set to 50. In this case 0%=0, and 100%=50. Example 2: *Parameter 3-02 Minimum Reference* is set to -70, and *parameter 3-03 Maximum Reference* is set to 50. In this case 0%=0, and 100%=70.

[18] Bit2	[17] Bit1	[16] Bit0	[16] Bit0
0	0	0	0
0	0	1	1
0	1	0	2
0	1	1	3
1	0	0	4
1	0	1	5
1	1	0	6
1	1	1	7

Table 7.1 Parameter Group 5-1* Digital Inputs Option [16], [17], and [18]

4-12 Motor Speed Low Limit

Range:		Function:
0.0 Hz*	[0.0-400.0 Hz]	Set the minimum motor speed limit corresponding to the minimum output frequency of the motor shaft. **NOTICE** **As the minimum output frequency is an absolute value, and the frequency converter cannot deviate from it.**

4-14 Motor Speed High Limit

Range:		Function:
65.0 Hz*	[0.0-400.0 Hz]	Set the maximum motor speed corresponding to the maximum output frequency of the motor shaft. **NOTICE** **The maximum output frequency is an absolute value, and the frequency converter cannot deviate from it.**

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6-22 Terminal 60 Low Current

Range:		Function:
		NOTICE **Set the value to a minimum of 2 mA to activate the live zero timeout function in *parameter 6-01 Live Zero Timeout Time*.** This reference signal should correspond to minimum reference value set in *parameter 6-24 Terminal 60 Low Ref./Feedb. Value*.
0.14 mA*	[0.00–20.00 mA]	Enter the low current value.

6-23 Terminal 60 High Current

Range:		Function:
		This reference signal should correspond to the high current value set in *parameter 6-25 Terminal 60 High Ref./Feedb. Value*.
20.00 mA*	[0.00–20.00 mA]	Enter high current value.

6-24 Terminal 60 Low Ref./Feedb. Value

Range:		Function:
		The scaling value corresponding to the low current set in *parameter 6-22 Terminal 60 Low Current*.
0.000*	[-4999–4999]	Enter analog input scaling value.

6-25 Terminal 60 High Ref./Feedb. Value

Range:		Function:
		The scaling value corresponding to the high current set in *parameter 6-23 Terminal 60 High Current*.
60.000 Hz or 50.000 Hz depending on the setting in par. 0-03.*	[-4999-4999]	Enter analog input scaling value.

6-26 Terminal 60 Filter Time Constant

Range:		Function:
		A first-order digital low-pass filter time constant for suppressing electrical noise in terminal 60. A high time constant value improves dampening, but also increases time delay through the filter. **NOTICE** **This parameter cannot be changed while the motor is running.**
0.01 s*	[0.01–10.00 s]	Enter the time constant.

7-20 Process CL Feedback Resources

Option:		Function:
		Select input to function as feedback signal.
[0] *	No Function	
[1]	Analog Input 53	
[2]	Analog Input 60	
[8]	Pulse Input 33	
[11]	Local Bus	

7-30 Process PI Normal/Inverse Control

Option:		Function:
[0] *	Normal	Feedback larger than setpoint results in a speed reduction. Feedback less than setpoint results in a speed increase.
[1]	Inverse	Feedback larger than setpoint results in a speed increase. Feedback less than setpoint results in a speed reduction.

7-31 Process PI Anti Windup

Option:		Function:
[0]	Disable	Regulation of a given error continues even when the output frequency cannot be increased/ decreased.
[1] *	Enable	PI controller ceases from regulating a given error when the output frequency cannot be increased/ decreased.

7-32 Process PI Start Speed

Range:		Function:
0.0 Hz*	[0.0–200.0 Hz]	Until the set motor speed has been reached, the frequency converter operates in open-loop mode.

7-33 Process PI Proportional Gain

Option:		Function:
[0.01] *	0.00–10.00	Enter the value for the proportional gain, that is, the multiplication factor of the error between the setpoint and the feedback signal. **NOTICE** **0.00=Off.**

7-34 Process PI Integral Time

Range:		Function:
9999.00 s*	[0.10–9999.00 s]	The integrator provides an increasing gain at a constant error between the setpoint and the feedback signal. The integral time is the time needed by the integrator to reach the same gain as the proportional gain.

7-38 Process Feed Forward Factor		
Range:		**Function:**
0%*	[0–400%]	The FF factor sends a part of the reference signal around the PI controller which then only affects part of the control signal. Activate the FF factor to obtain less overshoot and high dynamics when changing the setpoint. This parameter is always active when *parameter 1-00 Configuration Mode* is set to *[3] Process*.

7.5 Main Menu

[Main Menu] is used for programming all parameters. The Main Menu parameters can be accessed immediately unless a password has been created via *parameter 0-60 Main Menu Password*. For most VLT® Micro Drive applications it is not necessary to access the Main Menu parameters, but instead the Quick Menu provides the simplest and quickest access to the typical required parameters.

The Main Menu accesses all parameters.

1. Press [Menu] key until indicator light in the display is located above Main Menu.
2. Use [▲] [▼] to browse through the parameter groups.
3. Press [OK] to select a parameter group.
4. Use [▲] [▼] to browse through the parameters in the specific group.
5. Press [OK] to select the parameter.
6. Use [▲] [▼] to set/change the parameter value.

Press [Back] to go back 1 level.

7.6 Quick Transfer of Parameter Settings between Multiple Frequency Converters

When the set-up of a frequency converter is completed, it is recommended to store the data in the LCP or on a PC via MCT 10 Set-up Software.

Data transfer from the frequency converter to the LCP

1. Go to *parameter 0-50 LCP Copy*.
2. Press [OK].
3. Select *[1] All to LCP*.
4. Press [OK].

Connect the LCP to another frequency converter and copy the parameter settings to this frequency converter as well.

Data transfer from the LCP to the frequency converter

1. Go to *parameter 0-50 LCP Copy*.
2. Press [OK].
3. Select *[2] All from LCP*.
4. Press [OK].

7.7 Readout and Programming of Indexed Parameters

Use *chapter 7.4.2 Quick Menu Parameters - PI Basic Settings QM2* as an example.

- Press [OK] to select a parameter and use [▲]/[▼] for selecting the indexed values.
- To change a parameter value, select the value and press [OK].
- Change the value using [▲]/[▼].
- Press [OK] to accept the new setting.
- Pressing [OK] for more than 1 s activates the adjust mode. In the adjust mode, it is possible to make fast adjustment by pressing [▲]/[▼] together with [OK].
- Press [▲]/[▼] to change the value. Press [OK] to shift between digits. To exit the adjust mode, press [OK] for more than 1 s again to exit and save changes, or press [Back] to exit without saving changes.

7.8 Initialize the Frequency Converter to Default Settings in two Ways

Recommended initialization (via *parameter 14-22 Operation Mode*)

1. Select *parameter 14-22 Operation Mode*.
2. Press [OK].
3. Select *initialization* and Press [OK].
4. Cut off the mains supply and wait until the display turns off.
5. Reconnect the mains supply, the frequency converter is now reset.

The following parameters are not reset during the initialization:

- *Parameter 8-30 Protocol*
- *Parameter 8-31 Address*
- *Parameter 8-32 Baud Rate*
- *Parameter 8-33 Parity / Stop Bits*
- *Parameter 8-35 Minimum Response Delay*
- *Parameter 8-36 Maximum Response Delay*
- *Parameter 15-00 Operating hours* to *parameter 15-05 Over Volt's*
- *Parameter 15-03 Power Up's*
- *Parameter 15-04 Over Temp's*
- *Parameter 15-05 Over Volt's*
- *Parameter 15-30 Alarm Log: Error Code*
- Parameter group *15-4* Drive Identification parameters*

Initialization using [OK] and [Menu] keys:

1. Power off the frequency converter.
2. Press [OK] and [Menu].
3. Power up the frequency converter while still pressing the keys for 10 s.
4. The frequency converter is now reset, except for the following parameters:
    - *Parameter 15-00 Operating hours*
    - *Parameter 15-03 Power Up's*
    - *Parameter 15-04 Over Temp's*
    - *Parameter 15-05 Over Volt's*
    - Parameter group *15-4* Drive identification parameters*

The LCP display shows *alarm 80, Drive initialised to default value* after the power cycle.

8 RS485 Installation and Set-up

8.1 RS485 Installation and Set-up

8.1.1 Overview

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

NOTICE

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

Terminate each segment at both ends, using either the termination switch (S801) of the frequency converters or a biased termination resistor network. Always use shielded twisted pair (STP) cable for bus cabling, and always follow good common installation practice.
Low-impedance ground connection of the shield at every node is important, including at high frequencies. Thus, connect a large surface of the shield to ground, for example with a cable clamp or a conductive cable gland. It may be necessary to apply potential equalizing cables to maintain the same ground potential throughout the network, particularly in installations with long cables.
To prevent impedance mismatch, always use the same type of cable throughout the entire network. When connecting a motor to the frequency converter, always use shielded motor cable.

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

Table 8.1 Cable Specifications

8.1.2 Network Connection

Connect the frequency converter to the RS485 network as follows (see also *Illustration 8.1*):

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

NOTICE

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

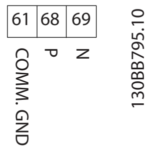

Illustration 8.1 Network Connection

8.1.3 Frequency Converter Hardware Set-up

To terminate the RS485 bus, use the terminator DIP switch on the main control board of the frequency converter.

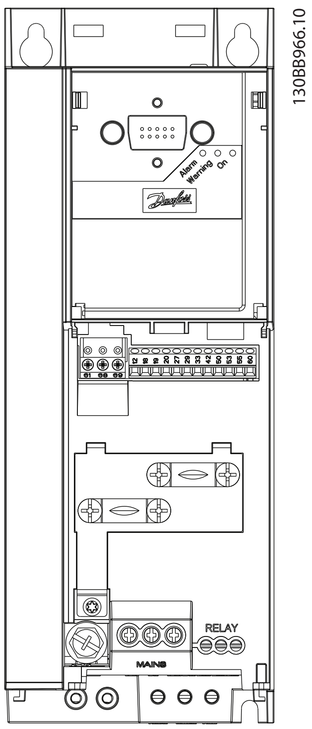

Illustration 8.2 Terminator Switch Factory Setting

The factory setting for the DIP switch is OFF.

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8.1.4 EMC Precautions

The following EMC precautions are recommended to achieve interference-free operation of the RS485 network.

Observe relevant national and local regulations, for example regarding protective ground connection. To avoid coupling of high frequency noise from 1 cable to another, keep the RS485 communication cable away from motor and brake resistor cables. Keep the greatest possible distance between the cables, especially where cables run in parallel over long distances. The minimum distance is 200 mm (8 inches). When crossing is unavoidable, the RS485 cable must cross motor cable and brake resistor cables at an angle of 90°.

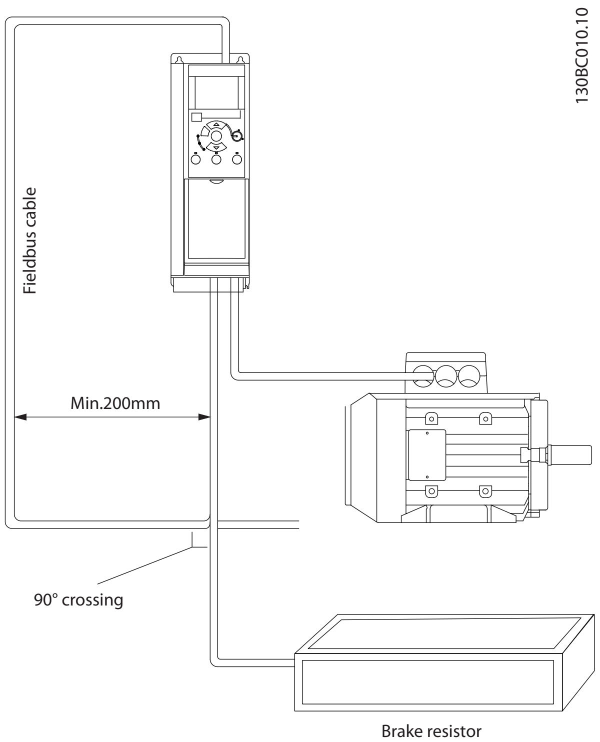

Illustration 8.3 EMC Precautions for RS485

8.1.5 Frequency Converter Parameter Settings for Modbus Communication

The following parameters apply to the RS485 interface (FC-port):

Parameter	Function
Parameter 8-30 Protocol	Select the application protocol to run on the RS485 interface.
Parameter 8-31 Address	Set the node address. **NOTICE** **The address range depends on the protocol selected in *parameter 8-30 Protocol*.**
Parameter 8-32 Baud Rate	Set the baud rate. **NOTICE** **The baud rate depends on the protocol selected in *parameter 8-30 Protocol*.**
Parameter 8-33 Parity / Stop Bits	Set the parity and number of stop bits. **NOTICE** **The selection depends on the protocol selected in *parameter 8-30 Protocol*.**
Parameter 8-35 Minimum Response Delay	Specify a minimum delay time between receiving a request and transmitting a response. This function is for overcoming modem turnaround delays.
Parameter 8-36 Maximum Response Delay	Specify a maximum delay time between transmitting a request and receiving a response.

Table 8.2 Parameters Related to RS485 Interface

8.2 FC Protocol Overview

8.2.1 Overview

The FC protocol, also referred to as FC fieldbus, is the Danfoss standard fieldbus. It defines an access technique according to the master/slave principle for communications via a fieldbus.
1 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 RS485, thus utilizing the RS485 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.

8.2.2 FC with Modbus RTU

The FC protocol 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 of the active set-up.
- Control of the 2 relays built into 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. Accessing the parameters offers a range of control options, including controlling the setpoint of the frequency converter when its internal PI controller is used.

8.3 Network Configuration

To enable the FC protocol for the frequency converter, set the following parameters.

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

Table 8.3 Parameters to Enable the Protocol

8.4 FC Protocol Message Framing Structure

8.4.1 Content of a Character (byte)

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

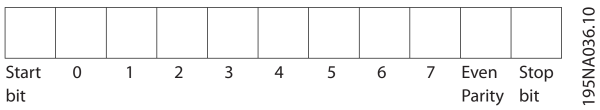

Illustration 8.4 Content of a Character

8.4.2 Telegram Structure

Each telegram has the following structure:

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

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

A data control byte (BCC) completes the telegram.

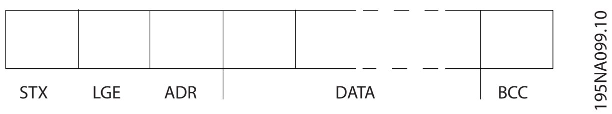

Illustration 8.5 Telegram Structure

8

8.4.3 Telegram Length (LGE)

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

4 data bytes	LGE=4+1+1=6 bytes
12 data bytes	LGE=12+1+1=14 bytes
Telegrams containing texts	10[1)]+n bytes

Table 8.4 Length of Telegrams

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

8.4.4 Frequency Converter Address (ADR)

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.

8.4.5 Data Control Byte (BCC)

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

8.4.6 The Data Field

The structure of data blocks depends on the type of telegram. There are 3 telegram types, and the type applies for both control telegrams (master⇒slave) and response telegrams (slave⇒master).

The 3 types of telegram are:

- Process block (PCD).
- Parameter block.
- Text block.

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

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

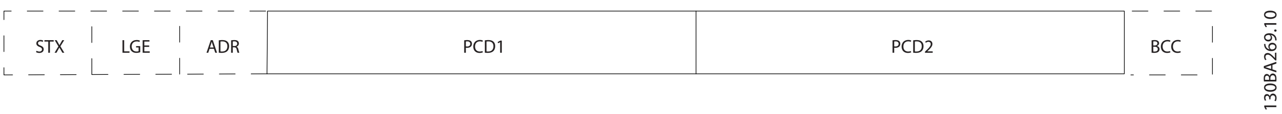

Illustration 8.6 Process Block

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.

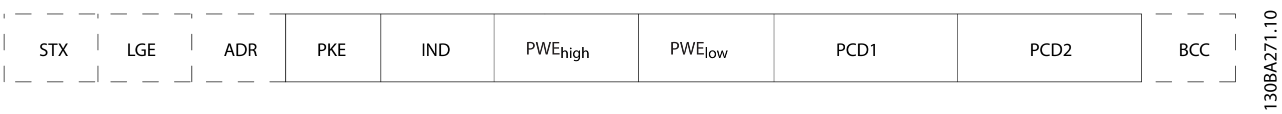

Illustration 8.7 Parameter Block

Text block

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

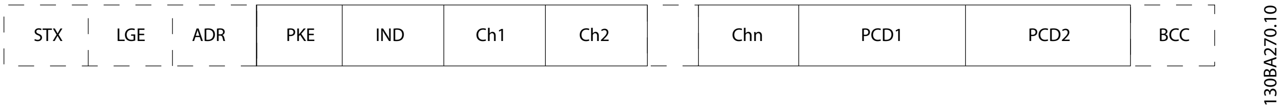

Illustration 8.8 Text Block

8.4.7 The PKE Field

The PKE field contains 2 subfields:

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

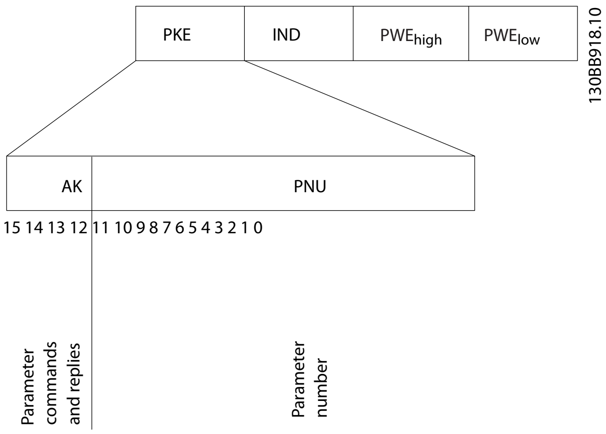

Illustration 8.9 PKE Field

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

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

Table 8.5 Parameter Commands

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

Table 8.6 Response

If the command cannot be performed, the slave sends this response *0111 Command cannot be performed* and issues the following fault report in *Table 8.7*.

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

Table 8.7 Slave Report

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8.4.8 Parameter Number (PNU)

Bits 0–11 transfer parameter numbers. The function of the relevant parameter is defined in the parameter description in the *VLT® Micro Drive FC 51 Programming Guide*.

8.4.9 Index (IND)

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

Only the low byte is used as an index.

8.4.10 Parameter Value (PWE)

The parameter value block consists of 2 words (4 bytes), and the value depends on the defined command (AK). The master prompts for a parameter value when the PWE block contains no value. To change a parameter value (write), write the new value in the PWE block and send from the master to the 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 several data options, for example *parameter 0-01 Language*, select the data value by entering the value in the PWE block. Serial communication is only capable of reading parameters containing data type 9 (text string).

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

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

8.4.11 Data Types Supported by the Frequency Converter

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

Table 8.8 Data Types

8.4.12 Conversion

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

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

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

Table 8.9 Conversion

8.4.13 Process Words (PCD)

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

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

Table 8.10 Process Words (PCD)

8.5 Examples

8.5.1 Writing a Parameter Value

Change *parameter 4-14 Motor Speed High Limit [Hz]* to 100 Hz.
Write the data in EEPROM.

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

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

Data value 1000, corresponding to 100 Hz, see *chapter 8.4.12 Conversion*.

The telegram looks like *Illustration 8.10*.

E19E H	0000 H	0000 H	03E8 H
PKE	IND	PWE high	PWE low

130BA092.10

Illustration 8.10 Telegram

NOTICE

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

The response from the slave to the master is shown in *Illustration 8.11*.

119E H	0000 H	0000 H	03E8 H
PKE	IND	PWE high	PWE low

130BA093.10

Illustration 8.11 Response from Master

8.5.2 Reading a Parameter Value

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

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

- IND = 0000 hex.
- PWE_{HIGH} = 0000 hex.
- PWE_{LOW} = 0000 hex.

1155 H	0000 H	0000 H	0000 H
PKE	IND	PWE high	PWE low

130BA094.10

Illustration 8.12 Telegram

If the value in *parameter 3-41 Ramp 1 Ramp Up Time* is 10 s, the response from the slave to the master is shown in *Illustration 8.13*.

1155 H	0000 H	0000 H	03E8 H
PKE	IND	PWE high	PWE low

130BA267.10

Illustration 8.13 Response

3E8 hex corresponds to 1000 decimal. The conversion index for *parameter 3-41 Ramp 1 Ramp Up Time* is -2, that is, 0.01.
Parameter 3-41 Ramp 1 Ramp Up Time is of the type *Unsigned 32*.

8

8.6 Modbus RTU Overview

8.6.1 Prerequisite Knowledge

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

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

8.6.2 What the User Should Already Know

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

8.6.3 Overview

Regardless of the type of physical communication networks, this section 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 telegram fields.

During communications over a Modbus RTU network, the protocol:

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

If a reply is required, the controller constructs the reply telegram and sends it.
Controllers communicate using a master/slave technique in which only the master can initiate transactions (called queries). Slaves respond by supplying the requested data to the master, or by acting as requested in the query.
The master can address individual slaves, or initiate a broadcast telegram to all slaves. Slaves return a response to queries that are addressed to them individually. No responses are returned to broadcast queries from the master.

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

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

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

8.6.4 Frequency Converter with Modbus RTU

The frequency converter communicates in Modbus RTU format over the built-in RS485 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.
- Various stops:
  - Coast stop.
  - Quick stop.
  - DC brake stop.
  - Normal (ramp) stop.
- Reset after a fault trip.
- Run at various preset speeds.
- Run in reverse.
- Change the active set-up.
- Control 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. Accessing the parameters offers a range of control options, including controlling the setpoint of the frequency converter when its internal PI controller is used.

8.7 Network Configuration

To enable Modbus RTU on the frequency converter, set the following parameters:

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

Table 8.11 Network Configuration

8.8 Modbus RTU Message Framing Structure

8.8.1 Introduction

The controllers are set up to communicate on the Modbus network using RTU (remote terminal unit) mode, with each byte in a telegram containing 2 4-bit hexadecimal characters. The format for each byte is shown in *Table 8.12*.

Start bit	Data byte								Stop/ parity	Stop

Table 8.12 Format for Each Byte

Coding system	8-bit binary, hexadecimal 0–9, A–F. 2 hexadecimal characters contained in each 8-bit field of the telegram.
Bits per byte	• 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	Cyclic redundancy check (CRC).

Table 8.13 Byte Details

8.8.2 Modbus RTU Telegram Structure

The transmitting device places a Modbus RTU telegram into a frame with a known beginning and ending point. This allows receiving devices to begin at the start of the telegram, read the address portion, determine which device is addressed (or all devices, if the telegram is broadcast), and to recognize when the telegram is completed. Partial telegrams are detected and errors set as a result. Characters for transmission must be in hexadecimal 00–FF format in each field. The 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 telegrams addressed to 0 are broadcast telegrams. No response is permitted for broadcast telegrams. A typical telegram frame is shown in *Table 8.14*.

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 8.14 Typical Modbus RTU Telegram Structure

8.8.3 Start/Stop Field

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

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

8.8.4 Address Field

The address field of a telegram 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 telegram. When the slave sends its response, it places its own address in this address field to let the master know which slave is responding.

8.8.5 Function Field

The function field of a message frame contains 8 bits. Valid codes are in the range of 1-FF. Function fields are used to send messages between master and follower. When a message is sent from a master to a follower device, the function code field tells the follower what kind of action to perform. When the follower responds to the master, it uses the function code field to indicate either a normal (error-free) response, or that some kind of error occurred (called an exception response). For a normal response, the follower simply echoes the original function code. For an exception response, the follower returns a code that is equivalent to the original function code with its most significant bit set to logic 1. In addition, the follower places a unique code into the data field of the response message. This tells the master what kind of error occurred, or the reason for the exception. Also refer to *chapter 8.8.10 Function Codes Supported by Modbus RTU* and *chapter 8.8.11 Modbus Exception Codes*.

8

8.8.6 Data Field

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

The information can include items such as:

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

8.8.7 CRC Check Field

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

8

8.8.8 Coil Register Addressing

In Modbus, all data is organized in coils and holding registers. Coils hold a single bit, whereas holding registers hold a 2 byte word (that is 16 bits). All data addresses in Modbus telegrams are referenced to 0. The first occurrence of a data item is addressed as item number 0. For example: The coil known as coil 1 in a programmable controller is addressed as coil 0000 in the data address field of a Modbus telegram. Coil 127 decimal is addressed as coil 007Ehex (126 decimal).
Holding register 40001 is addressed as register 0000 in the data address field of the telegram. The function code field already specifies a holding register operation. Therefore, the 4XXXX reference is implicit. Holding register 40108 is addressed as register 006Bhex (107 decimal).

Coil number	Description	Signal direction
1–16	Frequency converter control word (see *Table 8.16*).	Master to slave
17–32	Frequency converter speed or setpoint reference range 0x0–0xFFFF (-200% ... ~200%).	Master to slave
33–48	Frequency converter status word (see *Table 8.17*).	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). 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.	Master to slave
66–65536	Reserved.	–

Table 8.15 Coil Register

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

Table 8.16 Frequency Converter Control Word (FC Profile)

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

Table 8.17 Frequency Converter Status Word (FC Profile)

Bus address	Bus register[1)]	PLC register	Content	Access	Description
0	1	40001	Reserved	–	Reserved for legacy frequency converters VLT® 5000 and VLT® 2800.
1	2	40002	Reserved	–	Reserved for legacy frequency converters VLT® 5000 and VLT® 2800.
2	3	40003	Reserved	–	Reserved for legacy frequency converters VLT® 5000 and VLT® 2800.
3	4	40004	Free	–	–
4	5	40005	Free	–	–
5	6	40006	Modbus configuration	Read/Write	TCP only. Reserved for Modbus TCP (*parameter 12-28 Store Data Values* and *parameter 12-29 Store Always* - stored in, for example, EEPROM).
6	7	40007	Last fault code	Read only	Fault code received from parameter database, refer to WHAT 38295 for details.
7	8	40008	Last error register	Read only	Address of register with which last error occurred, refer to WHAT 38296 for details.
8	9	40009	Index pointer	Read/Write	Sub index of parameter to be accessed. Refer to WHAT 38297 for details.
9	10	40010	*Parameter 0-01 Language*	Dependent on parameter access	*Parameter 0-01 Language* (Modbus register = 10 parameter number) 20 bytes space reserved for parameter in Modbus map.
19	20	40020	*Parameter 0-02 Motor Speed Unit*	Dependent on parameter access	*Parameter 0-02 Motor Speed Unit* 20 bytes space reserved for parameter in Modbus map.
29	30	40030	*Parameter 0-03 Regional Settings*	Dependent on parameter access	*Parameter 0-03 Regional Settings* 20 bytes space reserved for parameter in Modbus map.

Table 8.18 Address/Registers

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

8.8.9 How to Control the Frequency Converter

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

8.8.10 Function Codes Supported by Modbus RTU

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

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

Table 8.19 Function Codes

8

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

Table 8.20 Function Codes

8.8.11 Modbus Exception Codes

For a full explanation of the structure of an exception code response, refer to *chapter 8.8.5 Function Field*.

8

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 succeeds, while a request with offset 96 and length 5 generates exception 02.
3	Illegal data value	A value contained in the query data field is not an allowable value for server (or slave). This indicates a fault in the structure of the remainder of a complex request, such as that the implied length is incorrect. It does NOT mean that a data item submitted for storage in a register has a value outside the expectation of the application program, since the Modbus protocol is unaware of the significance of any value of any register.
4	Slave device failure	An unrecoverable error occurred while the server (or slave) was attempting to perform the requested action.

Table 8.21 Modbus Exception Codes

8.9 How to Access Parameters

8.9.1 Parameter Handling

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

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

For information on the parameters, size, and conversion index, see *chapter 7 Programming*.

8.9.2 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).

8.9.3 IND (Index)

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

8.9.4 Text Blocks

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

8.9.5 Conversion Factor

The different attributes for each parameter can be seen in the section on factory settings. Since a parameter value can only be transferred as a whole number, a conversion factor must be used to transfer decimals. Refer to the *chapter 7.4 Quick Menu Parameters*.

8.9.6 Parameter Values

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

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

8.10 Examples

The following examples show various Modbus RTU commands. If an error occurs, refer to *chapter 8.8.11 Modbus Exception Codes*.

8.10.1 Read Coil Status (01 hex)

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

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

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

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

Table 8.22 Query

Response
The coil status in the response telegram is packed as 1 coil per bit of the data field. Status is indicated as: 1=ON; 0=OFF. The lsb of the first data byte contains the coil addressed in the query. The other coils follow toward the high-order end of this byte, and from low order to high order in subsequent bytes.
If the returned coil quantity is not a multiple of 8, the remaining bits in the final data byte are padded with values 0 (toward the high-order end of the byte). The byte count field specifies the number of complete bytes of data.

8

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

Table 8.23 Response

NOTICE

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

8.10.2 Force/Write Single Coil (05 hex)

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

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

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

Table 8.24 Query

Response

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

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

Table 8.25 Response

8

8.10.3 Force/Write Multiple Coils (0F hex)

Description

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

Query

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

NOTICE

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

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

Table 8.26 Query

Response

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

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

Table 8.27 Response

8.10.4 Read Holding Registers (03 hex)

Description

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

Query

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

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

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

Table 8.28 Query

Response

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

Example: hex 000088B8=35.000=35 Hz.

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

Table 8.29 Response

8.10.5 Preset Single Register (06 hex)

Description

This function presets a value into a single holding register.

Query

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

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

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

Table 8.30 Query

Response

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

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

Table 8.31 Response

8.10.6 Preset Multiple Registers (10 hex)

Description

This function presets values into a sequence of holding registers.

Query

The query telegram specifies the register references to be preset. Register addresses start at 0, that is, register 1 is addressed as 0. Example of a request to preset 2 registers (set *parameter 1-24 Motor Current* to 738 (7.38 A)):

Field name	Example (hex)
Slave address	01
Function	10
Starting address HI	04
Starting address LO	07
Number of registers HI	00
Number of registers LO	02
Byte count	04
Write data HI (Register 4: 1049)	00
Write data LO (Register 4: 1049)	00
Write data HI (Register 4: 1050)	02
Write data LO (Register 4: 1050)	E2
Error check (CRC)	–

Table 8.32 Query

Response

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

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

Table 8.33 Response

8

8.11 FC Drive Control Profile

8.11.1 Control Word According to FC Profile

Set *parameter 8-30 Protocol* to *[0] FC*.
Modbus Holding Register numbers for Input data – CTW and REF – and Output data – STW and MAV – are defined in *Table 8.34*:

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 value register (MAV)

Table 8.34 Modbus Holding Register Numbers for Input and Output Data

8

In *VLT® Micro Drive FC 51* after software version 2.32, the input/output data is also available in a lower holding register area:

02810 input data	Frequency converter control word register (CTW)
02811 input data	Bus reference register (REF)
02910 output data	Frequency converter status word register (STW)
02911 output data	Frequency converter main value register (MAV)

Table 8.35 Lower Register Numbers for Input and Output Data

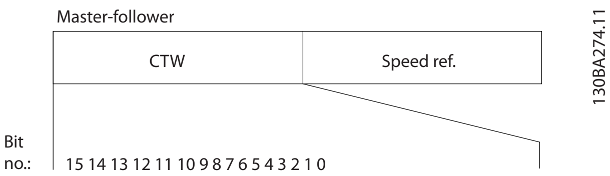

Illustration 8.14 Control Word

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

Table 8.36 Definition of Control Bits

Explanation of the control bits
Bits 00/01
Bits 00 and 01 are used to select between the 4 reference values, which are pre-programmed in *parameter 3-10 Preset Reference* according to the *Table 8.37*.

Programmed reference value	Parameter	Bit 01	Bit 00
1	*Parameter 3-10 Preset Reference* [0]	0	0
2	*Parameter 3-10 Preset Reference* [1]	0	1
3	*Parameter 3-10 Preset Reference* [2]	1	0
4	*Parameter 3-10 Preset Reference* [3]	1	1

Table 8.37 Control Bits

NOTICE

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

Bit 02, DC brake
Bit 02=0 leads to DC brake and stop. Set braking current and duration in *parameter 2-01 DC Brake Current* and *parameter 2-02 DC Braking Time*.
Bit 02=1 leads to ramping.

Bit 03, Coasting
Bit 03=0: The frequency converter immediately releases the motor, (the output transistors are shut off) and the motor coasts to a standstill.
Bit 03=1: The frequency converter starts the motor if the other starting conditions are met.

Make a selection in *parameter 8-50 Coasting Select* to define how bit 03 gates with the corresponding function on a digital input.

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

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

NOTICE

If freeze output is active, the frequency converter can only be stopped by the following:

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

Bit 06, Ramp stop/start
Bit 06=0: Causes a stop and makes the motor speed ramp down to stop via the selected ramp down parameter.
Bit 06=1: Allows the frequency converter to start the motor if the other starting conditions are met.

Make a selection in *parameter 8-53 Start Select* to define how bit 06 Ramp stop/start communicates 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 signal's leading edge, that is, when changing from logic 0 to logic 1.

Bit 08, Jog
Bit 08=1: The output frequency is determined by *parameter 3-11 Jog Speed [Hz]*.

Bit 09, Selection of ramp 1/2
Bit 09=0: Ramp 1 is active (*parameter 3-41 Ramp 1 Ramp Up Time* to *parameter 3-42 Ramp 1 Ramp Down Time*).
Bit 09=1: Ramp 2 (*parameter 3-51 Ramp 2 Ramp Up Time* to *parameter 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. Turn off the control word if not wanting to use it when updating or reading parameters.

Bit 11, Relay 01
Bit 11=0: Relay not activated.
Bit 11=1: Relay 01 activated if *[36] Control word bit 11* is selected in *parameter 5-40 Function Relay*.

Bit 12, Relay 02
Bit 12=0: Relay 02 is not activated.
Bit 12=1: Relay 02 is activated if *[37] Control word bit 12* is selected in *parameter 5-40 Function Relay*.

Bit 13, Selection of set-up
Use bit 13 to select from the 2 menu set-ups according to *Table 8.38*.

Set-up	Bit 13
1	0
2	1

Table 8.38 Set-up Selection

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

Make a selection in *parameter 8-55 Set-up Select* to define how bit 13 communicates 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 *parameter 8-54 Reversing Select*. Bit 15 causes reversing only when 1 of the following options is selected: *[1] Bus*, *[2] Logic AND*, *[3] Logic OR*.

8.11.2 Status Word According to FC Profile (STW)

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

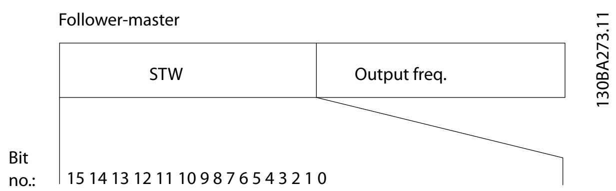

Illustration 8.15 Status Word

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Bit	Bit=0	Bit=1
00	Control not ready	Control ready
01	Frequency converter not ready	Frequency converter 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	Frequency converter OK	Stopped, auto start
13	Voltage OK	Voltage exceeded
14	Torque OK	Torque exceeded
15	Timer OK	Timer exceeded

Table 8.39 Status Word According to FC Profile

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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 supply (if there is 24 V external supply to controls).

Bit 01, Frequency converter ready
Bit 01=0: The frequency converter is not 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, Coast 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, press [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 runs, but the present speed is different from the preset speed reference. It might happen when the speed ramps up/down during start/stop.
Bit 08=1: The motor speed matches the preset speed reference.

Bit 09, Local operation/bus control
Bit 09=0: [Off/Reset] is activated on the control unit or *[2] Local* in *parameter 3-13 Reference Site* is selected. It is not possible to control the frequency converter 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 *parameter 4-12 Motor Speed Low Limit [Hz]* or *parameter 4-14 Motor Speed High Limit [Hz]*.
Bit 10=1: The output frequency is within the defined limits.

Bit 11, No operation/in operation
Bit 11=0: The motor is not running.
Bit 11=1: The frequency converter has a start signal without coast.

Bit 12, Frequency converter OK/stopped, auto start
Bit 12=0: There is no temporary overtemperature on the frequency converter.
Bit 12=1: The frequency converter stops because of overtemperature but the unit does not trip and resumes operation once the overtemperature normalizes.

Bit 13, Voltage OK/limit exceeded
Bit 13=0: There are no voltage warnings.
Bit 13=1: The DC voltage in the frequency converter’s DC link is too low or too high.

Bit 14, Torque OK/limit exceeded
Bit 14=0: The motor current is lower than the current limit selected in *parameter 4-18 Current Limit*.
Bit 14=1: The current limit in *parameter 4-18 Current Limit* is exceeded.

Bit 15, Timer OK/limit exceeded
Bit 15=0: The timers for motor thermal protection and thermal protection are not exceeded 100%.
Bit 15=1: 1 of the timers exceeds 100%.

8.11.3 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. The integer value 16384 (4000 hex) corresponds to 100%. Negative figures are formatted using 2's complement. The actual output frequency (MAV) is scaled in the same way as the bus reference.

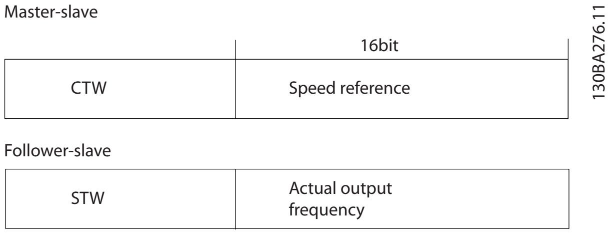

Illustration 8.16 Actual Output Frequency (MAV)

The reference and MAV are scaled as follows:

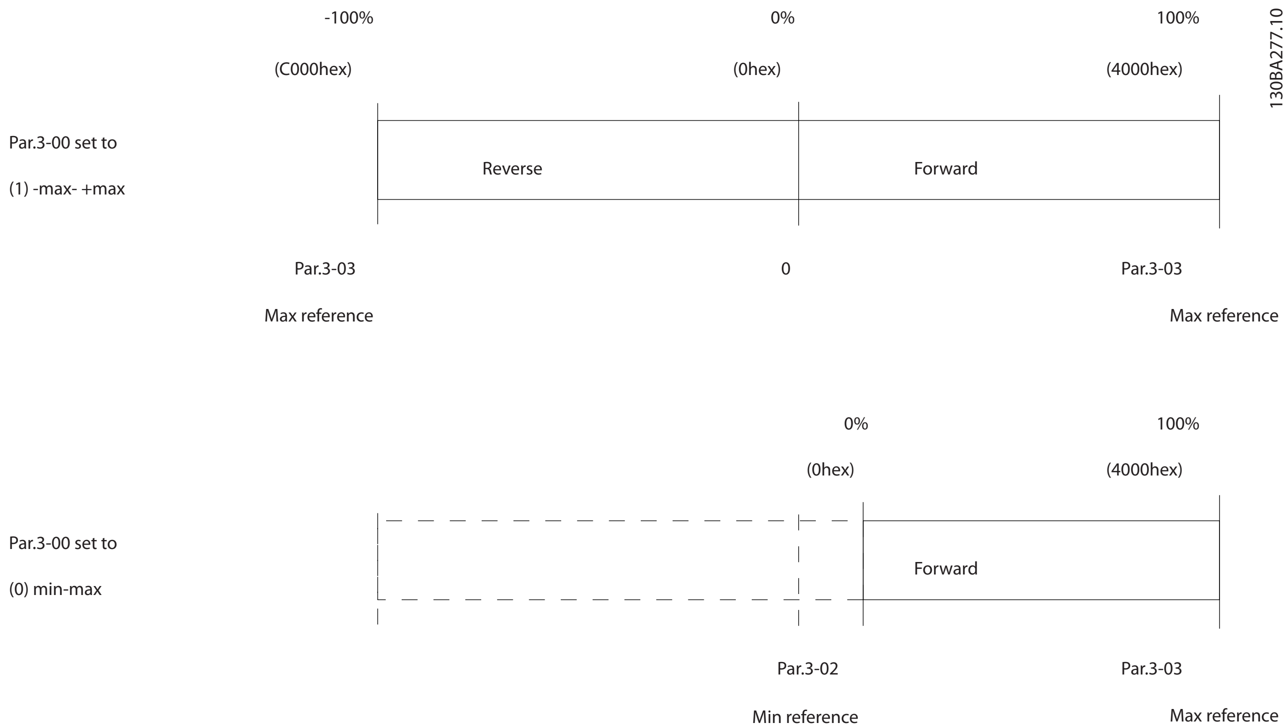

Illustration 8.17 Reference and MAV

9 Specifications

9.1.1 Mains Supply 1x200–240 V AC

Normal overload 150% for 1 minute					
Frequency converter Typical shaft output [kW]	**PK18** **0.18**	**PK37** **0.37**	**PK75** **0.75**	**P1K5** **1.5**	**P2K2** **2.2**
Typical shaft output [hp]	0.25	0.5	1	2	3
Enclosure protection rating IP20	M1	M1	M1	M2	M3
Output current					
Continuous (1x200–240 V AC) [A]	1.2	2.2	4.2	6.8	9.6
Intermittent (1x200–240 V AC) [A]	1.8	3.3	6.3	10.2	14.4
Maximum cable size:					
(Mains, motor) [mm^2/AWG]	4/10				
Maximum input current					
Continuous (1x200–240 V) [A]	3.3	6.1	11.6	18.7	26.4
Intermittent (1x200–240 V) [A]	4.5	8.3	15.6	26.4	37.0
Maximum mains fuses [A]	See *chapter 6.6.1 Fuses*				
Environment					
Estimated power loss [W], Best case/typical[1)]	12.5/ 15.5	20.0/ 25.0	36.5/ 44.0	61.0/ 67.0	81.0/ 85.1
Weight enclosure IP20 [kg]	1.1	1.1	1.1	1.6	3.0
Efficiency [%], Best case/typical[2)]	95.6/ 94.5	96.5/ 95.6	96.6/ 96.0	97.0/ 96.7	96.9/ 97.1

Table 9.1 Mains Supply 1x200–240 V AC

9.1.2 Mains Supply 3x200–240 V AC

Normal overload 150% for 1 minute						
Frequency converter Typical shaft output [kW]	**PK25** **0.25**	**PK37** **0.37**	**PK75** **0.75**	**P1K5** **1.5**	**P2K2** **2.2**	**P3K7** **3.7**
Typical shaft output [hp]	0.33	0.5	1	2	3	5
Enclosure protection rating IP20	M1	M1	M1	M2	M3	M3
Output current						
Continuous (3x200–240 V) [A]	1.5	2.2	4.2	6.8	9.6	15.2
Intermittent (3x200–240 V) [A]	2.3	3.3	6.3	10.2	14.4	22.8
Maximum cable size:						
(Mains, motor) [mm^2/AWG]	4/10					
Maximum input current						
Continuous (3x200–240 V) [A]	2.4	3.5	6.7	10.9	15.4	24.3
Intermittent (3x200–240 V) [A]	3.2	4.6	8.3	14.4	23.4	35.3
Maximum mains fuses [A]	See *chapter 6.6.1 Fuses*					
Environment						
Estimated power loss [W] Best case/typical[1)]	14.0/ 20.0	19.0/ 24.0	31.5/ 39.5	51.0/ 57.0	72.0/ 77.1	115.0/ 122.8
Weight enclosure IP20 [kg]	1.1	1.1	1.1	1.6	3.0	3.0
Efficiency [%] Best case/typical[2)]	96.4/ 94.9	96.7/ 95.8	97.1/ 96.3	97.4/ 97.2	97.2/ 97.4	97.3/ 97.4

Table 9.2 Mains Supply 3x200–240 V AC

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9.1.3 Mains Supply 3x380–480 V AC

Normal overload 150% for 1 minute						
Frequency converter Typical shaft output [kW]	**PK37** **0.37**	**PK75** **0.75**	**P1K5** **1.5**	**P2K2** **2.2**	**P3K0** **3.0**	**P4K0** **4.0**
Typical shaft output [hp]	0.5	1	2	3	4	5.5
Enclosure protection rating IP20	M1	M1	M2	M2	M3	M3
Output current						
Continuous (3x380–440 V) [A]	1.2	2.2	3.7	5.3	7.2	9.0
Intermittent (3x380–440 V) [A]	1.8	3.3	5.6	8.0	10.8	13.7
Continuous (3x440–480 V) [A]	1.1	2.1	3.4	4.8	6.3	8.2
Intermittent (3x440–480 V) [A]	1.7	3.2	5.1	7.2	9.5	12.3
Maximum cable size:						
(Mains, motor) [mm^2/AWG]	4/10					
Maximum input current						
Continuous (3x380–440 V) [A]	1.9	3.5	5.9	8.5	11.5	14.4
Intermittent (3x380–440 V) [A]	2.6	4.7	8.7	12.6	16.8	20.2
Continuous (3x440–480 V) [A]	1.7	3.0	5.1	7.3	9.9	12.4
Intermittent (3x440–480 V) [A]	2.3	4.0	7.5	10.8	14.4	17.5
Maximum mains fuses [A]	See *chapter 6.6.1 Fuses*					
Environment						
Estimated power loss [W] Best case/typical[1)]	18.5/ 25.5	28.5/ 43.5	41.5/ 56.5	57.5/ 81.5	75.0/ 101.6	98.5/ 133.5
Weight enclosure IP20 [kg]	1.1	1.1	1.6	1.6	3.0	3.0
Efficiency [%] Best case/typical[2)]	96.8/ 95.5	97.4/ 96.0	98.0/ 97.2	97.9/ 97.1	98.0/ 97.2	98.0/ 97.3

Table 9.3 Mains Supply 3x380–480 V AC

Normal overload 150% for 1 minute						
Frequency converter Typical shaft output [kW]	**P5K5** **5.5**	**P7K5** **7.5**	**P11K** **11**	**P15K** **15**	**P18K** **18.5**	**P22K** **22**
Typical shaft output [hp]	7.5	10	15	20	25	30
Enclosure protection rating IP20	M3	M3	M4	M4	M5	M5
Output current						
Continuous (3x380–440 V) [A]	12.0	15.5	23.0	31.0	37.0	43.0
Intermittent (3x380–440 V) [A]	18.0	23.5	34.5	46.5	55.5	64.5
Continuous (3x440–480 V) [A]	11.0	14.0	21.0	27.0	34.0	40.0
Intermittent (3x440–480 V) [A]	16.5	21.3	31.5	40.5	51.0	60.0
Maximum cable size:						
(Mains, motor) [mm^2/AWG]	4/10		16/6			
Maximum input current						
Continuous (3x380–440 V) [A]	19.2	24.8	33.0	42.0	34.7	41.2
Intermittent (3x380–440 V) [A]	27.4	36.3	47.5	60.0	49.0	57.6
Continuous (3x440–480 V) [A]	16.6	21.4	29.0	36.0	31.5	37.5
Intermittent (3x440–480 V) [A]	23.6	30.1	41.0	52.0	44.0	53.0
Maximum mains fuses [A]	See *chapter 6.6.1 Fuses*					
Environment						
Estimated power loss [W] Best case/typical[1)]	131.0/ 166.8	175.0/ 217.5	290.0/ 342.0	387.0/ 454.0	395.0/ 428.0	467.0/ 520.0
Weight enclosure IP20 [kg]	3.0	3.0				
Efficiency [%] Best case/typical[2)]	98.0/ 97.5	98.0/ 97.5	97.8/ 97.4	97.7/ 97.4	98.1/ 98.0	98.1/ 97.9

Table 9.4 Mains Supply 3x380–480 V AC

Protection and Features

- Electronic motor thermal protection against overload.
- Temperature monitoring of the heat sink ensures that the frequency converter trips if there is overtemperature.
- The frequency converter is protected against short circuits between motor terminals U, V, W.
- When a motor phase is missing, the frequency converter trips and issues an alarm.
- When a mains phase is missing, the frequency converter trips or issues a warning (depending on the load).
- Monitoring of the DC-link voltage ensures that the frequency converter trips when the DC-link voltage is too low or too high.
- The frequency converter is protected against ground faults on motor terminals U, V, W.

Mains supply (L1/L, L2, L3/N)

Supply voltage	200–240 V ±10%
Supply voltage	380–480 V ±10%
Supply frequency	50/60 Hz
Maximum imbalance temporary between mains phases	3.0% of rated supply voltage
True power factor	≥0.4 nominal at rated load
Displacement power factor (cosφ) near unity	(>0.98)
Switching on input supply L1/L, L2, L3/N (power-ups)	Maximum 2 times/minute
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 100000 RMS symmetrical Amperes, 240/480 V maximum.

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Motor output (U, V, W)

Output voltage	0–100% of supply voltage
Output frequency	0–200 Hz (VVC$^+$), 0–400 Hz (u/f)
Switching on output	Unlimited
Ramp times	0.05–3600 s

Cable length and cross-section

Maximum motor cable length, shielded/armored (EMC-correct installation)	15 m (49 ft)
Maximum motor cable length, unshielded/unarmored	50 m (164 ft)
Maximum cross-section to motor, mains1)	
Connection to load sharing/brake (M1, M2, M3)	6.3 mm insulated Faston plugs
Maximum cross-section to load sharing/brake (M4, M5)	16 mm^2/6 AWG
Maximum cross-section to control terminals, rigid wire	1.5 mm^2/16 AWG (2x0.75 mm^2)
Maximum cross-section to control terminals, flexible cable	1 mm^2/18 AWG
Maximum cross-section to control terminals, cable with enclosed core	0.5 mm^2/20 AWG
Minimum cross-section to control terminals	0.25 mm^2 (24 AWG)

1) See chapter 9 Specifications for more information.

Digital inputs (pulse/encoder inputs)

Programmable digital inputs (pulse/encoder)	5 (1)
Terminal number	18, 19, 27, 29, 33
Logic	PNP or NPN
Voltage level	0–24 V DC
Voltage level, logic 0 PNP	<5 V DC
Voltage level, logic 1 PNP	>10 V DC
Voltage level, logic 0 NPN	>19 V DC
Voltage level, logic 1 NPN	<14 V DC
Maximum voltage on input	28 V DC
Input resistance, R_i	Approximately 4000 Ω
Maximum pulse frequency at terminal 33	5000 Hz
Minimum pulse frequency at terminal 33	20 Hz

Analog inputs	
Number of analog inputs	2
Terminal number	53, 60
Voltage mode (terminal 53)	Switch S200=OFF(U)
Current mode (terminal 53 and 60)	Switch S200=ON(I)
Voltage level	0–10 V
Input resistance, R_i	Approximately 10000 Ω
Maximum voltage	20 V
Current level	0/4 to 20 mA (scaleable)
Input resistance, R_i	Approximately 200 Ω
Maximum current	30 mA

Analog output	
Number of programmable analog outputs	1
Terminal number	42
Current range at analog output	0/4–20 mA
Maximum load to common at analog output	500 Ω
Maximum voltage at analog output	17 V
Accuracy on analog output	Maximum error: 0.8% of full scale
Scan interval	4 ms
Resolution on analog output	8 bit
Scan interval	4 ms

Control card, RS485 serial communication	
Terminal number	68 (P, TX+, RX+), 69 (N, TX-, RX-)
Terminal number 61	Common for terminals 68 and 69

Control card, 24 V DC output	
Terminal number	12
Maximum load (M1 and M2)	100 mA
Maximum load (M3)	50 mA
Maximum load (M4 and M5)	80 mA

Relay output	
Programmable relay output	1
Relay 01 terminal number	01-03 (break), 01-02 (make)
Maximum terminal load (AC-1)[1)] on 01-02 (NO) (Resistive load)	250 V AC, 2 A
Maximum terminal load (AC-15)[1)] on 01-02 (NO) (Inductive load @ cosφ 0.4)	250 V AC, 0.2 A
Maximum terminal load (DC-1)[1)] on 01-02 (NO) (Resistive load)	30 V DC, 2 A
Maximum terminal load (DC-13)[1)] on 01-02 (NO) (Inductive load)	24 V DC, 0.1 A
Maximum terminal load (AC-1)[1)] on 01-03 (NC) (Resistive load)	250 V AC, 2 A
Maximum terminal load (AC-15)[1)] on 01-03 (NC) (Inductive load @ cosφ 0.4)	250 V AC, 0.2 A
Maximum terminal load (DC-1)[1)] on 01-03 (NC) (Resistive load)	30 V DC, 2 A
Minimum terminal load on 01-03 (NC), 01-02 (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

Control card, 10 V DC output	
Terminal number	50
Output voltage	10.5 V ±0.5 V
Maximum load	25 mA

NOTICE

All inputs, outputs, circuits, DC supplies, and relay contacts are galvanically isolated from the supply voltage (PELV) and other high voltage terminals.

9

Surroundings	
Enclosure protection rating	IP20
Enclosure kit available	IP21, TYPE 1
Vibration test	1.0 g
Maximum relative humidity	5%–95 % (IEC 60721-3-3; Class 3K3 (non-condensing) during operation
Aggressive environment (IEC 60721-3-3), coated	class 3C3
Test method according to IEC 60068-2-43 H2S (10 days)	
Ambient temperature[1)]	Maximum 40 °C (104 °F)
Minimum ambient temperature during full-scale operation	0 °C (32 °F)
Minimum ambient temperature at reduced performance	-10 °C (14 °F)
Temperature during storage/transport	-25 to +65/70 °C
Maximum altitude above sea level without derating[1)]	1000 m (3280 ft)
Maximum altitude above sea level with derating[1)]	3000 m (9842 ft)
Safety standards	EN/IEC 61800-5-1, UL 508C
EMC standards, Emission	EN 61800-3, EN 61000-6-3/4, EN 55011, IEC 61800-3
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
Energy efficiency class	IE2

1) Refer to chapter 4.2 Special Conditions for:

- *Derating for high ambient temperature.*
- *Derating for high altitude.*

2) Determined according to EN 50598-2 at:

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

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