MAKING MODERN LIVING POSSIBLE

Design Guide, 0.25-75 kW

VLT® AutomationDrive FC 300

VLT®
THE REAL DRIVE

Contents

1 How to Read this Design Guide

This Design Guide will introduce all aspects of your FC 300.

Available literature for FC 300

- The VLT® AutomationDrive Operating Instructions 0.25-75 kW provide the neccessary information for getting the frequency converter up and running.
- The VLT® AutomationDrive High Power Operating Instructions
- The VLT® AutomationDrive High Power Design Guide 90-1400 kW
- The VLT® AutomationDrive Programming Guide provides information on how to programme and includes complete parameter descriptions.
- The VLT® AutomationDrive Profibus Operating Instructions provide the information required for controlling, monitoring and programming the frequency converter via a Profibus fieldbus.
- The VLT® AutomationDrive DeviceNet Operating Instructions provide the information required for controlling, monitoring and programming the frequency converter via a DeviceNet fieldbus.

X = Revision number
YY = Language code

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

1.1.1 Symbols

The following symbols are used in this manual.

⚠WARNING

Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.

⚠CAUTION

Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury. It may also be used to alert against unsafe practices.

CAUTION

Indicates a situation that may result in equipment or property-damage-only accidents.

NOTE

Indicates highlighted information that should be regarded with attention to avoid mistakes or operate equipment at less than optimal performance.

1.1.2 Abbreviations

Alternating current	AC
American wire gauge	AWG
Ampere/AMP	A
Automatic Motor Adaptation	AMA
Current limit	I_{LIM}
Degrees Celsius	°C
Direct current	DC
Drive Dependent	D-TYPE
Electro Magnetic Compatibility	EMC
Electronic Thermal Relay	ETR
Frequency converter	FC
Gram	g
Hertz	Hz
Horsepower	hp
Kilohertz	kHz
Local Control Panel	LCP
Meter	m
Millihenry Inductance	mH
Milliampere	mA
Millisecond	ms
Minute	min
Motion Control Tool	MCT
Nanofarad	nF
Newton Meters	Nm
Nominal motor current	$I_{M,N}$
Nominal motor frequency	$f_{M,N}$
Nominal motor power	$P_{M,N}$
Nominal motor voltage	$U_{M,N}$
Permanent Magnet motor	PM motor
Protective Extra Low Voltage	PELV
Printed Circuit Board	PCB
Rated Inverter Output Current	I_{INV}
Revolutions Per Minute	RPM
Regenerative terminals	Regen
Second	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 1.1 Abbreviations

1

1.1.3 Definitions

Frequency converter

Coast

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

I_{MAX}

The maximum output current.

I_N

The rated output current supplied by the frequency converter.

U_{MAX}

The maximum output voltage.

Input

Control command

Start and stop the connected motor by means of LCP and the digital inputs.
Functions are divided into two groups.

Functions in group 1 have higher priority than functions in group 2.

Group 1	Reset, Coasting stop, Reset and Coasting stop, Quick-stop, DC braking, Stop and the "Off" key.
Group 2	Start, Pulse start, Reversing, Start reversing, Jog and Freeze output.

Table 1.2 Function Priorities

Motor

f_{JOG}

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

f_M

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

f_{MAX}

The maximum output frequency the frequency converter applies on its output. The maximum output frequency limit is set in *4-14 Motor Speed High Limit [Hz]* (*4-13 Motor Speed High Limit [RPM]*) and *4-19 Max Output Frequency*.

f_{MIN}

The minimum motor frequency from frequency converter. The minimum output frequency limit is set in *4-12 Motor Speed Low Limit [Hz]* (*4-11 Motor Speed Low Limit [RPM]*). Default 0 Hz.

$f_{M,N}$

The rated motor frequency (nameplate data).

I_M

The motor current.

$I_{M,N}$

The rated motor current (nameplate data).

$n_{M,N}$

The rated motor speed (nameplate data).

n_s

Synchronous motor speed

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

$P_{M,N}$

The rated motor power (nameplate data).

$T_{M,N}$

The rated torque (motor).

U_M

The instantaneous motor voltage.

$U_{M,N}$

The rated motor voltage (nameplate data).

Break-away torque

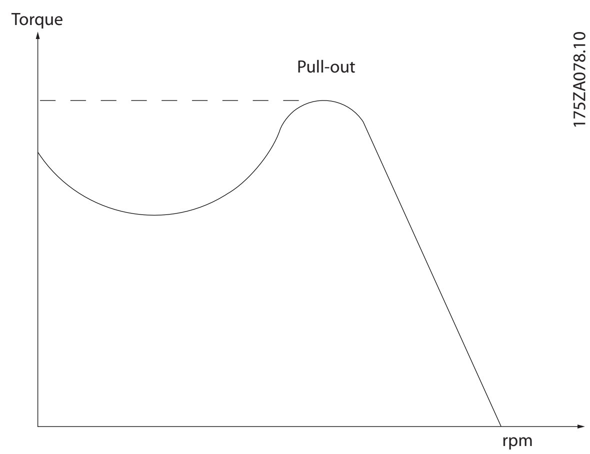


Illustration 1.1 Break-away Torque

η

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

Start-disable command

A stop command belonging to the group 1 control commands - see this group.

Stop command

See Control commands.

References

Analog Reference
An analog signal applied to input 53 or 54. The signal can be either Voltage 0-10V (FC 301 and FC 302) or -10 to +10V (FC 302). Current signal 0-20 mA or 4-20 mA.

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

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

Pulse Reference
A pulse reference applied to term 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*.

Miscellaneous

Analog Inputs
The analog inputs are used for controlling various functions of the frequency converter.
There are two types of analog inputs:
Current input, 0-20mA and 4-20mA
Voltage input, 0-10 V DC (FC 301)
Voltage input, -10 to +10 V DC (FC 302).

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

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

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

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

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

Digital Outputs
The frequency converter features two solid state outputs for FC 302 and one solid state output for FC 301. They can supply a 24 V DC (max. 40 mA) signal.

DSP
Digital Signal Processor.

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

Hiperface®
Hiperface® is a registered trademark by Stegmann.

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

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

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

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

lsb
Least significant bit.

msb
Most significant bit.

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

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

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

PCD
Process Data

Pulse Input/Incremental Encoder
An external digital sensor used for feedback information of motor speed and direction. Encoders are used for high

speed accuracy feedback and in high dynamic applications. The encoder connection is either via term 32 and 33 or encoder option MCB 102.

RCD
Residual Current Device.

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

SFAVM
Switching pattern called Stator Flux oriented Asynchronous Vector Modulation (*14-00 Switching Pattern*).

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

Smart Logic Control (SLC)
The SLC is a sequence of user defined actions executed when the associated user defined events are evaluated as true by the Smart Logic Controller. (Parameter group *13-** Smart Logic*.

STW
Status Word

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).

THD
Total Harmonic Distortion state the total contribution of harmonic.

Trip
A state entered in fault situations, e.g. if the frequency converter is subject to an over-temperature or when the frequency converter is protecting the motor, process or mechanism. Restart is prevented until the cause of the fault has disappeared and the trip state is cancelled by activating reset or, in some cases, by being programmed to reset automatically. Trip may not be used for personal safety.

Trip Locked
A state entered in fault situations when the frequency converter is protecting itself and requiring physical intervention, e.g. if the frequency converter is subject to a short circuit on the output. A locked trip can only be cancelled by cutting off mains, removing the cause of the fault, and reconnecting the frequency converter. Restart is prevented until the trip state is cancelled by activating reset or, in some cases, by being programmed to reset automatically. Trip may not be used for personal safety.

VT Characteristics
Variable torque characteristics used for pumps and fans.

VVC^{plus}
If compared with standard voltage/frequency ratio control, Voltage Vector Control (VVC^{plus}) improves the dynamics and the stability, both when the speed reference is changed and in relation to the load torque.

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

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

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

The power factor for 3-phase control:

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

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.
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.

2 Safety and Conformity

2.1 Safety Precautions

WARNING

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

Safety Regulations

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

Warning against unintended start

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

NOTE

When using the Safe Stop function, always follow the instructions in the section *Safe Stop* of the Design Guide.

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

2

⚠WARNING

High Voltage

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.
Systems where frequency converters are installed must, if necessary, be equipped with additional monitoring and protective devices according to the valid safety regulations, e.g law on mechanical tools, regulations for the prevention of accidents etc. Modifications on the frequency converters by means of the operating software are allowed.

NOTE

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

NOTE

Crane, Lifts and Hoists:
The controlling of external brakes must always have a redundant system. The frequency converter can in no circumstances be the primary safety circuit. Comply with relevant standards, e.g.
Hoists and cranes: IEC 60204-32
Lifts: EN 81

Protection Mode

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

NOTE

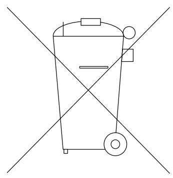
It is recommended to disable protection mode in hoisting applications (*14-26 Trip Delay at Inverter Fault* = 0)

The DC link capacitors remain charged after power has been disconnected. Be aware that there may be high voltage on the DC link even when the Control Card LEDs are turned off. To avoid electrical shock hazard, disconnect the frequency converter from mains before carrying out maintenance. When using a PM-motor, make sure it is disconnected. Before doing service on the frequency converter wait at least the amount of time indicated below:

Voltage	Power	Waiting Time
380 - 500 V	0.25 - 7.5 kW	4 minutes
	11 - 75 kW	15 minutes
525 - 690 V	11-75 kW (frame size B and C)	15 minutes

Table 2.1 Discharge Time

2.2.1 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.

FC 300
Design Guide
Software version: 6.6x

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

2.3.1 CE Conformity and Labelling

The machinery directive (2006/42/EC)
Frequency converters do not fall under the machinery directive. However, if a frequency converter is supplied for use in a machine, we provide information on safety aspects relating to the frequency converter.
What is CE Conformity and Labelling?
The purpose of CE labelling is to avoid technical trade obstacles within EFTA and the EU. The EU has introduced the CE label as a simple way of showing whether a product complies with the relevant EU directives. The CE label says nothing about the specifications or quality of

the product. Frequency converters are regulated by two EU directives:

The low-voltage directive (2006/95/EC)

Frequency converters must be CE labelled in accordance with the low-voltage directive of January 1, 1997. The directive applies to all electrical equipment and appliances used in the 50 - 1000V AC and the 75 - 1500V 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, we specify which standards our products comply with. We offer the filters presented in the specifications and provide other types of assistance to ensure the optimum EMC result.

The frequency converter is used by professionals of the trade, usually as a complex component forming part of a larger appliance, system or installation. It must be noted that to maintain the EMC properties of the frequency converter, it is the obligation of the installer to follow the installation instructions given by the manufacturer.

2.3.2 What Is Covered

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

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

2.3.3 Danfoss Frequency Converter and CE Labelling

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

However, CE labelling may cover many different specifi- cations. Thus, you have to 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, we guarantee 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.

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

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

2.3.4 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. It must be noted that the responsibility for the final EMC properties of the appliance, system or installation rests with the installer. As an aid to the installer, Danfoss has prepared EMC installation guidelines for the Power Drive system. The standards and test levels stated for Power Drive systems are complied with, provided that the EMC- correct instructions for installation are followed, see *Table 3.14*.

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.

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

CAUTION

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

Degree of protection as per IEC 60529
The safe Stop function may only be installed and operated in a control cabinet with degree of protection IP54 or higher (or equivalent environment). This is required to avoid cross faults and short circuits between terminals, connectors, tracks and safety-related circuitry caused by foreign objects.

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

Airborne Particles such as dust may cause mechanical, electrical, or thermal failure in the frequency converter. A typical indicator of excessive levels of airborne particles is dust particles around the frequency converter fan. In very dusty environments, use equipment with enclosure rating 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 will cause chemical processes on the frequency converter components.

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

NOTE

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

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

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

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

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

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

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

3 Introduction

3.1 Product Overview

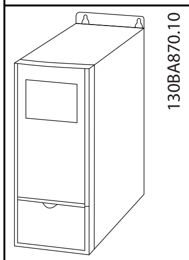
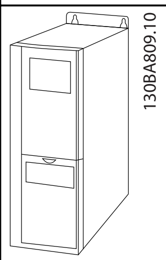
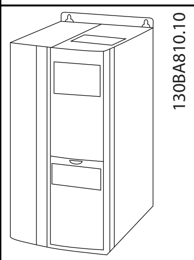
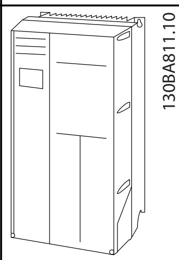
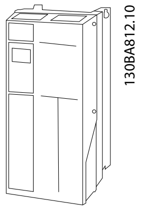
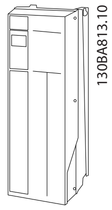
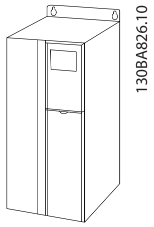
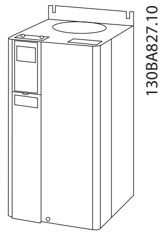
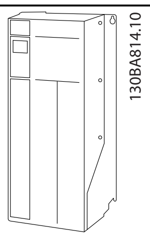
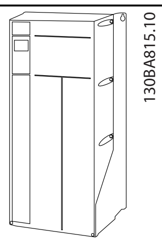
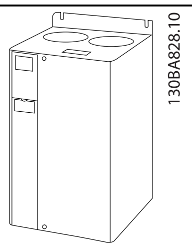
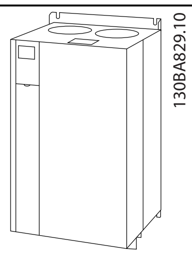
Frame size depends on enclosure type, power range and mains voltage						
Frame size		A1*	A2*	A3*	A4	A5
						
Enclosure protection	IP	20/21	20/21	20/21	55/66	55/66
	NEMA	Chassis/Type 1	Chassis/ Type 1	Chassis/ Type 1	Type 12	Type 12
High overload rated power - 160% overload torque		0.25–1.5 kW (200-240 V) 0.37–1.5 kW (380-480 V)	0.25-3 kW (200–240 V) 0.37-4.0 kW (380-480/500 V)	3.7 kW (200-240 V) 5.5-7.5 kW (380-480/500 V) 0.75-7.5 kW (525-600 V)	0.25-3 kW (200–240 V) 0.37-4.0 kW (380-480/500 V)	0.25-3.7 kW (200-240 V) 0.37-7.5 kW (380-480/500 V) 0.75 -7.5 kW (525-600 V)
Frame size		B1	B2	B3	B4	
						
Enclosure protection	IP	21/55/66	21/55/66	20	20	
	NEMA	Type 1/Type 12	Type 1/Type 12	Chassis	Chassis	
High overload rated power - 160% overload torque		5.5-7.5 kW (200-240 V) 11-15 kW (380-480/500V) 11-15 kW (525-600 V)	11 kW (200-250 V) 18.5-22 kW (380-480/500V) 18.5-22 kW (525-600 V) 11-2 2kW (525-690 V)	5.5-7.5 kW (200-240 V) 11-15 kW (380-480/500 V) 11-15 kW (525-600 V)	11-15 kW (200-240 V) 18.5-30 kW (380-480/500 V) 18.5-30 kW (525-600 V)	
Frame size		C1	C2	C3	C4	
						
Enclosure protection	IP	21/55/66	21/55/66	20	20	
	NEMA	Type 1/Type 12	Type 1/Type 12	Chassis	Chassis	
High overload rated power - 160% overload torque		15-22 kW (200-240 V) 30-45 kW (380-480/500 V) 30-45 kW (525-600 V)	30-37 kW (200-240 V) 55-75 kW (380-480/500 V) 55-90 kW (525-600 V) 30-75 kW (525-690 V)	18.5-22 kW (200-240 V) 37-45 kW (380-480/500 V) 37-45 kW (525-600 V)	30-37 kW (200-240 V) 55-75 kW (380-480/500 V) 55-90 kW (525-600 V)	

Table 3.1 Product Overview

** A1, A2 and A3 are bookstyle enclosures. All other sizes are compact enclosures.*

For larger frame sizes (D-F), see the VLT® AutomationDrive High Power Design Guide 90-1400 kW.

3

3.2 Controls

3.2.1 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 infinitely variable speed control of three-phased, standard AC motors and permanent magnet synchronous motors.

3.2.2 Controls

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

Speed control

There are two 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 will have 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^{plus} *[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 four quadrants and at all motor speeds.
- Open loop in VVC^{plus} 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 later in this section.

3.2.3 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^{plus}).
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.

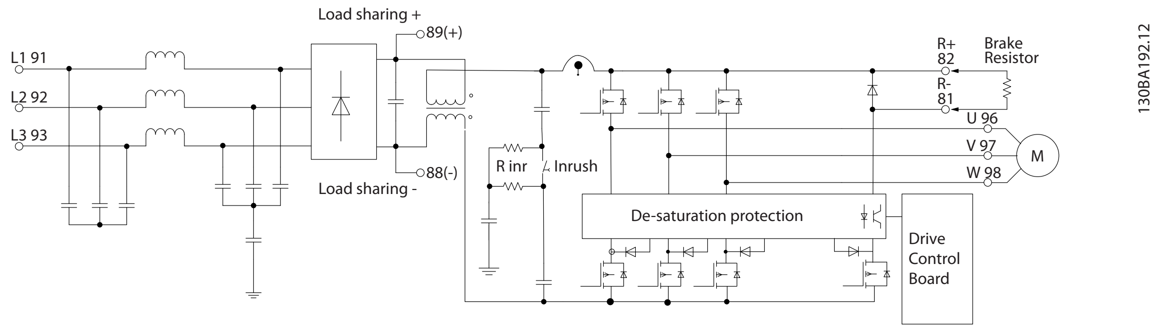


Illustration 3.1 FC 301

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^{plus} 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.

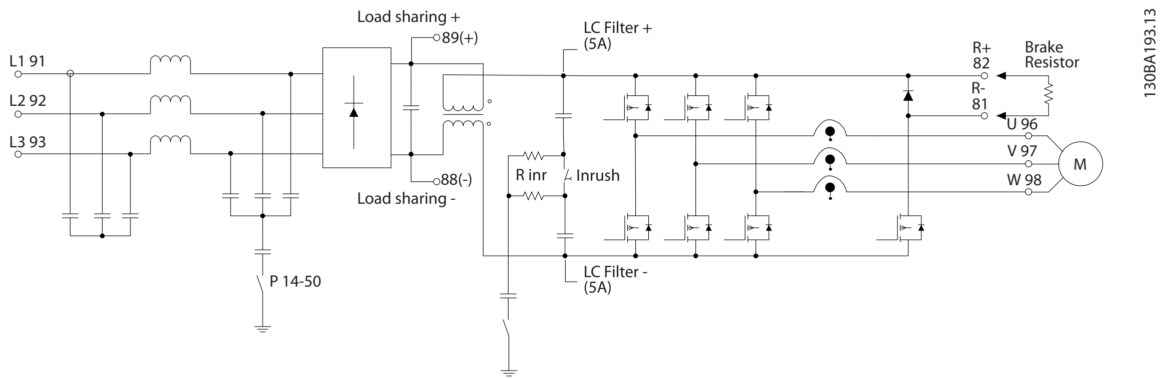


Illustration 3.2 FC 302

3.2.4 Control Structure in VVC^{plus}

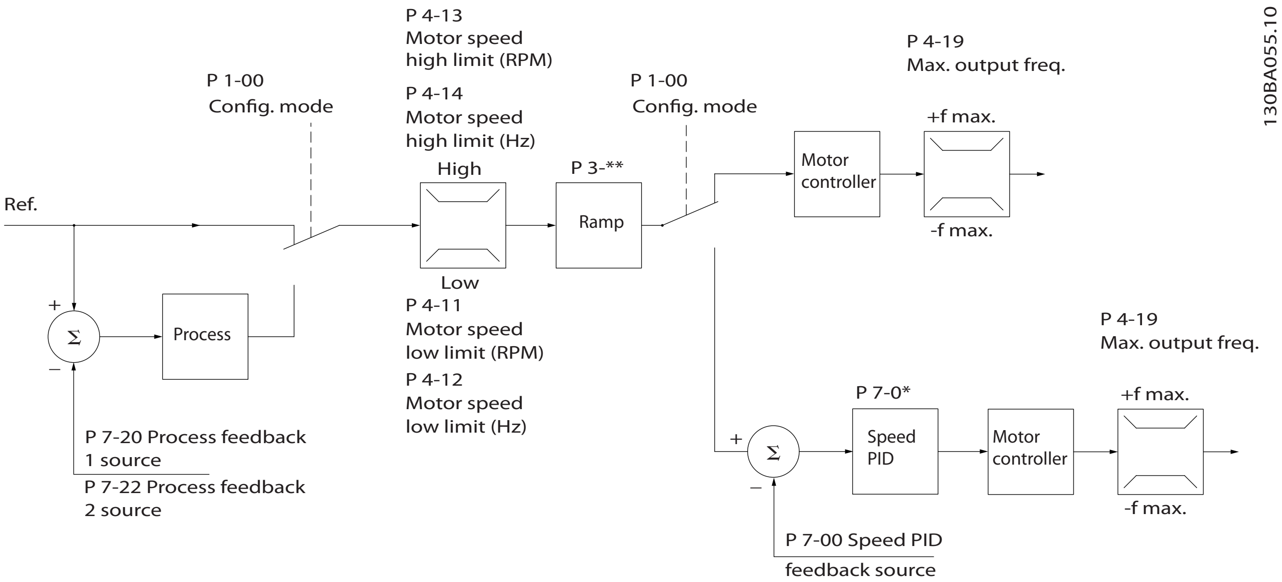


Illustration 3.3 Control Structure in VVC^{plus} Open Loop and Closed Loop Configurations

See the chapter *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 3.3*, *1-01 Motor Control Principle* is set to *[1] VVC^{plus}* and *1-00 Configuration Mode* is set to *[0] Speed open loop*. The resulting reference from the reference handling system is received and fed through the ramp limitation and speed limitation before being sent to the motor control. The output of the motor control is then limited by the maximum frequency limit.

If *1-00 Configuration Mode* is set to *[1] Speed closed loop* the resulting reference will be passed from the ramp limitation and speed limitation into a speed PID control. The Speed PID control parameters are located in 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.*.

3.2.5 Control Structure in Flux Sensorless (FC 302 only)

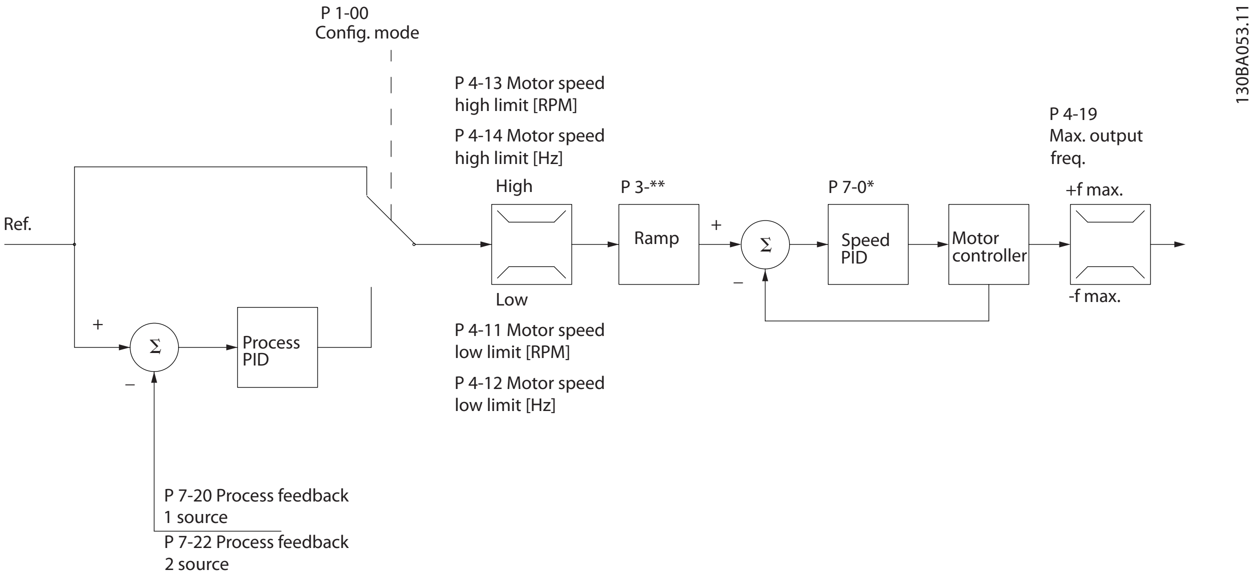


Illustration 3.4 Control Structure in Flux Sensorless Open Loop and Closed Loop Configurations

See the chapter *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*.

3.2.6 Control Structure in Flux with Motor Feedback

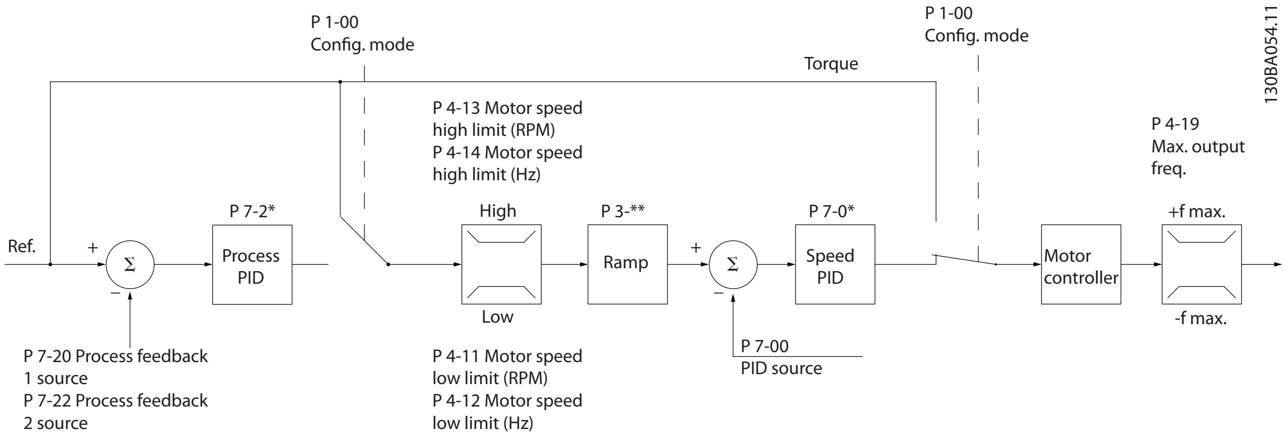


Illustration 3.5 Control Structure in Flux with Motor Feedback Configuration (only available in FC 302)

See the chapter *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 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*.

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

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

3.2.7 Internal Current Control in VVC^{plus} Mode

The frequency converter features an integral current limit control which is activated when the motor current, and thus the torque, is higher than the torque limits set in *4-16 Torque Limit Motor Mode*, *4-17 Torque Limit Generator Mode* and *4-18 Current Limit*.
When the frequency converter is at the current limit during motor operation or regenerative operation, the frequency converter will try to get below the preset torque limits as quickly as possible without losing control of the motor.

3.2.8 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 arrow key on the LCP.

After pressing [Auto On], the frequency converter goes into Auto mode and follows (as default) the Remote reference. In this mode, it is possible to control the frequency converter via the digital inputs and various serial interfaces (RS-485, USB, or an optional fieldbus). See more about starting, stopping, changing ramps and parameter set-ups etc. in parameter group *5-1* Digital Inputs* or parameter group 8-5* Serial communication.

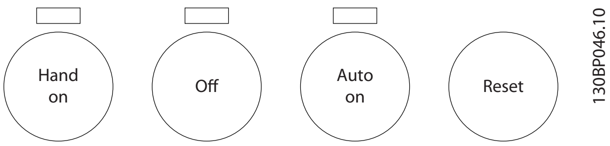


Illustration 3.6 Operation Keys

Active Reference and Configuration Mode

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

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

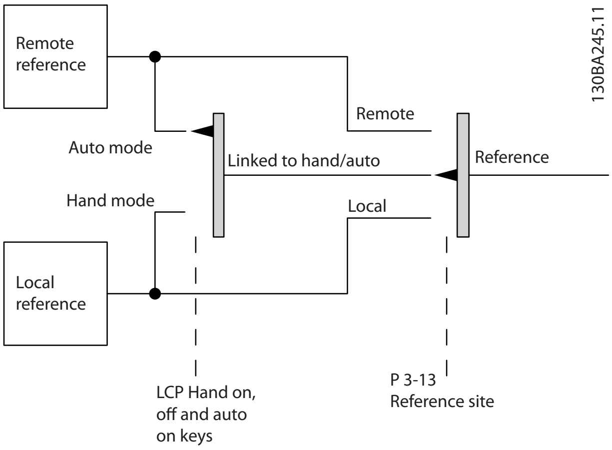


Illustration 3.7 Active Reference

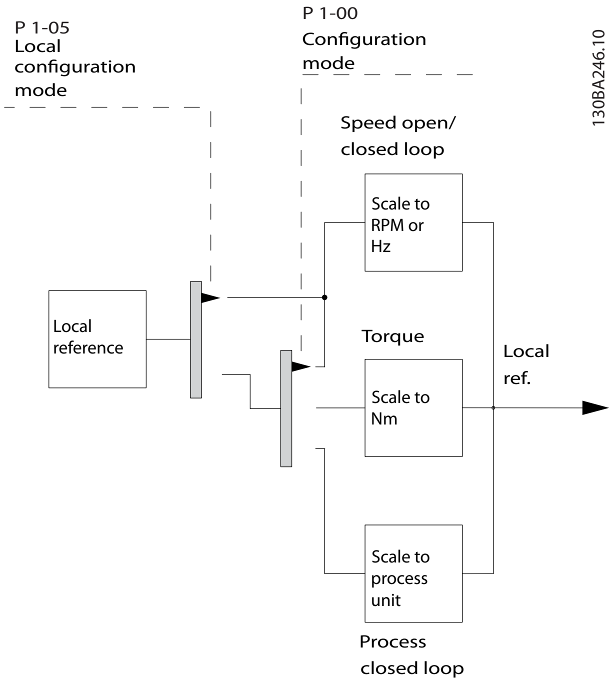


Illustration 3.8 Configuration Mode

Hand On AutoLCP 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 3.2 Conditions for Local/Remote Reference Activation

1-00 Configuration Mode determines what kind of application control principle (i.e. Speed, Torque or Process Control) is used when the remote reference is active.
1-05 Local Mode Configuration determines the kind of application control principle that is used when the local reference is active. One of them is always active, but both can not be active at the same time.

3.3 Reference Handling

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

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

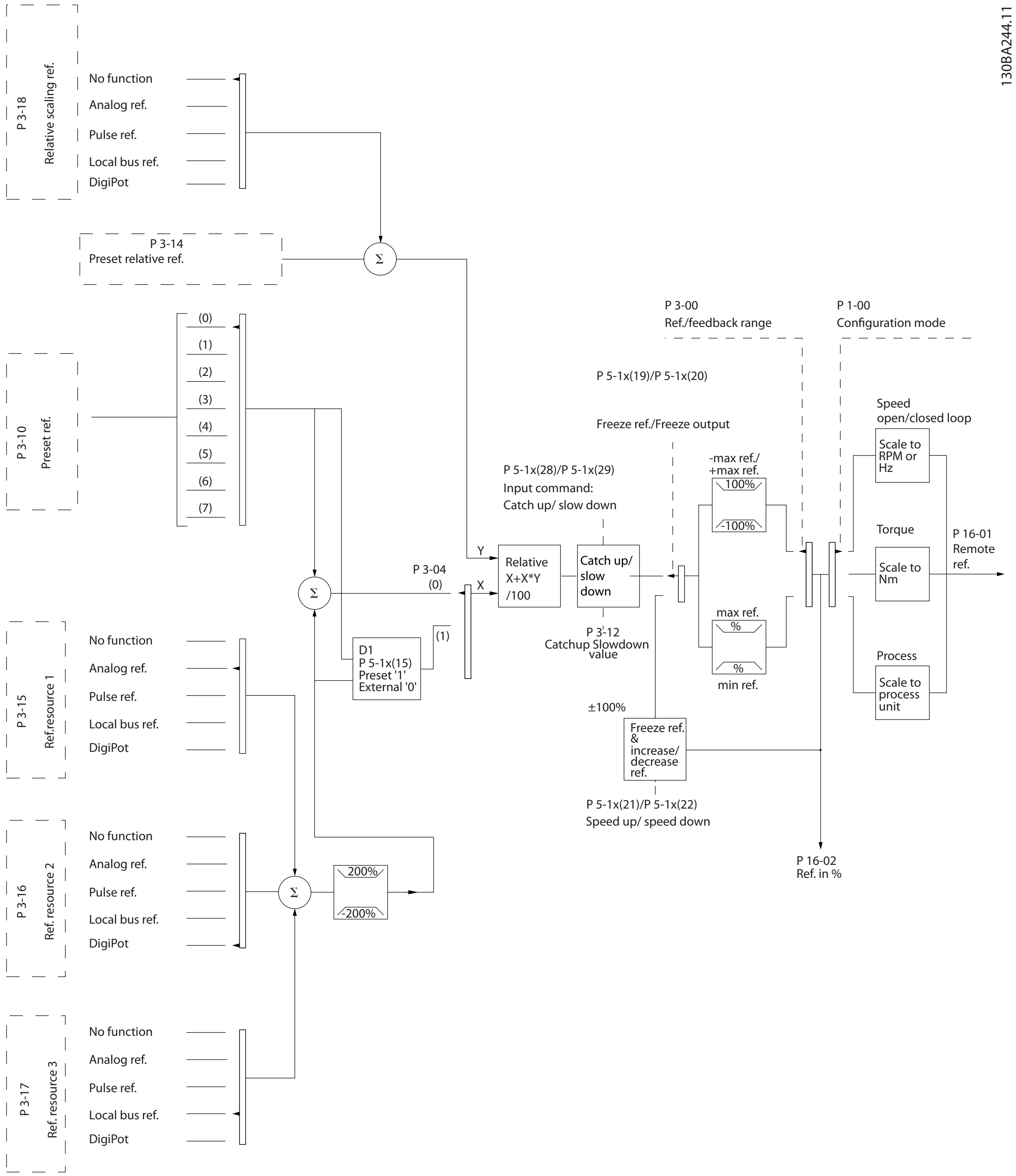


Illustration 3.9 Remote Reference

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

1. X (the actual reference): A sum (see *3-04 Reference Function*) of up to four externally selected references, comprising any combination (determined by the setting of *3-15 Reference Resource 1*, *3-16 Reference Resource 2* and *3-17 Reference Resource 3*) of a fixed preset reference (*3-10 Preset Reference*), variable 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 two types of reference inputs are combined in the following formula: Remote reference = X + X * Y/100%. If relative reference is not used *3-18 Relative Scaling Reference Resource* must be set to *[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*.

3.3.1 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 3.10*.

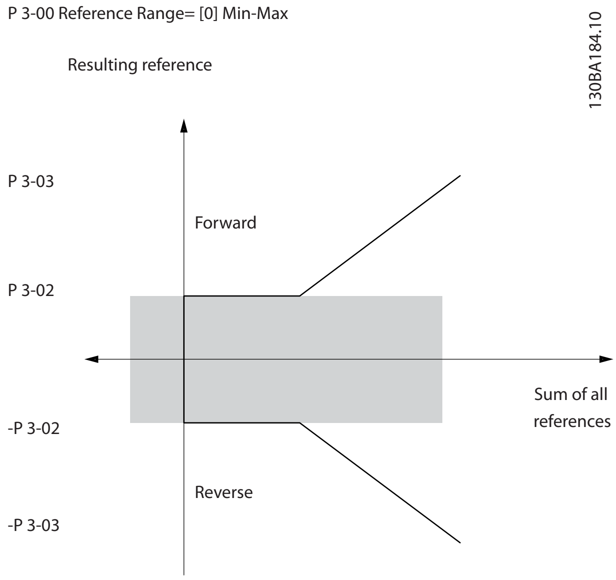


Illustration 3.10 Relation between Resulting Reference and the sum of all References

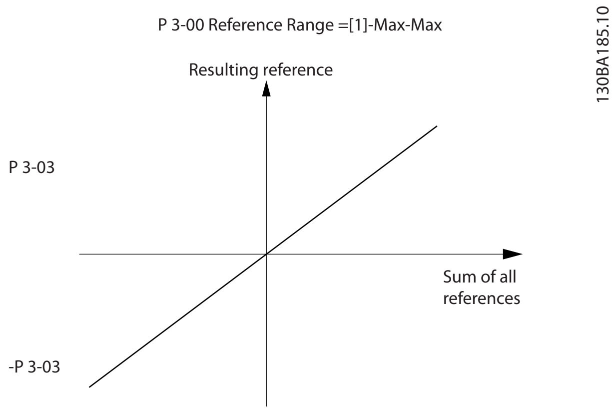


Illustration 3.11 Resulting Reference

The value of *3-02 Minimum Reference* can not be set to less than 0, unless *1-00 Configuration Mode* is set to *[3] Process*. In that case the following relations between the resulting reference (after clamping) and the sum of all references is as shown in *Illustration 3.12*.

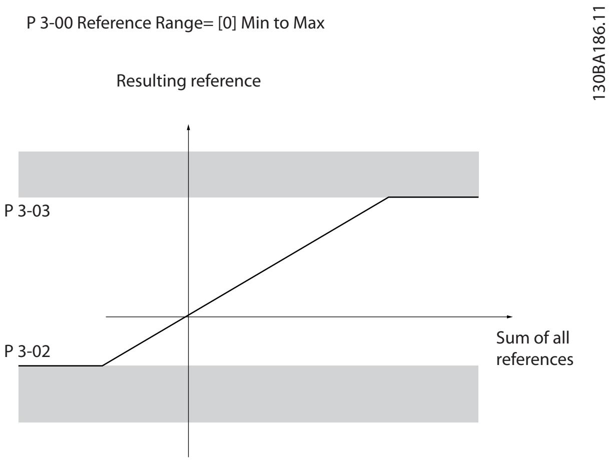


Illustration 3.12 Sum of all References with *1-00 Configuration Mode* set to *[3] Process*

3.3.2 Scaling of Preset References and Bus References

Preset references are scaled according to the following rules:

- When *3-00 Reference Range*: [0] Min - 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.

3.3.3 Scaling of Analog and Pulse References and Feedback

References and feedback are scaled from analog and pulse inputs in the same way. The only difference is that a reference above or below the specified minimum and maximum “endpoints” (P1 and P2 in *Illustration 3.13*) are clamped whereas a feedback above or below is not.

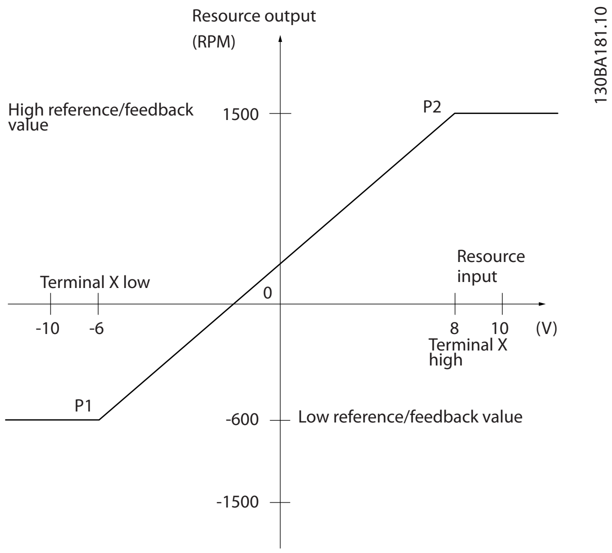


Illustration 3.13 Scaling of Analog and Pulse References and Feedback

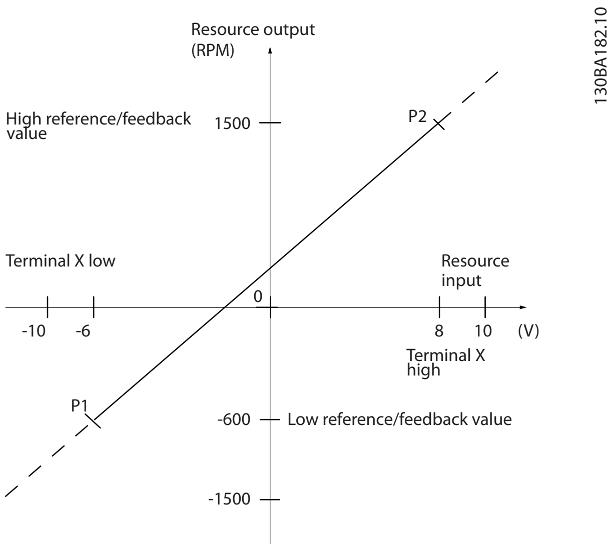


Illustration 3.14

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

Table 3.3 Parameters Defining the Endpoints P1 and P2 depending on which Analog or Pulse Input is used

3.3.4 Dead Band Around Zero

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

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

- Either Minimum Reference Value (see *Table 3.3* for relevant parameter) or Maximum Reference Value must be zero. In other words; Either P1 or P2 must be on the X-axis in *Illustration 3.15*.
- And both points defining the scaling graph are in the same quadrant.

The size of the Dead Band is defined by either P1 or P2 as shown in*Illustration 3.15*.

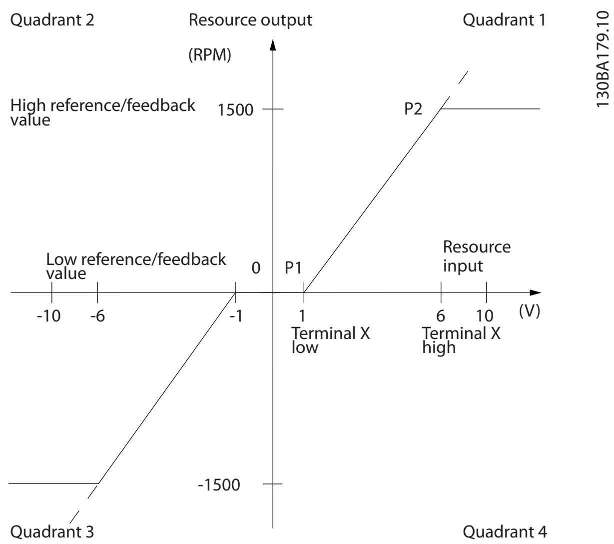


Illustration 3.15 Dead Band

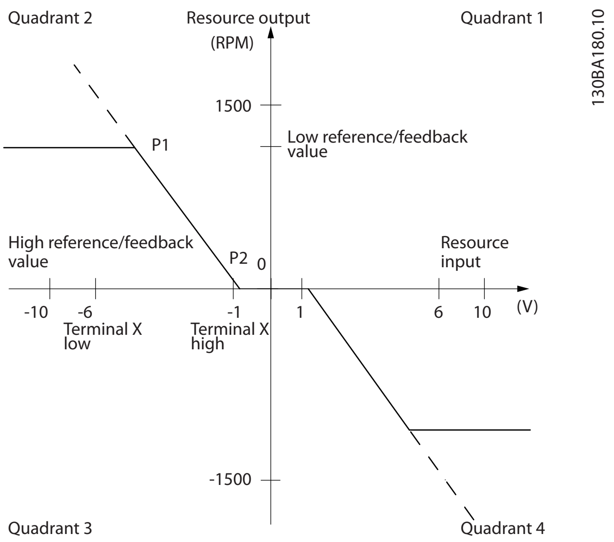


Illustration 3.16 Reverse Dead Band

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

Illustration 3.17 shows how reference input with limits inside Min – Max limits clamps.

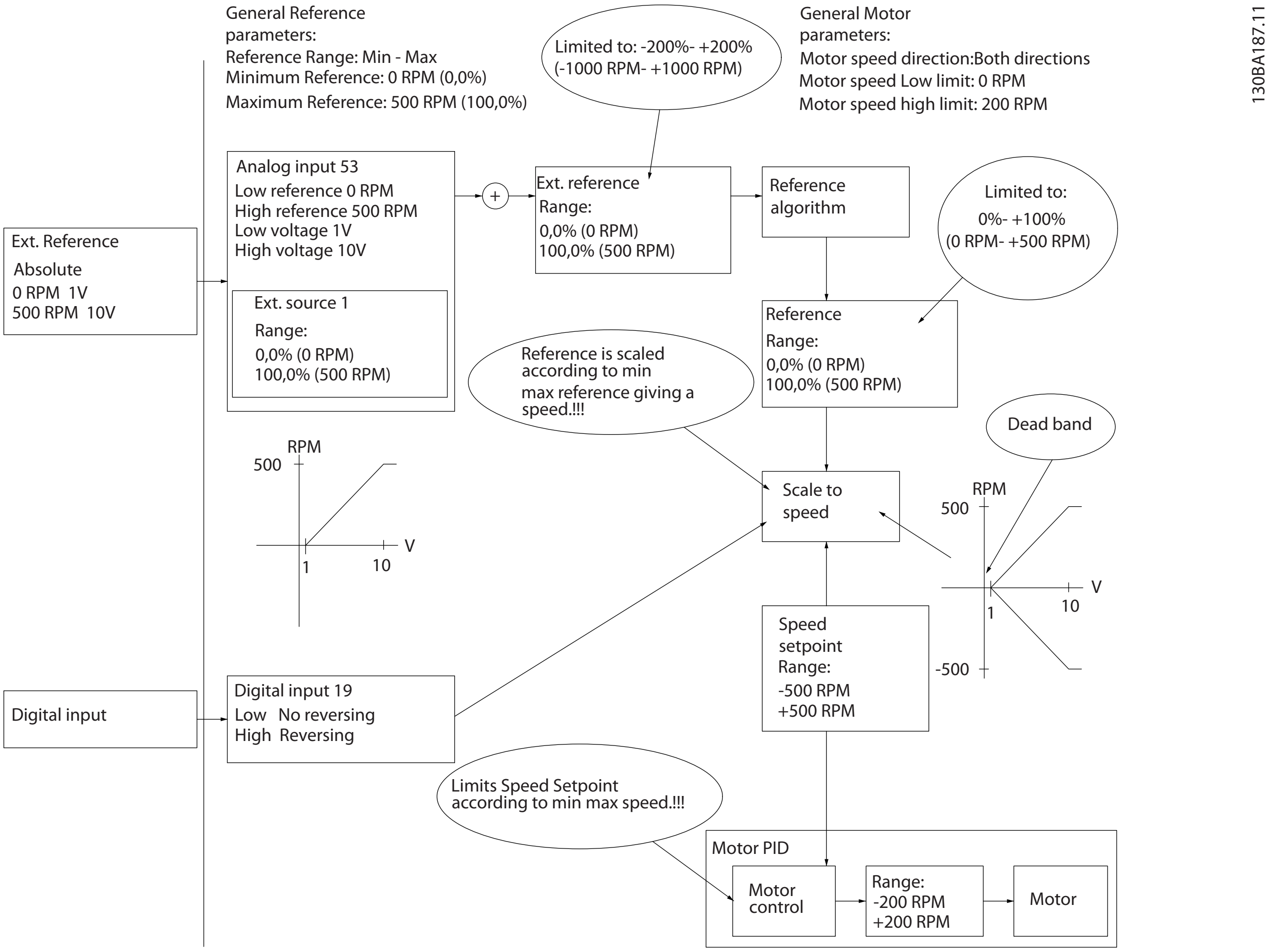


Illustration 3.17 Positive Reference with Dead Band, Digital input to Trigger Reverse

Illustration 3.18 shows how Reference input with limits outside -Max to +Max limits clamps to the inputs low and high limits before addition to actual reference. And how the actual reference is clamped to -Max to +Max by the Reference algorithm.

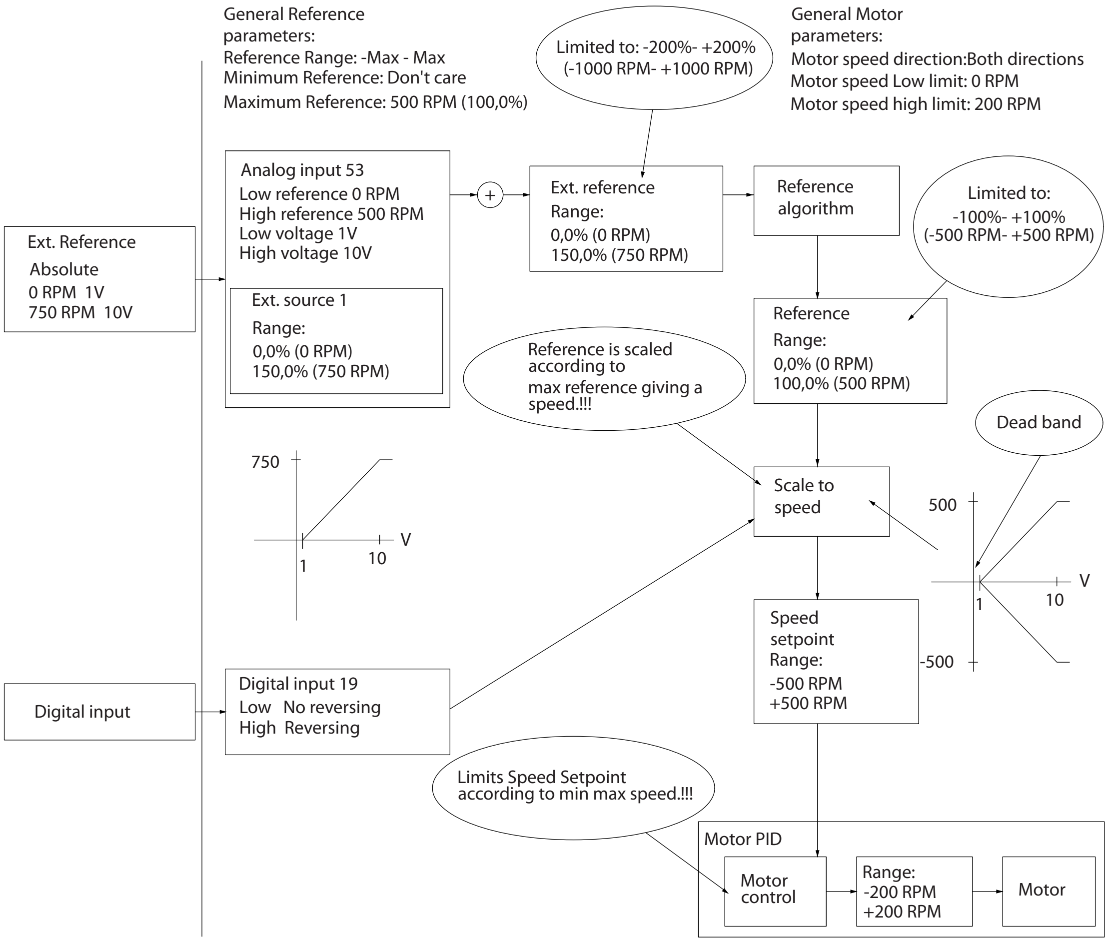


Illustration 3.18 Positive Reference with Dead Band, Digital Input to Trigger Reverse. Clamping Rules

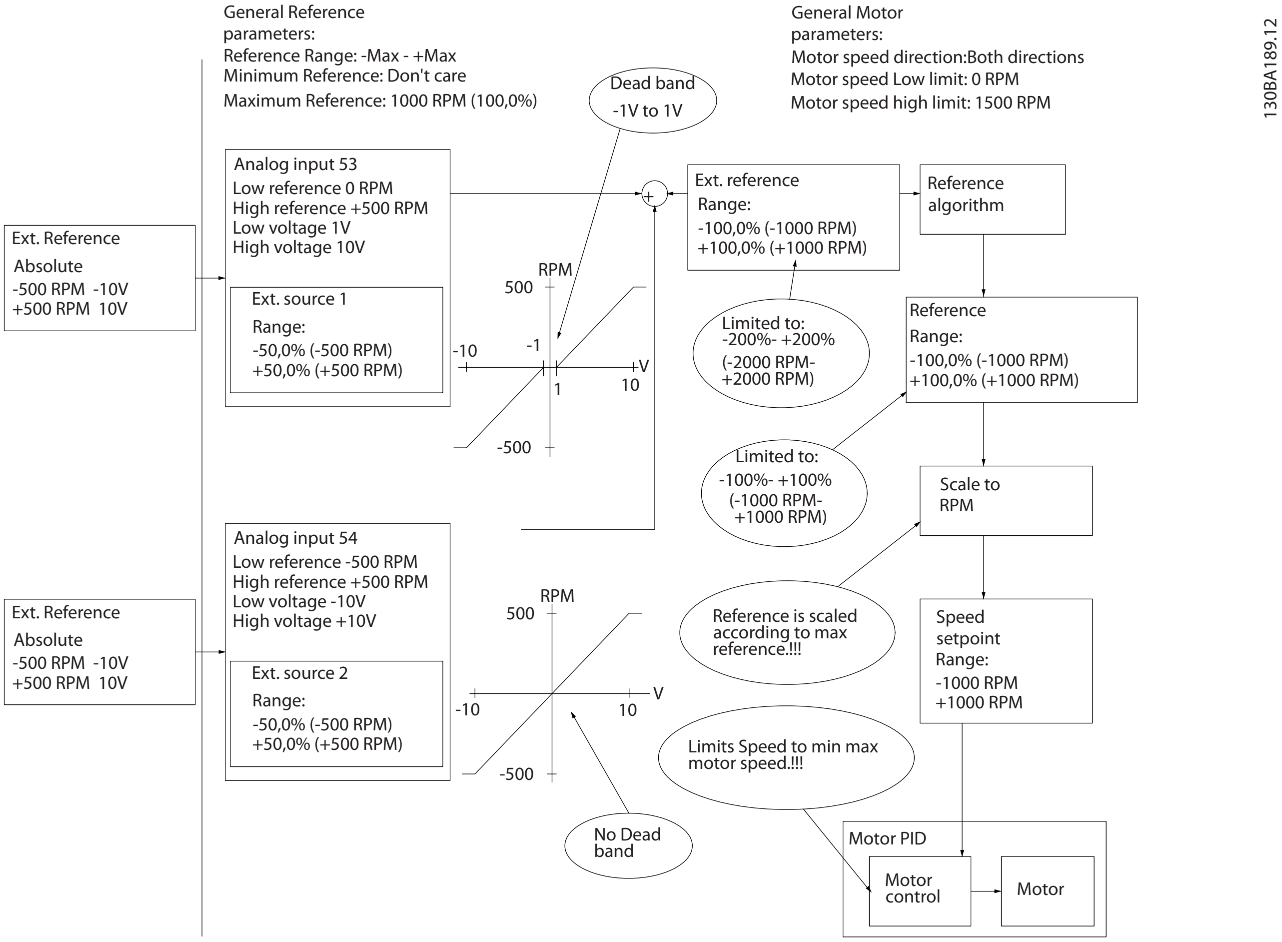


Illustration 3.19 Negative to Positive Reference with Dead Band, Sign Determines the Direction, -Max to +Max

3.4 PID Control

3.4.1 Speed PID Control

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

Table 3.4 Control Configurations where the Speed Control is Active

“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.

NOTE

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

<table>
<tr><th>Parameter</th><th>Description of function</th></tr>
<tr><td>7-00 Speed PID Feedback Source</td><td>Select from which input the Speed PID should get its feedback.</td></tr>
<tr><td>30-83 Speed PID Proportional Gain</td><td>The higher the value - the quicker the control. However, too high value may lead to oscillations.</td></tr>
<tr><td>7-03 Speed PID Integral Time</td><td>Eliminates steady state speed error. Lower value means quick reaction. However, too low value may lead to oscillations.</td></tr>
<tr><td>7-04 Speed PID Differentiation Time</td><td>Provides a gain proportional to the rate of change of the feedback. A setting of zero disables the differentiator.</td></tr>
<tr><td>7-05 Speed PID Diff. Gain Limit</td><td>If there are quick changes in reference or feedback in a given application - which means that the error changes swiftly - the differentiator may soon become too dominant. This is because it reacts to changes in the error. The quicker the error changes, the stronger the differentiator gain is. The differentiator gain can thus be limited to allow setting of the reasonable differentiation time for slow changes and a suitably quick gain for quick changes.</td></tr>
<tr><td>7-06 Speed PID Lowpass Filter Time</td><td>A low-pass filter that dampens oscillations on the feedback signal and improves steady state performance. However, too large filter time will deteriorate 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):
<table>
<tr><th>Encoder PPR</th><th>7-06 Speed PID Lowpass Filter Time</th></tr>
<tr><td>512</td><td>10 ms</td></tr>
<tr><td>1024</td><td>5 ms</td></tr>
<tr><td>2048</td><td>2 ms</td></tr>
<tr><td>4096</td><td>1 ms</td></tr>
</table></td></tr>
</table>

Table 3.5 Relevant Parameters for Speed Control

Example of how to Programme the Speed Control

In this case the Speed PID Control is used to maintain a constant motor speed regardless of the changing load on the motor. The required motor speed is set via a potentiometer connected to terminal 53. The speed range is 0 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.

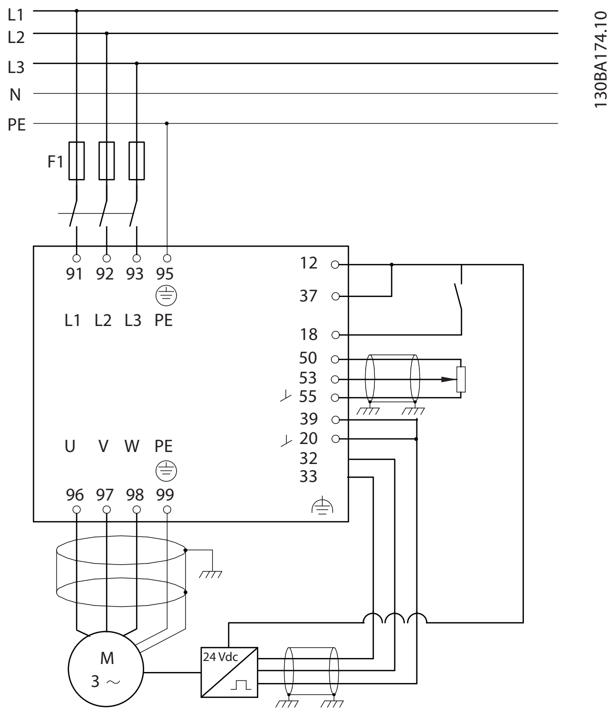


Illustration 3.20 Example - Speed Control Connections

3

The following must be programmed in order shown (see explanation of settings in the Programming Guide)
In *Table 3.6* 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
Have the frequency converter makes 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 the "Hand On" LCP key. Check that the motor is running and note in which direction it is turning (henceforth referred to as the "positive direction").		Set a **positive** reference.
Go to *16-20 Motor Angle*. Turn the motor slowly in the positive direction. It must be turned so slowly (only a few RPM) that it can be determined if the value in *16-20 Motor Angle* is increasing or decreasing.	16-20 Motor Angle	N.A. (read-only parameter) Note: An increasing value overflows at 65535 and starts again at 0.
If *16-20 Motor Angle* is decreasing then change the encoder direction in *5-71 Term 32/33 Encoder Direction*.	5-71 Term 32/33 Encoder Direction	[1] Counter clockwise (if *16-20 Motor Angle* is decreasing)
3) Make sure the 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)
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 (10V)	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 encoder inputs	5-14 Terminal 32 Digital Input 5-15 Terminal 33 Digital Input	[0] No operation (default)
Choose terminal 32/33 as motor feedback	1-02 Flux Motor Feedback Source	Not necessary (default)
Choose terminal 32/33 as Speed PID feedback	7-00 Speed PID Feedback Source	Not necessary (default)
7) Tune the Speed Control PID parameters		
Use the tuning guidelines when relevant or tune manually	7-0*	See the guidelines below
8) Finished!		

Function	Parameter	Setting
Save the parameter setting to the LCP for safe keeping	0-50 LCP Copy	[1] All to LCP

Table 3.6 Programming Order

3.4.2 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:

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

NOTE

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

A practical value for the Bandwith is 20 rad/s. Check the result of the *30-83 Speed PID Proportional Gain* calculation against the following formula (not required if you are using a high resolution feedback such as a SinCos feedback):

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

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)* (5V TTL on MCB102 Option).

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

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

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

3.4.3 Process PID Control

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

Table 3.7 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 the sections about the Control Structure to see where the Speed Control is active.

1-00 Configu-ration Mode	1-01 Motor Control Principle			
	U/f	VVC^{plus}	Flux Sensorless	Flux w/ enc. feedb
[3] Process	Not Active	Process	Process & Speed	Process & Speed

Table 3.7 Control Configurations with Process Control

NOTE

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

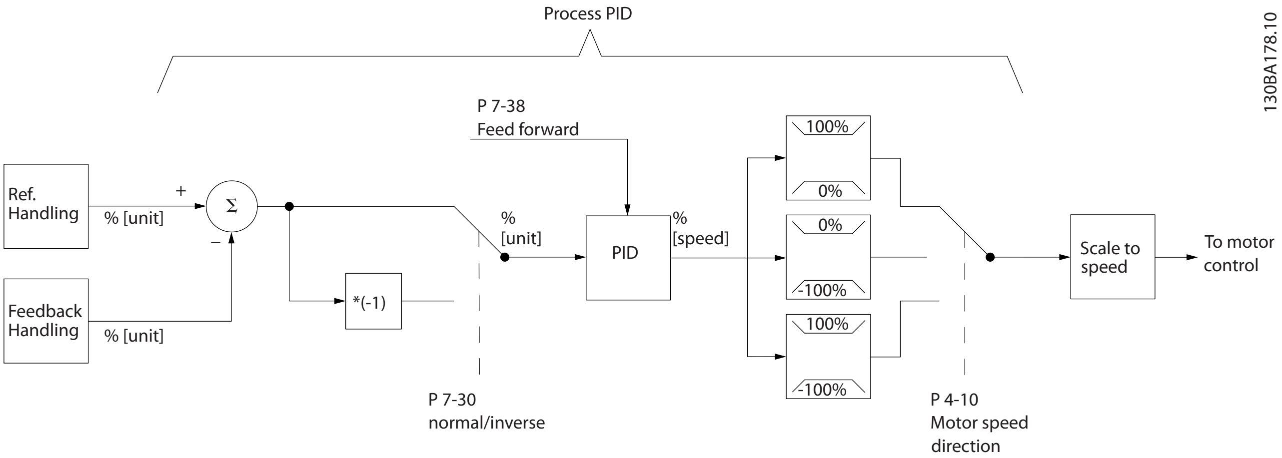


Illustration 3.21 Process PID Control Diagram

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 two feedback signals will be added together before being used in the Process PID Control.
7-30 Process PID Normal/ Inverse Control	Under [0] Normal operation the Process Control will respond with an increase of the motor speed if the feedback is getting lower than the reference. In the same situation, but under [1] Inverse operation, the Process Control will respond with a decreasing motor speed instead.
7-31 Process PID Anti Windup	The anti windup function ensures that when either a frequency limit or a torque limit is reached, the integrator will be set to a gain that corresponds to the actual frequency. This avoids integrating on an error that cannot in any case be compensated for by means of a speed change. This function can be disabled by selecting [0] "Off".
7-32 Process PID Start Speed	In some applications, reaching the required speed/set point can take a very long time. In such applications it might be an advantage to set a fixed motor speed from the frequency converter before the process control is activated. This is done by setting a Process PID Start Value (speed) in *7-32 Process PID Start Speed*.
7-33 Process PID Proportional Gain	The higher the value - the quicker the control. However, too large 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.

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

Table 3.8 Relevant Parameters for Process Control

Function	Parameter	Setting
Initialise the frequency converter	*14-22 Operation Mode*	*[2] Initialisation* - make a power cycling - press reset
1) Set motor parameters:		
Set the motor parameters according to name plate data	1-2*	As stated on motor name plate
Perform a full **A**utomation **M**otor **A**daptation	*1-29 Automatic Motor Adaptation (AMA)*	*[1] Enable complete AMA*
2) Check that motor is running in the right direction. When motor is connected to frequency converter with straight forward phase order as U - U; V- V; W - W motor shaft usually turns clockwise seen into shaft end.		
Press [Hand On"]. Check shaft direction by applying a manual reference.		
If motor turns opposite of required direction: 1. Change motor direction in *4-10 Motor Speed Direction* 2. Turn off mains - wait for DC link to discharge - switch two of the motor phases	4-10 Motor Speed Direction	Select correct motor shaft direction
Set configuration mode	1-00 Configu-ration Mode	*[3] Process*
Set Local Mode Configuration	1-05 Local Mode Configu-ration	*[0] Speed Open Loop*
3) Set reference configuration, ie. the range for reference handling. Set scaling of analog input in parameter 6-xx		
Set reference/feedback units Set min. reference (10 °C) Set max. reference (80 °C) If set value is determined from a preset value (array parameter), set other reference sources to No Function	3-01 Reference/ Feedback Unit 3-02 Minimum Reference 3-03 Maximum Reference 3-10 Preset Reference	[60] °C Unit shown on display 10 °C 80 °C [0] 35% $Ref = \frac{Par.\ 3-10_{(0)}}{100} \times ((Par.\ 3-03) - (par.\ 3-02)) = 24,5°\ C$ *3-14 Preset Relative Reference* to *3-18 Relative Scaling Reference Resource* [0] = No Function
4) Adjust limits for the frequency converter:		
Set ramp times to an appropriate value as 20 s	3-41 Ramp 1 Ramp Up Time 3-42 Ramp 1 Ramp Down Time	20 s 20 s

Function	Parameter	Setting
Set min. speed limits Set motor speed max. limit Set max. output frequency	4-11 Motor Speed Low Limit [RPM] 4-13 Motor Speed High Limit [RPM] 4-19 Max Output Frequency	300 RPM 1500 RPM 60 Hz
Set S201 or S202 to wanted analog input function (Voltage (V) or current (I)) NOTE! Switches are sensitive - Make a power cycling keeping default setting of V		
5) Scale analog inputs used for reference and feedback		
Set terminal 53 low voltage Set terminal 53 high voltage Set terminal 54 low feedback value Set terminal 54 high feedback value Set feedback source	6-10 Terminal 53 Low Voltage 6-25 Terminal 54 High Ref./ Feedb. Value 7-20 Process CL Feedback 1 Resource	0 V 10 V -5 °C 35 °C *[2] Analog input 54*
6) Basic PID settings		
Process PID Normal/Inverse	7-30 Process PID Normal/ Inverse Control	*[0] Normal*
Process PID Anti Wind-up	7-31 Process PID Anti Windup	*[1] On*
Process PID start speed	7-32 Process PID Start Speed	300 RPM
Save parameters to LCP	0-50 LCP Copy	*[1] All to LCP*

Table 3.9 Example of Process PID Control set-up

3.4.4 Optimisation of the Process Regulator

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

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

NOTE

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

3.4.5 Ziegler Nichols Tuning Method

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

This method is known as the Ziegler Nichols tuning method.

NOTE

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

The criteria for adjusting the parameters are based on evaluating the system at the limit of stability rather than on taking a step response. We increase the proportional gain until we observe continuous oscillations (as measured on the feedback), that is, until the system becomes marginally stable. The corresponding gain *(K_u)* is called the ultimate gain. The period of the oscillation *(P_u)* (called the ultimate period) is determined as shown in *Illustration 3.22*.

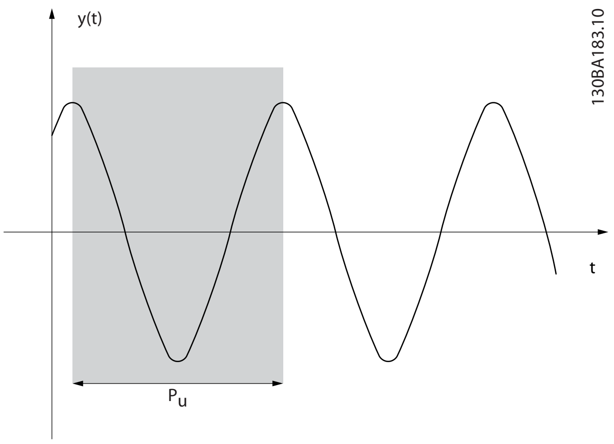


Illustration 3.22 Marginally Stable System

P_u should be measured when the amplitude of oscillation is quite small. Then we “back off” from this gain again, as shown in *Table 3.10*.

K_u is the gain at which the oscillation is obtained.

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

Table 3.10 Ziegler Nichols Tuning for Regulator, Based on a Stability Boundary

Experience has shown that the control setting according to Ziegler Nichols rule provides a good closed loop response for many systems. The process operator can do the final tuning of the control iteratively to yield satisfactory control.

Step-by-step Description

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

Step 2: Increase the value of the proportional gain until the point of instability is reached (sustained oscillations) and the critical value of gain, K_u, is reached.

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

Step 4: Use *Table 3.10* to calculate the necessary PID control parameters.

3

3.5 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 3.23*, 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 3.23*) 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 will in principle only be a small electro-magnetic field (I_4) from the screened motor cable according to the below figure.

The screen reduces the radiated interference but increases the low-frequency interference on the mains. The motor cable screen must be connected to the frequency converter enclosure as well as 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, the screen must be mounted on the enclosure at both ends. In some situations, however, it is necessary to break the screen to avoid current loops.

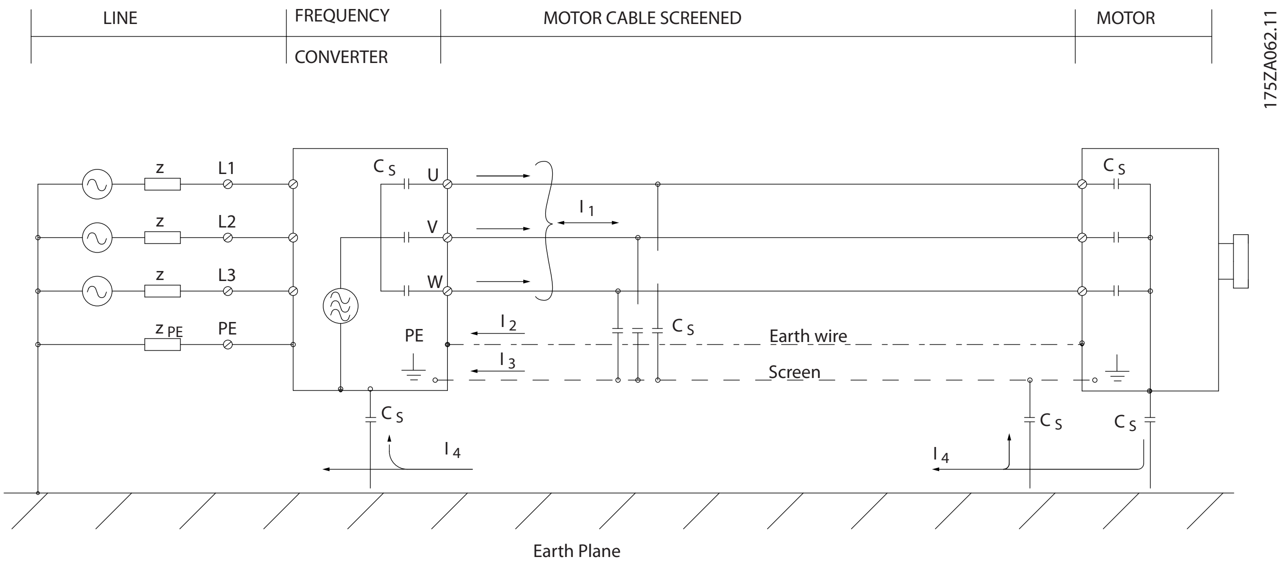


Illustration 3.23 Situation that Generates Leakage Currents

If the screen is to be placed on a mounting plate for the frequency converter, the mounting plate must be made of metal, 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.

In order 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.

3.5.1 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 motor and screened motor cable at nominal switching frequency. In *Table 3.11* 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 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							
FC 301	0-3.7 kW 200-240 V	No	No	5	No	No	No
FC 302	5.5-37 kW 200-240 V	No	No	25	No	No	No
	0-7.5 kW 380-500 V	No	No	5	No	No	No
	11-75 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
	30-75 kW 525-690 V 2, 4)	No	No	25	No	No	No
H3							
FC 301	0-1.5 kW 200-240V	2.5	25	50	No	Yes	Yes
	0-1.5 kW 380-480V	2.5	25	50	No	Yes	Yes
H4							
FC 302	11-22 kW 525-690 V 1)	No	100	100	No	Yes	Yes
	30-75 kW 525-690 V 2)	No	150	150	No	Yes	Yes
Hx 3)							
FC 302	0.75-75 kW 525-600 V	No	No	No	No	No	No

Table 3.11 EMC Test Results (Emission)

1) Frame size B

2) Frame size C

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

4) 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

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 (Frame size A1 only)

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

3.5.2 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 3.12*.

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 3.12 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 3.13 Limits at Generic Emission Standards

3.5.3 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.

In order 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 3.14*.

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 3.14 EMC Immunity Form

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

3.6 Mains Supply Interference/Harmonics

A frequency converter takes up a non-sinusoidal current from mains, which increases the input current I_{RMS}. A non-sinusoidal current is transformed by means of a Fourier analysis and split up into sine-wave currents with different frequencies, i.e. different harmonic currents I_N with 50 Hz as the basic frequency.

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

Table 3.15 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.

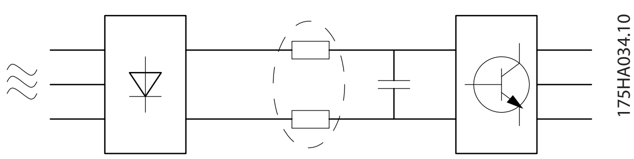


Illustration 3.24 Intermediate Circuit Coils

NOTE

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

	Input current
I_{RMS}	1.0
I_1	0.9
I_5	0.4
I_7	0.2
I_{11-49}	< 0.1

Table 3.16 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%.

3.6.1 The Effect of Harmonics in a Power Distribution System

In *Illustration 3.25* 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.

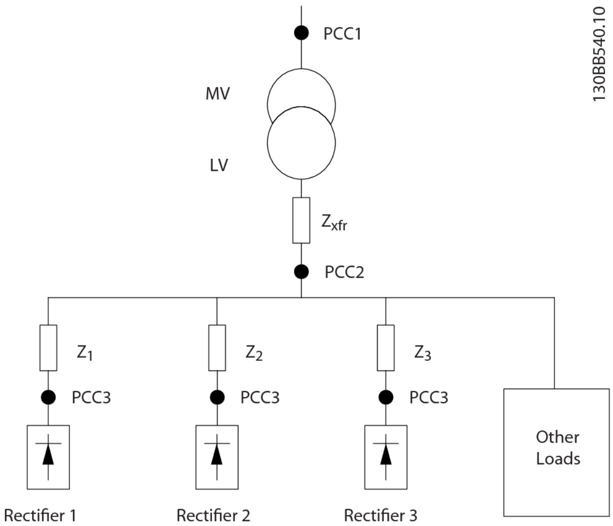


Illustration 3.25 Small Distribution System

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. In order to predict the distortion in the PCC the configuration of the distribution system and relevant impedances must be known.

A commonly used term for describing the impedance of a grid is the short circuit ratioshort circuit ratio R_{sce}, defined as the ratio between the short circuit apparent power of the supply at the PCC (S_{sc}) and the rated apparent power of the load (S_{equ}).

$$R_{sce} = \frac{S_{ce}}{S_{equ}}$$

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

The negative effect of harmonics is twofold

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

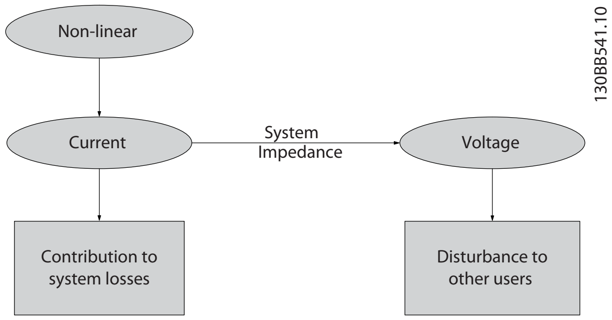


Illustration 3.26 Negative Effects of Harmonics

3.6.2 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 two 110 kW motors connected is sufficient if one of the motors is connected directly on-line and the other is supplied through a frequency converter. However, the transformer will be undersized if both motors are frequency converter supplied. Using additional means of harmonic reduction within the installation or choosing low harmonic drive variants makes it possible for both motors to run with frequency converters.

There are various harmonic mitigation standards, regulations and recommendations. Different standards apply in different geographical areas and industries. The following standards are the most common:

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

See the AHF005/010 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.

3.6.3 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.

3.6.4 Harmonic Calculation

Determining the degree of voltage pollution on the grid and needed precaution is done with the Danfoss MCT31 calculation software. Download the free tool VLT® Harmonic Calculation MCT 31 from www.danfoss.com. The software is built with a focus on user-friendliness and limited to involve only system parameters that are normally accessible.

3.7 Galvanic Isolation (PELV)

3.7.1 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 six locations (see *Illustration 3.27*):

In order 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.

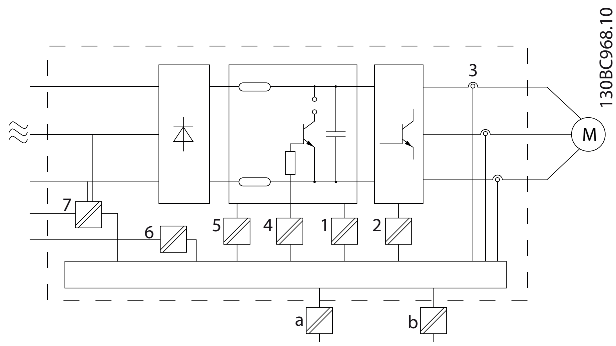


Illustration 3.27 Galvanic Isolation

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 A, B and C: At altitudes above 2 km, contact Danfoss regarding PELV.
380-500 V, enclosure D, E and F: At altitudes above 3 km, contact Danfoss regarding PELV.
525-690 V: At altitudes above 2 km, contact Danfoss regarding PELV.

3

⚠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.

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 will generate 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 contributions and depends on various system configurations including RFI filtering, screened motor cables, and frequency converter power.

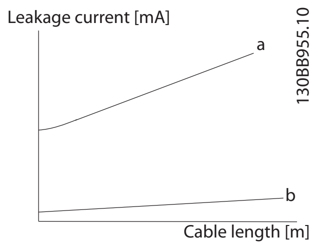


Illustration 3.28 Cable Length and Power Size Influence on Leakage Current. Pa > Pb

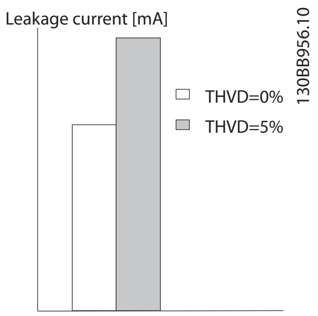


Illustration 3.29 Line Distortion Influences Leakage Current

NOTE

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 3.5mA. Earth grounding must be reinforced in one of the following ways:

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

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

Using RCDs

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

Use RCDs of type B only 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

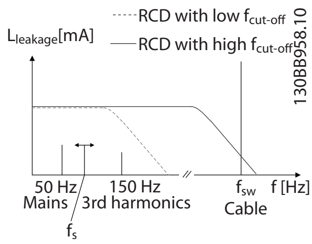


Illustration 3.30 Main Contributions to Leakage Current

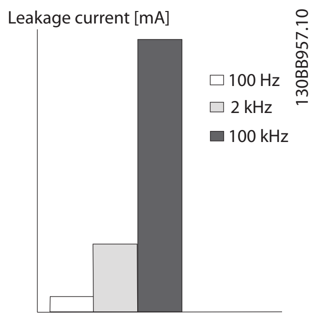


Illustration 3.31 The Influence of the Cut-off Frequency of the RCD on What Is Responded to/measured

See also RCD Application Note, MN90G

3.8 Brake Functions

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

3.8.1 Mechanical Holding Brake

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

NOTE

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

3.8.2 Dynamic Braking

Dynamic Brake established by:

- Resistor brake: A brake IGBT keep the overvoltage under a certain threshold by directing the brake energy from the motor to the connected brake resistor (*2-10 Brake Function* = [1]).
- AC brake: The brake energy is distributed in the motor by changing the loss conditions in the motor. The AC brake function cannot be used in applications with high cycling frequency since this will overheat the motor (*2-10 Brake Function* = [2]).
- DC brake: An over-modulated DC current added to the AC current works as an eddy current brake (*2-02 DC Braking Time*≠ 0 s).

3.8.3 Selection of Brake Resistor

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

NOTE

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

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

Duty cycle = t_b/T

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

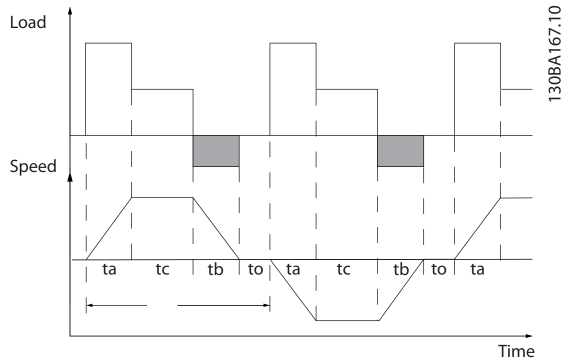


Illustration 3.32 Typical Braking Cycle

	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 3.17 Braking at High Overload Torque Level

1) 500 kW at 86% braking torque
560 kW at 76% braking torque
2) 500 kW at 130% braking torque
560 kW at 115% braking torque

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

NOTE

Make sure the resistor is designed to handle the required braking time.

The max. permissible load on the brake resistor is stated as a peak power at a given intermittent duty cycle and can be calculated as:

The brake resistance is calculated as shown:

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

where

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

As can be seen, 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 3 x 200-240 V	390 V (UDC)	405 V	410 V
FC 301 3 x 380-480 V	778 V	810 V	820 V
FC 302 3 x 380-500 V*	810 V/795 V	840 V/828 V	850 V/855 V
FC 302 3 x 525-600 V	943 V	965 V	975 V
FC 302 3 x 525-690 V	1084 V	1109 V	1130 V

Table 3.18 Brake Limits

** Power size dependent*

NOTE

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:

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

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

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

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

$$480V : R_{rec} = \frac{375300}{P_{motor}}[\Omega]\ 1)$$

$$480V : R_{rec} = \frac{428914}{P_{motor}}[\Omega]\ 2)$$

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

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

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

1) For frequency converters ≤ 7.5 kW shaft output
2) For frequency converters 11-75 kW shaft output

NOTE

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

NOTE

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

NOTE

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

CAUTION

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

3.8.4 Brake Resistor Cabling

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

For enhanced EMC performance a metal screen can be used.

3.8.5 Control with Brake Function

The brake is protected against short-circuiting of the brake resistor, and the brake transistor is monitored to ensure that short-circuiting of the transistor is detected. A relay/digital output can be used for protecting the brake resistor against overloading in connection with a fault in the frequency converter.
In addition, the brake makes it possible to read out the momentary power and the mean power for the latest 120 s. The brake can also monitor the power energizing and make sure it does not exceed a limit selected in *2-12 Brake Power Limit (kW)*. In *2-13 Brake Power Monitoring*, select the function to carry out when the power transmitted to the brake resistor exceeds the limit set in *2-12 Brake Power Limit (kW)*.

NOTE

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

Over voltage control (OVC) (exclusive brake resistor) can be selected as an alternative brake function in *2-17 Over-voltage Control*. This function is active for all units. The function ensures that a trip can be avoided if the DC link voltage increases. This is done by increasing the output frequency to limit the voltage from the DC link. It is a very 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.

NOTE

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

3.9 Mechanical brake control

For controlling the brake, a relay output (relay1 or relay2) or a programmed digital output (terminal 27 or 29) is required. Normally, this output must be closed for as long as the frequency converter is unable to 'hold' the motor, e.g. because of too big load. In *5-40 Function Relay* (Array parameter), *5-30 Terminal 27 Digital Output*, or *5-31 Terminal 29 Digital Output*, select *[32] Mechanical brake control* for applications with an electro-magnetic brake.

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

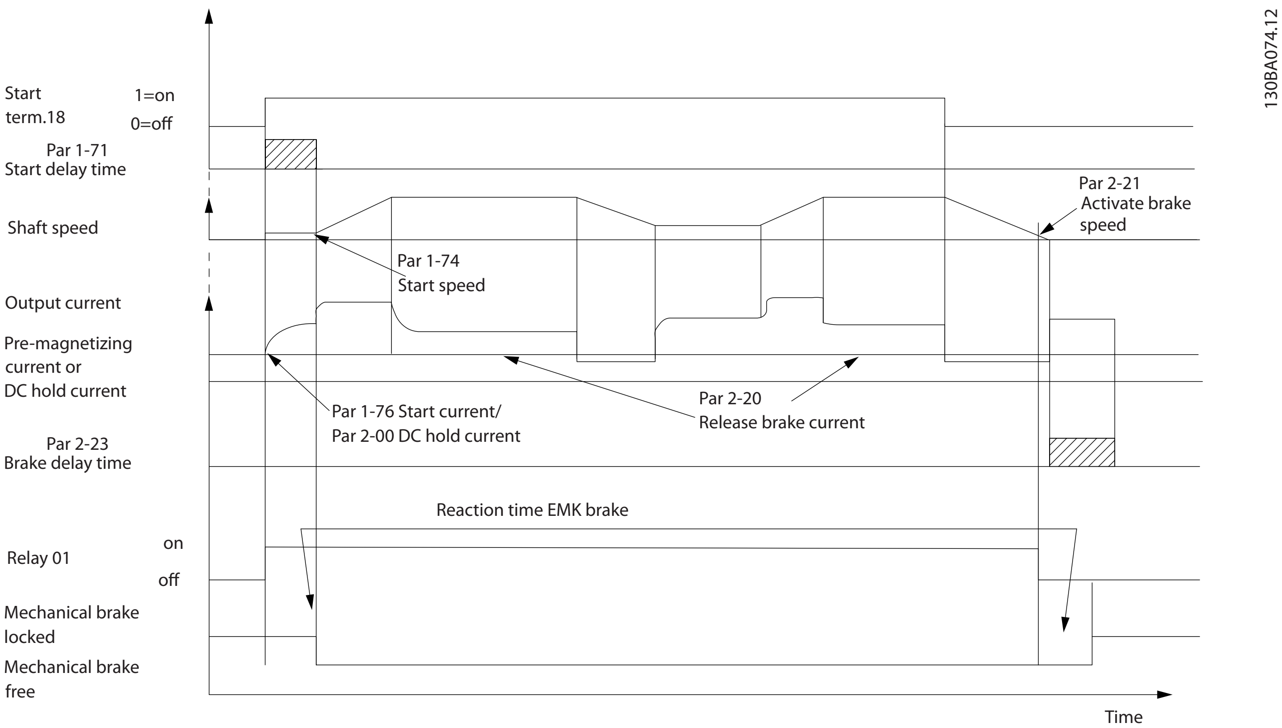


Illustration 3.33 Mechanical brake control in open loop

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

Step-by-step Description

- To control the mechanical brake any relay output or digital output (terminal 27 or 29) can be used. If necessary use a suitable contactor.
- Ensure that the output is switched off as long as the frequency converter is unable to drive the motor, for example due to the load being too heavy or due to the fact that the motor has not been mounted yet.
- Select *[32] Mechanical brake control* in parameter groups *5-4* Relays* (or *5-3* Digital Outputs*) before connecting the mechanical brake.
- The brake is released when the motor current exceeds the preset value in *2-20 Release Brake Current*.
- The brake is engaged when the output frequency is less than the frequency set in *2-21 Activate Brake Speed [RPM]* or *2-22 Activate Brake Speed [Hz]* and only if the frequency converter carries out a stop command.

NOTE

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

NOTE

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

3.9.1 Hoist Mechanical Brake

The VLT® AutomationDrive features a mechanical brake control specifically designed for hoisting applications. The hoist mechanical brake is activated by choice *[6] Hoist Mech. Brake Rel* in *1-72 Start Function*. The main difference compared to the regular mechanical brake control, where a relay function monitoring the output current is used, is that the hoist mechanical brake function has direct control over the brake relay. This means that instead of setting a current for release of the brake, the torque applied against the closed brake before release is defined. Because the torque is defined directly the setup is more straightforward for hoisting applications.
By using *2-28 Gain Boost Factor* a quicker control when releasing the brake can be obtained. The hoist mechanical brake strategy is based on a 3-step sequence, where motor control and brake release are synchronized in order to obtain the smoothest possible brake release.

3-step sequence

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

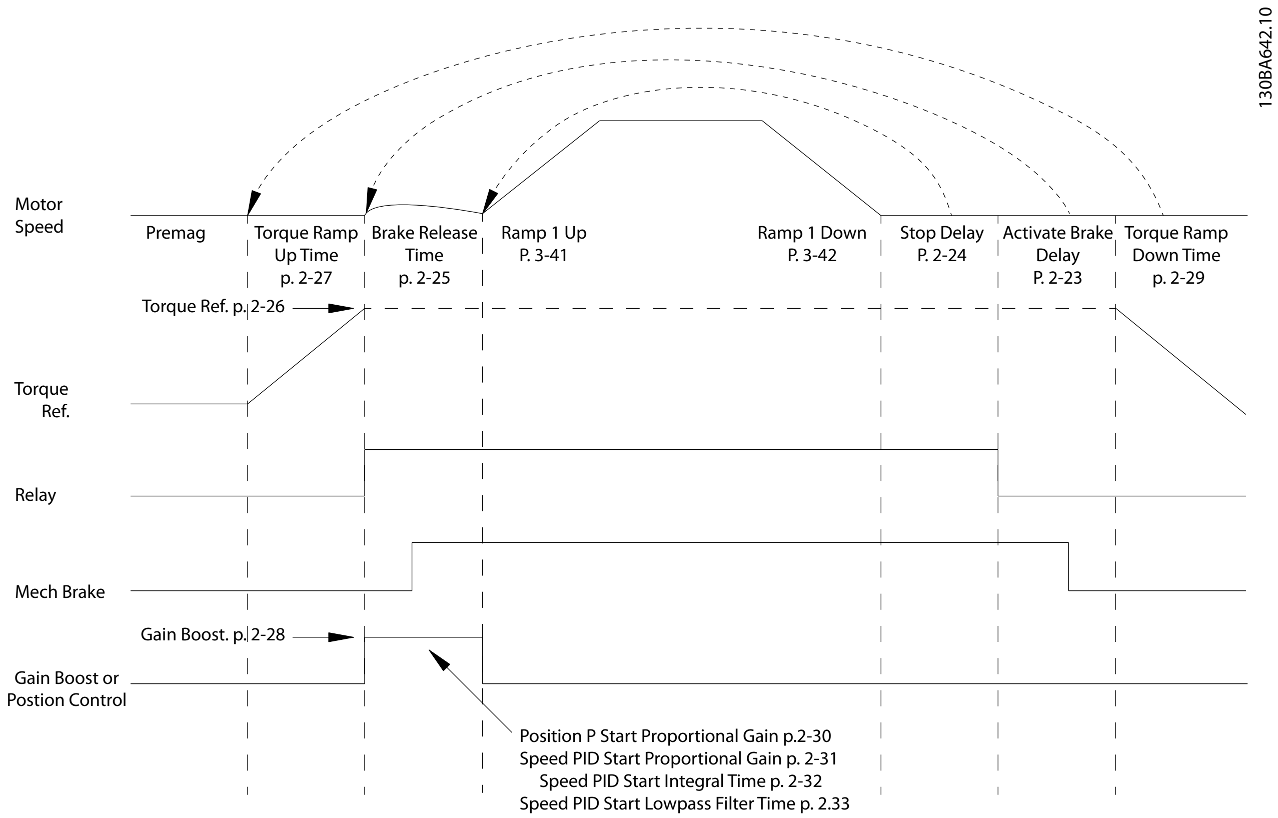


Illustration 3.34 Hoist mechanical brake control for FC 302 FLUX with motor feedback

I) *Activate brake delay:* The frequency converter starts again from the *mechanical brake engaged* position.

II) *Stop delay:* When the time between successive starts is shorter than the setting in *2-24 Stop Delay*, the frequency converter starts without applying the mechanical brake (e.g. reversing).

NOTE

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

3.10 Smart Logic Controller

Smart Logic Control (SLC) is essentially a sequence of user defined actions (see *13-52 SL Controller Action* [x]) executed by the SLC when the associated user defined *event* (see *13-51 SL Controller Event* [x]) is evaluated as TRUE by the SLC.
The condition for an event can be a particular status or that the output from a Logic Rule or a Comparator Operand becomes TRUE. That will lead to an associated Action as illustrated.

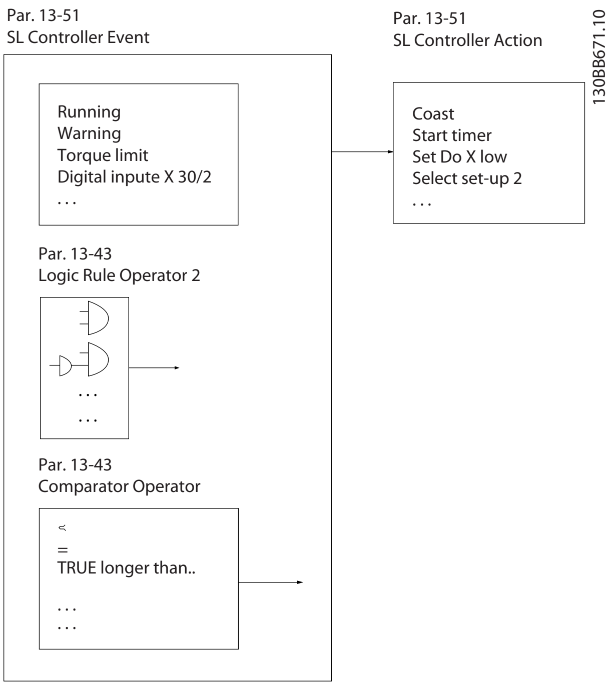


Illustration 3.35 Current Control Status/Event and Action

Events and *actions* are each numbered and linked together 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] will be evaluated and if evaluated TRUE, *action* [1] will be executed and so on. Only one *event* will be evaluated at any time. If an *event* is evaluated as FALSE, nothing happens (in the SLC) during the current scan interval and no other *events* will be evaluated. This means that when the SLC starts, it evaluates *event* [0] (and only *event* [0]) each scan interval. Only when *event* [0] is evaluated TRUE, will the SLC execute *action* [0] and start 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]. The illustration shows an example with three event/actions:

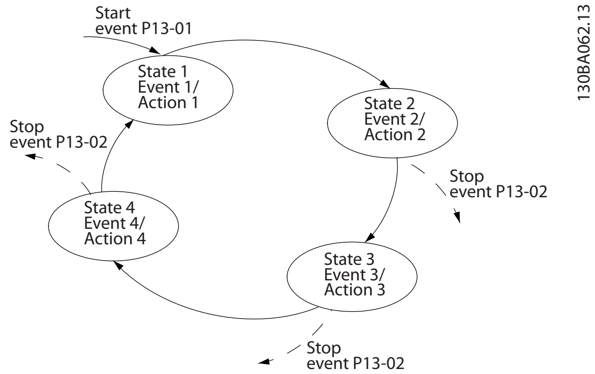


Illustration 3.36 Example - Internal Current Control

Comparators

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

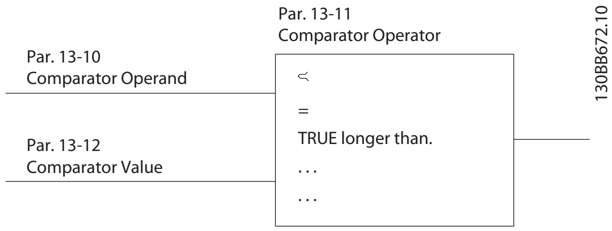


Illustration 3.37 Comparators

Logic Rules

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

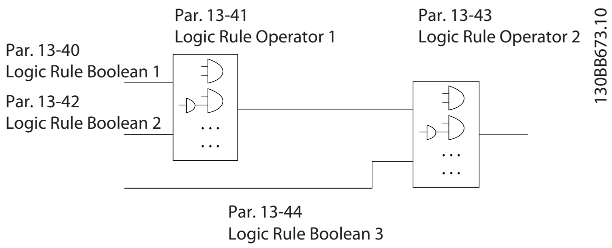
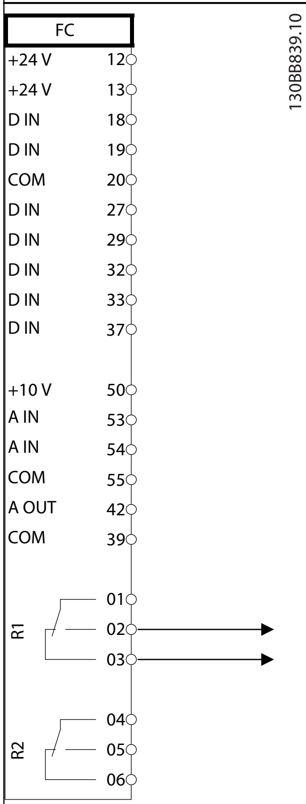


Illustration 3.38 Logic Rules

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 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: 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 3.19 Using SLC to Set a Relay

3.11 Extreme Running Conditions

Short Circuit (Motor Phase – Phase)
The frequency converter is protected against short circuits by means of current measurement in each of the three motor phases or in the DC link. A short circuit between two output phases will cause an overcurrent in the inverter. The inverter will be turned off individually when the short circuit current exceeds the permitted value (Alarm 16 Trip Lock).
To protect the frequency converter against a short circuit at the load sharing and brake outputs see the design guidelines.

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 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), ie. the load generates energy.
2. During deceleration ("ramp-down") if the moment of inertia is high, the friction is low and the ramp-down time is too short for the energy to be dissipated as a loss in the frequency converter, the motor and the installation.
3. Incorrect slip compensation setting may cause higher DC link voltage.
4. Back-EMF from PM motor operation. If coasted at high rpm the PM motor back-EMF may potentially exceed the maximum voltage tolerance of the frequency converter and cause damage. To help prevent this, the value of *4-19 Max Output Frequency* is automatically limited based on an internal calculation based on the value of *1-40 Back EMF at 1000 RPM*, *1-25 Motor Nominal Speed* and *1-39 Motor Poles*. If it is possible that the motor may overspeed (e.g. due to excessive windmilling effects) then it is recommended to equip a brake resistor.

⚠WARNING

The frequency converter must be equipped with a break chopper.

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

NOTE

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

Mains Drop-out
During a mains drop-out, the frequency converter keeps running until the intermediate circuit voltage drops below the minimum stop level, which is typically 15% below the

frequency converter's lowest rated supply voltage. The mains voltage before the drop-out and the motor load determines how long it takes for the inverter to coast.

Static Overload in VVC^{plus} mode
When the frequency converter is overloaded (the torque limit in *4-16 Torque Limit Motor Mode*/*4-17 Torque Limit Generator Mode* is reached), the controls 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*.

3.11.1 Motor Thermal Protection

To protect the application from serious damages VLT® AutomationDrive offers several dedicated features
Torque Limit
The Torque limit feature the motor is protected for being overloaded 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 shall trip is controlled in *14-25 Trip Delay at Torque Limit*.
Current Limit
The current limit is controlled in *4-18 Current Limit* and the time before the current limit warning shall trip is controlled in *14-24 Trip Delay at Current Limit*.
Min Speed Limit
(*4-11 Motor Speed Low Limit [RPM]* or *4-12 Motor Speed Low Limit [Hz]*) limit the operating speed range to 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 (Electronic Thermal relay)
The frequency converter ETR function measures actual current, speed and time to calculate motor temperature and protect the motor from being overheated (Warning or trip). An external thermistor input is also available. ETR is an electronic feature that simulates a bimetal relay based on internal measurements. The characteristic is shown in *Illustration 3.39*:

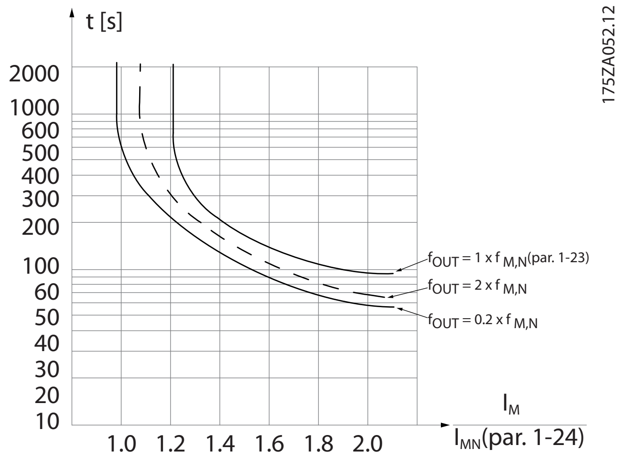


Illustration 3.39 ETR: The X-axis shows the ratio between I_{motor} and I_{motor} nominal. The Y- axis shows the time in seconds before the ETR cut of and trips the frequency converter. The curves show the characteristic nominal speed, at twice the nominal speed and at 0,2 x the nominal speed.
At lower speed the ETR cuts of at lower heat due to less cooling of the motor. In that way the motor 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 *FC 51 Micro Drive Programming Guide*.

3.12 Safe Stop

The FC 302, and also the FC 301 in A1 enclosure, can perform the safety function *Safe Torque Off* (STO, as defined by EN IEC 61800-5-2[1]) and *Stop Category 0* (as defined in EN 60204-1[2]).
Danfoss has named this functionality *Safe Stop*. Before integrating and using Safe Stop in an installation, a thorough risk analysis on the installation must be carried out in order to determine whether the Safe Stop 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 Stop
The Safe Stop (STO) function is activated by removing the voltage at Terminal 37 of the Safe Inverter. By connecting the Safe Inverter to external safety devices providing a safe delay, an installation for a safe Stop Category 1 can be obtained. The Safe Stop function of FC 302 can be used for

asynchronous, synchronous motors and permanent magnet motors. See examples in *3.12.1 Terminal 37 Safe Stop Function*.

NOTE

FC 301 A1 enclosure: When Safe Stop is included in the frequency converter, position 18 of Type Code must be either T or U. If position 18 is B or X, Safe Stop Terminal 37 is not included!
Example:
Type Code for FC 301 A1 with Safe Stop:
FC-301PK75T4Z20H4TGCXXXSXXXXA0BXCXXXXD0

WARNING

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

Safe Stop 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) = 1=-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 measure, 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 3.20 Abbreviations related to Functional Safety

3.12.1 Terminal 37 Safe Stop Function

The FC 302 and FC 301 (optional for A1 enclosure) is available with safe stop functionality via control terminal 37. Safe stop disables the control voltage of the power semiconductors of the frequency converter output stage which in turn prevents generating the voltage required to rotate the motor. When the Safe Stop (T37) is activated, the frequency converter issues an alarm, trips the unit, and coasts the motor to a stop. Manual restart is required. The safe stop function can be used for stopping the frequency converter in emergency stop situations. In the normal operating mode when safe stop is not required, use the frequency converters regular stop function instead. When automatic restart is used – the requirements according to ISO 12100-2 paragraph 5.3.2.5 must be fulfilled.

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

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

Standards
Use of safe stop on terminal 37 requires that the user satisfies all provisions for safety including relevant laws, regulations and guidelines. The optional safe stop 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 instruction manual are not sufficient for a proper and safe use of the safe stop 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 in order to eliminate hazards

Safe Stop Installation and Set-Up

⚠WARNING

SAFE STOP FUNCTION!

The safe stop function does NOT isolate mains voltage to the frequency converter or auxiliary circuits. Perform work on electrical parts of the frequency converter or the motor only after isolating the mains voltage supply and waiting the length of time specified 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 will trip and stop 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 3.40.*)
2. Connect an external Safety monitoring relay via a NO safety function (the instruction for the safety device must be followed) to terminal 37 (safe stop) and either terminal 12 or 13 (24 V DC). The Safety monitoring relay must comply with Category 3/PL “d” (ISO 13849-1) or SIL 2 (EN 62061).

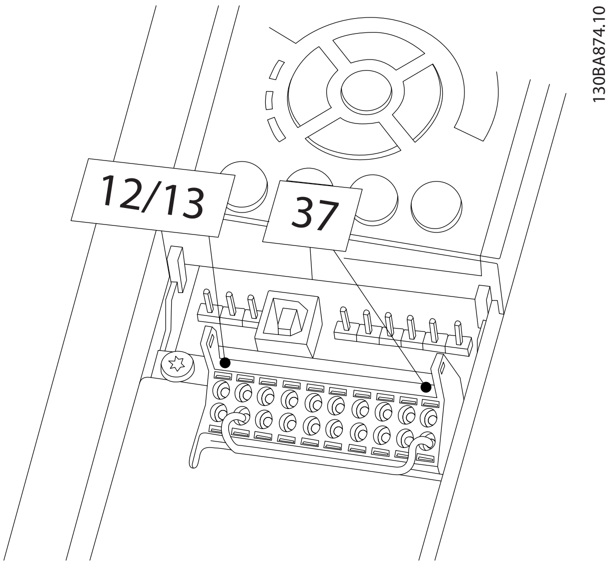


Illustration 3.40 Jumper between Terminal 12/13 (24 V) and 37

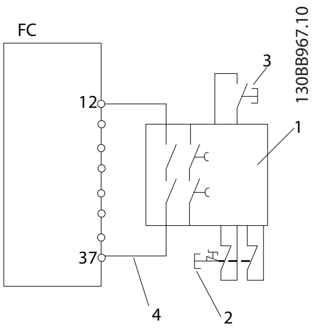


Illustration 3.41 Installation to Achieve a Stopping Category 0 (EN 60204-1) with Safety Cat. 3/PL "d" (ISO 13849-1) or SIL 2 (EN 62061).

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 3.21 Legend to*Illustration 3.41*

Safe Stop Commissioning Test

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

Example with STO

A safety relay evaluates the E-Stop button signals and triggers an STO function on the frequency converter in the event of an activation of the E-Stop button (See *Illustration 3.42*). This safety function corresponds to a category 0 stop (uncontrolled stop) in accordance with IEC 60204-1. If the function is triggered during operation, the motor will run down in an uncontrolled manner. The power to the motor is safely removed, so that no further movement is possible. It is not necessary to monitor plant at a standstill. If an external force effect is to be anticipated, additional measures should be provided to safely prevent any potential movement (e.g. mechanical brakes).

NOTE

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

Example with SS1

SS1 correspond to a controlled stop, stop category 1 according to IEC 60204-1 (see *Illustration 3.43*). When activating the safety function a normal controlled stop will be performed. This can be activated through terminal 27. After the safe delay time has expired on the external safety module, the STO will be triggered and terminal 37 will be set low. Ramp down will be performed as configured in the frequency converter. If the frequency converter is not stopped after the safe delay time the activation of STO will coast the frequency converter.

NOTE

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 two channels for the STO function to achieve Category 4/PL e, one channel can be implemented by Safe Stop T37 (STO) and the other by a contactor, which may be connected in either the frequency converter input or output power circuits and controlled by the Safety relay (see *Illustration 3.44*). The contactor must be monitored through an auxiliary guided contact, and connected to the reset input of the Safety Relay.

Paralleling of Safe Stop input the one Safety Relay

Safe Stop inputs T37 (STO) may be connected directly together if it is required to control multiple frequency converters from the same control line via one Safety Relay (see *Illustration 3.45*). Connecting inputs together 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.

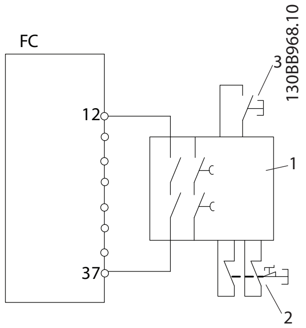


Illustration 3.42 STO Example

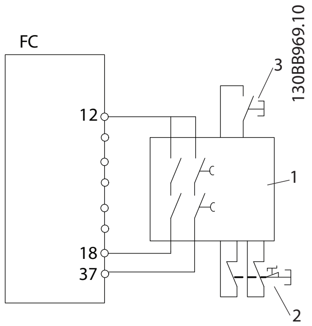


Illustration 3.43 SS1 Example

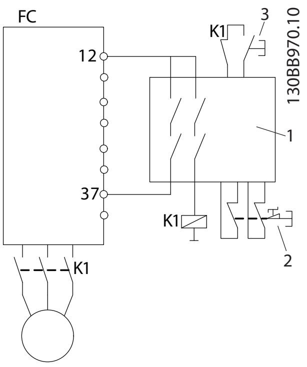


Illustration 3.44 STO Category 4 Example

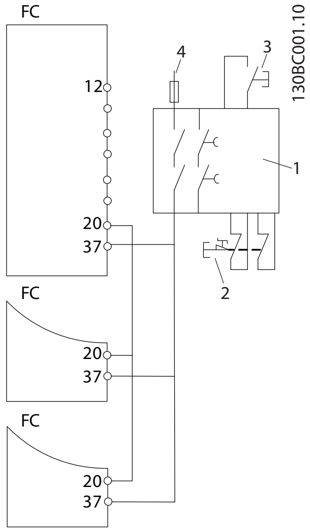


Illustration 3.45 Paralleling of Multiple Frequency Converters Example

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

Table 3.22 Legend to *Illustration 3.42* to *Illustration 3.45*

⚠WARNING

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

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

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

NOTE

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.

In order to resume operation after activation of Safe Stop, first 24 V DC voltage must be reapplied to terminal 37 (text Safe Stop activated is still displayed), second a Reset signal must be created (via bus, Digital I/O, or [Reset] key on inverter).

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

The Safe Stop function can be set to an Automatic Restart behaviour by setting the value of *5-19 Terminal 37 Safe Stop* from default value [1] to value [3]. If 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 Stop is terminated, and normal operation is resumed, as soon as the 24 V DC are applied to Terminal 37, no Reset signal is required.

⚠WARNING

Automatic Restart Behaviour is only allowed in one of the two situations:

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

3.12.2 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 Stop. This means that the output to Safe Stop terminal 37 is HIGH (24 V) only if both the signal from MCB 112 output X44/12 and the signal from the safety-related sensor are HIGH. If at least one of the two signals is LOW, then the output to Terminal 37 must be LOW, too. The safety device with this AND logic itself must conform to IEC 61508, SIL 2. The connection from the output of the safety device with safe AND logic to Safe Stop terminal 37 must be short-circuit protected. See *Illustration 3.46*.

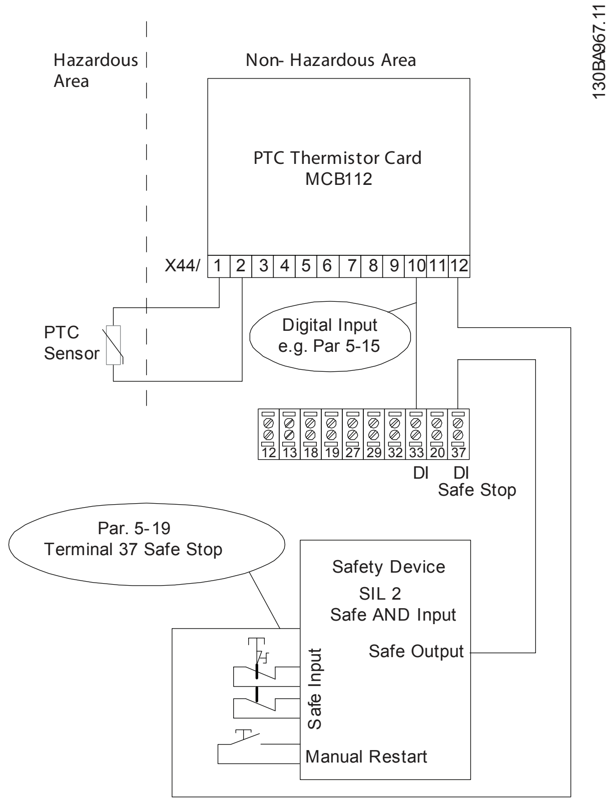


Illustration 3.46 Illustration of the essential aspects for installing a combination of a Safe Stop application and a MCB 112 application. The diagram shows a Restart input for the external Safety Device. This means that in this installation *5-19 Terminal 37 Safe Stop* might be set to value [7] or [8]. Refer to MCB 112 operating instuctions, MG.33.VX.YY 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 Stop Alarm* and *[3] Safe Stop Warning* are still available but are not to be used as those are for installations without MCB 112 or any external safety devices. If *[1]* Safe Stop Alarm* or *[3] Safe Stop Warning* should be chosen by mistake and MCB 112 is triggered, then the frequency converter will react with an alarm ”Dangerous Failure [A72]” and coast the frequency converter safely, without Automatic Restart. Selections *[4] PTC 1 Alarm* and *[5] PTC 1 Warning* are not to be selected when an external safety device is used. Those selections are for when only MCB 112 uses the Safe Stop. If

selection *[4] PTC 1 Alarm* or *[5] PTC 1 Warning* is chosen by mistake and the external safety device triggers Safe Stop then the frequency converter issues an alarm ”Dangerous Failure [A72]” and coast the frequency converter safely, without Automatic Restart.
Selections *[6] PTC 1 & Relay A* to *[9] PTC 1 & Relay W/A* must be chosen for the combination of external safety device and MCB 112.

NOTE

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:

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

See *9.8 MCB 112 PTC Thermistor Card* and the operating instructions for the MCB 112 for further information.

3.12.3 Safe Stop Commissioning Test

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

NOTE

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

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

Case 1: restart prevention for Safe Stop is required (i.e. Safe Stop only where *5-19 Terminal 37 Safe Stop* is set to default value [1], or combined Safe Stop and 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 302 (i.e. mains supply is not interrupted). The test step is passed if the motor reacts with a coast and the mechanical brake (if connected) is activated, and if an LCP is mounted, the alarm “Safe Stop [A68]” is displayed.

1.2 Send Reset signal (via Bus, Digital I/O, or [Reset] key). The test step is passed if the motor remains in the Safe Stop state, and the mechanical brake (if connected) remains activated.

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

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

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

Case 2: Automatic Restart of Safe Stop is wanted and allowed (i.e. Safe Stop only where *5-19 Terminal 37 Safe Stop* is set to [3], or combined Safe Stop and 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 302 (i.e. mains supply is not interrupted). The test step is passed if the motor reacts with a coast and the mechanical brake (if connected) is activated, and if an LCP is mounted, the warning “Safe Stop [W68]” is displayed.

2.2 Reapply 24 V DC to terminal 37.

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

NOTE

See warning on the restart behaviour in *3.12.1 Terminal 37 Safe Stop Function*

4 FC 300 Selection

4.1 Electrical Data - 200-240 V

	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	3.7
Enclosure IP20/IP21	A2	A2	A2	A2	A2	A2	A2	A3	A3
Enclosure IP20 (FC 301 only)	A1	A1	A1	A1	A1	A1	-	-	-
Enclosure IP55, IP66	A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A5	A5
Output current									
Continuous (3x200-240 V) [A]	1.8	2.4	3.5	4.6	6.6	7.5	10.6	12.5	16.7
Intermittent (3x200-240 V) [A]	2.9	3.8	5.6	7.4	10.6	12.0	17.0	20.0	26.7
Continuous kVA (208 V AC) [kVA]	0.65	0.86	1.26	1.66	2.38	2.70	3.82	4.50	6.00
Max. input current									
Continuous (3x200-240 V) [A]	1.6	2.2	3.2	4.1	5.9	6.8	9.5	11.3	15.0
Intermittent (3x200-240 V) [A]	2.6	3.5	5.1	6.6	9.4	10.9	15.2	18.1	24.0
Additional specifications									
IP20, IP21 max. cable cross section[5)] (mains, motor, brake and load sharing) [mm^2 (AWG)][2)]	4,4,4 (12,12,12) (min. 0.2 (24))								
IP55, IP66 max. cable cross section[5)] (mains, motor, brake and load sharing) [mm^2 (AWG)]	4,4,4 (12,12,12)								
Max. cable cross section[5)]with disconnect	6,4,4 (10,12,12)								
Estimated power loss at rated max. load [W] [4)]	21	29	42	54	63	82	116	155	185
Weight, enclosure IP20 [kg]	4.7	4.7	4.8	4.8	4.9	4.9	4.9	6.6	6.6
A1 (IP20)	2.7	2.7	2.7	2.7	2.7	2.7	-	-	-
A5 (IP55, IP66)	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5
Efficiency [4)]	0.94	0.94	0.95	0.95	0.96	0.96	0.96	0.96	0.96
0.25-3.7 kW only available as 160% high overload.									

Table 4.1 Mains Supply 3x200-240 V AC

	P5K5		P7K5		P11K	
High/Normal Load[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	B1		B1		B2	
Enclosure IP55, IP66	B1		B1		B2	
Output current						
Continuous (3x200-240 V) [A]	24.2	30.8	30.8	46.2	46.2	59.4
Intermittent (60 s overload) (3x200-240 V) [A]	38.7	33.9	49.3	50.8	73.9	65.3
Continuous kVA (208 V AC) [kVA]	8.7	11.1	11.1	16.6	16.6	21.4
Max. input current						
Continuous (3x200-240 V) [A]	22	28	28	42	42	54
Intermittent (60 s overload) (3x200-240 V) [A]	35.2	30.8	44.8	46.2	67.2	59.4
Additional specifications						
IP21 max. cable cross-section[5] (mains, brake, load sharing) [mm^2 (AWG)] [2]	16,10, 16 (6,8,6)		16,10, 16 (6,8,6)		35,-,- (2,-,-)	
IP21 max. cable cross-section[5] (motor) [mm^2 (AWG)] [2]	10,10,- (8,8,-)		10,10,- (8,8,-)		35,25,25 (2,4,4)	
IP20 max. cable cross-section[5] (mains, brake, motor and load sharing)	10,10,- (8,8,-)		10,10,- (8,8,-)		35,-,- (2,-,-)	
Max. cable cross-section with Disconnect [mm^2 (AWG)] [2]	16,10,10 (6,8,8)					
Estimated power loss at rated max. load [W] [4]	239	310	371	514	463	602
Weight, enclosure IP21, IP55, IP66 [kg]	23		23		27	
Efficiency[4]	0.964		0.959		0.964	

Table 4.2 Mains Supply 3x200-240 V AC

	P15K		P18K		P22K		P30K		P37K	
High/Normal Load[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	C1		C1		C1		C2		C2	
Enclosure IP55, IP66	C1		C1		C1		C2		C2	
Output current										
Continuous (3x200-240 V) [A]	59.4	74.8	74.8	88	88	115	115	143	143	170
Intermittent (60 s overload) (3x200-240 V) [A]	89.1	82.3	112	96.8	132	127	173	157	215	187
Continuous kVA (208 V AC) [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 (3x200-240 V) [A]	54	68	68	80	80	104	104	130	130	154
Intermittent (60 s overload) (3x200-240 V) [A]	81	74.8	102	88	120	114	156	143	195	169
Additional specifications										
IP20 max. cable cross-section[5] (mains, brake, motor and load sharing)	35 (2)		50 (1)		50 (1)		150 (300MCM)		150 (300MCM)	
IP21, IP55, IP66 max. cable cross-section[5] (mains, motor) [mm^2 (AWG)] [2]	50 (1)		50 (1)		50 (1)		150 (300MCM)		150 (300MCM)	
IP21, IP55, IP66 max. cable cross-section[5] (brake, load sharing) [mm^2 (AWG)] [2]	50 (1)		50 (1)		50 (1)		95 (3/0)		95 (3/0)	
Max cable size with mains disconnect [mm^2 (AWG)] [2]	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] [4]	624	737	740	845	874	1140	1143	1353	1400	1636
Weight, enclosure IP21, IP55/IP66 [kg]	45		45		45		65		65	
Efficiency[4]	0.96		0.97		0.97		0.97		0.97	

Table 4.3 Mains Supply 3x200-240 V AC

For fuse ratings, see 7.2.1 Fuses

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

2) American Wire Gauge.

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

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

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

	PK 37	PK 55	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	4	5.5	7.5
Enclosure IP20/IP21	A2	A2	A2	A2	A2	A2	A2	A2	A3	A3
Enclosure IP20 (FC 301 only)	A1	A1	A1	A1	A1					
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 (3x380-440 V) [A]	1.3	1.8	2.4	3	4.1	5.6	7.2	10	13	16
Intermittent (3x380-440 V) [A]	2.1	2.9	3.8	4.8	6.6	9.0	11.5	16	20.8	25.6
Continuous (3x441-500 V) [A]	1.2	1.6	2.1	2.7	3.4	4.8	6.3	8.2	11	14.5
Intermittent (3x441-500 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 AC) [kVA]	0.9	1.3	1.7	2.1	2.8	3.9	5.0	6.9	9.0	11.0
Continuous kVA (460 V AC) [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 (3x380-440 V) [A]	1.2	1.6	2.2	2.7	3.7	5.0	6.5	9.0	11.7	14.4
Intermittent (3x380-440 V) [A]	1.9	2.6	3.5	4.3	5.9	8.0	10.4	14.4	18.7	23.0
Continuous (3x441-500 V) [A]	1.0	1.4	1.9	2.7	3.1	4.3	5.7	7.4	9.9	13.0
Intermittent (3x441-500 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[5)] (mains, motor, brake and load sharing) [mm² (AWG)][2)]	4,4,4 (12,12,12) (min. 0.2(24))									
IP55, IP66 max. cable cross section[5)] (mains, motor, brake and load sharing) [mm² (AWG)]	4,4,4 (12,12,12)									
Max. cable cross section[5)]with disconnect	6,4,4 (10,12,12)									
Estimated power loss at rated max. load [W] [4)]	35	42	46	58	62	88	116	124	187	255
Weight, enclosure IP20	4.7	4.7	4.8	4.8	4.9	4.9	4.9	4.9	6.6	6.6
Enclosure IP55, IP66	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	14.2	14.2
Efficiency [4)]	0.93	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.97
0.37-7.5 kW only available as 160% high overload.										

Table 4.4 Mains Supply 3x380-500 V AC (FC 302), 3x380-480 V AC (FC 301)

	P11K		P15K		P18K		P22K	
High/Normal Load[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 (3x380-440 V) [A]	24	32	32	37.5	37.5	44	44	61
Intermittent (60 s overload) (3x380-440 V) [A]	38.4	35.2	51.2	41.3	60	48.4	70.4	67.1
Continuous (3x441-500 V) [A]	21	27	27	34	34	40	40	52
Intermittent (60 s overload) (3x441-500 V) [A]	33.6	29.7	43.2	37.4	54.4	44	64	57.2
Continuous kVA (400 V AC) [kVA]	16.6	22.2	22.2	26	26	30.5	30.5	42.3
Continuous kVA (460 V AC) [kVA]		21.5		27.1		31.9		41.4
Max. input current								
Continuous (3x380-440 V) [A]	22	29	29	34	34	40	40	55
Intermittent (60 s overload) (3x380-440 V) [A]	35.2	31.9	46.4	37.4	54.4	44	64	60.5
Continuous (3x441-500 V) [A]	19	25	25	31	31	36	36	47
Intermittent (60 s overload) (3x441-500 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[5)] (mains, brake, load sharing) [mm^2 (AWG)] [2)]	16, 10, 16 (6, 8, 6)		16, 10, 16 (6, 8, 6)		35,-,-(2,-,-)		35,-,-(2,-,-)	
IP21, IP55, IP66 max. cable cross-section[5)] (motor) [mm^2 (AWG)] [2)]	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[5)] (mains, brake, motor and load sharing)	10, 10,- (8, 8,-)		10, 10,- (8, 8,-)		35,-,-(2,-,-)		35,-,-(2,-,-)	
Max. cable cross-section with Disconnect [mm^2 (AWG)] [2)]	16, 10, 10 (6, 8, 8)							
Estimated power loss at rated max. load [W] [4)]	291	392	379	465	444	525	547	739
Weight, enclosure IP20 [kg]	12		12		23.5		23.5	
Weight, enclosure IP21, IP55, 66 [kg]	23		23		27		27	
Efficiency[4)]	0.98		0.98		0.98		0.98	

Table 4.5 Mains Supply 3x380-500 V AC (FC 302), 3x380-480 V AC (FC 301)

4

	P30K		P37K		P45K		P55K		P75K	
High/Normal Load[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 IP20	B4		C3		C3		C4		C4	
Enclosure IP21	C1		C1		C1		C2		C2	
Enclosure IP55, IP66	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 (3x441-500 V) [A]	52	65	65	80	80	105	105	130	130	160
Intermittent (60 s overload) (3x441-500 V) [A]	78	71.5	97.5	88	120	116	158	143	195	176
Continuous kVA (400 V AC) [kVA]	42.3	50.6	50.6	62.4	62.4	73.4	73.4	102	102	123
Continuous kVA (460 V AC) [kVA]		51.8		63.7		83.7		104		128
Max. 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 (3x441-500 V) [A]	47	59	59	73	73	95	95	118	118	145
Intermittent (60 s overload) (3x441-500 V) [A]	70.5	64.9	88.5	80.3	110	105	143	130	177	160
Additional specifications										
IP20 max. cable cross-section[5] (mains and motor)	35 (2)		50 (1)		50 (1)		150 (300 MCM)		150 (300 MCM)	
IP20 max. cable cross-section[5] (brake and load sharing)	35 (2)		50 (1)		50 (1)		95 (4/0)		95 (4/0)	
IP21, IP55, IP66 max. cable cross-section[5] (mains, motor) [mm^2 (AWG)] [2]	50 (1)		50 (1)		50 (1)		150 (300 MCM)		150 (300MCM)	
IP21, IP55, IP66 max. cable cross-section[5] (brake, load sharing) [mm^2 (AWG)] [2]	50 (1)		50 (1)		50 (1)		95 (3/0)		95 (3/0)	
Max cable size with mains disconnect [mm^2 (AWG)] [2]	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] [4]	570	698	697	843	891	1083	1022	1384	1232	1474
Weight, enclosure IP21, IP55, IP66 [kg]	45		45		45		65		65	
Efficiency[4]	0.98		0.98		0.98		0.98		0.99	

Table 4.6 Mains Supply 3x380-500 V AC (FC 302), 3x380-480 V AC (FC 301)

For fuse ratings, see 7.2.1 Fuses

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

2) American Wire Gauge.

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

4) The typical power loss is at nominal load conditions and expected to be within ±15% (tolerence relates to variety in voltage and cable conditions).
Values are based on a typical motor efficiency (eff2/eff3 border line). Motors with lower efficiency will also add to the power loss in the frequency converter and opposite.
If the switching frequency is increased compared to the default setting, the power losses may rise significantly.

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

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

	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 (3x525-550 V) [A]	1.8	2.6	2.9	4.1	5.2	6.4	9.5	11.5
Intermittent (3x525-550 V) [A]	2.9	4.2	4.6	6.6	8.3	10.2	15.2	18.4
Continuous (3x551-600 V) [A]	1.7	2.4	2.7	3.9	4.9	6.1	9.0	11.0
Intermittent (3x551-600 V) [A]	2.7	3.8	4.3	6.2	7.8	9.8	14.4	17.6
Continuous kVA (525 V AC) [kVA]	1.7	2.5	2.8	3.9	5.0	6.1	9.0	11.0
Continuous kVA (575 V AC) [kVA]	1.7	2.4	2.7	3.9	4.9	6.1	9.0	11.0
Max. input current								
Continuous (3x525-600 V) [A]	1.7	2.4	2.7	4.1	5.2	5.8	8.6	10.4
Intermittent (3x525-600 V) [A]	2.7	3.8	4.3	6.6	8.3	9.3	13.8	16.6
Additional specifications								
IP20, IP21 max. cable cross section[5)] (mains, motor, brake and load sharing) [mm^2 (AWG)][2)]	4,4,4 (12,12,12) (min. 0.2 (24))							
IP55, IP66 max. cable cross section[5)] (mains, motor, brake and load sharing) [mm^2 (AWG)]	4,4,4 (12,12,12)							
Max. cable cross section[5)]with disconnect	6,4,4 (10,12,12)							
Estimated power loss at rated max. load [W] [4)]	35	50	65	92	122	145	195	261
Weight, Enclosure IP20 [kg]	6.5	6.5	6.5	6.5	6.5	6.5	6.6	6.6
Weight, enclosure IP55 [kg]	13.5	13.5	13.5	13.5	13.5	13.5	14.2	14.2
Efficiency [4)]	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97

Table 4.7 Mains Supply 3x525-600 V AC (FC 302 only)

	P11K		P15K		P18K		P22K		P30K	
High/Normal Load[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 IP21, IP55, IP66	B1		B1		B2		B2		C1	
Enclosure IP20	B3		B3		B4		B4		B4	
Output current										
Continuous (3x525-550 V) [A]	19	23	23	28	28	36	36	43	43	54
Intermittent (3x525-550 V) [A]	30	25	37	31	45	40	58	47	65	59
Continuous (3x551-600 V) [A]	18	22	22	27	27	34	34	41	41	52
Intermittent (3x551-600 V) [A]	29	24	35	30	43	37	54	45	62	57
Continuous kVA (550 V AC) [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 AC) [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										
IP21, IP55, IP66 max. cable cross-section[5)] (mains, brake, load sharing) [mm² (AWG)] [2)]	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[5)] (motor) [mm² (AWG)] [2)]	10, 10,- (8, 8,-)		10, 10,- (8, 8,-)		35, 25, 25 (2, 4, 4)		35, 25, 25 (2, 4, 4)		50,-,- (1,-,-)	
IP20 max. cable cross-section[5)] (mains, brake, motor and load sharing)	10, 10,- (8, 8,-)		10, 10,- (8, 8,-)		35,-,-(2,-,-)		35,-,-(2,-,-)		35,-,-(2,-,-)	
Max. cable cross-section with Disconnect [mm² (AWG)] [2)]	16, 10, 10 (6, 8, 8)								50, 35, 35 (1,2, 2)	
Estimated power loss at rated max. load [W] [4)]	225		285		329		700		700	
Weight, enclosure IP21, [kg]	23		23		27		27		27	
Weight, enclosure IP20 [kg]	12		12		23.5		23.5		23.5	
Efficiency [4)]	0.98		0.98		0.98		0.98		0.98	

Table 4.8 Mains Supply 3x525-600 V AC (FC 302 only)

	P37K		P45K		P55K		P75K	
High/Normal Load 1)	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft Output [kW]	37	45	45	55	55	75	75	90
Enclosure IP21, IP55, IP66	C1	C1	C1		C2		C2	
Enclosure IP20	C3	C3	C3		C4		C4	
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 (3x551-600 V) [A]	52	62	62	83	83	100	100	131
Intermittent (3x551-600 V) [A]	78	68	93	91	125	110	150	144
Continuous kVA (550 V AC) [kVA]	51.4	61.9	61.9	82.9	82.9	100.0	100.0	130.5
Continuous kVA (575 V AC) [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 5) (mains and motor)	50 (1)				150 (300 MCM)			
IP20 max. cable cross-section 5) (brake and load sharing)	50 (1)				95 (4/0)			
IP21, IP55, IP66 max. cable cross-section 5) (mains, motor) [mm^2 (AWG)] 2)	50 (1)				150 (300 MCM)			
IP21, IP55, IP66 max. cable cross-section 5) (brake, load sharing) [mm^2 (AWG)] 2)	50 (1)				95 (4/0)			
Max cable size with mains disconnect [mm^2 (AWG)] 2)	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] 4)	850		1100		1400		1500	
Weight, enclosure IP20 [kg]	35		35		50		50	
Weight, enclosure IP21, IP55 [kg]	45		45		65		65	
Efficiency 4)	0.98		0.98		0.98		0.98	

Table 4.9 Mains Supply 3x525-600 V AC (FC 302 only)

	P1K1	P1K5	P2K2	P3K0	P4K0	P5K5	P7K5
Typical Shaft Output [kW]	1.1	1.5	2.2	3	4	5.5	7.5
Enclosure IP20 (only)	A3	A3	A3	A3	A3	A3	A3
Output current High overload 160% 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]	3.4	4.3	6.2	7.8	9.8	14.4	17.6
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]	2.6	3.5	5.1	7.2	8.8	12	16
Continuous kVA 525 V AC	1.9	2.5	3.5	4.5	5.5	8.2	10
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]	3.0	3.9	5.6	7.1	8.8	13	16
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]	2.3	3.2	4.6	6.5	7.9	10.8	14.4
Additional specifications							
IP20 max. cable cross section[5)] (mains, motor, brake and load sharing) [mm^2 (AWG)]	0.2-4 (24-12)						
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 4.10 A3 Frame,
Mains Supply 3x525-690 V AC IP20/Protected Chassis

	P11K		P15K		P18K		P22K	
High/Normal Load[1)]	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 575 V [hp]	11	15	15	20	20	25	25	30
Typical Shaft output at 690 V [kW]	11	15	15	18.5	18.5	22	22	30
Enclosure IP21, IP55	B2		B2		B2		B2	
Output current								
Continuous (3x525-550 V) [A]	14	19	19	23	23	28	28	36
Intermittent (60 s overload) (3x525-550 V) [A]	22.4	20.9	30.4	25.3	36.8	30.8	44.8	39.6
Continuous (3x551-690 V) [A]	13	18	18	22	22	27	27	34
Intermittent (60 s overload) (3x551-690 V) [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 575 V) [KVA]	12.9	17.9	17.9	21.9	21.9	26.9	26.9	33.9
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 (3x525-690 V) [A]	15	19.5	19.5	24	24	29	29	36
Intermittent (60 s overload) (3x525-690 V) [A]	23.2	21.5	31.2	26.4	38.4	31.9	46.4	39.6
Additional specifications								
Max. cable cross section (mains, load share and brake) [mm^2 (AWG)]	35,-,- (2,-,-)							
Max. cable cross section (motor) [mm^2 (AWG)]	35, 25, 25 (2, 4, 4)							
Max cable size with mains disconnect [mm^2 (AWG)] [2)]	16,10,10 (6,8, 8)							
Estimated power loss at rated max. load [W][4)]	228		285		335		375	
Weight, enclosure IP21, IP55 [kg]	27							
Efficiency[4)]	0.98		0.98		0.98		0.98	

Table 4.11 B2 Frame,
Mains Supply 3x525-690 V AC IP21/IP55 - NEMA 1/NEMA 12 (FC 302 only)

	P30K		P37K		P45K		P55K		P75K	
High/Normal Load*	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 575 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
Enclosure IP21, IP55	C2		C2		C2		C2		C2	
Output current										
Continuous (3x525-550 V) [A]	36	43	43	54	54	65	65	87	87	105
Intermittent (60 s overload) (3x525-550 V) [A]	54	47.3	64.5	59.4	81	71.5	97.5	95.7	130.5	115.5
Continuous (3x551-690 V) [A]	34	41	41	52	52	62	62	83	83	100
Intermittent (60 s overload) (3x551-690 V) [A]	51	45.1	61.5	57.2	78	68.2	93	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	100.0
Continuous KVA (at 575 V) [KVA]	33.9	40.8	40.8	51.8	51.8	61.7	61.7	82.7	82.7	99.6
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	49	49	59	59	71	71	87	87	99
Continuous (at 575 V) [A]	54	53.9	72	64.9	87	78.1	105	95.7	129	108.9
Additional specifications										
Max. cable cross section (mains and motor) [mm² (AWG)]	150 (300 MCM)									
Max. cable cross section (load share and brake) [mm² (AWG)]	95 (3/0)									
Max cable size with mains disconnect [mm² (AWG)] 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] 4)	480		592		720		880		1200	
Weight, enclosure IP21, IP55 [kg]	65									
Efficiency4)	0.98		0.98		0.98		0.98		0.98	

Table 4.12 C2 Frame,
Mains Supply 3x525-690 V AC IP21/IP55 - NEMA 1/NEMA 12 (FC 302 only)

	P37K		P45K	
High/Normal Load[1)]	HO	NO	HO	NO
Typical Shaft output at 550 V [kW]	30	37	37	45
Typical Shaft output at 575 V [hp]	40	50	50	60
Typical Shaft output at 690 V [kW]	37	45	45	55
Enclosure IP20 only	C3		C3	
Output current 150% for 1 min (HO), 110% for 1 min (NO)				
Continuous (3x525-550 V) [A]	43	54	54	65
Intermittent (60 s overload) (3x525-550 V) [A]	64.5	59.4	81	71.5
Continuous (3x551-690 V) [A]	41	52	52	62
Intermittent (60 s overload) (3x551-690 V) [A]	61.5	57.2	78	68.2
Continuous KVA (at 550 V) [KVA]	41	51.4	51.4	62
Continuous KVA (at 690 V) [KVA]	49	62.2	62.2	74.1
Max. input current				
Continuous (at 550 V) [A]	41.5	52.1	52.1	62.7
Intermittent (at 550 V) [A]	62.2	57.3	78.1	68.9
Continuous (at 690 V) [A]	39.5	50.1	50.1	59.8
Intermittent (at 690 V) [A]	59.3	55.1	75.2	65.8
Additional specifications				
Max. cable cross section (mains, load share and brake) [mm^2 (AWG)]	50 (1)			
Max. cable cross section (motor) [mm^2 (AWG)]	50 (1)			
Estimated power loss at rated max. load [W] [4)]	592		720	
Weight, enclosure IP20 [kg]	35		35	
Efficiency[4)]	0.98		0.98	

Table 4.13 C3 Frame,
Mains Supply 3x525-690 V AC IP20/Protected Chassis (FC 302 only)

For fuse ratings, see 7.2.1 Fuses

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

[2)] American Wire Gauge.

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

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

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

4

4.2 General Specifications

Mains supply

Supply Terminals (6-Pulse)	L1, L2, L3
Supply Terminals (12-Pulse)	L1-1, L2-1, L3-1, L1-2, L2-2, L3-2
Supply voltage	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.

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.

Motor output (U, V, W)

Output voltage	0-100% of supply voltage
Output frequency (0.25-75 kW)	0-590 Hz
Output frequency in Flux Mode	0-300 Hz
Switching on output	Unlimited
Ramp times	0.01-3600 s

1) Voltage and power dependent

Torque characteristics

Starting torque (constant torque)	maximum 160% for 60 s[1)] 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^{plus} (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.

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 3.12 Safe Stop for further information about terminal 37 and Safe Stop.

4) When using a contactor with a DC coil inside in combination with Safe Stop, it is important to make a return way for the current from the coil when turning it off. This can be done by using a freewheel diode (or, alternatively, a 30 or 50 V MOV for quicker response time) across the coil. Typical contactors can be bought with this diode.

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.

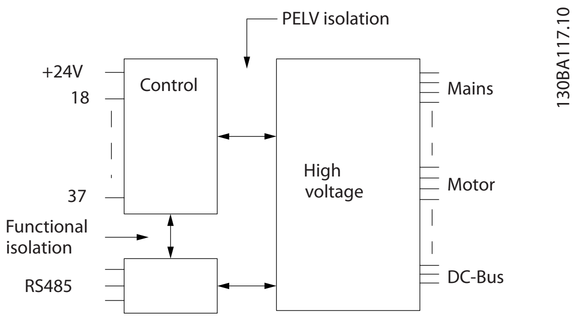


Illustration 4.1 PELV Isolation

Pulse/encoder inputs	
Programmable pulse/encoder inputs	2/1
Terminal number pulse/encoder	29[1], 33[2] / 32[3], 33[3]
Max. frequency at terminal 29, 32, 33	110 kHz (Push-pull driven)
Max. frequency at terminal 29, 32, 33	5 kHz (open collector)
Min. frequency at terminal 29, 32, 33	4 Hz
Voltage level	see 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

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.

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 AC2A

Cable lengths and cross sections for control cables[1]	
Max. motor cable length, screened	150 m
Max. motor cable length, unscreened	300 m
Maximum cross section to control terminals, flexible/rigid wire without cable end sleeves	1.5 mm^2/16 AWG
Maximum cross section to control terminals, flexible wire with cable end sleeves	1 mm^2/18 AWG
Maximum cross section to control terminals, flexible wire with cable end sleeves with collar	0.5 mm^2/20 AWG
Minimum cross section to control terminals	0.25 mm^2/24 AWG

[1]For power cables, see 4.1 Electrical Data - 200-240 V.

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

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Environment	
Enclosure	IP20[1)]/Type 1, IP21[2)]/Type 1, IP55/Type 12, IP66
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[3)]	Max. 50 °C (24-hour average maximum 45 °C)

[1)] Only for ≤ 3.7 kW (200-240 V), ≤ 7.5 kW (400-480/500 V)
[2)] As enclosure kit for ≤ 3.7 kW (200-240 V), ≤ 7.5 kW (400-480/500 V)
[3)] Derating for high ambient temperature, see special conditions in the Design Guide

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

Derating for high altitude, see special conditions in the Design Guide.

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

See section on special conditions in 4.6 Special Conditions.

4.2.1 Measured Values for dU/dt Testing

Measured values for dv/dt test results

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 4.14 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 4.15 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 4.16 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 4.17 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 4.18 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 4.19 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 4.20 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 4.21 P37KT2

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 4.22 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 4.23 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 4.24 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 4.25 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 4.26 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 4.27 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 4.28 P22KT4

Cable length [m]	Mains voltage	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 4.29 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 4.30 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 4.31 P45KT4

Cable length [m]	Mains voltage [V]	Rise time [μs]	Upeak [kV]	du/dt [kV/μs]
5	480	0.371	1.170	2.523

Table 4.32 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 4.33 P75KT5

4.3 Efficiency

Efficiency of the frequency converter
The load on the frequency converter has little effect on its efficiency. In general, the efficiency is the same as the rated motor frequency $f_{M,N}$, if the motor is supplying 100% of the rated shaft torque or less, such as in case of part loads.

This also means that the 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 of above 5 kHz. The efficiency is also slightly reduced when the mains voltage is 480 V, or the motor cable is longer than 30 m.

Efficiency calculation
Calculate the efficiency of the frequency converter at different loads based on *Illustration 4.2*. Multiply the factor in this graph with the specific efficiency factor listed in *4.2 General Specifications*.

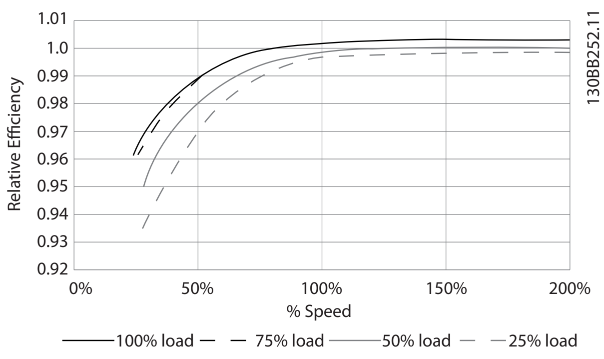

Illustration 4.2 Typical Efficiency Curves

Example: Assume a 55 kW, 380-480 V AC converter with 25% load at 50% speed. The graph is showing 0.97 rated efficiency for a 55 kW converter is 0.98. The actual efficiency is then: 0.97 x 0.98=0.95.

Efficiency of the motor
The efficiency of a motor connected to the converter depends on magnetizing level. In general, the efficiency equals the mains. 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.

Efficiency of the system
To calculate the system efficiency, the efficiency of the converter is multiplied by the efficiency of the motor.

4.4 Acoustic noise

Acoustic noise from the frequency converter comes from three sources

- DC link (intermediate circuit) coils
- RFI filter choke
- Internal fans

See *Table 4.34* for acoustic noise ratings.

Frame size	50% fan speed [dBA]	Full fan speed [dBA]
A1	51	60
A2	51	60
A3	51	60
A5	54	63
B1	61	67
B2	58	70
C1	52	62
C2	55	65
C4	56	71

Table 4.34 Acoustic Noise Ratings

Values are measured 1 m from the unit.

4.5 dU/dt Conditions

To avoid damage to motors without phase insulation paper or other insulation reinforcement designed for frequency converter operation, it is strongly recommend to install a dU/dt filter or LC filter on the output of the 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 intermediate circuit.

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 FC frequency converter complies with IEC 60034-25 and IEC 60034-17 for motor design.

4.6 Special Conditions

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

4.6.1 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

4.6.2 Derating for Ambient Temperature, Frame Size A

60° AVM - Pulse Width Modulation

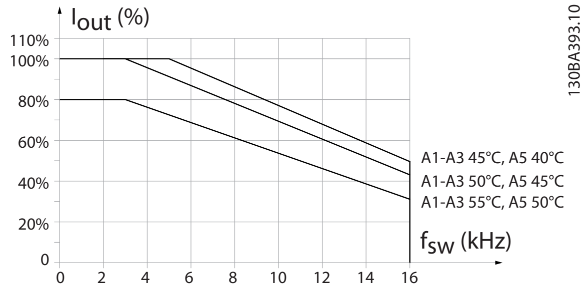

Illustration 4.3 Derating of I_{out} for different $T_{AMB,\ MAX}$ for frame size A, using 60° AVM

SFAVM - Stator Frequency Asyncron Vector Modulation

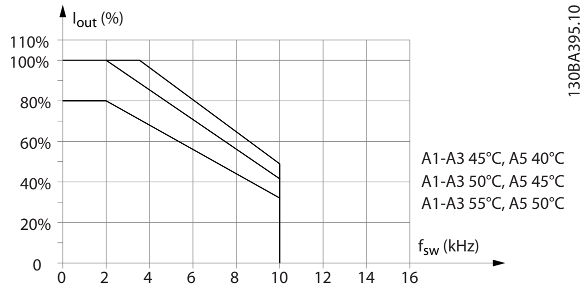

Illustration 4.4 Derating of I_{out} for different $T_{AMB,\ MAX}$ for frame size A, using SFAVM

When using only 10 m motor cable or less in frame 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

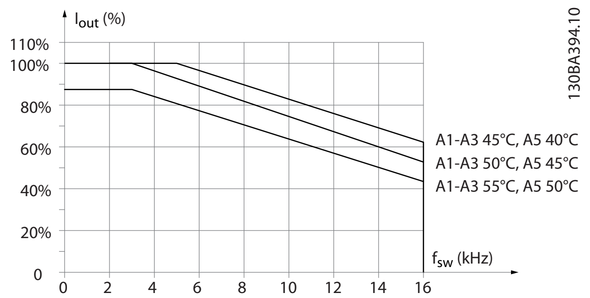

Illustration 4.5 Derating of I_{out} for different $T_{AMB,\ MAX}$ for frame size A, using 60° AVM and maximum 10 m motor cable

4

SFAVM

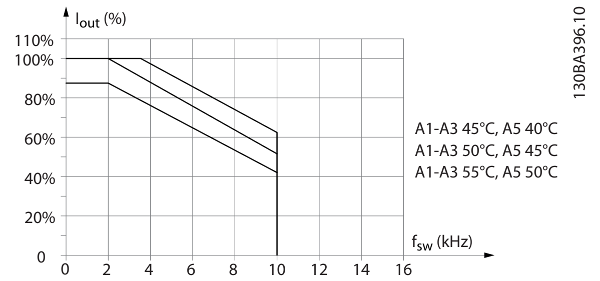

Illustration 4.6 Derating of I_{out} for different $T_{AMB, MAX}$ for frame size A, using SFAVM and maximum 10 m motor cable

4.6.3 Derating for Ambient Temperature, Frame Size B

4.6.3.1 Frame Size B, T2, T4 and T5

For the B and C frames the derating also depends on the overload mode selected in *1-04 Overload Mode*

60° AVM - Pulse Width Modulation

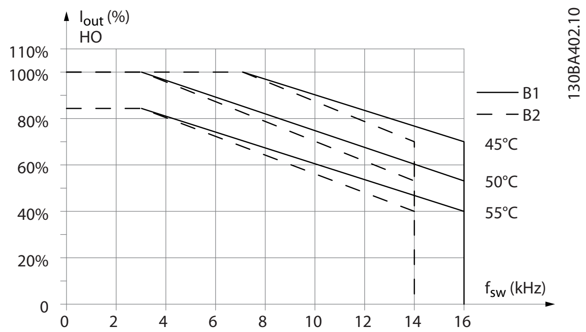

Illustration 4.7 Derating of I_{out} for different $T_{AMB, MAX}$ for frame size B1 and B2, using 60° AVM in High overload mode (160% over torque)

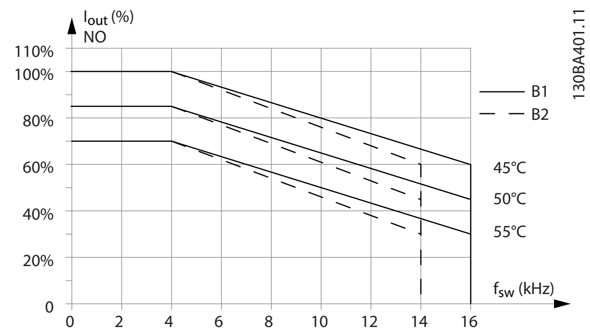

Illustration 4.8 Derating of I_{out} for different $T_{AMB, MAX}$ for frame size B1 and B2, using 60° AVM in Normal overload mode (110% over torque)

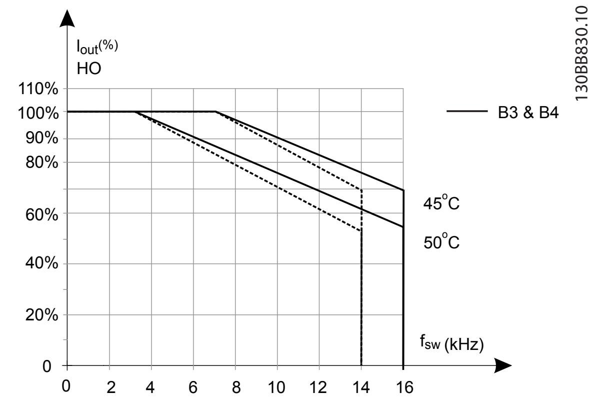

Illustration 4.9 Derating of I_{out} for different $T_{AMB, MAX}$ for frame size B3 and B4, using 60° AVM in High overload mode (160% over torque)

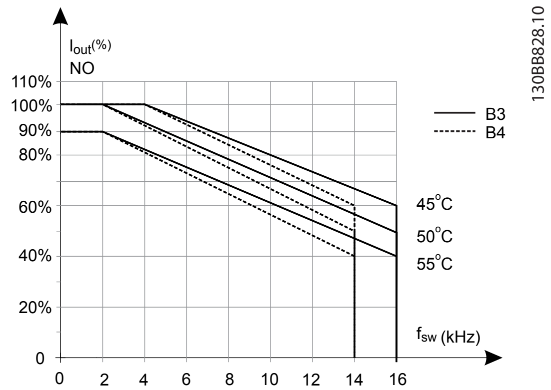

Illustration 4.10 Derating of I_{out} for different $T_{AMB, MAX}$ for frame size B3 and B4, using 60° AVM in Normal overload mode (110% over torque)

SFAVM - Stator Frequency Asyncron Vector Modulation

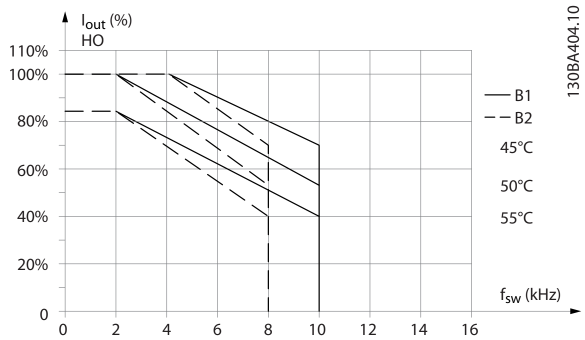

Illustration 4.11 Derating of I_{out} for different $T_{AMB, MAX}$ for frame size B1 and B2, using SFAVM in High overload mode (160% over torque)

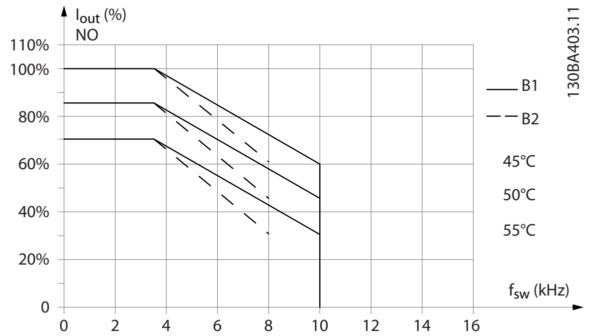

Illustration 4.12 Derating of I_{out} for different $T_{AMB, MAX}$ for frame size B1 and B2, using SFAVM in Normal overload mode (110% over torque)

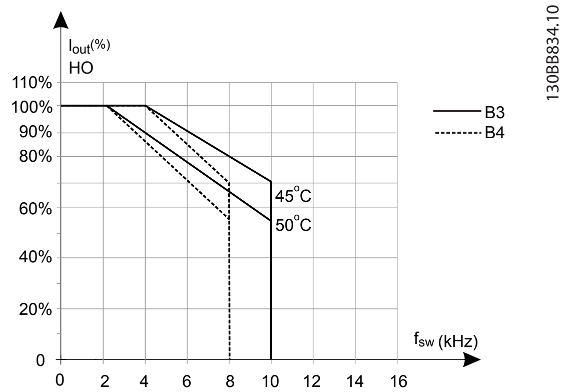

Illustration 4.13 Derating of I_{out} for different $T_{AMB, MAX}$ for frame size B3 and B4, using SFAVM in High overload mode (160% over torque)

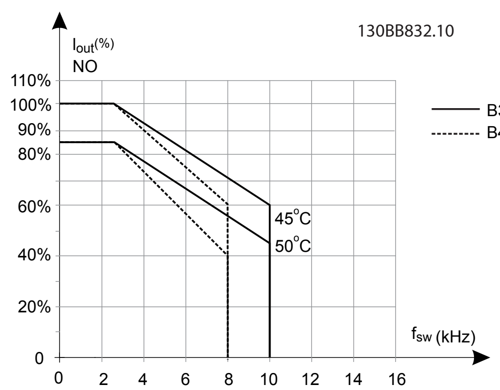

Illustration 4.14 Derating of I_{out} for different $T_{AMB, MAX}$ for frame size B3 and B4, using SFAVM in Normal overload mode (110% over torque)

4.6.3.2 Frame Size B, T6

60° AVM - Pulse Width Modulation

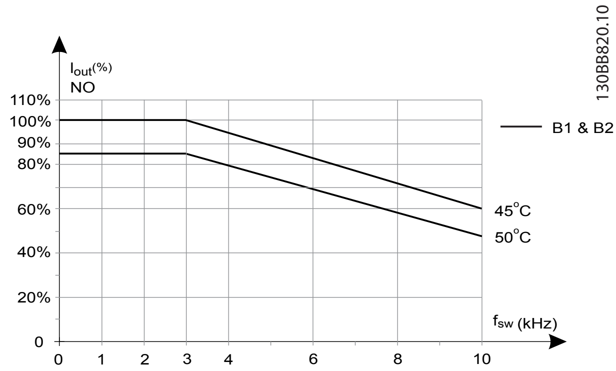

Illustration 4.15 Output current derating with switching frequency and ambient temperature for 600 V frequency converters, frame size B, 60 AVM, NO

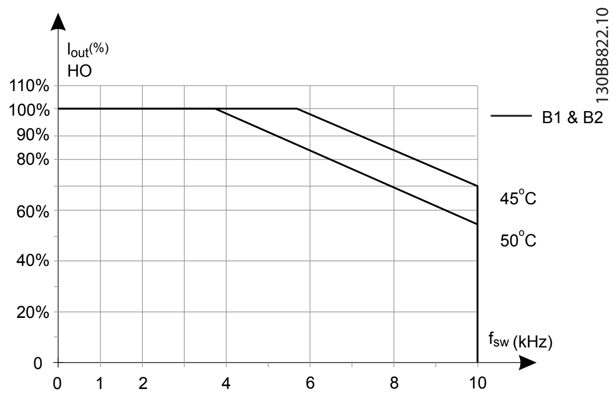

Illustration 4.16 Output current derating with switching frequency and ambient temperature for 600 V frequency converters, frame size B, 60 AVM, HO

SFAVM - Stator Frequency Asyncron Vector Modulation

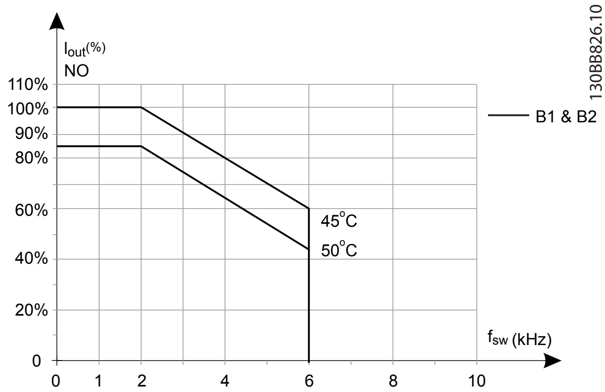

Illustration 4.17 Output current derating with switching frequency and ambient temperature for 600 V frequency converters, frame size B; SFAVM, NO

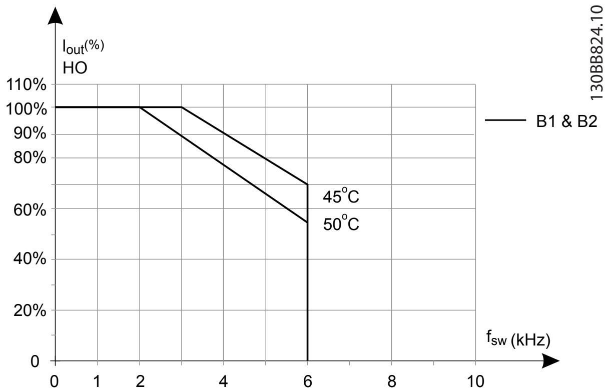

Illustration 4.18 Output current derating with switching frequency and ambient temperature for 600 V frequency converters, frame size B; SFAVM, HO

4.6.3.3 Frame Size B, T7

Frame Size B2, 525-690 V

60° AVM - Pulse Width Modulation

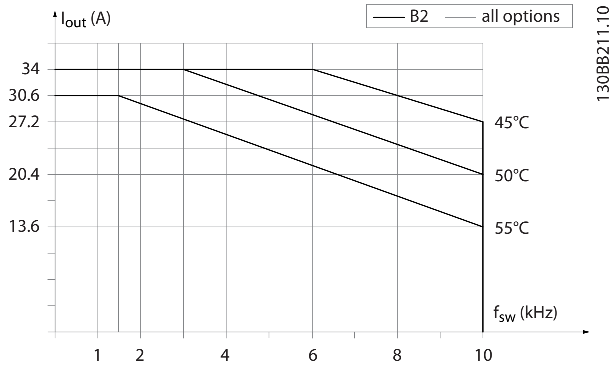

Illustration 4.19 Output current derating with switching frequency and ambient temperature for frame size B2, 60° AVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.

SFAVM - Stator Frequency Asyncron Vector Modulation

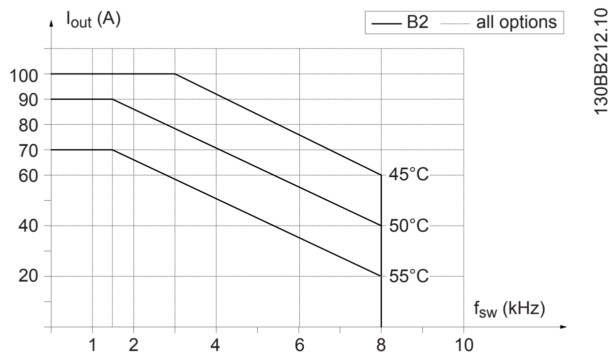

Illustration 4.20 Output current derating with switching frequency and ambient temperature for frame size B2, SFAVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.

4.6.4 Derating for Ambient Temperature, Frame Size C

4.6.4.1 Frame Size C, T2, T4 and T5

60° AVM - Pulse Width Modulation

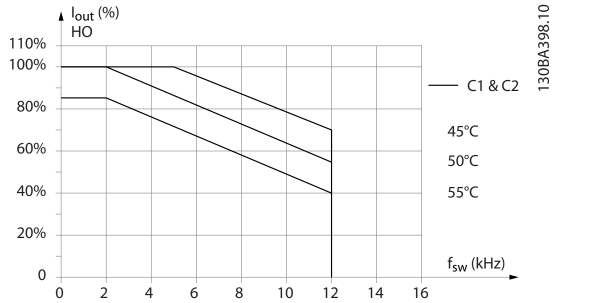

Illustration 4.21 Derating of I_{out} for different $T_{AMB, MAX}$ for frame size C1 and C2, using 60° AVM in High overload mode (160% over torque)

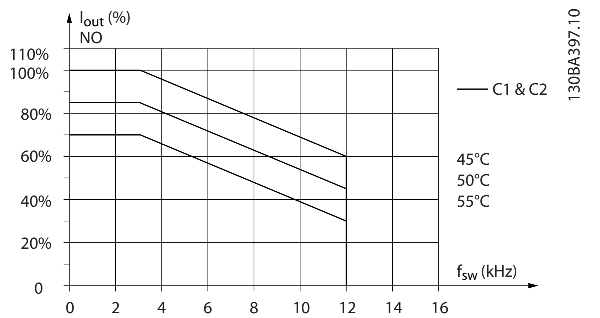

Illustration 4.22 Derating of I_{out} for different $T_{AMB, MAX}$ for frame size C1 and C2, using 60° AVM in Normal overload mode (110% over torque)

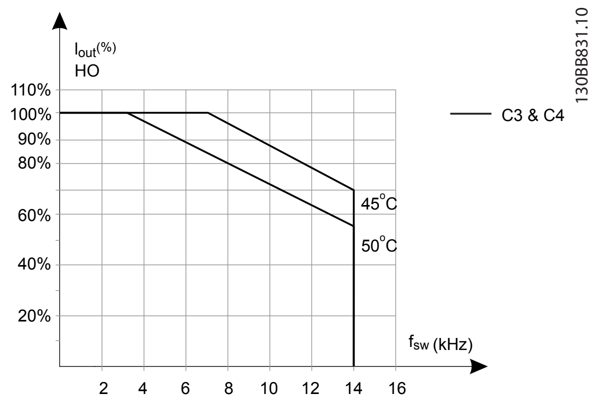

Illustration 4.23 Derating of I_{out} for different $T_{AMB, MAX}$ for frame size C3 and C4, using 60° AVM in High overload mode (160% over torque)

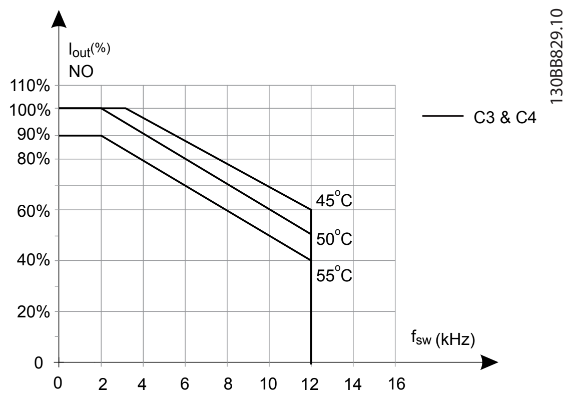

Illustration 4.24 Derating of I_{out} for different $T_{AMB, MAX}$ for frame size C3 and C4, using 60° AVM in Normal overload mode (110% over torque)

SFAVM - Stator Frequency Asyncron Vector Modulation

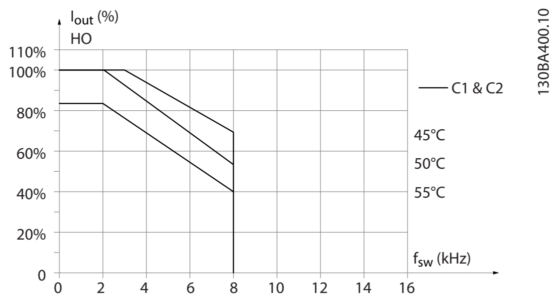

Illustration 4.25 Derating of I_{out} for different $T_{AMB, MAX}$ for frame size C1 and C2, using SFAVM in High overload mode (160% over torque)

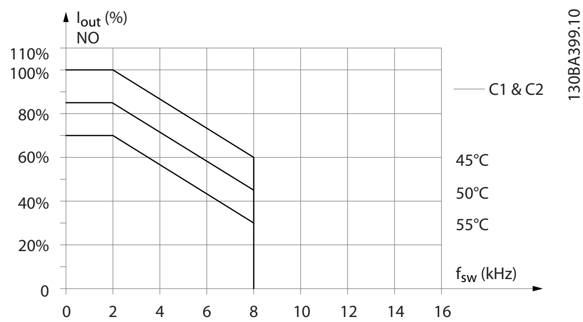

Illustration 4.26 Derating of I_{out} for different $T_{AMB, MAX}$ for frame size C1 and C2, using SFAVM in Normal overload mode (110% over torque)

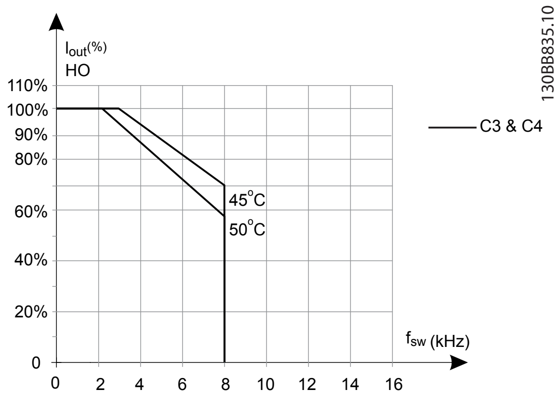

Illustration 4.27 Derating of I_{out} for different $T_{AMB, MAX}$ for frame size C3 and C4, using SFAVM in High overload mode (160% over torque)

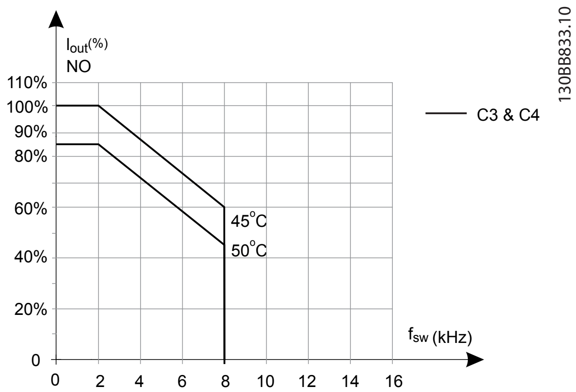

Illustration 4.28 Derating of I_{out} for different $T_{AMB, MAX}$ for frame size C3 and C4, using SFAVM in Normal overload mode (110% over torque)

4.6.4.2 Frame Size C, T6

60° AVM - Pulse Width Modulation

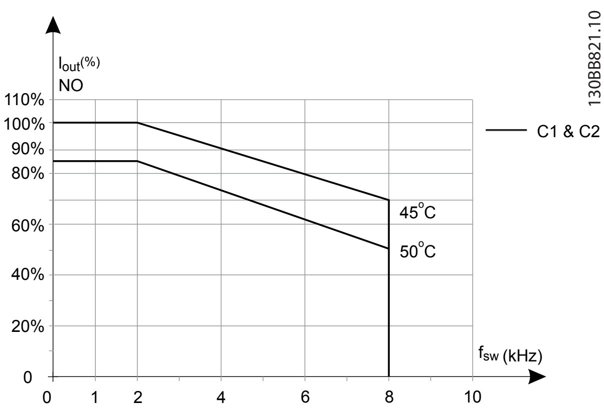

Illustration 4.29 Output current derating with switching frequency and ambient temperature for 600 V frequency converters, frame size C, 60 AVM, NO

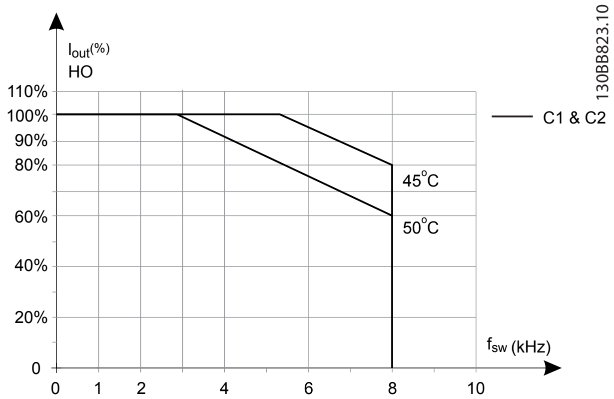

Illustration 4.30 Output current derating with switching frequency and ambient temperature for 600 V frequency converters, frame size C, 60 AVM, HO

SFAVM - Stator Frequency Asyncron Vector Modulation

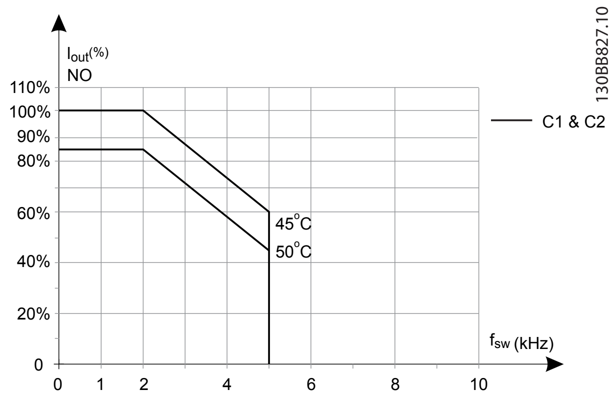

Illustration 4.31 Output current derating with switching frequency and ambient temperature for 600 V frequency converters, frame size C; SFAVM, NO

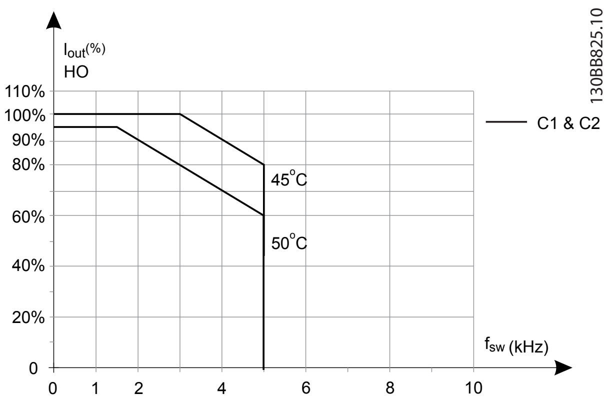

Illustration 4.32 Output current derating with switching frequency and ambient temperature for 600 V frequency converters, frame size C; SFAVM, HO

4.6.4.3 Frame Size C, T7

60° AVM - Pulse Width Modulation

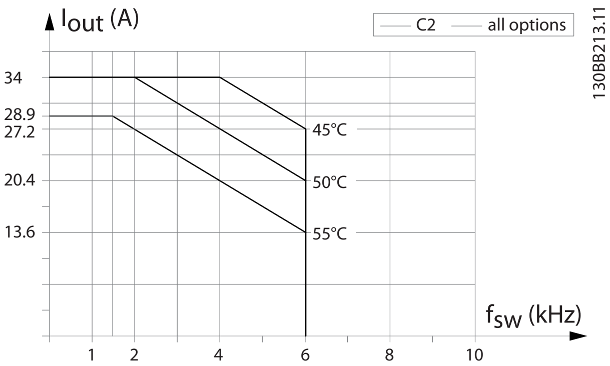

Illustration 4.33 Output current derating with switching frequency and ambient temperature for frame size C2, 60° AVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.

SFAVM - Stator Frequency Asyncron Vector Modulation

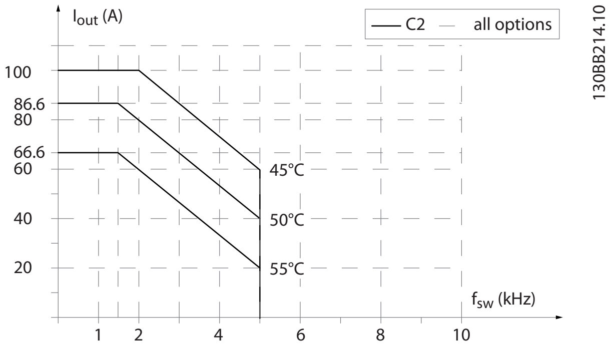

Illustration 4.34 Output current derating with switching frequency and ambient temperature for frame size C2, SFAVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.

4.6.5 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 s 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 choosing a larger motor. However, the design of the 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.

4.6.6 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 4.35*.

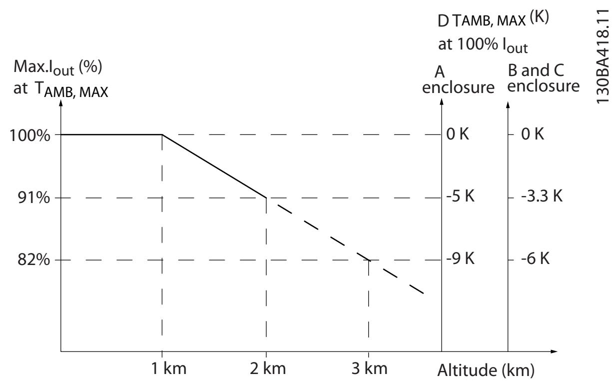

Illustration 4.35 Derating of output current versus altitude at $T_{AMB, MAX}$ for frame sizes A, B and C. At altitudes above 2 km, contact Danfoss regarding PELV.

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 km is elaborated for a B-frame 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.

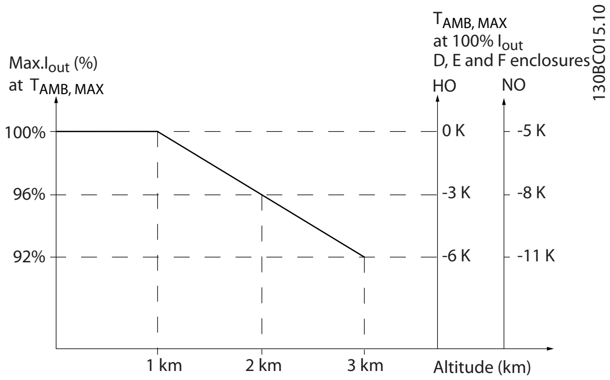

Illustration 4.36 Derating of output current versus altitude at $T_{AMB, MAX}$ for frame sizes D, E and F.

4.6.7 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.

NOTE

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

5 How to Order

5.1.1 Ordering from Type Code

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

130BB836.10

Table 5.1

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

Table 5.2

Not all choices/options are available for each FC 301/FC 302 variant. To verify if the appropriate version is available, consult the Drive Configurator on the Internet.

5.1.2 Drive Configurator

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

The FC 300 Series offers standard frequency converters and frequency converters with integral options. To order, send a type code string describing the product to the local Danfoss sales office, i.e.:

FC-302PK75T5E20H1BGCXXXSXXXXA0BXCXXXXD0

The meaning of the characters in the string can be located in the pages containing the ordering numbers in this chapter. In the example above, a Profibus DP V1 and a 24 V back-up option is included in the frequency converter.

Configure the right frequency converter for the right application from the Internet based Drive Configurator and generate the type code string. The Drive Configurator will automatically generate an eight-digit sales number to be delivered to your local sales office.
Furthermore, it is possible to establish a project list with several products and send it to a Danfoss sales representative.

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

frequency converters will automatically be delivered with a language package relevant to the region from which it is ordered. Four regional language packages cover the following languages:

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

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

Language package 3
English, German, Slovenian, Bulgarian, Serbian, Romanian, Hungarian, Czech and Russian.
Language package 4
English, German, Spanish, English US, Greek, Brazilian Portuguese, Turkish and Polish.
To order frequency converters with a different language package, contact the local sales office.

NOTE

For power sizes over 75 kW, see the VLT® AutomationDrive FC 300 90-1400 kW Design Guide.

5

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	T 2: 200-240V AC T 4: 380-480V AC T 5: 380-500V AC T 6: 525-600V AC T 7: 525-690V AC
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
RFI filter	16-17	H1: RFI filter class A1/B1 H2: RFI filter, class A2 H3: RFI filter class A1/B1 1) H4: RFI filter, class A1 (690 V, FC 302 B2, C2) HX: No filter (600V only)
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 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
Software release	24-27	SXXX: Latest release - standard software
Software language	28	X: Not used

1): FC 301/frame size A1 only
2) US Market only
3): A and B frames have load-sharing built-in by default

Table 5.3 Ordering Type Code Frame Sizes 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 VLT3000 AU: MCA 114 Profibus Converter VLT5000 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

Description	Pos	Possible choices
C0/ E0 options	33-34	CX: No option C4: MCO 305, Programmable Motion Controller BK: MCB 101 General purpose I/O in E0 BZ: MCB 108 Safety PLC Interface in E0
C1 options/ A/B in C Option Adaptor	35	X: No option R: MCB 113 Ext. Relay Card Z: MCA 140 Modbus RTU OEM option E: MCF 106 A/B in C Option Adaptor
C option software/E1 options	36-37	XX: Standard controller 10: MCO 350 Synchronizing control 11: MCO 351 Positioning control 12: MCO 352 Center winder AN: MCA 121 Ethernet IP in E1 BK: MCB 101 General purpose I/O in E1 BZ: MCB 108 Safety PLC Interface in E1
D options	38-39	DX: No option D0: MCB 107 Ext. 24V DC back-up

Table 5.4 Ordering Type Code, Options

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5.2.1 Ordering Numbers: Options and Accessories

Type	Description	Ordering no.	
		Uncoated	Coated
Miscellaneous hardware			
A5 panel through kit	Panel through kit for frame size A5	130B1028	
B1 panel through kit	Panel through kit for frame size B1	130B1046	
B2 panel through kit	Panel through kit for frame size B2	130B1047	
C1 panel through kit	Panel through kit for frame size C1	130B1048	
C2 panel through kit	Panel through kit for frame size C2	130B1049	
MCF 1xx kit	Mounting Brackets frame size A5	130B1080	
MCF 1xx kit	Mounting Brackets frame size B1	130B1081	
MCF 1xx kit	Mounting Brackets frame size B2	130B1082	
MCF 1xx kit	Mounting Brackets frame size C1	130B1083	
MCF 1xx kit	Mounting Brackets frame size C2	130B1084	
IP 21/4X top/TYPE 1 kit	Enclosure, frame size A1: IP21/IP 4X Top/TYPE 1	130B1121	
IP 21/4X top/TYPE 1 kit	Enclosure, frame size A2: IP21/IP 4X Top/TYPE 1	130B1122	
IP 21/4X top/TYPE 1 kit	Enclosure, frame sizeA3: IP21/IP 4X Top/TYPE 1	130B1123	
IP 21/Type 1 Kit, A2 Frame	IP21/NEMA 1 enclosure Top Cover A2	130B1132	
IP 21/Type 1 Kit, A3 Frame	IP21/NEMA 1 enclosure Top Cover A3	130B1133	
MCF 108 Backplate	A5 IP55/ NEMA 12	130B1098	
MCF 108 Backplate	B11 IP21/IP55/NEMA 12	130B3383	
MCF 108 Backplate	B2 IP21/IP55/NEMA 12	130B3397	
MCF 108 Backplate	B4 IP20/Chassis	130B4172	
MCF 108 Backplate	C1 IP21/IP5/NEMA 12	130B3910	
MCF 108 Backplate	C2 IP21/IP55/NEMA 12	130B3911	
MCF 108 Backplate	C3 IP20/Chassis	130B4170	
MCF 108 Backplate	C4 IP20/Chassis	130B4171	
MCF 108 Backplate	A5 IP66/NEMA 4x Stainless steel	130B3242	
MCF 108 Backplate	B1 IP66/NEMA 4x Stainless steel	130B3434	
MCF 108 Backplate	B2 IP66/NEMA 4x Stainless steel	130B3465	
MCF 108 Backplate	C1 IP66/NEMA 4x Stainless steel	130B3468	
MCF 108 Backplate	C2 IP66/NEMA 4x Stainless steel	130B3491	
Profibus D-Sub 9	D-Sub connector kit for IP20, frame sizes A1, A2 and A3	130B1112	
Profibus screen plate	Profibus screen plate kit for IP20, frame sizes A1, A2 and A3	130B0524	
DC link connector	Terminal block for DC link connection on frame size A2/A3	130B1064	
Terminal blocks	Screw terminal blocks for replacing spring loaded terminals 1 pc 10 pin 1 pc 6 pin and 1 pc 3 pin connectors	130B1116	
USB Cable Extension for A5/B1		130B1155	
USB Cable Extension for B2/C1/C2		130B1156	
Footmount frame for flat pack resistors, frame size A2		175U0085	
Footmount frame for flat pack resistors, frame size A3		175U0088	
Footmount frame for 2 flat pack resistors, frame size A2		175U0087	
Footmount frame for 2 flat pack resistors, frame size A3		175U0086	
LCP			
LCP 101	Numerical Local Control Panel (NLCP)	130B1124	
LCP 102	Graphical Local Control Panel (GLCP)	130B1107	
LCP cable	Separate LCP cable, 3 m	175Z0929	
Panel Mounting Kit for all LCP	The kit includes fasteners and gasket. No LCP and no cable included.	130B1170	
Panel Mounting Kit, graphical LCP	The kit includes graphical LCP, fasteners, 3 m cable and gasket.	130B1113	
Panel Mounting Kit, numerical LCP	The kit includes numerical LCP, fasteners, 3 m cable and gasket.	130B1114	

Type	Description	Ordering no.	
		Uncoated	Coated
Panel Mounting Kit for all LCP	The kit includes fasteners, 3 m cable and gasket. There is no LCP included.	130B1117	
Panel Mounting Kit, IP55/IP66	The kit includes fasteners, 8 m cable, gasket and a blind cover to ensure IP55/66 after the LCP has been mounted elsewhere. The 8 m cable is openin one end and the connector block is included in the package. No LCP included.	130B1129	
Blind Cover, IP21	Flat blind cover for IP21	130B1078	
Blind Cover, IP55/66	Deep blind cover for IP55/66	130B1077	
Options for Slot A			
MCA 101	Profibus option DP V0/V1	130B1100	130B1200
MCA 104	DeviceNet option	130B1102	130B1202
MCA 105	CANopen	130B1103	130B1205
MCA 113	Profibus VLT 3000 protocol converter	130B1245	
MCA 114	Profibus VLT 5000 protocol converter		130B1246
MCA 120	PROFINET	130B1135	130B1235
MCA 121	EtherNet/IP	130B1119	130B1219
MCA 122	Modbus TCP	130B1196	130B1296
MCA 123	POWERLINK	130B1489	130B1490
MCA 124	EtherCAT	130B5546	130B5646
MCA 194	DeviceNet Converter	130B1102	130B1202
Options for Slot B			
MCB 101	General purpose Input Output option	130B1125	130B1212
MCB 102	Encoder option	130B1115	130B1203
MCB 103	Resolver option	130B1127	130B1227
MCB 105	Relay option	130B1110	130B1210
MCB 108	Safety PLC interface (DC/DC Converter)	130B1120	130B1220
MCB 112	ATEX PTC Thermistor Card		130B1137
MCB 140	Safe option	130B6443	
MCB 141	External safe option	130B6447	
MCB 150	Safe option TTL		130B3280
MCB 151	Safe option HTL		130B3290
Mounting Kits			
Mounting kit for frame size A2 and A3 (40 mm for one C option)		130B7530	
Mounting kit for frame size A2 and A3 (60 mm for C0 + C1 option)		130B7531	
Mounting kit for frame size A5		130B7532	
Mounting kit for frame size B, C, D, E and F (except B3)		130B7533	
Mounting kit for frame size B3 (40 mm for one C option)		130B1413	
Mounting kit for frame size B3 (60 mm for C0 + C1 option)		130B1414	
Options for Slot C			
MCO 305	Programmable Motion Controller	130B1134	130B1234
MCO 350	Synchronizing controller	130B1152	130B1252
MCO 351	Positioning controller	130B1153	120B1253
MCO 352	Center Winder Controller	130B1165	130B1166
MCB 113	Extended Relay Card	130B1164	130B1264
MCF 106	A/B in C option adaptor	130B1130	130B1230
Option for Slot D			
MCB 107	24 V DC back-up	130B1108	130B1208
External Options			
Ethernet IP	Ethernet master	175N2584	
PC Software			
MCT 10	MCT 10 set-up software - 1 user	130B1000	
MCT 10	MCT 10 set-up software - 5 users	130B1001	

Type	Description	Ordering no.	
		Uncoated	Coated
MCT 10	MCT 10 set-up software - 10 users	130B1002	
MCT 10	MCT 10 set-up software - 25 users	130B1003	
MCT 10	MCT 10 set-up software - 50 users	130B1004	
MCT 10	MCT 10 set-up software - 100 users	130B1005	
MCT 10	MCT 10 set-up software - unlimited users	130B1006	
Options can be ordered as factory built-in options, see ordering information. For information on fieldbus and application option combatibility with older software versions, contact a Danfoss supplier.			

Table 5.5 Ordering Numbers for Options and Accessories

5.2.2 Ordering Numbers: Spare Parts

Type	Description	Ordering no.	
Spare Parts			
Control board FC 302	Coated version	-	130B1109
Control board FC 301	Coated version	-	130B1126
Fan A2	Fan, frame size A2	130B1009	-
Fan A3	Fan, frame size A3	130B1010	-
Fan A5	Fan, frame size A5	130B1017	
Fan B1	Fan, frame size B1 external	130B1013	
Fan option C		130B7534	-
Connectors FC 300 Profibus	10 pieces Profibus connectors	130B1075	
Connectors FC 300 DeviceNet	10 pieces DeviceNet connectors	130B1074	
Connectors FC 302 10 pole	10 pieces 10 pole spring loaded connectors	130B1073	
Connectors FC 301 8 pole	10 pieces 8 pole spring loaded connectors	130B1072	
Connectors FC 300 6 pole	10 pieces 6 pole spring loaded connectors	130B1071	
Connectors FC 300 RS-485	10 pieces 3 pole spring loaded connectors for RS-485	130B1070	
Connectors FC 300 3 pole	10 pieces 3 pole connectors for relay 01	130B1069	
Connectors FC 302 3 pole	10 pieces 3 pole connectors for relay 02	130B1068	
Connectors FC 300 Mains	10 pieces mains connectors IP20/21	130B1067	
Connectors FC 300 Mains	10 pieces mains connctors IP 55	130B1066	
Connectors FC 300 Motor	10 pieces motor connectors	130B1065	
Accessory bag MCO 305		130B7535	

Table 5.6 Ordering Numbers for Spare Parts

5.2.3 Ordering Numbers: Accessory Bags

Type	Description	Ordering no.
Accessory Bags		
Accessory bag A1	Accessory bag, frame size A1	130B1021
Accessory bag A2/A3	Accessory bag, frame size A2/A3	130B1022
Accessory bag A5	Accessory bag, frame size A5	130B1023
Accessory bag A1–A5	Accessory bag, frame size A1-A5 Brake and load sharing connector	130B0633
Accessory bag B1	Accessory bag, frame size B1	130B2060
Accessory bag B2	Accessory bag, frame size B2	130B2061
Accessory bag B3	Accessory bag, frame size B3	130B0980
Accessory bag B4	Accessory bag, frame size B4, 18.5-22 kW	130B1300
Accessory bag B4	Accessory bag, frame size B4, 30 kW	130B1301
Accessory bag C1	Accessory bag, frame size C1	130B0046
Accessory bag C2	Accessory bag, frame size C2	130B0047
Accessory bag C3	Accessory bag, frame size C3	130B0981
Accessory bag C4	Accessory bag, frame size C4, 55 kW	130B0982
Accessory bag C4	Accessory bag, frame size C4, 75 kW	130B0983

Table 5.7 Ordering Numbers for Accessory Bags

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5.2.4 Ordering Numbers: Brake Resistors FC 301

FC 301				Horizontal braking							
Frequency converter data				Brake Resistor data						Installation	
						Ordering no.					
Mains	P_m	R_{min}	$R_{br,nom}$	R_{rec}	$P_{br,cont.}$	Wire IP54	Screw Terminal IP21	Screw Terminal IP65	Screw Terminal IP20	Cable Cross section	Thermal relay
[type]	[kW]	[Ohm]	[Ohm]	[Ohm]	[kW]	[p/n]	[p/n]	[p/n]	[p/n]	[mm²]	[A]
T2	0,25	368	415,9	410	0,100	175u3004	x	x	x	1,5	0,5
T2	0,37	248	280,7	300	0,100	175u3006	x	x	x	1,5	0,6
T2	0,55	166	188,7	200	0,100	175u3011	x	x	x	1,5	0,7
T2	0,75	121	138,4	145	0,100	175u3016	x	x	x	1,5	0,8
T2	1,1	81,0	92,0	100	0,100	175u3021	x	x	x	1,5	0,9
T2	1,5	58,5	66,5	70	0,200	175u3026	x	x	x	1,5	1,6
T2	2,2	40,2	44,6	48	0,200	175u3031	x	x	x	1,5	1,9
T2	3	29,1	32,3	35	0,300	175u3325	x	x	x	1,5	2,7
T2	3,7	22,5	25,9	27	0,360	175u3326	175u3477	175u3478	x	1,5	3,5
T2	5,5	17,7	19,7	18	0,570	175u3327	175u3442	175u3441	x	1,5	5,3
T2	7,5	12,6	14,3	13	0,680	175u3328	175u3059	175u3060	x	1,5	6,8
T2	11	8,7	9,7	9	1,130	175u3329	175u3068	175u3069	x	2,5	10,5
T2	15	5,3	7,5	5,7	1,400	175u3330	175u3073	175u3074	x	4	14,7
T2	18,5	5,1	6,0	5,7	1,700	175u3331	175u3483	175u3484	x	4	16,2
T2	22	3,2	5,0	3,5	2,200	175u3332	175u3080	175u3081	x	6	23,5
T2	30	3,0	3,7	3,5	2,800	175u3333	175u3448	175u3447	x	10	26,5
T2	37	2,4	3,0	2,8	3,200	175u3334	175u3086	175u3087	x	16	31,7
T4	0,37	620	1121,4	1200	0,100	175u3000	x	x	x	1,5	0,3
T4	0,55	620	749,8	850	0,100	175u3001	x	x	x	1,5	0,4
T4	0,75	485	547,6	630	0,100	175u3002	x	x	x	1,5	0,4
T4	1,1	329	365,3	410	0,100	175u3004	x	x	x	1,5	0,5
T4	1,5	240	263,0	270	0,200	175u3007	x	x	x	1,5	0,8
T4	2,2	161	176,5	200	0,200	175u3008	x	x	x	1,5	0,9
T4	3	117	127,9	145	0,300	175u3300	x	x	x	1,5	1,3
T4	4	86,9	94,6	110	0,450	175u3335	175u3450	175u3449	x	1,5	1,9
T4	5,5	62,5	68,2	80	0,570	175u3336	175u3452	175u3451	x	1,5	2,5
T4	7,5	45,3	49,6	56	0,680	175u3337	175u3027	175u3028	x	1,5	3,3
T4	11	34,9	38,0	38	1,130	175u3338	175u3034	175u3035	x	1,5	5,2
T4	15	25,3	27,7	28	1,400	175u3339	175u3039	175u3040	x	1,5	6,7
T4	18,5	20,3	22,3	22	1,700	175u3340	175u3047	175u3048	x	1,5	8,3
T4	22	16,9	18,7	19	2,200	175u3357	175u3049	175u3050	x	1,5	10,1
T4	30	13,2	14,5	14	2,800	175u3341	175u3055	175u3056	x	2,5	13,3
T4	37	10,6	11,7	12	3,200	175u3359	175u3061	175u3062	x	2,5	15,3
T4	45	8,7	9,6	9,5	4,200	x	175u3065	175u3066	x	4	19,7
T4	55	6,6	7,8	7,0	5,500	x	175u3070	175u3071	x	6	26,3
T4	75	4,2	5,7	5,5	7,000	x	x	x	175u3231	10	35,7

Table 5.8 Horizontal Braking

FC 301				Vertical braking							
Frequency converter data				Brake Resistor data						Installation	
				R_{rec}	$P_{br,cont.}$	Ordering no.				Cable Cross section	Thermal relay
Mains	P_m	R_{min}	$R_{br,nom}$			Wire IP54	Screw Terminal IP21	Screw Terminal IP65	Screw Terminal IP20		
[type]	[kW]	[Ohm]	[Ohm]	[Ohm]	[kW]	[p/n]	[p/n]	[p/n]	[p/n]	[mm²]	[A]
T2	0,25	368	415,9	410	0,100	175u3004	x	x	x	1,5	0,5
T2	0,37	248	280,7	300	0,200	175u3096	x	x	x	1,5	0,8
T2	0,55	166	188,7	200	0,200	175u3008	x	x	x	1,5	0,9
T2	0,75	121	138,4	145	0,300	175u3300	x	x	x	1,5	1,3
T2	1,1	81,0	92,0	100	0,450	175u3301	175u3402	175u3401	x	1,5	2
T2	1,5	58,5	66,5	70	0,570	175u3302	175u3404	175u3403	x	1,5	2,7
T2	2,2	40,2	44,6	48	0,960	175u3303	175u3406	175u3405	x	1,5	4,2
T2	3	29,1	32,3	35	1,130	175u3304	175u3408	175u3407	x	1,5	5,4
T2	3,7	22,5	25,9	27	1,400	175u3305	175u3410	175u3409	x	1,5	6,8
T2	5,5	17,7	19,7	18	2,200	175u3306	175u3412	175u3411	x	1,5	10,4
T2	7,5	12,6	14,3	13	3,200	175u3307	175u3414	175u3413	x	2,5	14,7
T2	11	8,7	9,7	9	5,500	x	175u3176	175u3177	x	4	23,2
T2	15	5,3	7,5	5,7	6,000	x	x	x	175u3233	10	32,5
T2	18,5	5,1	6,0	5,7	8,000	x	x	x	175u3234	10	37,6
T2	22	3,2	5,0	3,5	9,000	x	x	x	175u3235	16	50,8
T2	30	3,0	3,7	3,5	14,000	x	x	x	175u3224	25	63,3
T2	37	2,4	3,0	2,8	17,000	x	x	x	175u3227	35	78
T4	0,37	620	1121,4	1200	0,200	175u3101	x	x	x	1,5	0,4
T4	0,55	620	749,8	850	0,200	175u3308	x	x	x	1,5	0,5
T4	0,75	485	547,6	630	0,300	175u3309	x	x	x	1,5	0,7
T4	1,1	329	365,3	410	0,450	175u3310	175u3416	175u3415	x	1,5	1
T4	1,5	240	263,0	270	0,570	175u3311	175u3418	175u3417	x	1,5	1,4
T4	2,2	161	176,5	200	0,960	175u3312	175u3420	175u3419	x	1,5	2,1
T4	3	117	127,9	145	1,130	175u3313	175u3422	175u3421	x	1,5	2,7
T4	4	86,9	94,6	110	1,700	175u3314	175u3424	175u3423	x	1,5	3,7
T4	5,5	62,5	68,2	80	2,200	175u3315	175u3138	175u3139	x	1,5	5
T4	7,5	45,3	49,6	56	3,200	175u3316	175u3428	175u3427	x	1,5	7,1
T4	11	34,9	38,0	38	5,000	x	x	x	175u3236	1,5	11,5
T4	15	25,3	27,7	28	6,000	x	x	x	175u3237	2,5	14,7
T4	18,5	20,3	22,3	22	8,000	x	x	x	175u3238	4	19,1
T4	22	16,9	18,7	19	10,000	x	x	x	175u3203	4	23
T4	30	13,2	14,5	14	14,000	x	x	x	175u3206	10	31,7
T4	37	10,6	11,7	12	17,000	x	x	x	175u3210	10	37,7
T4	45	8,7	9,6	9,5	21,000	x	x	x	175u3213	16	47,1
T4	55	6,6	7,8	7,0	26,000	x	x	x	175u3216	25	61
T4	75	4,2	5,7	5,5	36,000	x	x	x	175u3219	35	81

Table 5.9 Vertical Braking

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5.2.5 Ordering Numbers: Brake Resistors FC 302

FC 302				Horizontal braking							
Frequency converter data				Brake Resistor data						Installation	
						Ordering no.					
Mains	P_m	R_{min}	$R_{br,nom}$	R_{rec}	P_{br},cont.	Wire IP54	Screw Terminal IP21	Screw Terminal IP65	Screw Terminal IP20	Cable Cross section	Thermal relay
[type]	[kW]	[Ohm]	[Ohm]	[Ohm]	[kW]	[p/n]	[p/n]	[p/n]	[p/n]	[mm²]	[A]
T2	0,25	380	475,3	410	0,100	175u3004	x	x	x	1,5	0,5
T2	0,37	275	320,8	300	0,100	175u3006	x	x	x	1,5	0,6
T2	0,55	188	215,7	200	0,100	175u3011	x	x	x	1,5	0,7
T2	0,75	130	158,1	145	0,100	175u3016	x	x	x	1,5	0,8
T2	1,1	81,0	105,1	100	0,100	175u3021	x	x	x	1,5	0,9
T2	1,5	58,5	76,0	70	0,200	175u3026	x	x	x	1,5	1,6
T2	2,2	45,0	51,0	48	0,200	175u3031	x	x	x	1,5	1,9
T2	3	31,5	37,0	35	0,300	175u3325	x	x	x	1,5	2,7
T2	3,7	22,5	29,7	27	0,360	175u3326	175u3477	175u3478	x	1,5	3,5
T2	5,5	17,7	19,7	18	0,570	175u3327	175u3442	175u3441	x	1,5	5,3
T2	7,5	12,6	14,3	13,0	0,680	175u3328	175u3059	175u3060	x	1,5	6,8
T2	11	8,7	9,7	9,0	1,130	175u3329	175u3068	175u3069	x	2,5	10,5
T2	15	5,3	7,5	5,7	1,400	175u3330	175u3073	175u3074	x	4	14,7
T2	18,5	5,1	6,0	5,7	1,700	175u3331	175u3483	175u3484	x	4	16,2
T2	22	3,2	5,0	3,5	2,200	175u3332	175u3080	175u3081	x	6	23,5
T2	30	3,0	3,7	3,5	2,800	175u3333	175u3448	175u3447	x	10	26,5
T2	37	2,4	3,0	2,8	3,200	175u3334	175u3086	175u3087	x	16	31,7
T5	0,37	620	1389,2	1200	0,100	175u3000	x	x	x	1,5	0,3
T5	0,55	620	928,8	850	0,100	175u3001	x	x	x	1,5	0,4
T5	0,75	558	678,3	630	0,100	175u3002	x	x	x	1,5	0,4
T5	1,1	382	452,5	410	0,100	175u3004	x	x	x	1,5	0,5
T5	1,5	260	325,9	270	0,200	175u3007	x	x	x	1,5	0,8
T5	2,2	189	218,6	200	0,200	175u3008	x	x	x	1,5	0,9
T5	3	135	158,5	145	0,300	175u3300	x	x	x	1,5	1,3
T5	4	99,0	117,2	110	0,450	175u3335	175u3450	175u3449	x	1,5	1,9
T5	5,5	72,0	84,4	80	0,570	175u3336	175u3452	175u3451	x	1,5	2,5
T5	7,5	50,0	61,4	56	0,680	175u3337	175u3027	175u3028	x	1,5	3,3
T5	11	36,0	41,2	38	1,130	175u3338	175u3034	175u3035	x	1,5	5,2
T5	15	27,0	30,0	28	1,400	175u3339	175u3039	175u3040	x	1,5	6,7
T5	18,5	20,3	24,2	22	1,700	175u3340	175u3047	175u3048	x	1,5	8,3
T5	22	18,0	20,3	19	2,200	175u3357	175u3049	175u3050	x	1,5	10,1
T5	30	13,4	15,8	14	2,800	175u3341	175u3055	175u3056	x	2,5	13,3
T5	37	10,8	12,7	12	3,200	175u3359	175u3061	175u3062	x	2,5	15,3
T5	45	8,8	10,4	9,5	4,200	x	175u3065	175u3066	x	4	19,7
T5	55	6,5	8,5	7,0	5,500	x	175u3070	175u3071	x	6	26,3
T5	75	4,2	6,2	5,5	7,000	x	x	x	175u3231	10	35,7
T5	90	3,6	5,1	4,7	9,000	x	x	x	175u3079	16	43,8
T6	0,75	620	914,2	850	0,100	175u3001	x	x	x	1,5	0,4
T6	1,1	550	611,3	570	0,100	175u3003	x	x	x	1,5	0,4
T6	1,5	380	441,9	415	0,200	175u3005	x	x	x	1,5	0,7
T6	2,2	260	296,4	270	0,200	175u3007	x	x	x	1,5	0,8
T6	3	189	214,8	200	0,300	175u3342	x	x	x	1,5	1,1
T6	4	135	159,2	145	0,450	175u3343	175u3012	175u3013	x	1,5	1,7
T6	5,5	99,0	114,5	100	0,570	175u3344	175u3136	175u3137	x	1,5	2,3
T6	7,5	69,0	83,2	72	0,680	175u3345	175u3456	175u3455	x	1,5	2,9

FC 302				Horizontal braking							
Frequency converter data				Brake Resistor data						Installation	
						Ordering no.					
Mains	P_m	R_{min}	$R_{br,nom}$	R_{rec}	$P_{br,cont.}$	Wire IP54	Screw Terminal IP21	Screw Terminal IP65	Screw Terminal IP20	Cable Cross section	Thermal relay
[type]	[kW]	[Ohm]	[Ohm]	[Ohm]	[kW]	[p/n]	[p/n]	[p/n]	[p/n]	[mm²]	[A]
T6	11	48,6	56,1	52	1,130	175u3346	175u3458	175u3457	x	1,5	4,4
T6	15	35,1	40,8	38	1,400	175u3347	175u3460	175u3459	x	1,5	5,7
T6	18,5	27,0	32,9	31	1,700	175u3348	175u3037	175u3038	x	1,5	7
T6	22	22,5	27,6	27	2,200	175u3349	175u3043	175u3044	x	1,5	8,5
T6	30	17,1	21,4	19	2,800	175u3350	175u3462	175u3461	x	2,5	11,4
T6	37	13,5	17,3	14	3,200	175u3358	175u3464	175u3463	x	2,5	14,2
T6	45	10,8	14,2	13,5	4,200	x	175u3057	175u3058	x	4	16,5
T6	55	8,8	11,6	11	5,500	x	175u3063	175u3064	x	6	21
T6	75	6,6	8,4	7,0	7,000	x	x	x	175u3245	10	31,7
T7	1,1	620	830	630	0,100	175u3002	x	x	x	1,5	0,4
T7	1,5	513	600	570	0,100	175u3003	x	x	x	1,5	0,4
T7	2,2	340	403	415	0,200	175u3005	x	x	x	1,5	0,7
T7	3	243	292	270	0,300	175u3361	x	x	x	1,5	1
T7	4	180	216	200	0,360	x	175u3009	175u3010	x	1,5	1,3
T7	5,5	130	156	145	0,450	x	175u3012	175u3013	x	1,5	1,7
T7	7,5	94	113	105	0,790	x	175u3481	175u3482	x	1,5	2,6
T7	11	69,7	76,2	72	1,130	175u3351	175u3466	175u3465	x	1,5	3,8
T7	15	46,8	55,5	52	1,400	175u3352	175u3468	175u3467	x	1,5	4,9
T7	18,5	36,0	44,7	42	1,700	175u3353	175u3032	175u3033	x	1,5	6
T7	22	33,7	37,5	31	2,200	175u3354	175u3470	175u3469	x	1,5	7,9
T7	30	22,5	29,1	27	2,800	175u3355	175u3472	175u3471	x	2,5	9,6
T7	37	18,0	23,5	22	3,200	175u3356	175u3479	175u3480	x	2,5	11,3
T7	45	13,5	19,3	15,5	4,200	x	175u3474	175u3473	x	4	15,4
T7	55	13,5	15,7	13,5	5,500	x	175u3476	175u3475	x	6	18,9
T7	75	8,8	11,5	11	7,000	x	x	x	175u3232	10	25,3
T7	90	8,8	9,5	9,1	9,000	x	x	x	175u3067	16	31,5

Table 5.10 FC 302 Horizontal Braking

FC 302				Vertical braking							
Frequency converter data				Brake Resistor data						Installation	
						Ordering no.					
Mains	P_m	R_{min}	$R_{br,nom}$	R_{rec}	$P_{br,cont.}$	Wire IP54	Screw Terminal IP21	Screw Terminal IP65	Screw Terminal IP20	Cable Cross section	Thermal relay
[type]	[kW]	[Ohm]	[Ohm]	[Ohm]	[kW]	[p/n]	[p/n]	[p/n]	[p/n]	[mm²]	[A]
T2	0,25	380	475,3	410	0,100	175u3004	x	x	x	1,5	0,5
T2	0,37	275	320,8	300	0,200	175u3096	x	x	x	1,5	0,8
T2	0,55	188	215,7	200	0,200	175u3008	x	x	x	1,5	0,9
T2	0,75	130	158,1	145	0,300	175u3300	x	x	x	1,5	1,3
T2	1,1	81,0	105,1	100	0,450	175u3301	175u3402	175u3401	x	1,5	2
T2	1,5	58,5	76,0	70	0,570	175u3302	175u3404	175u3403	x	1,5	2,7
T2	2,2	45,0	51,0	48	0,960	175u3303	175u3406	175u3405	x	1,5	4,2
T2	3	31,5	37,0	35	1,130	175u3304	175u3408	175u3407	x	1,5	5,4
T2	3,7	22,5	29,7	27	1,400	175u3305	175u3410	175u3409	x	1,5	6,8
T2	5,5	17,7	19,7	18	2,200	175u3306	175u3412	175u3411	x	1,5	10,4
T2	7,5	12,6	14,3	13,0	3,200	175u3307	175u3414	175u3413	x	2,5	14,7

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FC 302				Vertical braking							
Frequency converter data				Brake Resistor data						Installation	
						Ordering no.					
Mains	P_m	R_{min}	$R_{br,nom}$	R_{rec}	$P_{br,cont.}$	Wire IP54	Screw Terminal IP21	Screw Terminal IP65	Screw Terminal IP20	Cable Cross section	Thermal relay
[type]	[kW]	[Ohm]	[Ohm]	[Ohm]	[kW]	[p/n]	[p/n]	[p/n]	[p/n]	[mm²]	[A]
T2	11	8,7	9,7	9,0	5,500	x	175u3176	175u3177	x	4	23,2
T2	15	5,3	7,5	5,7	6,000	x	x	x	175u3233	10	32,5
T2	18,5	5,1	6,0	5,7	8,000	x	x	x	175u3234	10	37,6
T2	22	3,2	5,0	3,5	9,000	x	x	x	175u3235	16	50,8
T2	30	3,0	3,7	3,5	14,000	x	x	x	175u3224	25	63,3
T2	37	2,4	3,0	2,8	17,000	x	x	x	175u3227	35	78
T5	0,37	620	1389,2	1200	0,200	175u3101	x	x	x	1,5	0,4
T5	0,55	620	928,8	850	0,200	175u3308	x	x	x	1,5	0,5
T5	0,75	558	678,3	630	0,300	175u3309	x	x	x	1,5	0,7
T5	1,1	382	452,5	410	0,450	175u3310	175u3416	175u3415	x	1,5	1
T5	1,5	260	325,9	270	0,570	175u3311	175u3418	175u3417	x	1,5	1,4
T5	2,2	189	218,6	200	0,960	175u3312	175u3420	175u3419	x	1,5	2,1
T5	3	135	158,5	145	1,130	175u3313	175u3422	175u3421	x	1,5	2,7
T5	4	99,0	117,2	110	1,700	175u3314	175u3424	175u3423	x	1,5	3,7
T5	5,5	72,0	84,4	80	2,200	175u3315	175u3138	175u3139	x	1,5	5
T5	7,5	50,0	61,4	56	3,200	175u3316	175u3428	175u3427	x	1,5	7,1
T5	11	36,0	41,2	38	5,000	x	x	x	175u3236	1,5	11,5
T5	15	27,0	30,0	28	6,000	x	x	x	175u3237	2,5	14,7
T5	18,5	20,3	24,2	22	8,000	x	x	x	175u3238	4	19,1
T5	22	18,0	20,3	19	10,000	x	x	x	175u3203	4	23
T5	30	13,4	15,8	14	14,000	x	x	x	175u3206	10	31,7
T5	37	10,8	12,7	12	17,000	x	x	x	175u3210	10	37,7
T5	45	8,8	10,4	9,5	21,000	x	x	x	175u3213	16	47,1
T5	55	6,5	8,5	7,0	26,000	x	x	x	175u3216	25	61
T5	75	4,2	6,2	5,5	36,000	x	x	x	175u3219	35	81
T5	90	3,6	5,1	4,7	42,000	x	x	x	175u3221	50	94,6
T6	0,75	620	914,2	850	0,280	175u3317	175u3104	175u3105	x	1,5	0,6
T6	1,1	550	611,3	570	0,450	175u3318	175u3430	175u3429	x	1,5	0,9
T6	1,5	380	441,9	415	0,570	175u3319	175u3432	175u3431	x	1,5	1,1
T6	2,2	260	296,4	270	0,960	175u3320	175u3434	175u3433	x	1,5	1,8
T6	3	189	214,8	200	1,130	175u3321	175u3436	175u3435	x	1,5	2,3
T6	4	135	159,2	145	1,700	175u3322	175u3126	175u3127	x	1,5	3,3
T6	5,5	99,0	114,5	100	2,200	175u3323	175u3438	175u3437	x	1,5	4,4
T6	7,5	69,0	83,2	72	3,200	175u3324	175u3440	175u3439	x	1,5	6,3
T6	11	48,6	56,1	52	5,500	x	175u3148	175u3149	x	1,5	9,7
T6	15	35,1	40,8	38	6,000	x	x	x	175u3239	2,5	12,6
T6	18,5	27,0	32,9	31	8,000	x	x	x	175u3240	4	16,1
T6	22	22,5	27,6	27	10,000	x	x	x	175u3200	4	19,3
T6	30	17,1	21,4	19	14,000	x	x	x	175u3204	10	27,2
T6	37	13,5	17,3	14	17,000	x	x	x	175u3207	10	34,9
T6	45	10,8	14,2	13,5	21,000	x	x	x	175u3208	16	39,5
T6	55	8,8	11,6	11	26,000	x	x	x	175u3211	25	48,7
T6	75	6,6	8,4	7,0	30,000	x	x	x	175u3241	35	65,5
T7	1,1	620	830	630	0,360	x	175u3108	175u3109	x	1,5	0,8
T7	1,5	513	600	570	0,570	x	175u3110	175u3111	x	1,5	1
T7	2,2	340	403	415	0,790	x	175u3112	175u3113	x	1,5	1,3
T7	3	243	292	270	1,130	x	175u3118	175u3119	x	1,5	2

FC 302				Vertical braking							
Frequency converter data				Brake Resistor data						Installation	
						Ordering no.					
Mains	P_m	R_{min}	R_{br},nom	R_{rec}	P_{br},cont.	Wire IP54	Screw Terminal IP21	Screw Terminal IP65	Screw Terminal IP20	Cable Cross section	Thermal relay
[type]	[kW]	[Ohm]	[Ohm]	[Ohm]	[kW]	[p/n]	[p/n]	[p/n]	[p/n]	[mm^2]	[A]
T7	4	180	216	200	1,700	x	175u3122	175u3123	x	1,5	2,8
T7	5,5	130	156	145	2,200	x	175u3106	175u3107	x	1,5	3,7
T7	7,5	94	113	105	3,200	x	175u3132	175u3133	x	1,5	5,2
T7	11	69,7	76,2	72	4,200	x	175u3142	175u3143	x	1,5	7,2
T7	15	46,8	55,5	52	6,000	x	x	x	175u3242	2,5	10,8
T7	18,5	36,0	44,7	42	8,000	x	x	x	175u3243	2,5	13,9
T7	22	33,7	37,5	31	10,000	x	x	x	175u3244	4	18
T7	30	22,5	29,1	27	14,000	x	x	x	175u3201	10	22,8
T7	37	18,0	23,5	22	17,000	x	x	x	175u3202	10	27,8
T7	45	13,5	19,3	15,5	21,000	x	x	x	175u3205	16	36,9
T7	55	13,5	15,7	13,5	26,000	x	x	x	175u3209	16	43,9
T7	75	8,8	11,5	11	36,000	x	x	x	175u3212	25	57,3
T7	90	8,8	9,5	9,1	42,000	x	x	x	175u3214	35	68

Table 5.11 FC 302 Vertical Braking

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 minimum value based upon PVC insulated copper cable, 30 °C ambient temperature with normal heat dissipation.
All cabling must comply with national and local regulations on cable cross-sections and ambient temperature. Copper (60/75°C) conductors are recommended.
Thermal relay: Brake current setting of external thermal relay. All resistors has a build-in thermal relay switch N.C.
IP54: flat pack type with 1000 mm fixed unscreened cable. Vertical and horizontal mounting. Derating required by horizontal mounting.
IP21 & IP65: with screw terminal for cable termination. Vertical and horizontal mounting. Derating required by horizontal mounting.
IP20: with screw terminal for cable termination. Floor mounting.
P_m: Frequency converter nominal output power as HO.
R_{min}: Minimum permissible brake resistor value by frequency converter.
$R_{br,nom}$ is the nominal resistor value that ensure a brake power on motor shaft of 150%/160% for 1 minute.
R_{rec}: resistor value and resistance of the brake resistor.
$P_{br,cont}$: Power rating of the brake the brake resistor as the average power during continuous braking.

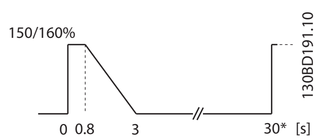

Illustration 5.1 Horizontal reference brake profile

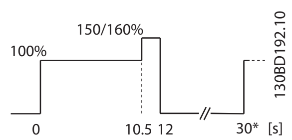

Illustration 5.2 Vertical reference brake profile

* Maximum 120 s repetition rates with equal average power or duty cycle.

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5.2.6 Miscellaneous Flat Packs

FC 301				Flatpack IP65 for horizontal conveyors		
	P_m	R_{min}	$R_{br, nom}$	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 5.12 FC 301 Mains: 200-240 V (T2)

FC 302				Flatpack IP65 for horizontal conveyors		
	P_m	R_{min}	$R_{br. nom}$	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 5.13 FC 302 Mains: 200-240 V (T2)

FC 301				Flatpack IP65 for horizontal conveyors		
	P_m	R_{min}	$R_{br. nom}$	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 5.14 FC 301 Mains: 380-480 V (T4)

FC 302	P_m	R_{min}	$R_{br.\ nom}$	Flatpack 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 5.15 FC 302 Mains: 380-500 V (T5)

IP65: flat pack type with fixed cable.

P_m: *Frequency converter nominal output power as HO.*

R_{min}: *Minimum permissible brake resistor value by frequency converter.*

$R_{br,nom}$ *is the nominal resistor value that ensure a brake power on motor shaft of 150%/160% for 1 minute.*

R_{rec}: *resistor value and resistance of the brake resistor.*

Duty cycle: resulting duty cycle based on resistor power and frequency converter data.

5

5.2.7 Ordering Numbers: 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. Sufficient airflow through the filter must be secured 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 AHF005		Ordering no AHF010	
[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
P90K	171	90	171	130B1445	130B1250	130B1294	130B1213

Table 5.16 380-415 V, 50 Hz

** HO ratings*

Power and Current Ratings		Typical motor	Filter current rating 50 Hz	Ordering no AHF005		Ordering no AHF010	
[kW]	[A]*	[kW]	[A]	IP00	IP20	IP00	IP20
PK37-P4K0	1,2-9	3	10	130B3095	130B1257	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
P90K	171	90	171	130B3130	130B2868	130B3089	130B2499

Table 5.17 380-41 5V, 60 Hz

** HO ratings*

Power and Current Ratings		Typical motor	Filter current rating	Ordering no AHF005		Ordering no AHF010	
			50 Hz				
[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
P90K	154	90	154	130B1798	130B1763	130B1781	130B1495

Table 5.18 440-480 V, 60 Hz

** HO ratings*

Power and Current Ratings		Typical motor	Filter current rating	Ordering no AHF005		Ordering no AHF010	
			50Hz				
[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
P90K	106	100	109	130B5270	130B5255	130B5238	130B5221

Table 5.19 600 V, 60 Hz

** HO ratings*

Power and Current Ratings		Typical motor	Power and Current Ratings		Typical motor	Filter current rating	Ordering no AHF005		Ordering no AHF010	
500-550 V			551-690 V			50 Hz				
[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
P90K	110	75	P90K	104	90	109	130B5026	130B5172	130B5327	130B5289

Table 5.20 600 V, 60 Hz

** HO ratings*

5

5.2.8 Ordering Numbers: Sine Wave Filters

Frequency converter 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*
[kW]	Current [A]	[kW]	Current [A]	[kW]	Current [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 5.21 Sine Wave Filter 3x380-500 V

Frequency converter 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*
[kW]	Current [A]	[kW]	Current [A]	[kW]	Current [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 5.22 Sine Wave Filter 3x525-600 V

Frequency converter power rating: power ratings correspond to both HO and NO ratings. Changing the FC 300 to NO will change the operating conditions.

Parameter	Setting
14-00 Switching Pattern	Select 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	Select sine-wave fixed.
14-56 Capacitance Output Filter*	Set according the individual filter. Listed at filter product label and in output filter manual.
14-57 Inductance Output Filter*	Set according the individual filter. Listed at filter product label and in output filter manual.

Table 5.23 Parameter Settings for Sine-wave Filter Operation

** For Flux control principle.*

5.2.9 Ordering Numbers: dU/dt Filters, 200-690 V AC

Frequency converter ratings										Filter current rating				Ordering no.		
200-240 V		380-440 V		441-500 V		525-550 V		551-690 V		380 V@60 Hz 200-400/440 V@50 Hz	460/480 V@60 Hz 500/525 V@5 0Hz	575/600 V@60 Hz	690 V@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	13	N/A	130B 7367*	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	130B 2835	130B 2836	130B 2837
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	130B 2838	130B 2839	130B 2840
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	103B 2841	103B 2842	103B 2843
-	-							75	83							
30	115	75	147	90	130	75	113	90	108	177	160	131	108	130B 2844	130B 2845	130B 2846
37	143	90	177	-	-	90	137	-	-							
45	170	-	-	-	-	-	-	-	-							

Table 5.24 dU/dt Filters 3x200-690 V IP00/IP20/IP54

Frequency converter power rating: power ratings correspond to both HO and NO ratings. Changing the FC 300 to NO will change the operating conditions.

** Dedicated A3 enclosure types 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	Select no filter.
14-56 Capacitance Output Filter*	Set according the individual filter. Listed at filter product label and in output filter manual.
14-57 Inductance Output Filter*	Set according the individual filter. Listed at filter product label and in output filter manual.

Table 5.25 Parameter Settings for dU/dt Filter Operation

** For Flux control principle.*

6 Mechanical Installation - Frame Sizes A, B and C

6.1.1 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 .
If the ambient temperature is in the range of 45 °C - 55 °C, derating of the frequency converter will become relevant, see .
The service life of the frequency converter is reduced if derating for ambient temperature is not taken into account.

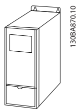
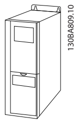
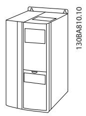
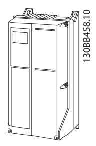
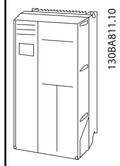
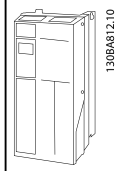
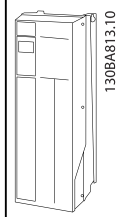
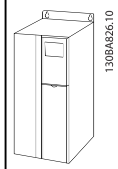
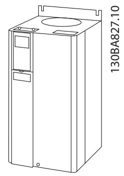
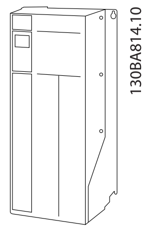
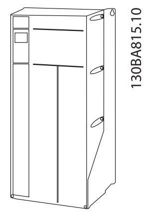
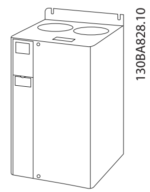
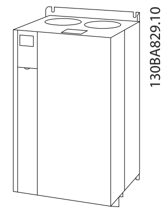
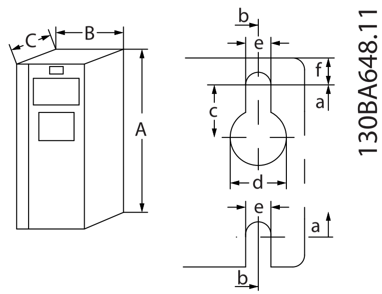
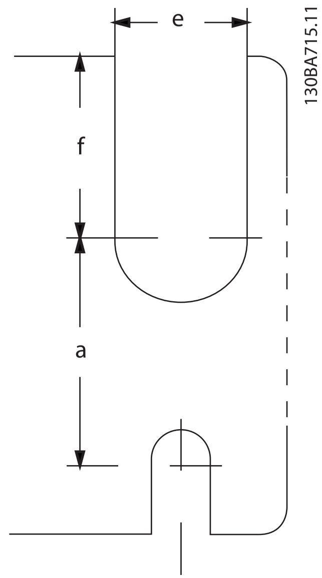
A1	A2	A3	A4	A5	B1	B2	B3	B4	C1	C2	C3	C4
												
IP20	IP20/21	IP20/21	IP55/66	IP55/66	IP21/55/66	IP21/55/66	IP20	IP20	IP21/55/66	IP21/55/66	IP20	IP20
												
Accessory bags containing necessary brackets, screws and connectors are included with the frequency converters upon delivery.											Top and bottom mounting holes (B4, C3 and C4 only)	
All measurements in mm. * A5 in IP55/66 only												

Table 6.1 Mechanical Dimensions

Frame Size			A1	A2		A3		A4	A5	B1	B2	B3	B4	C1	C2	C3	C4
Rated	200-240V		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	15-22	30-37	18.5-22	30-37
Power	380-480/500V		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	30-45	55-75	37-45	55-75
[kW]	525-600V					0.75-7.5			0.75-7.5	11-15	18.5-22	11-15	18.5-30	30-45	55-90	37-45	55-90
	525-690V										11-22				30-75		
IP NEMA			20 Chassis	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	200	268	375	268	375	390	420	480	650	399	520	680	770	550	660
Height with de-coupling plate for Fieldbus cables		A	316	374		374	-	-	-	-	-	420	595			630	800
Distance between mounting holes		a	190	257	350	257	350	401	402	454	624	380	495	648	739	521	631
Width [mm]																	
Width of back plate		B	75	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 two C options [mm]		B		150	150	190	190		242	242	242	225	230	308	370	308	370
Distance between mounting holes		b	60	70	70	110	110	171	215	210	210	140	200	272	334	270	330
Depth [mm]																	
Depth without option A/B		C	207	205	207	205	207	175	200	260	260	249	242	310	335	333	333
With option A/B		C	222	220	222	220	222	175	200	260	260	262	242	310	335	333	333
Screw holes [mm]																	
		c	6.0	8.0	8.0	8.0	8.0	8.25	8.25	12	12	8		12.5	12.5		
		d	ø8	ø11	ø11	ø11	ø11	ø12	ø12	ø19	ø19	12		ø19	ø19		
		e	ø5	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	5	9	9	6.5	6.5	6	9	9	9	7.9	15	9.8	9.8	17	17
Max weight [kg]			2.7	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	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 6.2

6

6.1.2 Mechanical Mounting

All frame sizes allow side-by-side installation except when a *IP21/IP4X/TYPE 1 Enclosure Kit* is used (see *9 Options and Accessories*).

Side-by-side mounting

IP20 A and B frames can be arranged side-by-side with no clearance required between them, but the mounting order is important. *Illustration 6.1* shows how to mount the frames correctly.

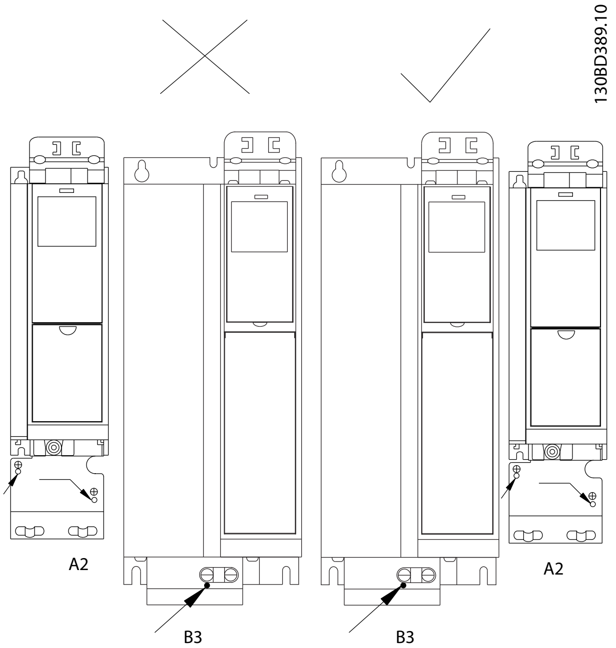


Illustration 6.1 Correct Side-by-side Mounting

If the IP 21 Enclosure kit is used on frame size 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 6.3*.

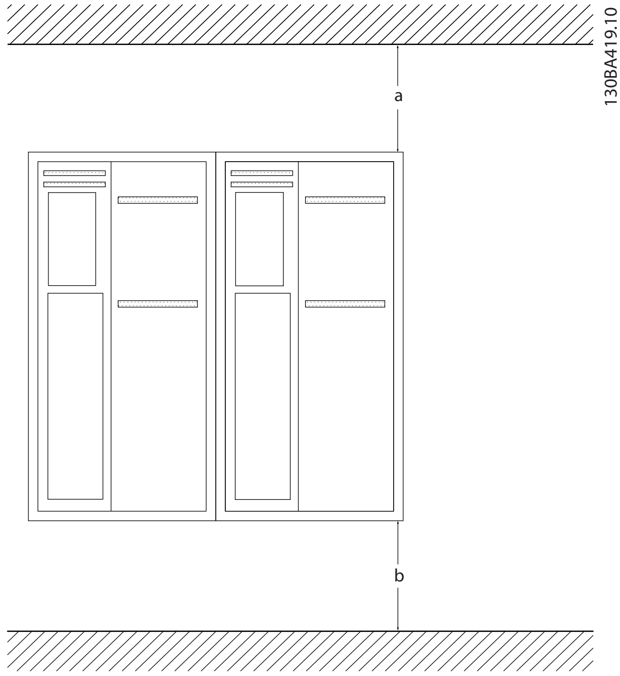


Illustration 6.2 Clearance

Frame size	A1*/A2/A3/A4/A5/B1	B2/B3/B4/C1/C3	C2/C4
a [mm]	100	200	225
b [mm]	100	200	225

Table 6.3 Air Passage for Different Frame Sizes

** FC 301 only*

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

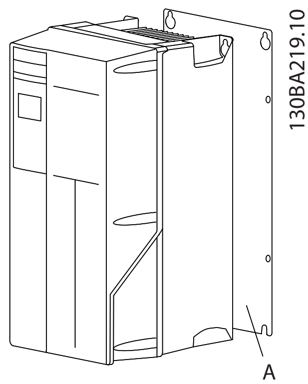


Illustration 6.3 Proper Mounting with Back Plate

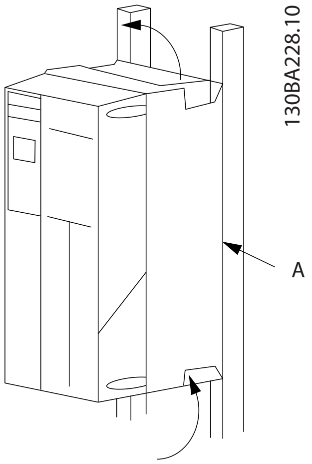


Illustration 6.4 Proper Mounting with Railings

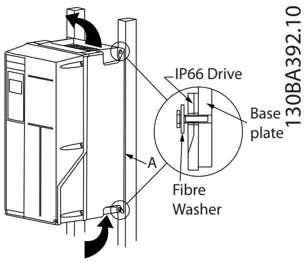


Illustration 6.5 Mounting on a Non-solid Back Wall

Mounting frame sizes A4, A5, B1, B2, C1 and C2 on a non-solid back wall, the frequency converter must be provided with a back plate, “A”, due to insufficient cooling air over the heat sink.

Frame	IP20	IP21	IP55	IP66
A1	*	-	-	-
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 6.4 Tightening torque for covers (Nm)

6.1.3 Field Mounting

For field mounting the IP 21/IP 4X top/TYPE 1 kits or IP 54/55 units are recommended.

7 Electrical Installation

7.1 Connections- Frame Sizes A, B and C

NOTE

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 two days due to softness of the aluminium. It is crucial to keep the connection a gas tight joint, otherwise the aluminium surface will oxidize again.

7

Frame size	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	-		
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
				Earth	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
				Earth	2-3
B3	5.5-7.5	11-15	-	Mains, Brake resistor, load sharing, Motor cables	1.8
				Relay	0.5-0.6
				Earth	2-3
B4	11-15	18.5-30	-	Mains, Brake resistor, load sharing, Motor cables	4.5
				Relay	0.5-0.6
				Earth	2-3
C1	15-22	30-45	-	Mains, Brake resistor, load sharing cables	10
				Motor cables	10
				Relay	0.5-0.6
				Earth	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
				Earth	2-3
C3	18.5-22	30-37	-	Mains, Brake resistor, load sharing, Motor cables	10
				Relay	0.5-0.6
				Earth	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
				Earth	2-3

Table 7.1 Tightening-up Torque

7.1.1 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 you intend to remove.
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.

7.1.2 Connection to Mains and Earthing

NOTE

The plug connector for power is plugable on frequency converters up to 7.5 kW.

1. Fit the two screws in the de-coupling plate, slide it into place and tighten the screws.
2. Make sure the frequency converter is properly earthed. Connect to earth 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.

NOTE

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 10mm² 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.

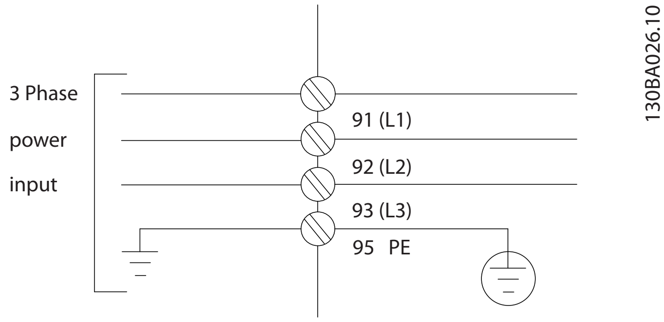


Illustration 7.1 Mains Connection

Mains connection for frame sizes A1, A2 and A3:

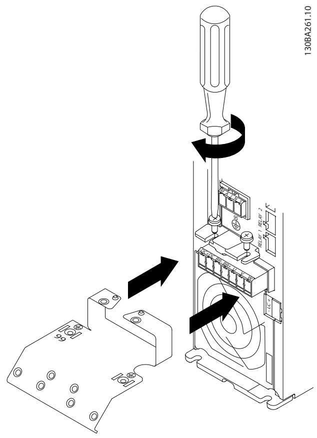


Illustration 7.2 Fitting the Mounting Plate

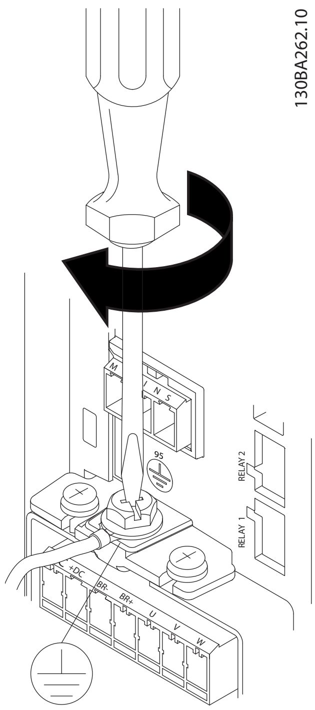


Illustration 7.3 Tightening the Earth Cable

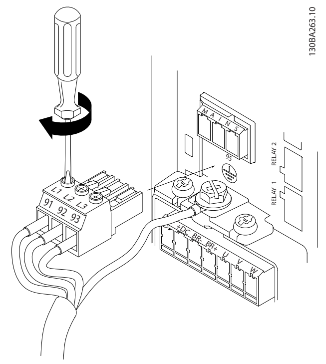


Illustration 7.4 Mounting Mains Plug and Tightening Wires

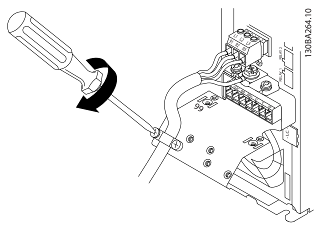


Illustration 7.5 Tighten Support Bracket

Mains connector frame size A4/A5 (IP55/66)

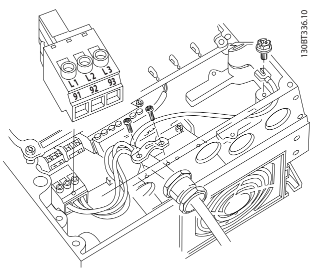


Illustration 7.6 Connecting to Mains and Earthing without Disconnector

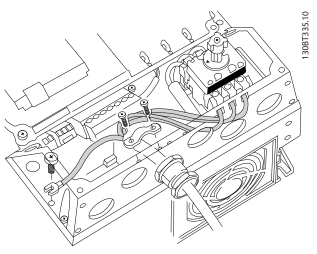


Illustration 7.7 Connecting to Mains and Earthing with Disconnector

When disconnector is used (frame size A4/A5) the PE must be mounted on the left side of the frequency converter.

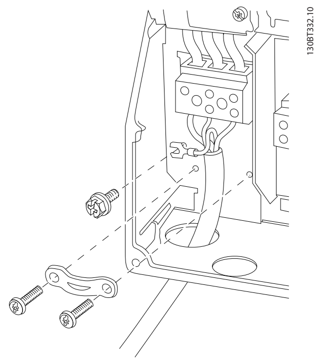


Illustration 7.8 Mains Connection Frame Sizes B1 and B2 (IP21/ NEMA Type 1 and IP55/66/ NEMA Type 12)

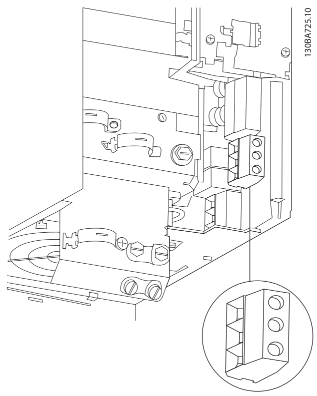


Illustration 7.9 Mains Connection Frame Size B3 (IP20)

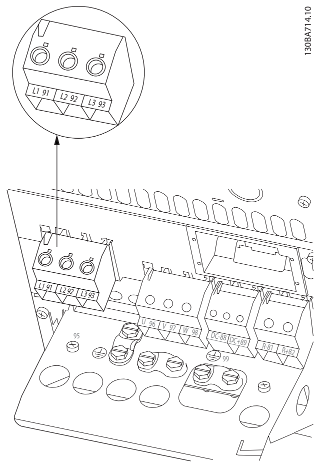


Illustration 7.10 Mains Connection Frame Size B4 (IP20)

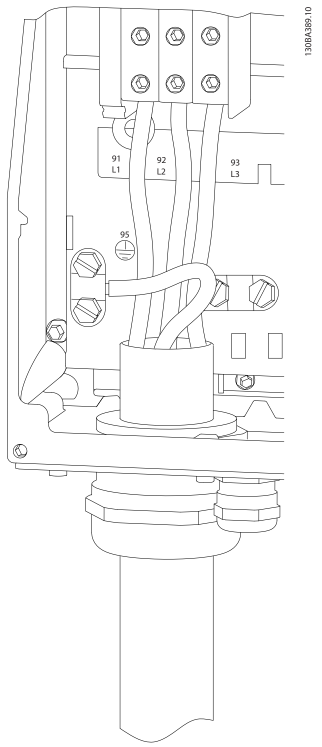


Illustration 7.11 Mains Connection Frame Size C1 and C2 (IP21/ NEMA Type 1 and IP55/66/NEMA Type 12).

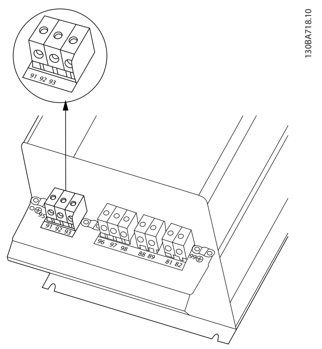


Illustration 7.12 Mains Connection Frame size C3 (IP20).

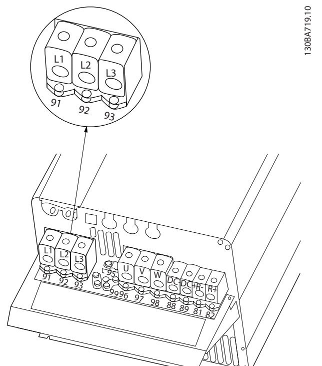


Illustration 7.13 Mains Connection Frame size C4 (IP20).

Usually the power cables for mains are unscreened cables.

7.1.3 Motor Connection

NOTE

To comply with EMC emission specifications, screened/ armoured cables are required. For more information, see *3.5.1 EMC Test Results*.

See *4.2 General Specifications* for correct dimensioning of motor cable cross-section and length.

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

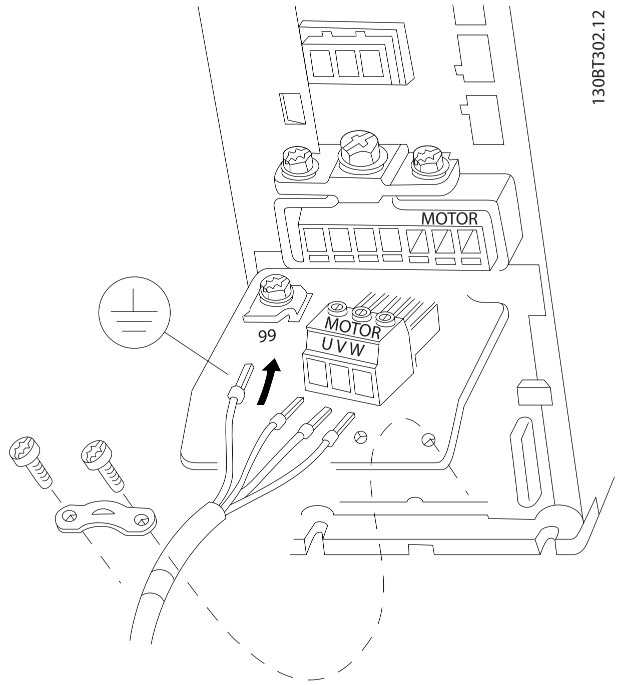


Illustration 7.14 Motor Connection for Frame Size A1, A2 and A3

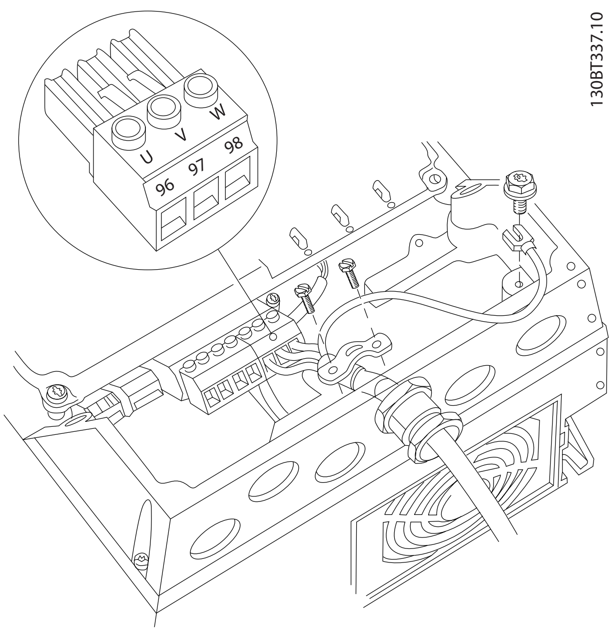


Illustration 7.15 Motor Connection for Frame size A4/A5 (IP55/66/NEMA Type 12)

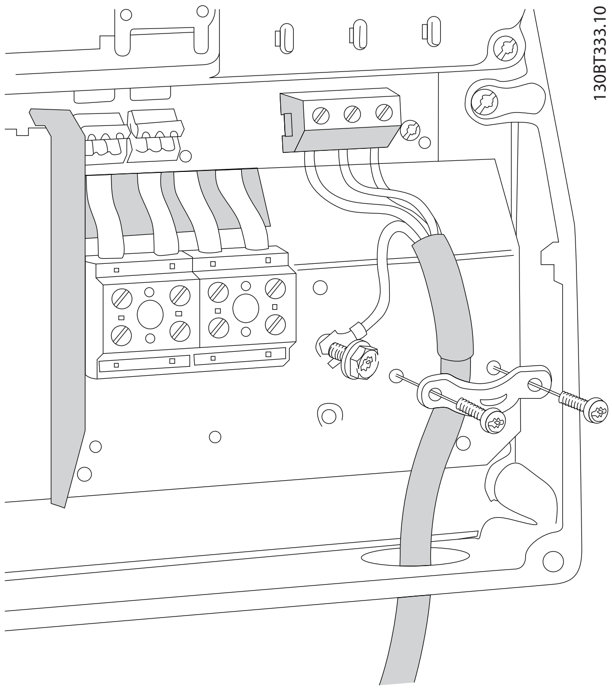


Illustration 7.16 Motor Connection for Frame size B1 and B2 (IP21/NEMA Type 1, IP55/NEMA Type 12 and IP66/NEMA Type 4X)

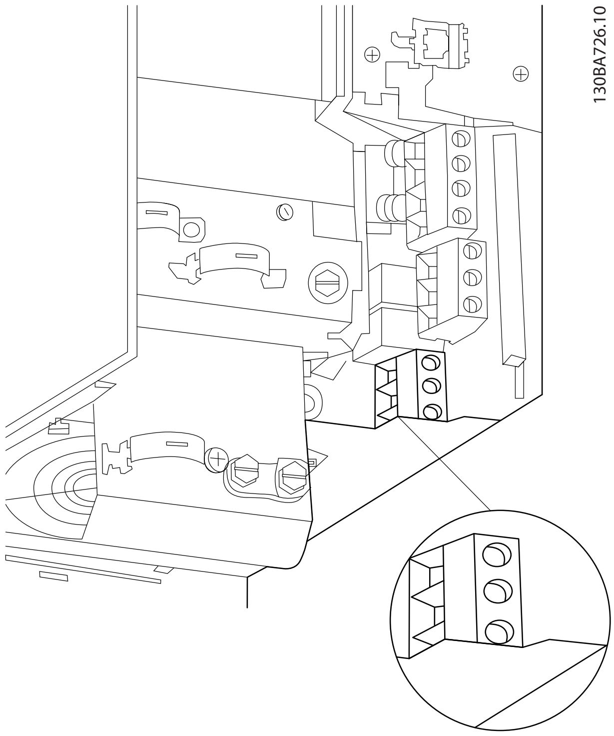


Illustration 7.17 Motor Connection for Frame size B3.

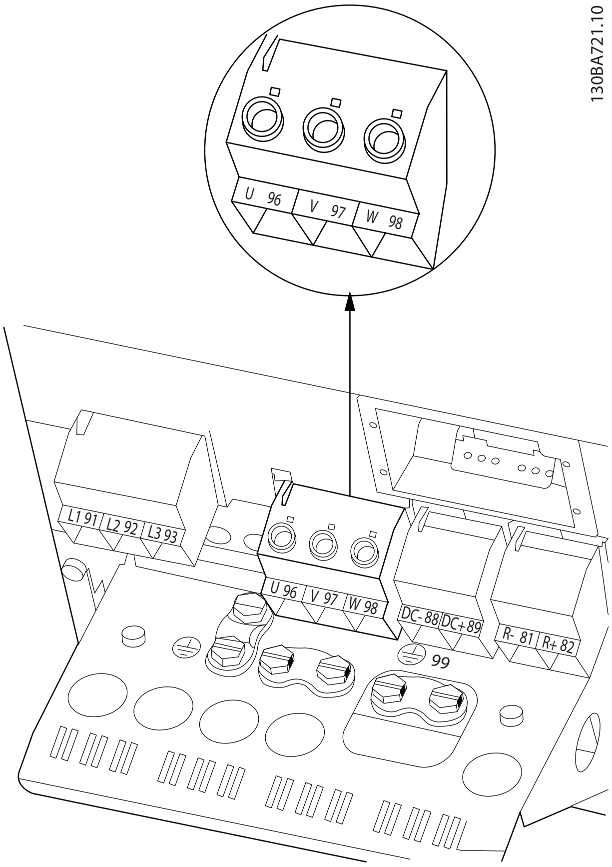


Illustration 7.18 Motor Connection for Frame size B4 .

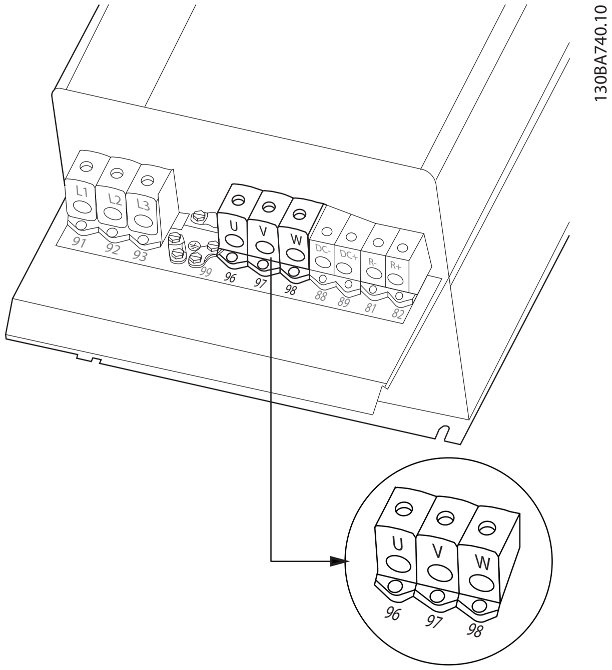


Illustration 7.20 Motor Connection for Frame size C3 and C4.

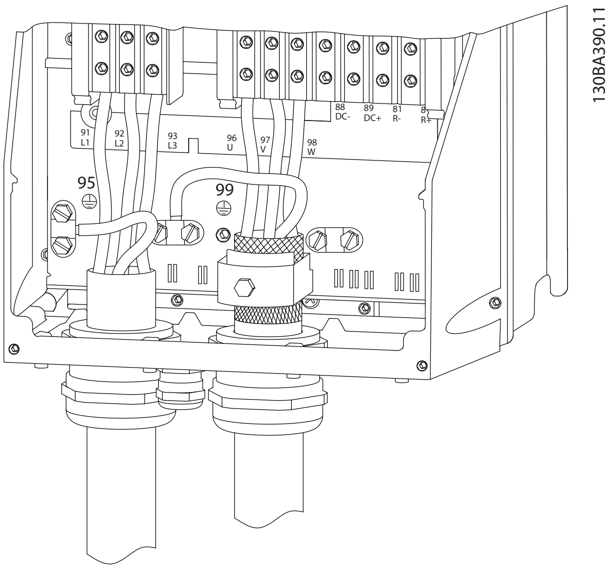


Illustration 7.19 Motor Connection Frame size C1 and C2 (IP21/ NEMA Type 1 and IP55/66/NEMA Type 12)

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

Table 7.2 Terminal Descriptions

[1)]*Protected Earth Connection*

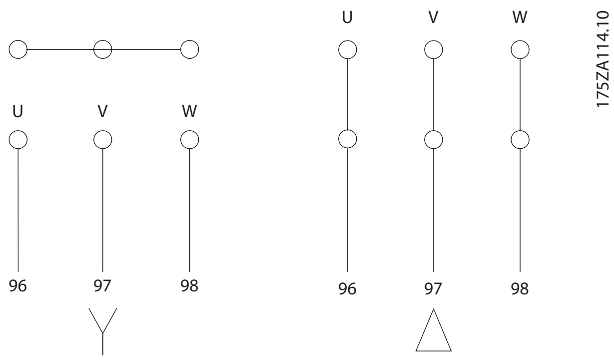


Illustration 7.21 Star and Delta Connections

NOTE

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

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

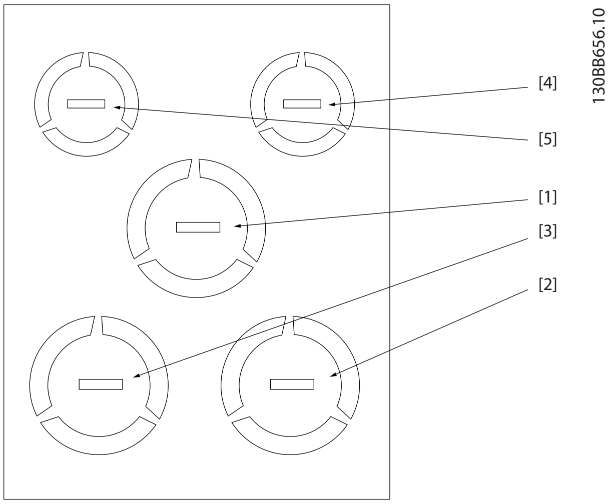


Illustration 7.22 A2 - IP21

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 S	3/4	28.4	M25
4) Control Cable	1/2	22.5	M20
5) Control Cable	1/2	22.5	M20

Table 7.3 Legend to *Illustration 7.22*

[1)] Tolerance ± 0.2 mm

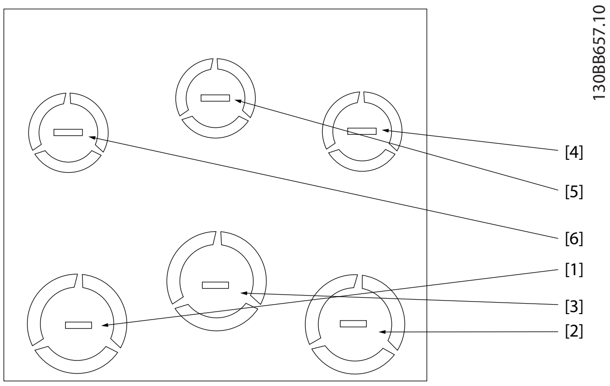


Illustration 7.23 A3 - IP21

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) Control Cable	1/2	22.5	M20
6) Control Cable	1/2	22.5	M20

Table 7.4 Legend to *Illustration 7.23*

[1)] Tolerance ± 0.2 mm

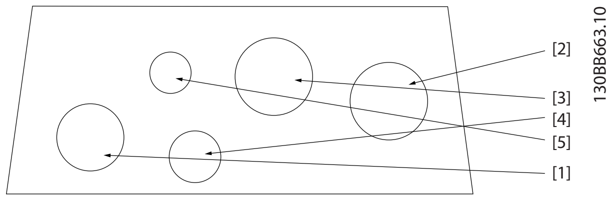


Illustration 7.24 A4 - IP55

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 7.5 Legend to *Illustration 7.24*

[1)] Tolerance ± 0.2 mm

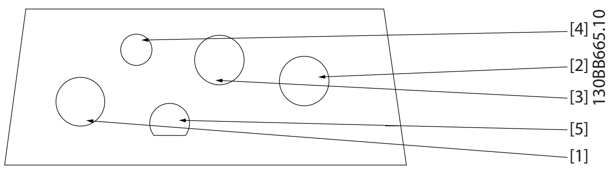


Illustration 7.25 A4 - IP55 Threaded Gland Holes

Hole Number and recommended use	Dimensions
1) Mains	M25
2) Motor	M25
3) Brake/Load Sharing	M25
4) Control Cable	M16
5) Control Cable	M20

Table 7.6 Legend to *Illustration 7.25*

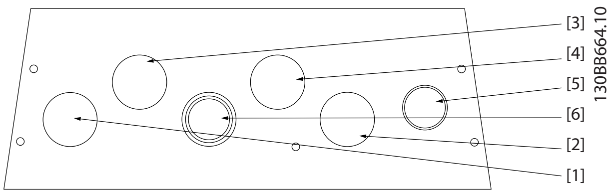


Illustration 7.26 A5 - IP55

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 7.7 Legend to *Illustration 7.26*

[1)] *Tolerance ± 0.2 mm*

[2)] *Knock-out hole*

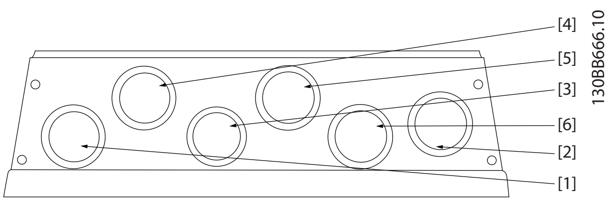


Illustration 7.27 A5- IP55 Threaded Gland Holes

Hole Number and recommended use	Dimensions
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 7.8 Legend to *Illustration 7.27*

[1)] *Knock-out hole*

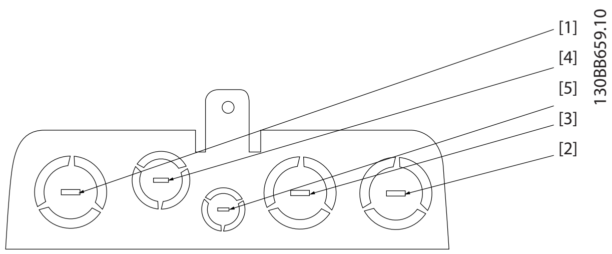


Illustration 7.28 B1 - IP21

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 7.9 Legend to *Illustration 7.28*

[1)] *Tolerance ± 0.2 mm*

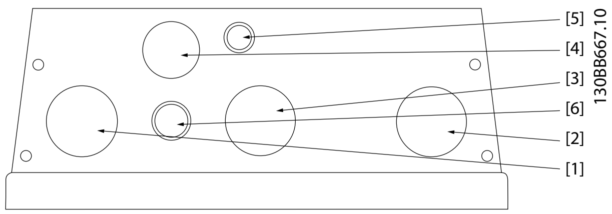


Illustration 7.29 B1 - IP55

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 7.10 Legend to *Illustration 7.29*

[1)] *Tolerance ± 0.2 mm*

[2)] *Knock-out hole*

7

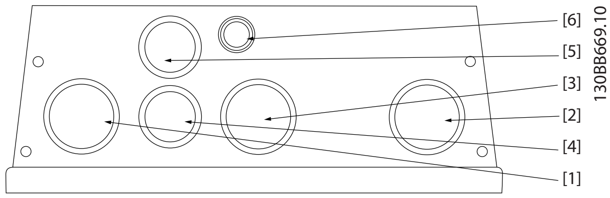


Illustration 7.30 B1 - IP55 Threaded Gland Holes

Hole Number and recommended use	Dimensions
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 7.11 Legend to *Illustration 7.30*

[1] *Knock-out hole*

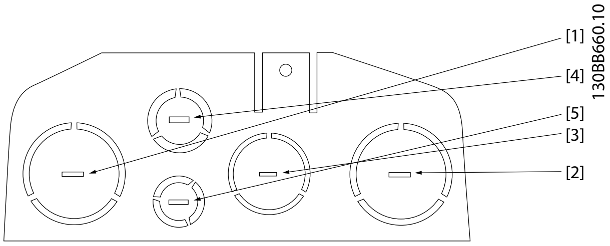


Illustration 7.31 B2 - IP21

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 7.12 Legend to *Illustration 7.31*

[1] *Tolerance ± 0.2 mm*

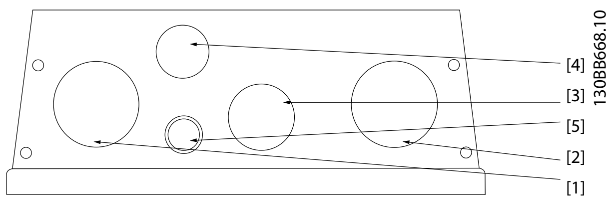


Illustration 7.32 B2 - IP55

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 7.13 Legend to *Illustration 7.32*

[1] *Tolerance ± 0.2 mm*

[2] *Knock-out hole*

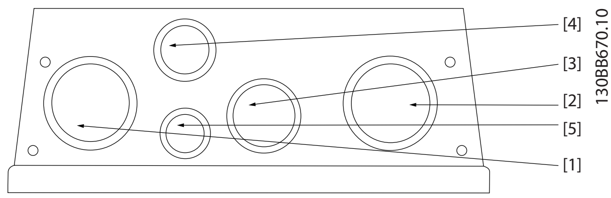


Illustration 7.33 B2 - IP55 Threaded Gland Holes

Hole Number and recommended use	Dimensions
1) Mains	M40
2) Motor	M40
3) Brake/Load Sharing	M32
4) Control Cable	M25
5) Control Cable	M20

Table 7.14 Legend to *Illustration 7.33*

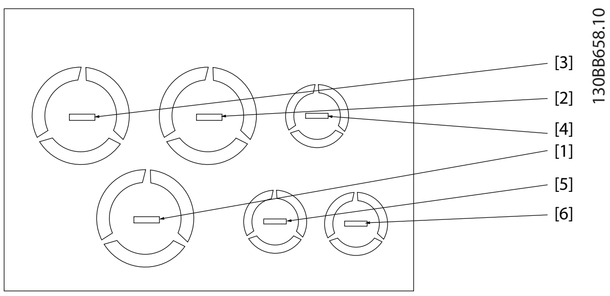


Illustration 7.34 B3 - IP21

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 7.15 Legend to *Illustration 7.34*

[1)] *Tolerance ± 0.2 mm*

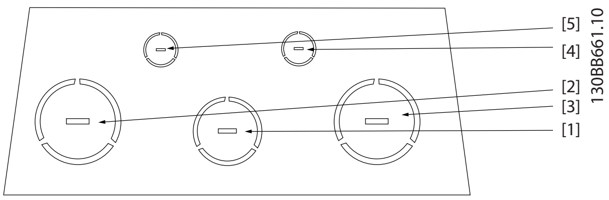


Illustration 7.35 C1 - IP21

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 7.16 Legend to *Illustration 7.35*

[1)] *Tolerance ± 0.2 mm*

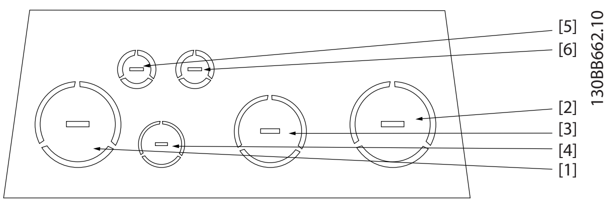


Illustration 7.36 C2 - IP21

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 7.17 Legend to *Illustration 7.36*

[1)] *Tolerance ± 0.2 mm*

7.1.4 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 7.18 Description of Relays

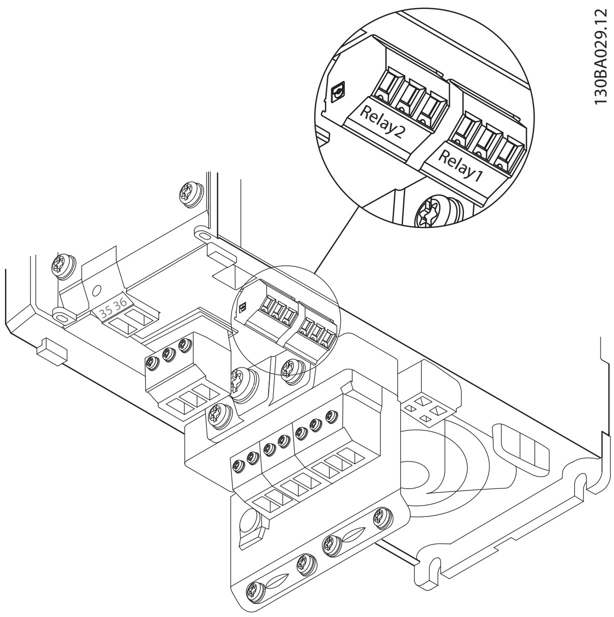


Illustration 7.37 Terminals for relay connection (Frame sizes A1, A2 and A3).

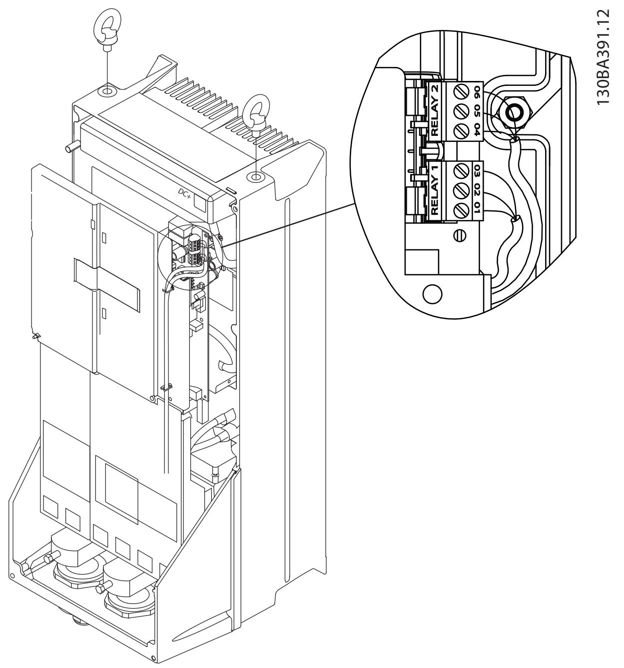


Illustration 7.38 Terminals for relay connection (Frame sizes C1 and C2).

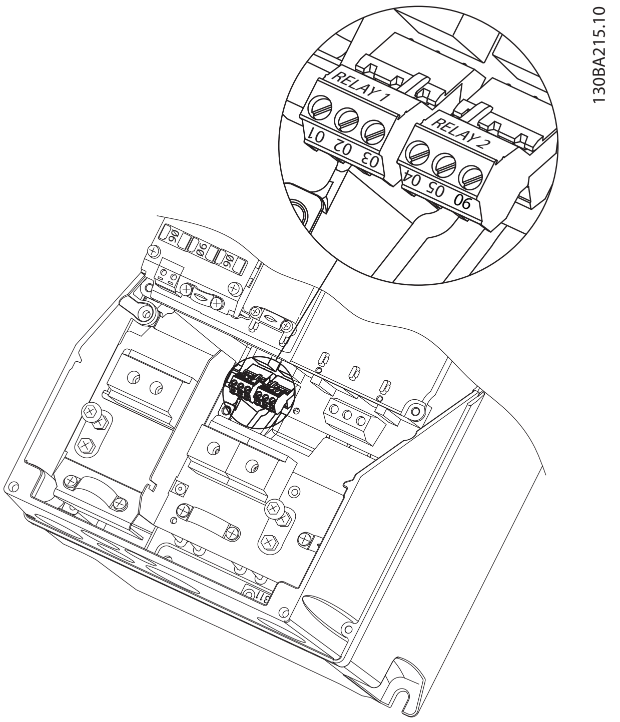


Illustration 7.39 Terminals for relay connection (Frame sizes A5, B1 and B2).

7.2 Fuses and Circuit Breakers

7.2.1 Fuses

It is recommended to use fuses and/or circuit breakers on the supply side as protection in case of component break-down inside the frequency converter (first fault).

NOTE

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

⚠WARNING

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

Branch Circuit Protection

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

NOTE

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

Short-circuit protection

Danfoss recommends using the fuses/Circuit Breakers mentioned below to protect service personnel and property in case of component break-down in the frequency converter.

7.2.2 Recommendations

⚠WARNING

In case of malfunction, not following the recommendation may result in personnel risk and damage to the frequency converter and other equipment.

The following tables list the recommended rated current. Recommended fuses are of the type gG for small to medium power sizes. For larger powers, aR fuses are recommended. For Circuit Breakers, Moeller types have been tested to have a recommendation. Other types of circuit breakers may be used provide 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 chosen, possible damages on the frequency converter will mainly be limited to damages inside the unit.

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

7.2.3 CE Compliance

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, 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 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:

Enclosure size	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	PKZM0-16	16
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
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
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
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
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

Table 7.19 200-240 V, Frame Sizes A, B and C

Enclosure size	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	PKZM0-16	16
A2	0.37-4.0	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
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
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
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
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

Table 7.20 380-500 V, Frame Sizes A, B and C

Enclosure size	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	PKZM0-25	25
A3	5.5-7.5	gG-10 (5.5) gG-16 (7.5)	gG-32	PKZM0-25	25
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
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
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
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

Table 7.21 525-600 V, Frame Sizes A, B and C

Enclosure size	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	gG-25 (11) gG-32 (15) gG-32 (18) gG-40 (22)	gG-63	-	-
C2	30 37 45 55 75	gG-63 (30) gG-63 (37) gG-80 (45) gG-100 (55) gG-125 (75)	gG-80 (30) gG-100 (37) gG-125 (45) gG-160 (55-75)	-	-
C3	37 45	gG-80 gG-100	gG-100 gG-125	-	-

Table 7.22 525-690 V, Frame Sizes A, B and C

7

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
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 7.23 200-240 V, Frame Sizes 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 7.24 200-240 V, Frame Sizes 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 7.25 200-240 V, Frame Sizes 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
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 7.26 380-500 V, Frame Sizes 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 7.27 380-500 V, Frame Sizes 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 7.28 380-500 V, Frame Sizes 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
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 7.29 525-600 V, Frame Sizes 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 7.30 525-600 V, Frame Sizes 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	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 7.31 525-690 V, Frame Sizes 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 7.32 *525-690 V, Frame Sizes B and C

** UL compliance only 525-600 V*

7.3 Disconnectors and Contactors

7.3.1 Mains Disconnectors

Assembling of IP55/NEMA Type 12 (A5 housing) with mains disconnector

Mains switch is placed on left side on frame sizes B1, B2, C1 and C2. Mains switch on A5 frames is placed on right side

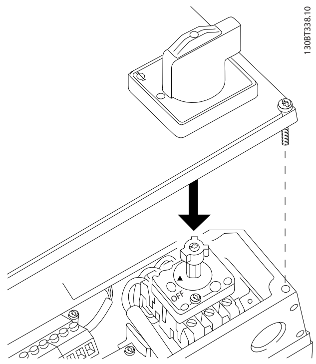


Illustration 7.40 Location of Mains Switch

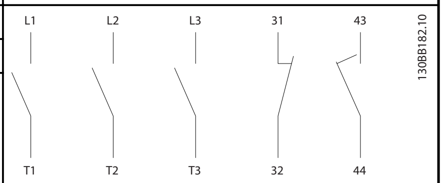
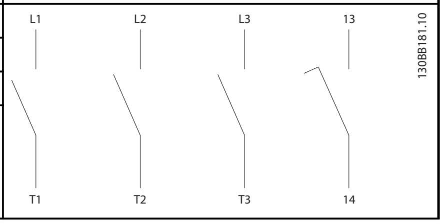
Frame size	Type	Terminal connections
A5	Kraus&Naimer KG20A T303	
B1	Kraus&Naimer KG64 T303	
B2	Kraus&Naimer KG64 T303	
C1 37 kW	Kraus&Naimer KG100 T303	
C1 45-55 kW	Kraus&Naimer KG105 T303	
C2 75 kW	Kraus&Naimer KG160 T303	
C2 90 kW	Kraus&Naimer KG250 T303	

Table 7.33 Terminal Connections for Various Frame Sizes

7

7.4 Additional Motor Information

7.4.1 Motor Cable

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

Terminal No.	Function
96, 97, 98, 99	Mains U/T1, V/T2, W/T3 Earth (Ground)

Table 7.34 Terminal Functions

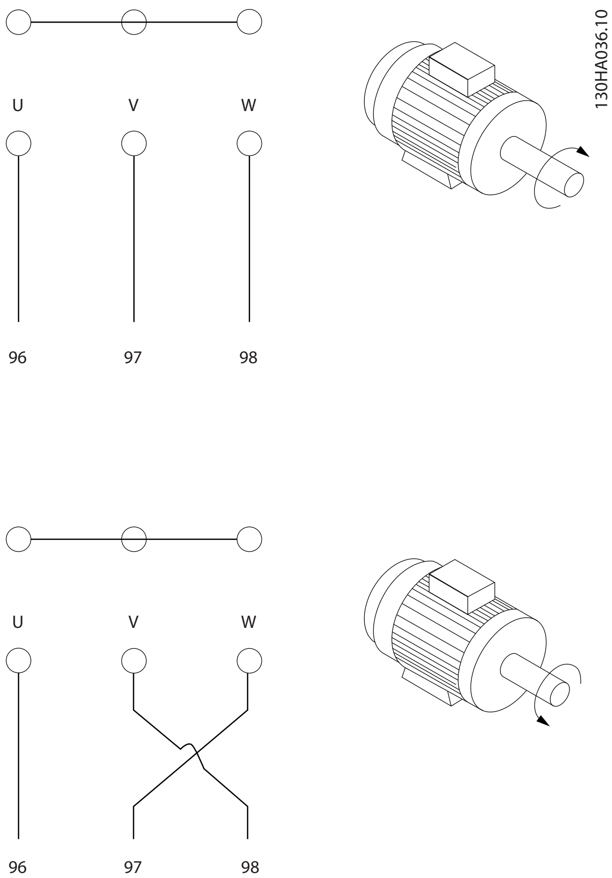


Illustration 7.41 Terminal Connection for Clockwise and Counter-clockwise Rotation

- 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 two phases in the motor cable or by changing the setting of *4-10 Motor Speed Direction*.

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

NOTE

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.

7.4.2 Motor Thermal Protection

The electronic thermal relay in the frequency converter has received UL-approval for single motor protection, when *1-90 Motor Thermal Protection*is set for *ETR Trip* and *1-24 Motor Current* is set to the rated motor current (see motor name plate).
For thermal motor protection it is also possible to use the MCB 112 PTC Thermistor Card option. This card provides ATEX certificate to protect motors in explosion hazardous areas, Zone 1/21 and Zone 2/22. When *1-90 Motor Thermal Protection* is set to [20] ATEX ETR is combined with the use of MCB 112, it is possible to control an Ex-e motor in explosion hazardous areas. Consult the programming guide for details on how to set up the frequency converter for safe operation of Ex-e motors.

7.4.3 Parallel Connection of Motors

The frequency converter can control several parallel-connected motors. When using parallel motor connection 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).

NOTE

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

NOTE

When motors are connected in parallel, *1-02 Flux Motor Feedback Source* cannot be used, and *1-01 Motor Control Principle* must be set to *Special motor characteristics (U/f)*.

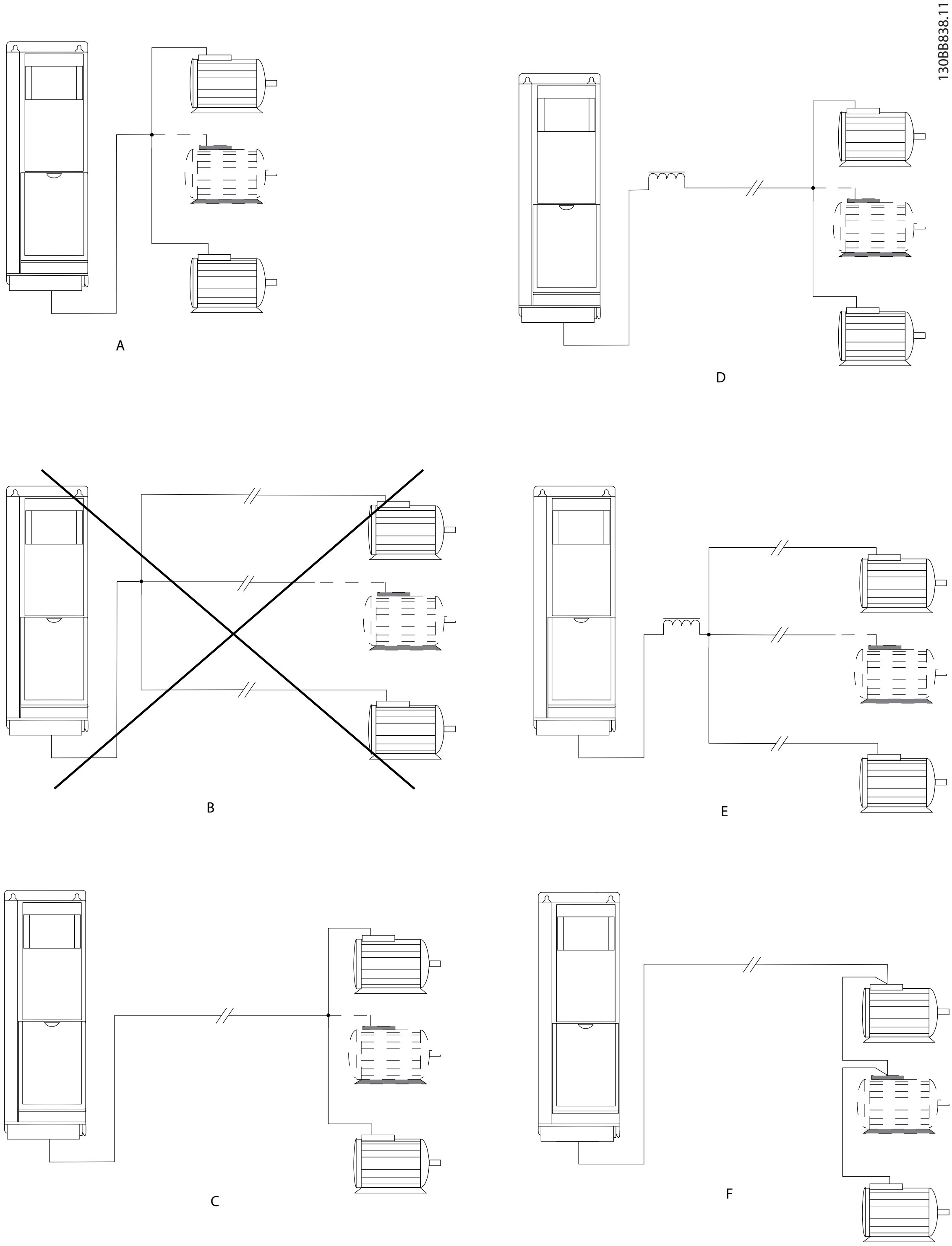


Illustration 7.42 Parallel Motor Connection

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 7.35*.
e) Use LC filter for long parallel cables.

Frame Size	Power Size [kW]	Voltage [V]	1 cable [m]	2 cables [m]	3 cables [m]	4 cables [m]
A1, A2, A5	0.37-0.75	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	11-75	400	150	75	50	37
		500	150	75	50	37

Table 7.35 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).

7.4.4 Motor Insulation

For motor cable lengths ≤ the maximum cable length listed in *4.2 General Specifications*, the following motor insulation ratings are recommended because the peak voltage can be up to twice the DC link voltage, 2.8 times the mains voltage, due to transmission line effects in the motor cable. If a motor has lower insulation rating it recommended to use a dU/dt or sine wave filter.

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

Table 7.36 Motor Insulation

7.4.5 Motor Bearing Currents

All motors installed with FC 302 90 kW or higher power frequency converter should have NDE (Non-Drive End) insulated bearings installed to eliminate circulating bearing currents. To minimize DE (Drive End) bearing and shaft currents proper grounding of the frequency converter, motor, driven machine, and motor to the driven machine is required.

Standard Mitigation Strategies:

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

7

7.5 Control Cables and Terminals

7.5.1 Access to Control Terminals

All terminals to the control cables are located underneath the terminal cover on the front of the frequency converter. Remove the terminal cover by means of a screwdriver (see illustration).

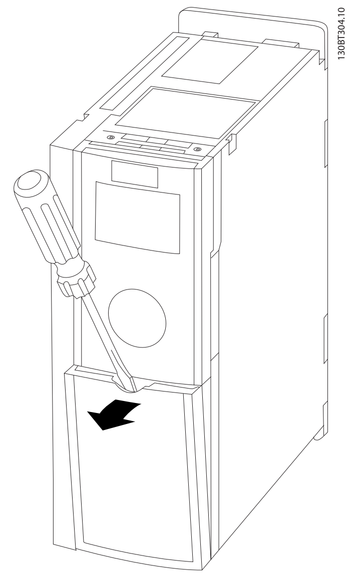


Illustration 7.43 Frame sizes A1, A2, A3, B3, B4, C3 and C4

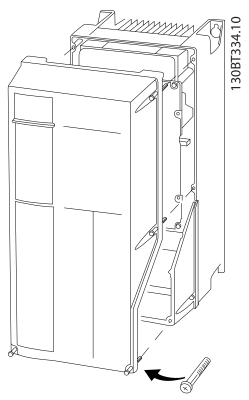


Illustration 7.44 Frame sizes A5, B1, B2, C1 and C2

7.5.2 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 illustrations).

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

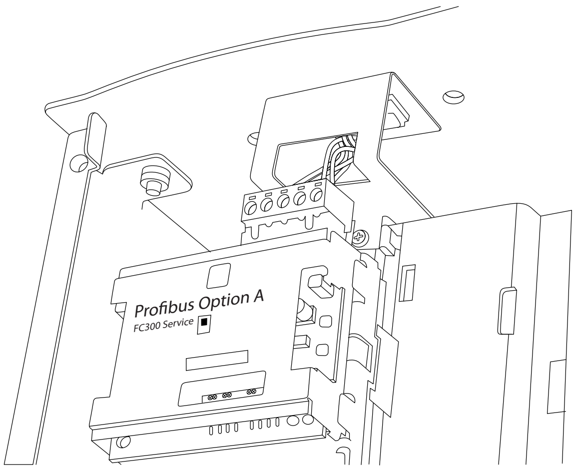


Illustration 7.45 Inside Location of Fieldbus

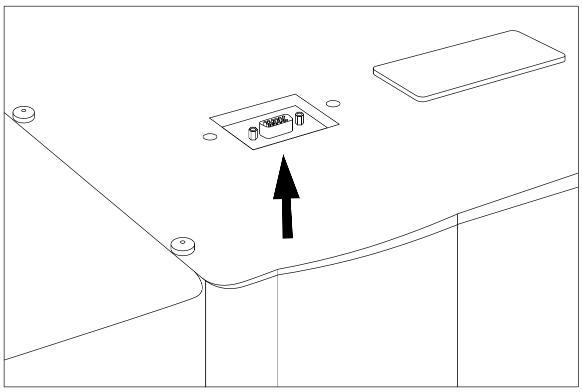


Illustration 7.46 Top Connection for Fieldbus on IP00

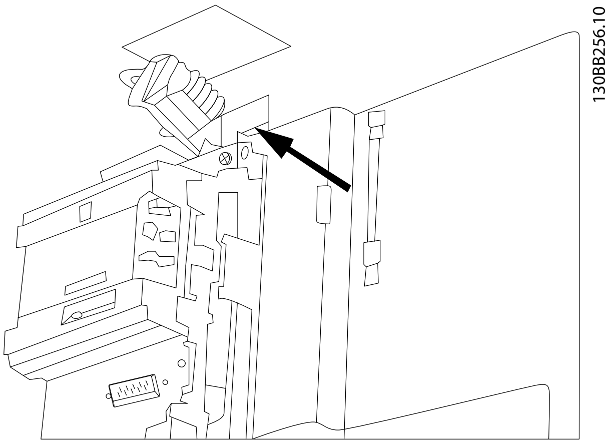


Illustration 7.47 Top Connection for Fieldbus NEMA 1 Units

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 7.37 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. Note that a warning of low voltage will be given when 24 VDC has been connected; however, there will be no tripping.

WARNING

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

7.5.3 Control Terminals

Control Terminals, FC 301

Drawing reference numbers:

1. 8 pole plug digital I/O.
2. 3 pole plug RS-485 Bus.
3. 6 pole analog I/O.
4. USB Connection.

Control Terminals, FC 302

Drawing reference numbers:

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

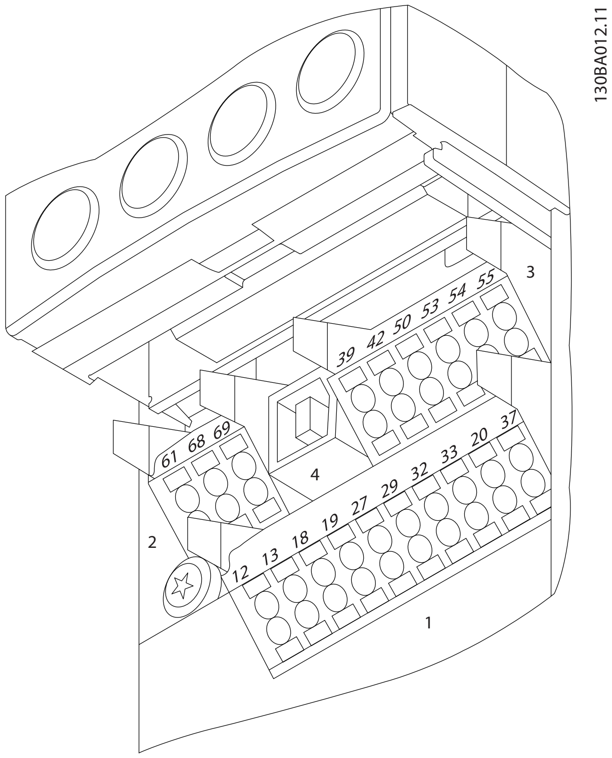


Illustration 7.48 Control terminals (all frame sizes)

7.5.4 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 respectively.

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

See *Illustration 7.55*.

Default setting:

S201 (A53) = OFF (voltage input)

S202 (A54) = OFF (voltage input)

S801 (Bus termination) = OFF

NOTE

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.

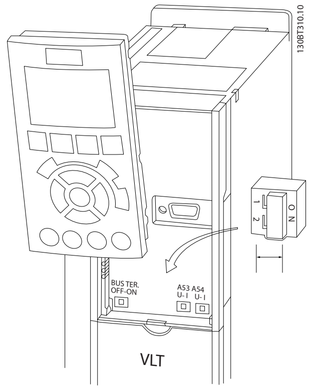


Illustration 7.49 Location of S201, S202 and S801 Switches

7.5.5 Electrical Installation, Control Terminals

To mount the cable to the terminal:

1. Strip insulation of 9-10 mm

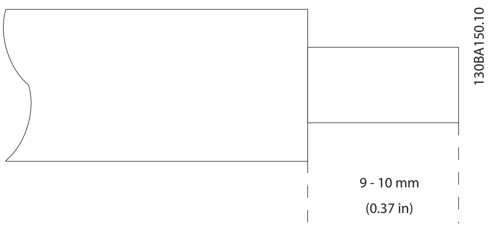


Illustration 7.50

2. Insert a screwdriver[1)] in the square hole.

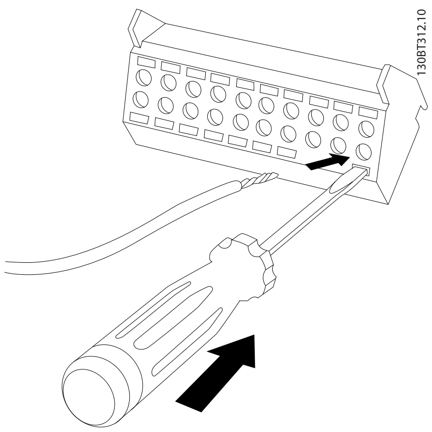


Illustration 7.51

3. Insert the cable in the adjacent circular hole.

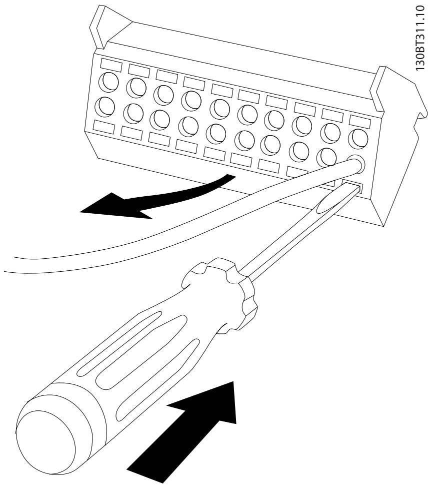


Illustration 7.52

4. Remove the screw driver. The cable is now mounted to the terminal.

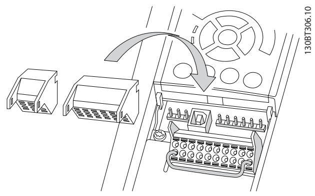


Illustration 7.53

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

7.5.6 Basic Wiring Example

1. Mount terminals from the accessory bag to the front of the frequency converter.
2. Connect terminals 18, 27 and 37 (FC 302 only) to +24 V (terminal 12/13)

Default settings:
18 = Start, *5-10 Terminal 18 Digital Input* [9]
27 = Stop inverse, *5-12 Terminal 27 Digital Input* [6]
37 = safe stop inverse

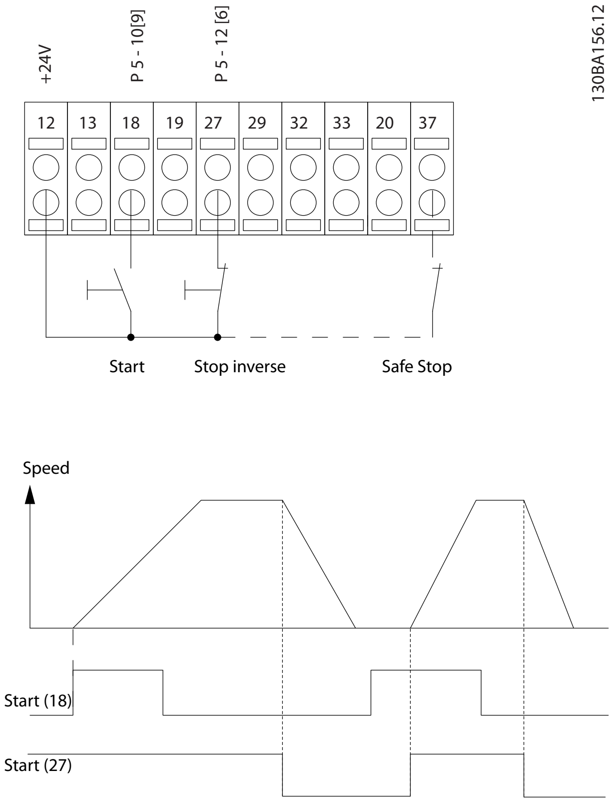


Illustration 7.54 Basic Wiring

7.5.7 Electrical Installation, Control Cables

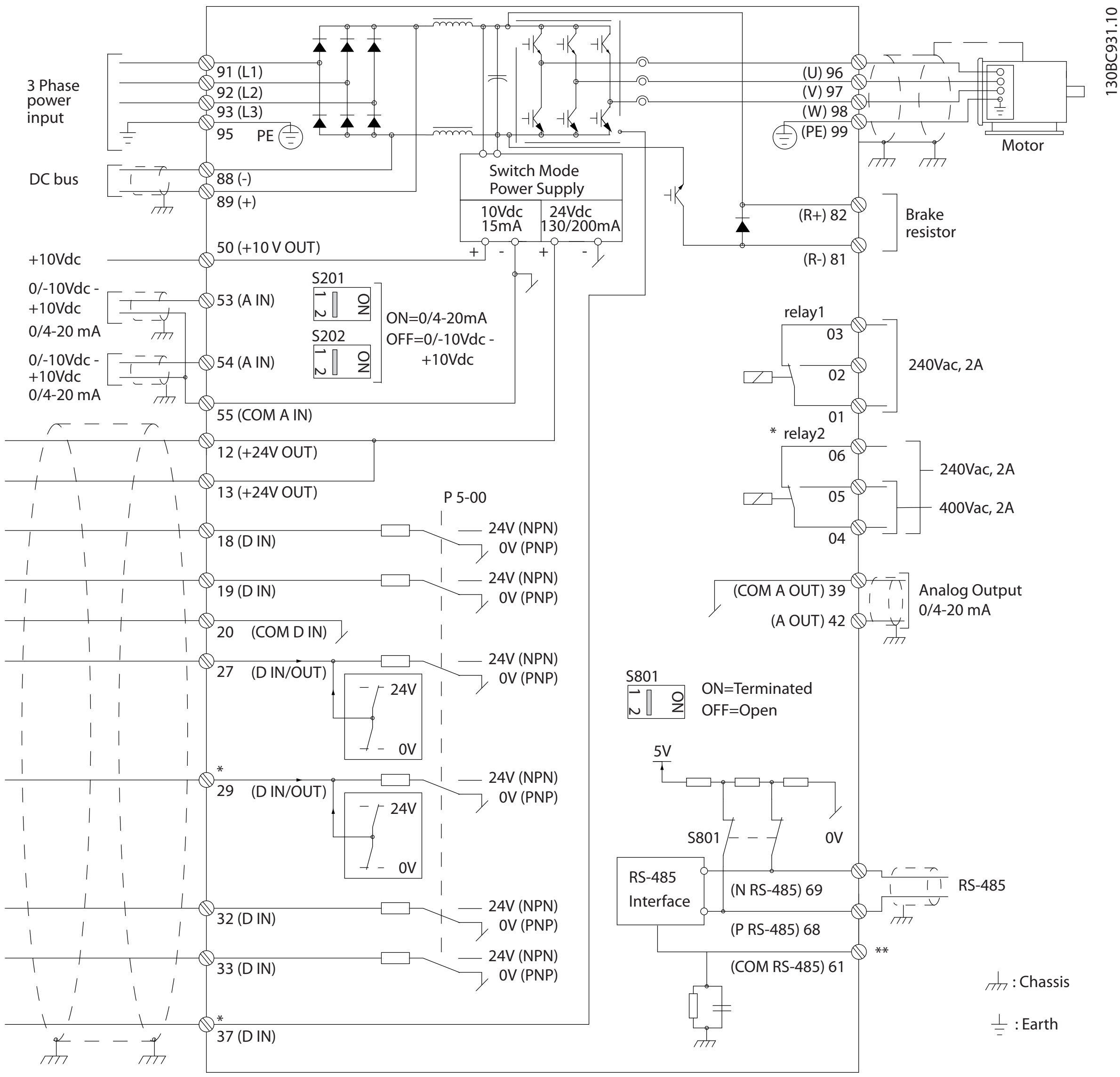


Illustration 7.55 Basic Wiring Schematic Drawing

A=Analog, D=Digital
Terminal 37 is used for Safe Stop. For Safe Stop installation instructions, refer to the Design Guide.
* Terminal 37 is not included in FC 301 (except frame size A1). Relay 2 and terminal 29 have no function in FC 301.
** Do not connect cable screen.

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

Input polarity of control terminals

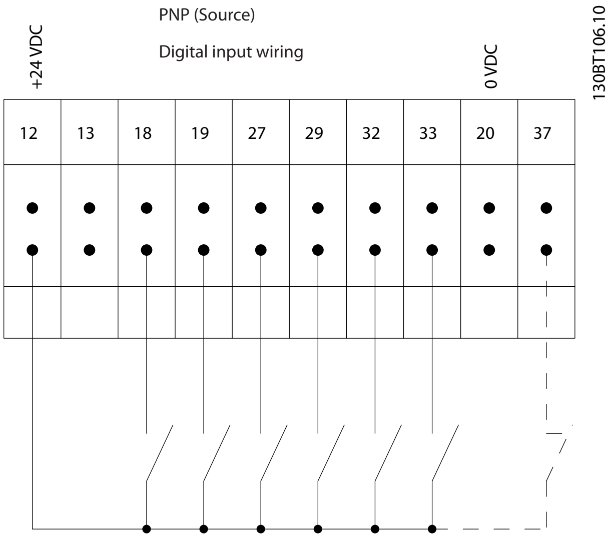


Illustration 7.56 Input Polarity PNP (Source)

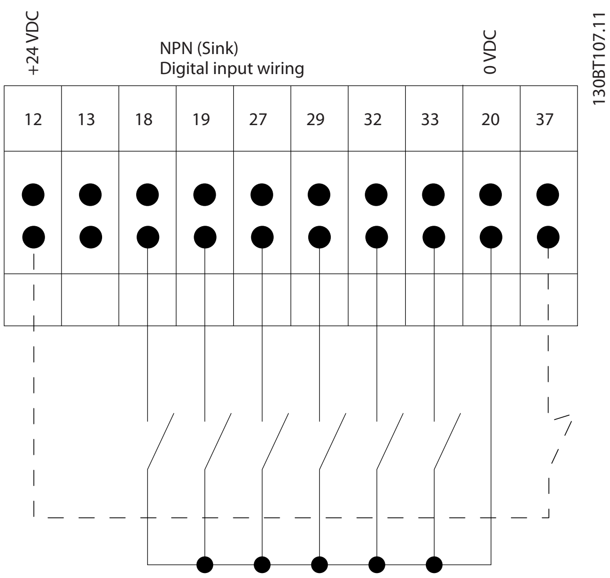


Illustration 7.57 Input Polarity NPN (Sink)

NOTE

To comply with EMC emission specifications, screened/armoured cables are recommended. If an unscreened/unarmoured cable is used, see *3.5.1 EMC Test Results*.

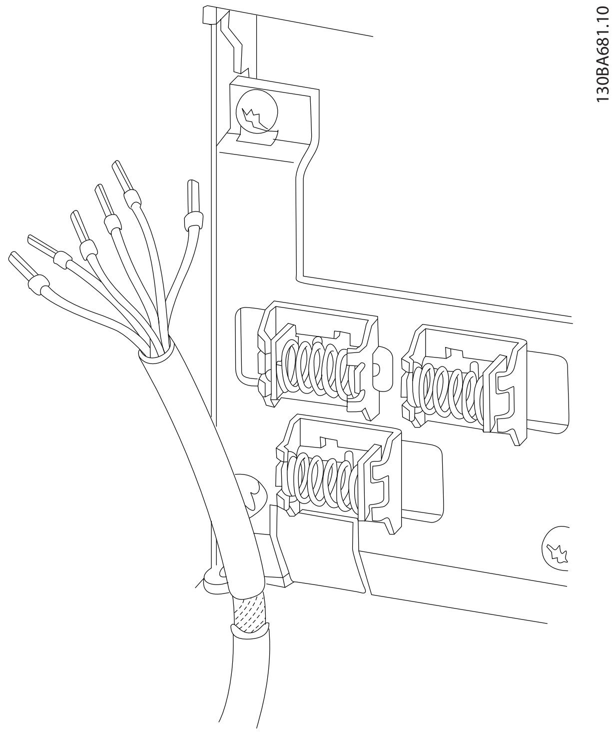


Illustration 7.58 Earthing of Screened/Armoured Control Cables

7.5.8 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 option module MCB 105.

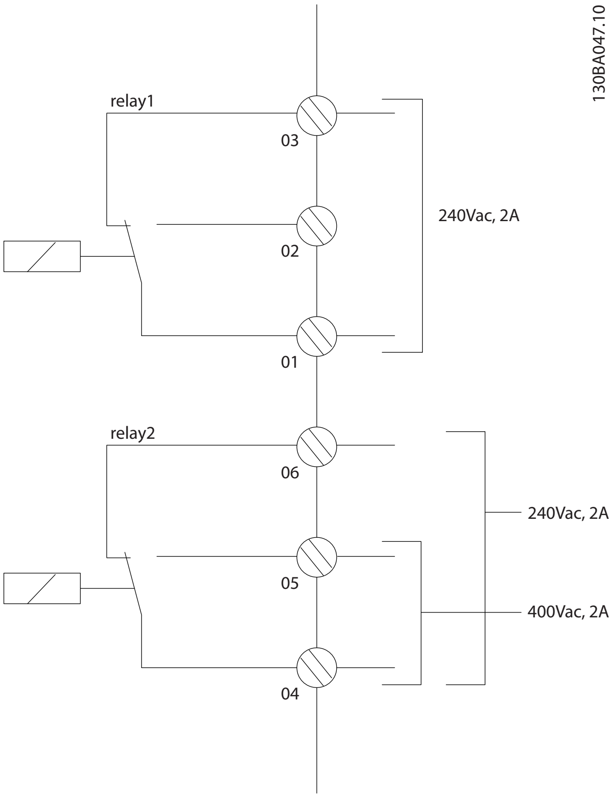


Illustration 7.59 Relay Outputs 1 and 2

7.6 Additional Connections

7.6.1 DC Bus Connection

The DC bus terminal is used for DC back-up, with the intermediate circuit being supplied from an external source. It uses terminals 88 and 89.

Contact Danfoss if further information is required.

7.6.2 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

7.6.3 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.

NOTE

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

CAUTION

Note that voltages up to 1099 V DC, depending on the supply voltage, may occur on the terminals.

7.6.4 How to Connect a PC to the Frequency Converter

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

USB is a serial bus utilizing 4 shielded wires with Ground pin 4 connected to the shield in the PC USB port. Connecting the PC to a frequency converter through the USB cable, there is a potential risk of damaging the PC USB

host controller. All standard PC's are manufactured without galvanic isolation in the USB port.
Any earth ground potential difference caused by not following the recommendations described in the Operating Instructions manual "Connection to Mains and Earthing", can damage the USB host controller through the shield of the USB cable.
It is recommended to use a USB isolator with galvanic isolation to protect the PC USB host controller from earth ground potential differences, when connecting the PC to a frequency converter through a USB cable.
It is recommended not to use a PC power cable with a ground plug when the PC is connected to the frequency converter through a USB cable. It reduces the earth ground potential difference but does not eliminate all potential differences due to the Ground and shield connected in the PC USB port.

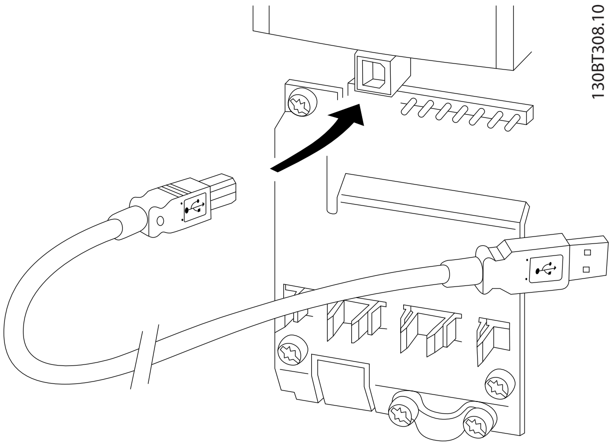


Illustration 7.60 USB Connection.

7.6.5 PC Software

Data storage in PC via MCT 10 Set-Up Software

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

All parameters are now stored.

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

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

All parameters are now transferred to the frequency converter.

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

7.7 Safety

7.7.1 High Voltage Test

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

⚠WARNING

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

7.7.2 Earthing

The following basic issues need to be considered when installing a frequency converter, so as to obtain electro-magnetic compatibility (EMC).

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

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

7.7.3 Safety Earth Connection

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

⚠WARNING

The earth leakage current from the frequency converter exceeds 3.5 mA. To ensure a good mechanical connection from the earth cable to the earth connection (terminal 95), the cable cross-section must be at least 10 mm^2 or 2 rated earth wires terminated separately.

7.7.4 Spark Free 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 7.61*.
- Check if relay options are installed. No other relay options than MCB 113 are allowed (remove relay plugs as above).

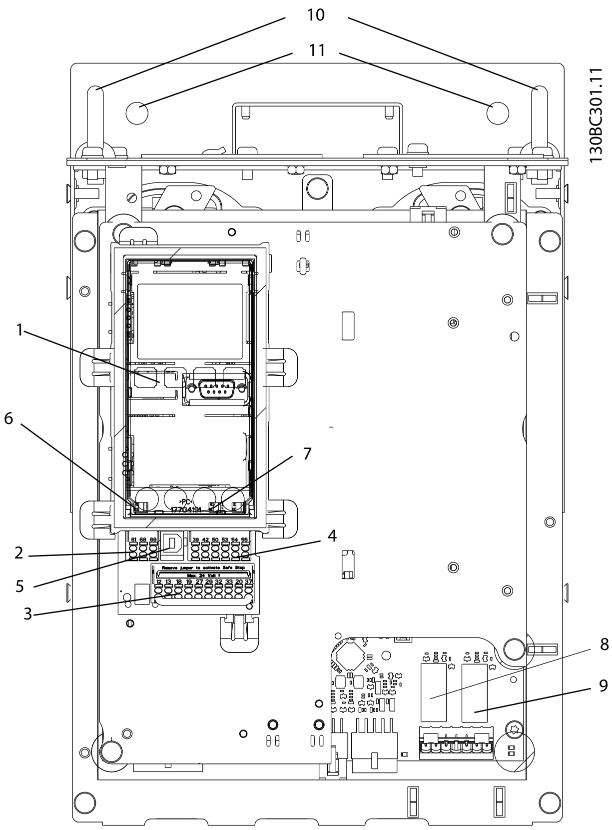


Illustration 7.61 Location of Relay Plugs

Manufacturers declaration is available upon request

7.8 EMC-correct Installation

7.8.1 Electrical Installation - EMC Precautions

The following is a guideline to good engineering practice when installing frequency converters. Follow these guidelines to comply with EN 61800-3 *First environment*. If the installation is in EN 61800-3 *Second environment,* i.e. industrial networks, or in an installation with its own transformer, deviation from these guidelines is allowed but not recommended. See also paragraphs *CE Labelling, General Aspects of EMC Emission* and *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 earth at both ends for motor cables as well as for control cables. In some cases, it is not possible to connect the screen in both ends. If so, connect the screen at the frequency converter. See also *Earthing of Braided Screened/Armoured 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), whenever this can be avoided.

Leave the screen as close to the connectors as possible.

Illustration 7.62 shows an example of an EMC-correct electrical installation of an IP 20 frequency converter. The frequency converter is fitted in an installation cabinet with an output contactor and connected to a PLC, which is installed in a separate cabinet. Other ways of doing the installation 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 the paragraph *EMC test results*.

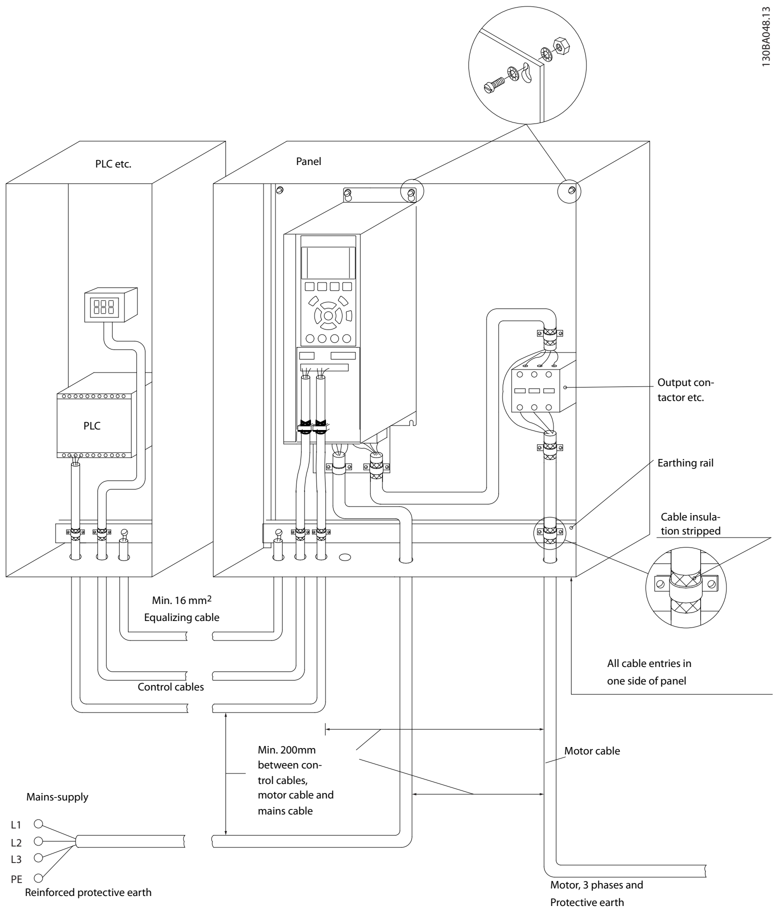


Illustration 7.62 EMC-correct Electrical Installation of a Frequency Converter in Cabinet

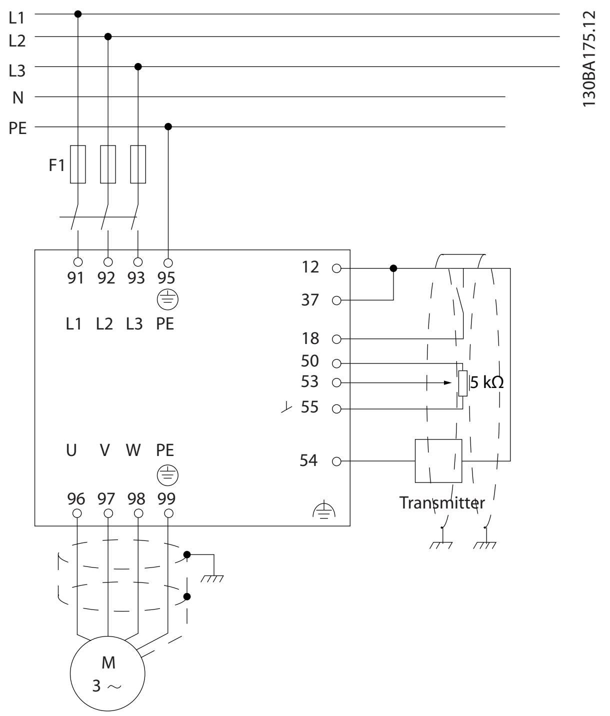


Illustration 7.63 Electrical Connection Diagram

7.8.2 Use of EMC-Correct Cables

Danfoss recommends braided screened/armoured cables to optimise EMC immunity of the control cables and the EMC emission from the motor cables.

The ability of a cable to reduce the 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

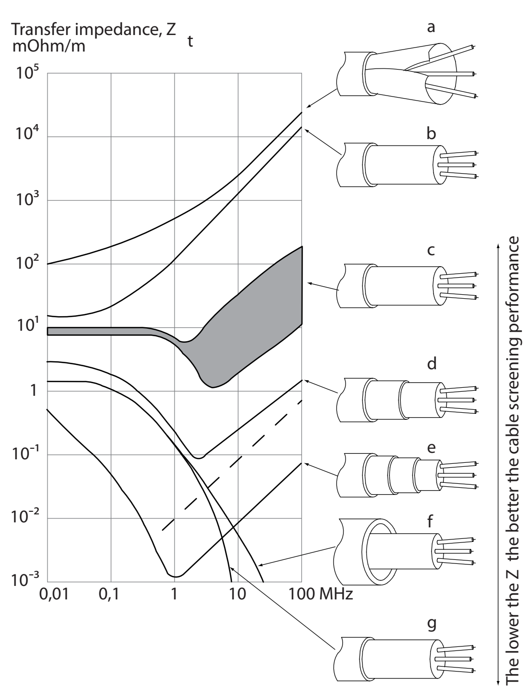


Illustration 7.64 Transfer Impedance

7.8.3 Earthing 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 earth potential between the frequency converter and the PLC is different, electric noise may occur that will disturb the entire system. Solve this problem by fitting an equalizing cable next to the control cable. Minimum cable cross section: 16 mm².

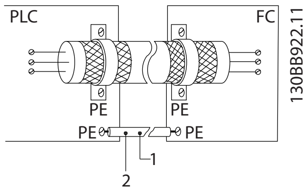


Illustration 7.65 Control Cable with Equalising Cable

1	Min. 16 mm²
2	Equalizing cable

Table 7.38

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

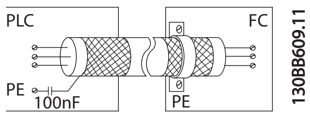


Illustration 7.66 Screen-to-ground Connected to a 100nF Capacitor

Avoid EMC noise on serial communication
This terminal is connected to earth via an internal RC link. Use twisted-pair cables to reduce interference between conductors. The recommended method is shown below:

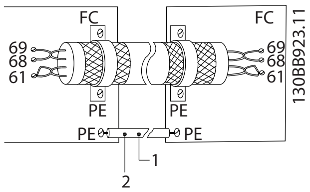


Illustration 7.67 Twisted-pair Cables

1	Min. 16 mm²
2	Equalizing cable

Table 7.39

Alternatively, the connection to terminal 61 can be omitted:

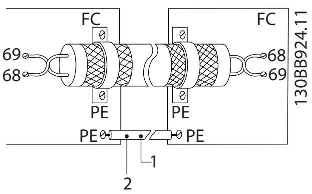


Illustration 7.68 Terminal 61 not Connected

1	Min. 16 mm²
2	Equalizing cable

Table 7.40

7.8.4 RFI Switch

Mains supply isolated from earth
If the frequency converter is supplied from an isolated mains source (IT mains, floating delta) or TT/TN-S mains with grounded leg (grounded delta), the RFI switch must be turned off (OFF) via *14-50 RFI Filter*.
In OFF, the internal capacitors between the chassis (ground/earth), the input RFI filter and the intermediate circuit are cut off. As the RFI switch is turned off, the frequency converter will not be able to meet optimum EMC performance.
By opening the RFI filter switch the earth 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 together 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*.

NOTE

If the RFI switch is not turned off and the frequency converter is running on isolated grids, earth faults can potentially lead to charge up of the intermediate circuit and cause DC capacitor damage or result in reduced product life.

7.9 Residual Current Device

Use RCD relays, multiple protective earthing or earthing as extra protection, provided that local safety regulations are complied with.
If an earth fault appears, a DC content may develop in the faulty current.
If RCD relays are used, local regulations must be observed. Relays must be suitable for protection of 3-phase equipment with a bridge rectifier and for a brief discharge on power-up see *3.8 Earth Leakage Current* for further information.

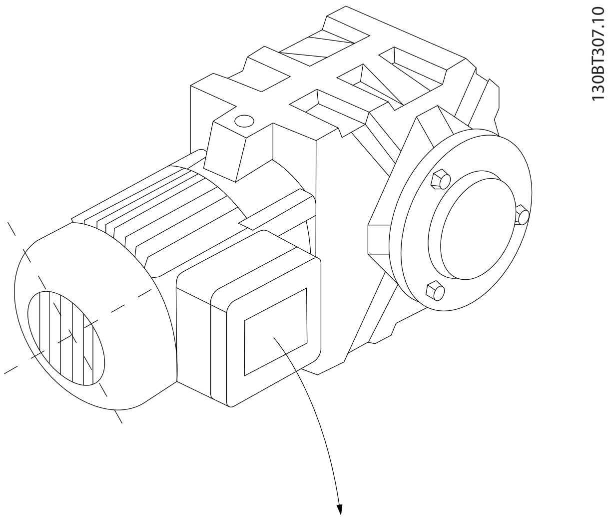
7.10 Final Setup and Test

To test the setup and ensure that the frequency converter is running, follow these steps.

Step 1. Locate the motor name plate

NOTE

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



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

Illustration 7.69 Motor Name plate

Step 2. Enter the motor name plate data in this parameter list.

To access this list, first press [Quick Menu] then select "Q2 Quick Setup".

1. *1-20 Motor Power [kW]*
   1-21 Motor Power [HP]
2. *1-22 Motor Voltage*
3. *1-23 Motor Frequency*
4. *1-24 Motor Current*
5. *1-25 Motor Nominal Speed*

Step 3. Select OGD motor data

1. Set *1-11 Motor Model* to 'Danfoss OGD LA10'.

Step 4. Set speed limit and ramp times

Set up the desired limits for speed and ramp time:

3-02 Minimum Reference

3-03 Maximum Reference

4-11 Motor Speed Low Limit [RPM] or *4-12 Motor Speed Low Limit [Hz]*

4-13 Motor Speed High Limit [RPM] or *4-14 Motor Speed High Limit [Hz]*

3-41 Ramp 1 Ramp Up Time

3-42 Ramp 1 Ramp Down Time

8 Application Examples

NOTE

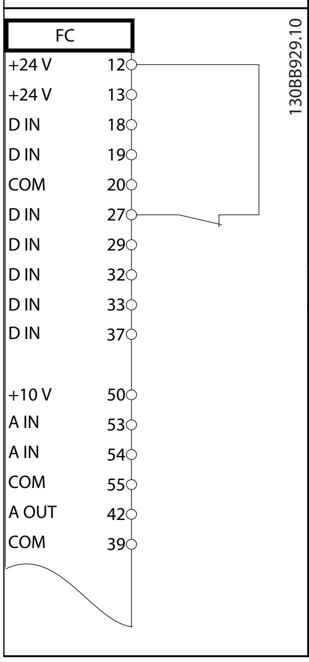
When the optional safe stop feature is used, a jumper wire may be required between terminal 12 (or 13) and terminal 37 for the frequency converter to operate when using factory default programming values.

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

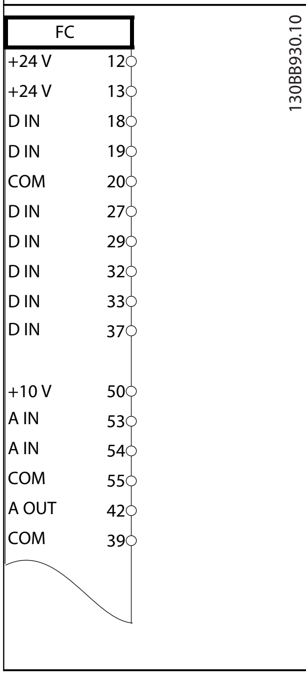
CAUTION

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



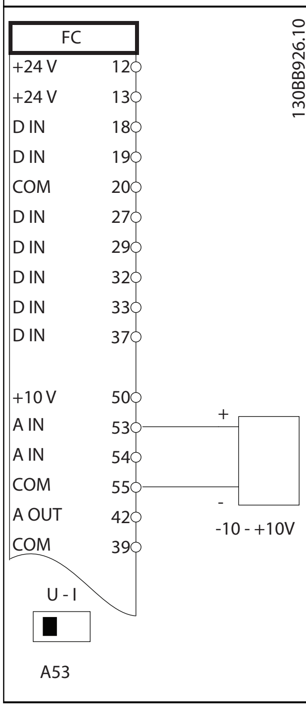
Parameters	
Function	Setting
1-29 Automatic Motor Adaptation (AMA)	[1] Enable complete AMA
5-12 Terminal 27 Digital Input	[2]* Coast inverse
*=Default Value	
Notes/comments: Parameter group *1-2* Motor Data* must be set according to motor	

Table 8.1 AMA with T27 Connected



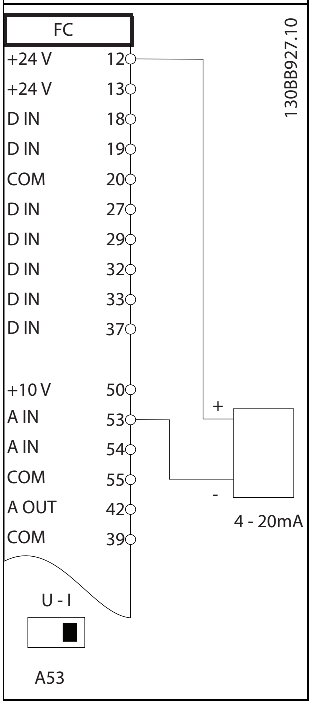
Parameters	
Function	Setting
1-29 Automatic Motor Adaptation (AMA)	[1] Enable complete AMA
5-12 Terminal 27 Digital Input	[0] No operation
*=Default Value	
Notes/comments: Parameter group *1-2* Motor Data* must be set according to motor	

Table 8.2 AMA without T27 Connected



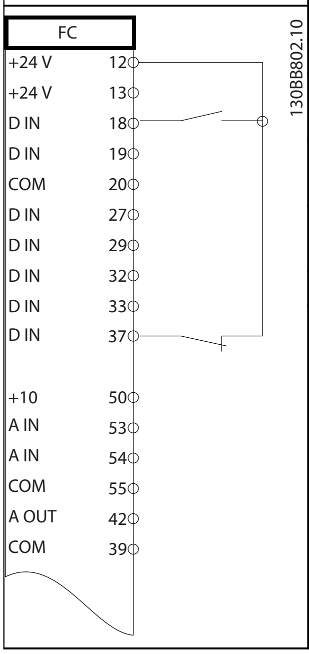
Parameters	
Function	Setting
6-10 Terminal 53 Low Voltage	0.07 V*
6-11 Terminal 53 High Voltage	10 V*
6-14 Terminal 53 Low Ref./Feedb. Value	0 RPM
6-15 Terminal 53 High Ref./Feedb. Value	1500 RPM
*=Default Value	
Notes/comments:	

Table 8.3 Analog Speed Reference (Voltage)



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

Table 8.4 Analog Speed Reference (Current)



Parameters	
Function	**Setting**
5-10 Terminal 18 Digital Input	[8] Start*
5-12 Terminal 27 Digital Input	[0] No operation
5-19 Terminal 37 Safe Stop	[1] Safe Stop Alarm
*=Default Value	
Notes/comments: If *5-12 Terminal 27 Digital Input* is set to *[0] No operation*, a jumper wire to terminal 27 is not needed.	

Table 8.5 Start/Stop Command with Safe Stop

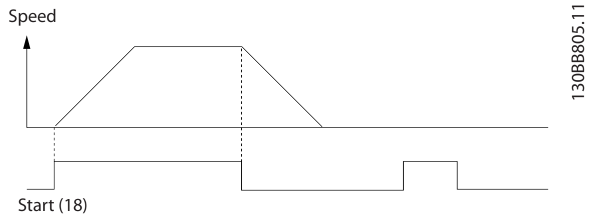
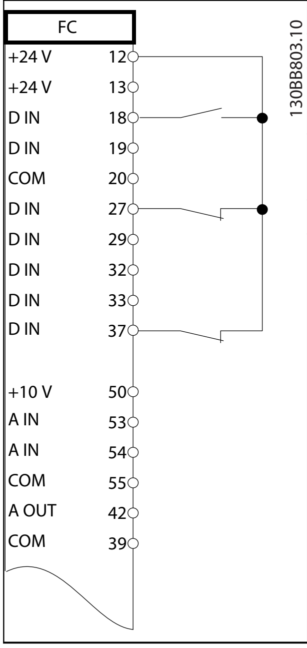


Illustration 8.1 Start/Stop with Safe Stop



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

Table 8.6 Pulse Start/Stop

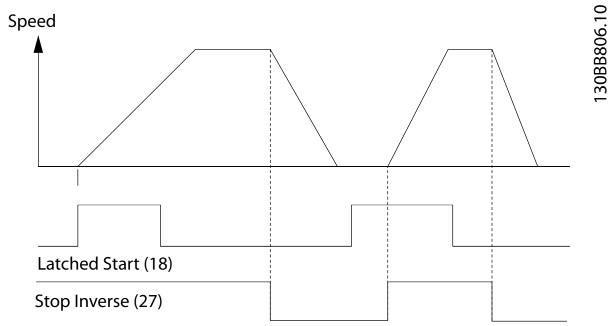
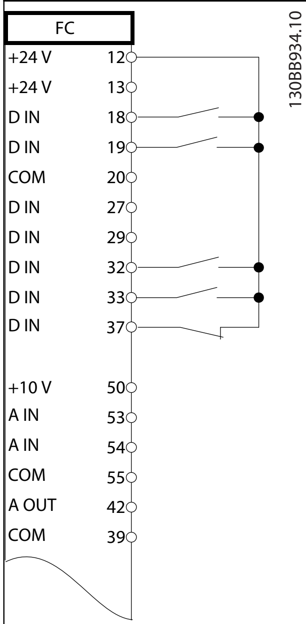
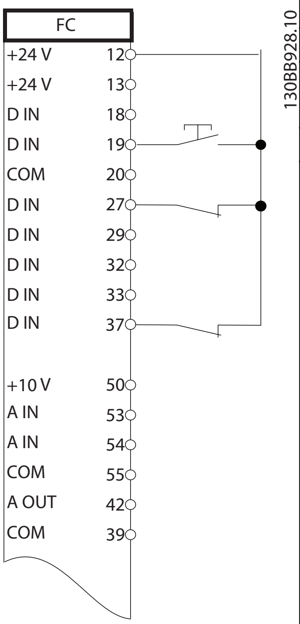


Illustration 8.2 Latched Start/Stop Inverse



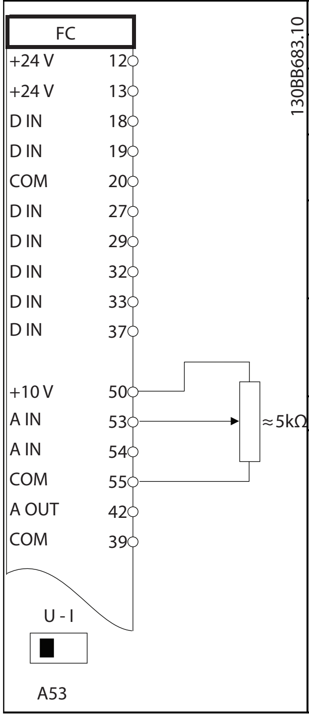
Parameters	
Function	Setting
5-10 Terminal 18 Digital Input	[8] Start
5-11 Terminal 19 Digital Input	[10] Reversing*
5-12 Terminal 27 Digital Input	[0] No operation
5-14 Terminal 32 Digital Input	[16] Preset ref bit 0
5-15 Terminal 33 Digital Input	[17] Preset ref bit 1
3-10 Preset Reference Preset ref.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

Table 8.7 Start/Stop with Reversing and 4 Preset Speeds



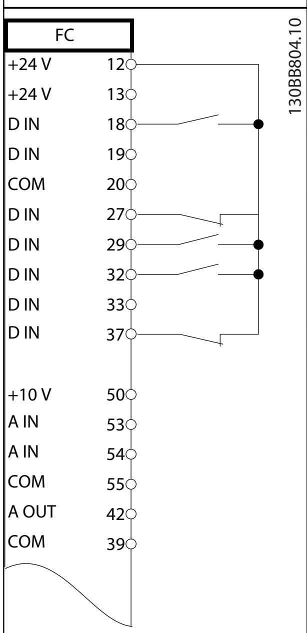
Parameters	
Function	Setting
5-11 Terminal 19 Digital Input	[1] Reset
*=Default Value	
Notes/comments:	

Table 8.8 External Alarm Reset



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

Table 8.9 Speed Reference (using a Manual Potentiometer)



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

Table 8.10 Speed Up/Down

8

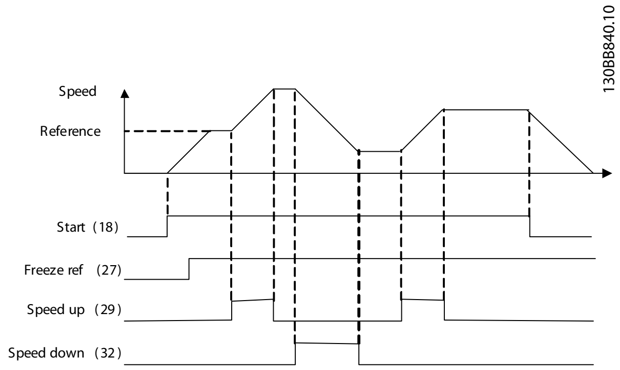


Illustration 8.3 Speed Up/Down

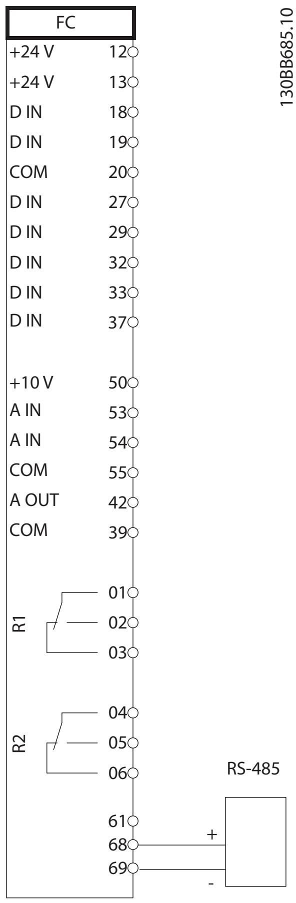
	Parameters	
	Function	Setting
	8-30 Protocol	FC*
	8-31 Address	1*
	8-32 Baud Rate	9600*
	*=Default Value	
	Notes/comments: Select protocol, address and baud rate in the above mentioned parameters.	

Table 8.11 RS-485 Network Connection

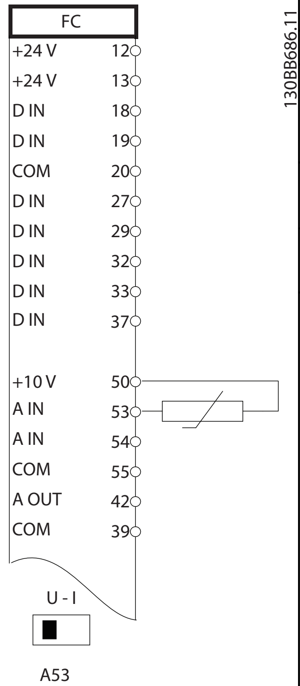
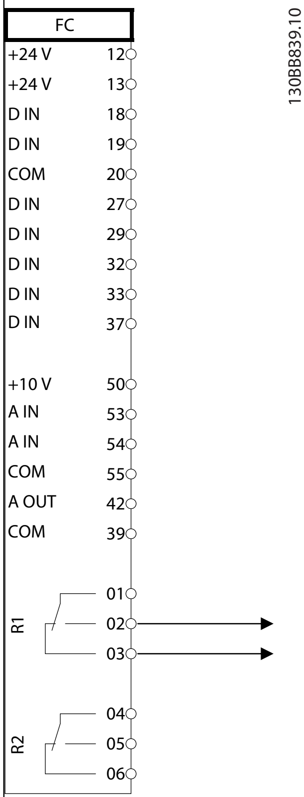
	Parameters	
	Function	Setting
	1-90 Motor Thermal Protection	[2] Thermistor trip
	1-93 Thermistor Source	[1] Analog input 53
	*=Default Value	
	Notes/comments: If only a warning is desired, *1-90 Motor Thermal Protection* should be set to *[1] Thermistor warning*.	

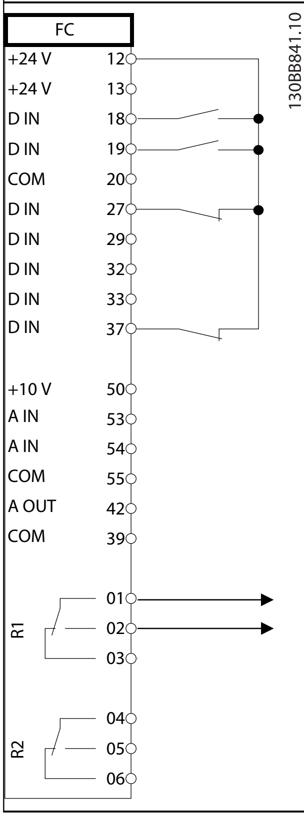
Table 8.12 Motor Thermistor



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

Notes/comments:
If the limit in the feedback monitor is exceeded, Warning 90 will be issued. The SLC monitors Warning 90 and in the case that Warning 90 becomes TRUE then Relay 1 is triggered.
External equipment may then indicate that service may be required. If the feedback error goes below the limit again within 5 s then the frequency converter continues and the warning disappears. But Relay 1 will still be triggered until [Reset] on the LCP.

Table 8.13 Using SLC to Set a Relay



Parameters	
Function	**Setting**
5-40 Function Relay	[32] Mech. brake ctrl.
5-10 Terminal 18 Digital Input	[8] Start*
5-11 Terminal 19 Digital Input	[11] Start reversing
1-71 Start Delay	0.2
1-72 Start Function	[5] VVC^{plus}/ 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 8.14 Mechanical Brake Control

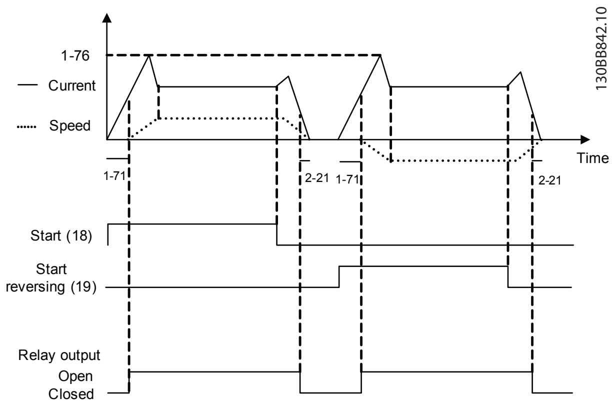


Illustration 8.4 Mechanical Brake Control

8

8

8.1.1 Closed Loop Drive System

A drive system consist usually of more elements such as:

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

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

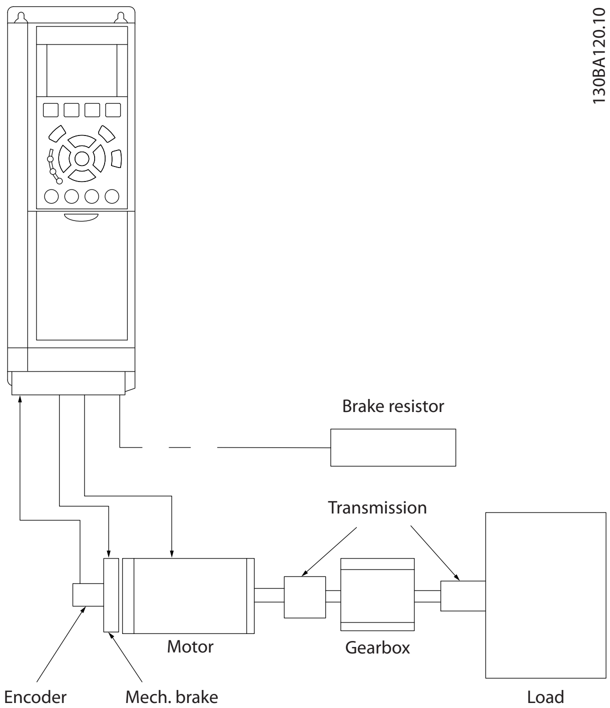


Illustration 8.5 Basic Set-up for FC 302 Closed Loop Speed Control

8.1.2 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 Torque limit and stop [27]) is activated. The signal to terminal 27 changes from 'logic 1' to 'logic 0', and the motor starts to coast, thereby ensuring that the hoist stops even if the frequency converter itself cannot handle the required torque (i.e. due to excessive overload).

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

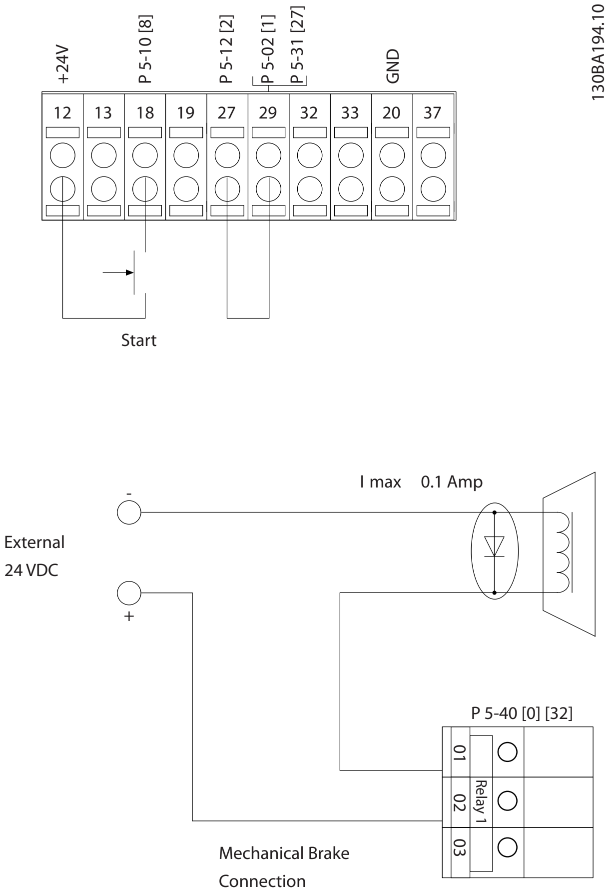


Illustration 8.6 External Electro-mechanical Brake

9 Options and Accessories

Danfoss offers a wide range of options and accessories.

9.1.1 Mounting of Option Modules in Slot A

Slot A position is dedicated to Fieldbus options. For further information, see separate operating instructions.

9.1.2 Mounting of Option Modules in Slot B

The power to the frequency converter must be disconnected.

It is strongly recommended to make sure the parameter data is saved (i.e. by MCT 10 software) before option modules are inserted/removed from the drive.

- Remove the LCP (Local Control Panel), the terminal cover, and the LCP frame from the frequency converter.
- Fit the MCB10xy option card into slot B.
- Connect the control cables and relieve the cable by the enclosed cable strips.
  * Remove the knock out in the extended LCP frame, so that the option will fit under the extended LCP frame.
- Fit the extended LCP frame and terminal cover.
- Fit the LCP or blind cover in the extended LCP frame.
- Connect power to the frequency converter.
- Set up the input/output functions in the corresponding parameters, as mentioned in .

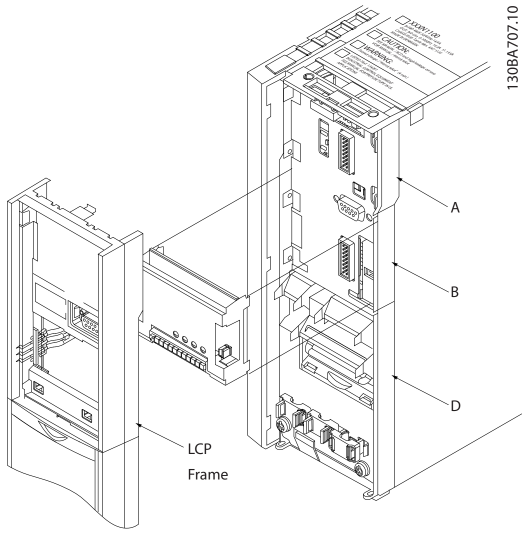


Illustration 9.1 Frame Sizes A2, A3 and B3

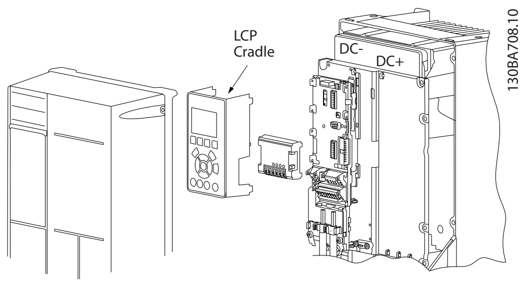


Illustration 9.2 Frame Sizes A5, B1, B2, B4, C1, C2, C3 and C4

9.1.3 Mounting of Options in Slot C

The power to the frequency converter must be disconnected.

It is strongly recommended to make sure the parameter data is saved (i.e. by MCT 10 software) before option modules are inserted/removed from the drive.
When installing a C option, a mounting kit is required. Please refer to *5 How to Order* for a list of ordering numbers. The installation is illustrated using MCB 112 as an example. For more information on installation of MCO 305, see *9.2 MCO 305 Programmable Motion Controller* and separate operating instructions.

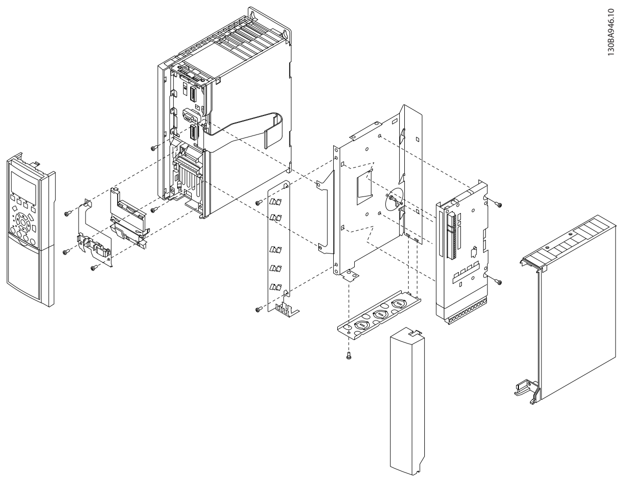


Illustration 9.3 Frame Sizes A2, A3 and B3

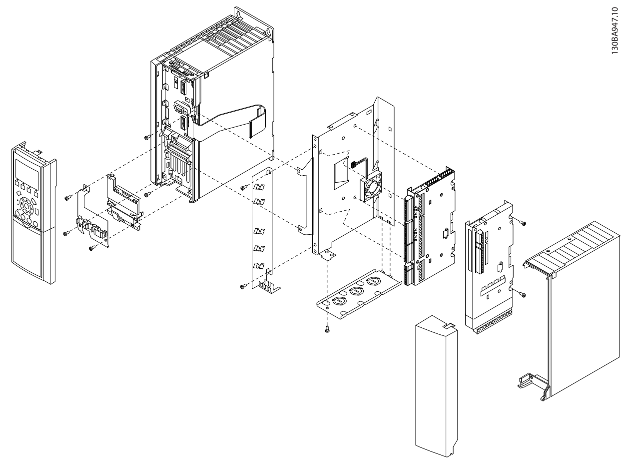


Illustration 9.5 Frame Sizes A2, A3 and B3

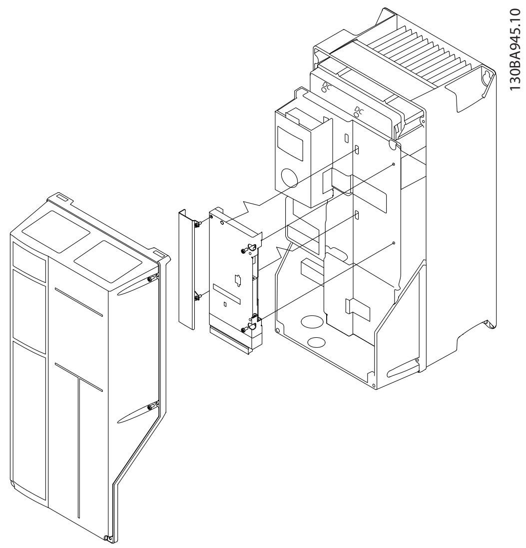


Illustration 9.4 Frame Sizes A5, B1, B2, B4, C1, C2, C3 and C4

If both C0 and C1 options are to be installed, the installation is carried out as shown in *Illustration 9.5*. Note that this is only possible for frame sizes A2, A3 and B3.

9.2 MCO 305 Programmable Motion Controller

NOTE

See the MCO 305 Operating Instructions for more information.

The VLT Motion Control Option MCO 305 is an integrated free programmable Motion Controller for VLT AutomationDrive FC 301 and 302. It can be supplied either as an option card for field installation or as a built-in option. For retrofit, a mounting kit must be purchased. There is a different mounting kit for different frames. MCO 305 is to be used in slot C0 but can be combined with another option in slot C1.

Mounting kit depending on frame	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 9.1 Mounting Kit Ordering Numbers

Do not mount the small fan for B4, C3 and C4.

9

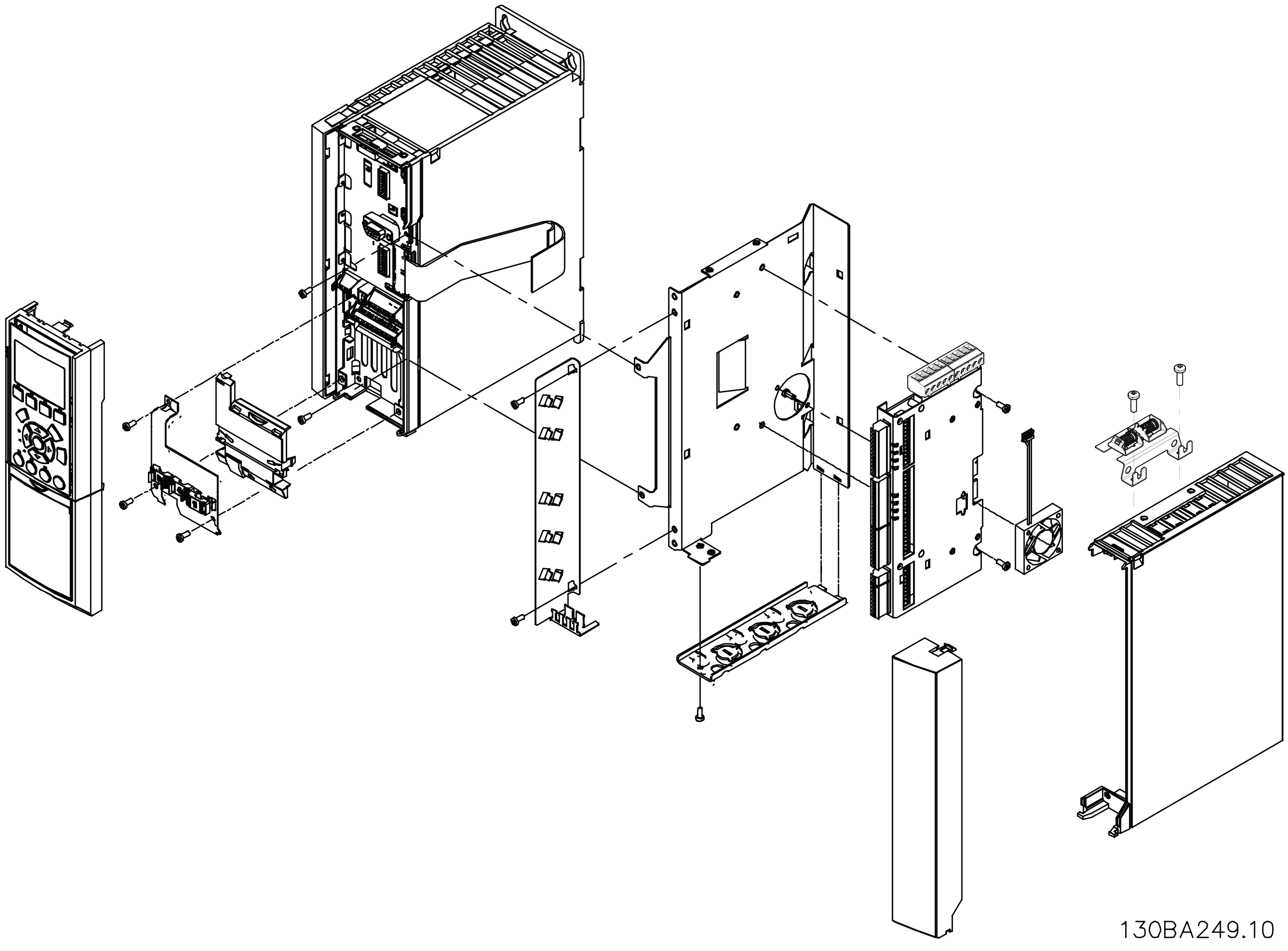


Illustration 9.6 Bookstyle - A2, A3 and B3

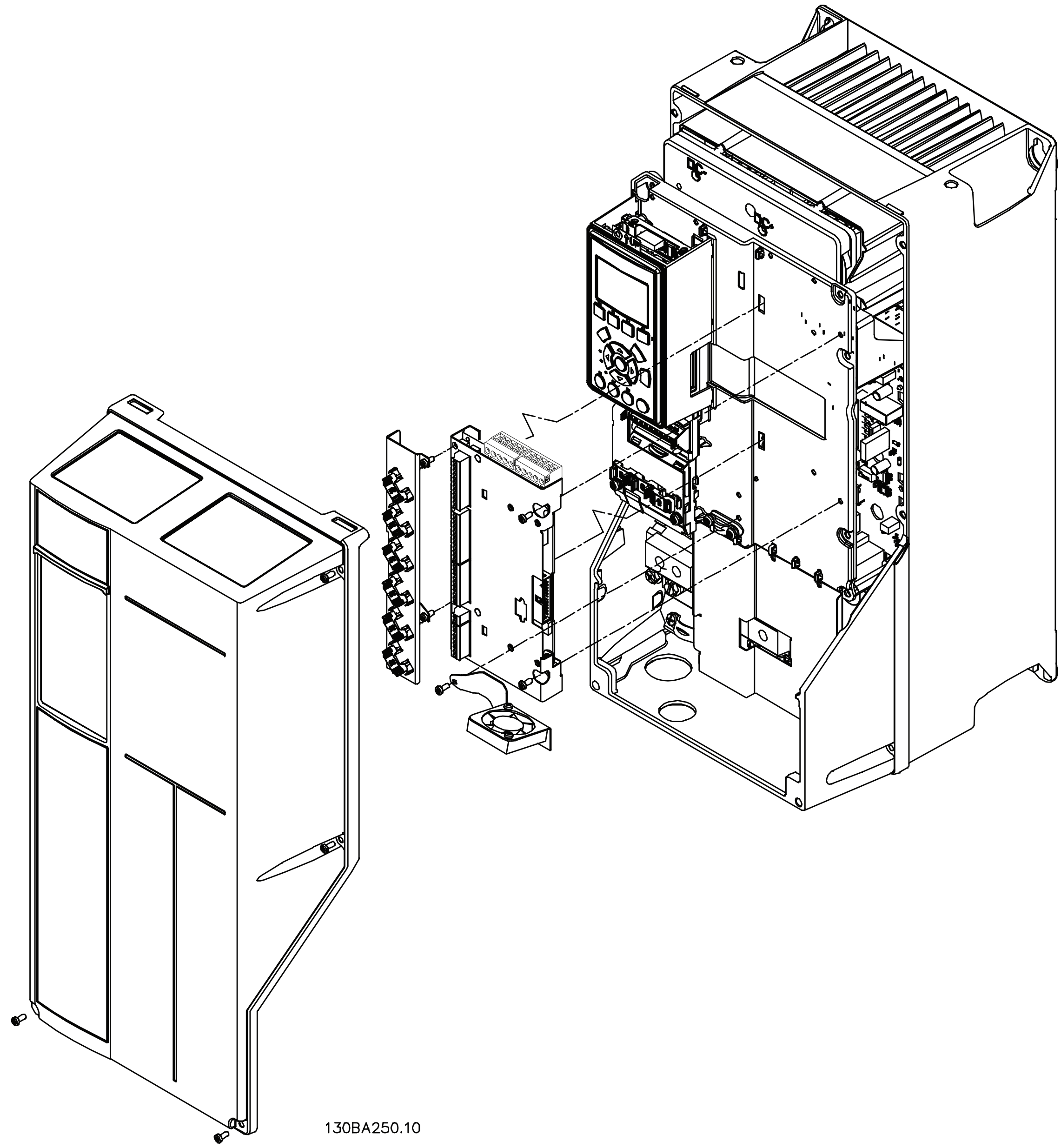


Illustration 9.7 Compact - A5, B (except B3) and C

MCO 305 Control Terminals

For frame sizes A2 and A3, encoder and I/O terminal are located behind the C option terminal cover, see *Illustration 9.8*. MCO CAN bus terminals and debug terminals (RS-485) are located on the top of the c-option cover. If these connections are used cut out the plastic parts above the connectors and mount the cable relief.

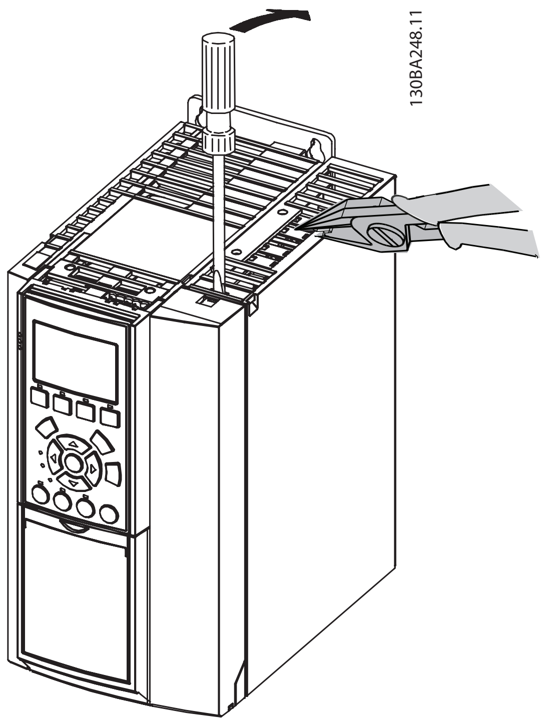


Illustration 9.8 Location of Encoder and I/O Terminals

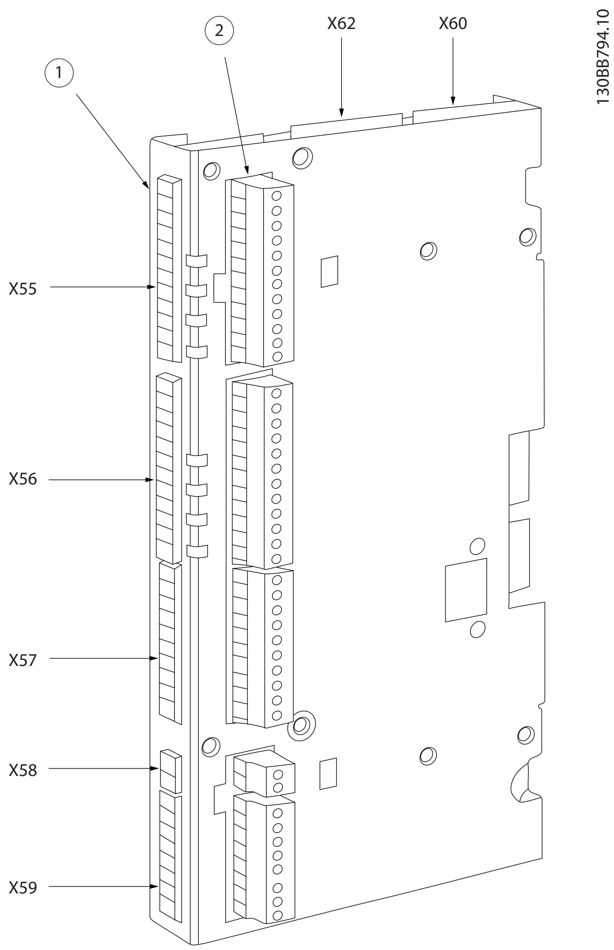


Illustration 9.9 Location of Terminal Blocks

For frame sizes A5, B1 and B2 all MCO 305 terminals are located next to the VLT® AutomationDrive 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 frame size.

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)

Terminal block 1 is to be used with bookstyle and terminal block 2 with compact.

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 9.2 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 9.3 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 9.4 Terminal Block X57

Terminal number	Descriptive Name Supply
1	+24 V Supply
2	GND

Table 9.5 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 9.6 Terminal Block X59

Terminal number	MCO Debug (RS485)
[1]CS	Control Select
62	RxD/TxD - P
63	RxD/TxD - N
66	0 V
67	+5 V

Table 9.7 Terminal Block X60

Terminal number	MCO CAN Bus
1	N/A
2	CAN - L
3	DRAIN
4	CAN - H
5	N/A

Table 9.8 Terminal Block X62

9.3 General Purpose Input Output Module MCB 101

MCB 101 is used for extension of digital and analog inputs and outputs of FC 301 and FC 302.

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

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

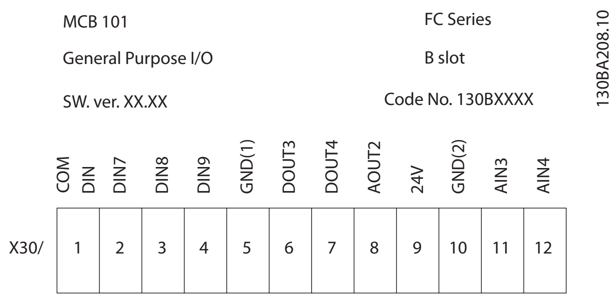


Illustration 9.10 MCB 101 Option

9.3.1 Galvanic Isolation in the MCB 101

Digital/analog inputs are galvanically isolated from other inputs/outputs on the MCB 101 and in the control card of the frequency converter. Digital/analog outputs in the MCB 101 are galvanically isolated from other inputs/outputs on the MCB 101, but not from 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 illustrated in *Illustration 9.11* has to be established.

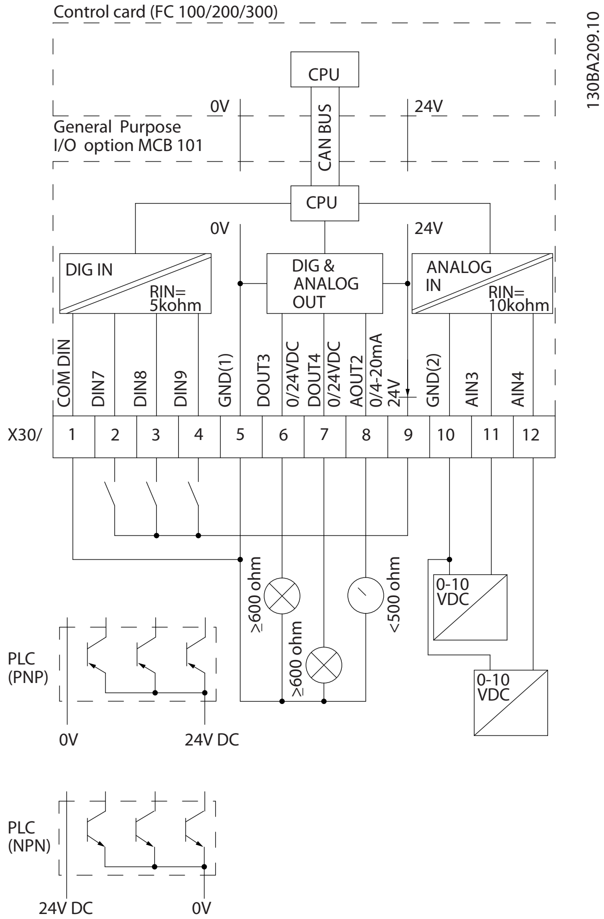


Illustration 9.11 Principle Diagram

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

9.4 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^{plus} closed loop
- Flux Vector Speed control
- Flux Vector Torque control
- Permanent magnet motor

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

NOTE

Incremental encoders are not recommended for use with PM motors due to risk of wrong polarity.

NOTE

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.

9

NOTE

The LEDs are only visible when removing the LCP. Reaction in case of an encoder error can be selected in *17-61 Feedback Signal Monitoring*: None, Warning or Trip.

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

When the encoder option kit is ordered separately the kit includes:

- Encoder Option MCB 102
- Enlarged LCP fixture and enlarged terminal cover

Connector Designation X31	Incremental Encoder (refer to *Illustration 9.12*)	SinCos Encoder Hiperface® (refer to *Illustration 9.13*)	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 9.9

** Supply for encoder: see data on encoder*

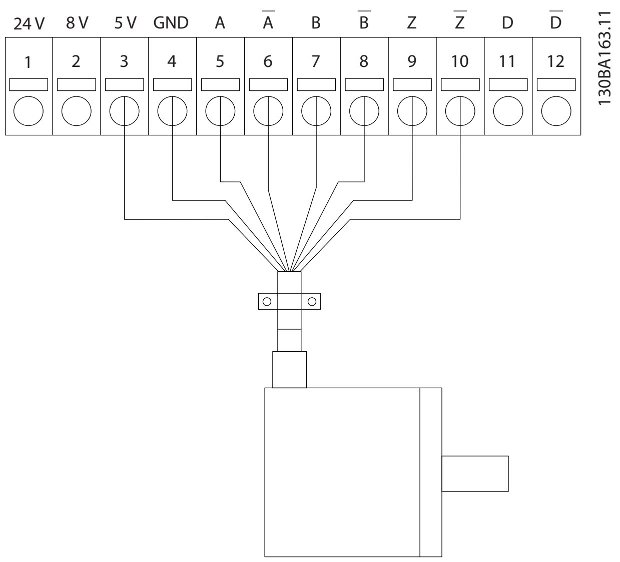


Illustration 9.12 Incremental Encoder

NOTE

Max. cable length 150 m.

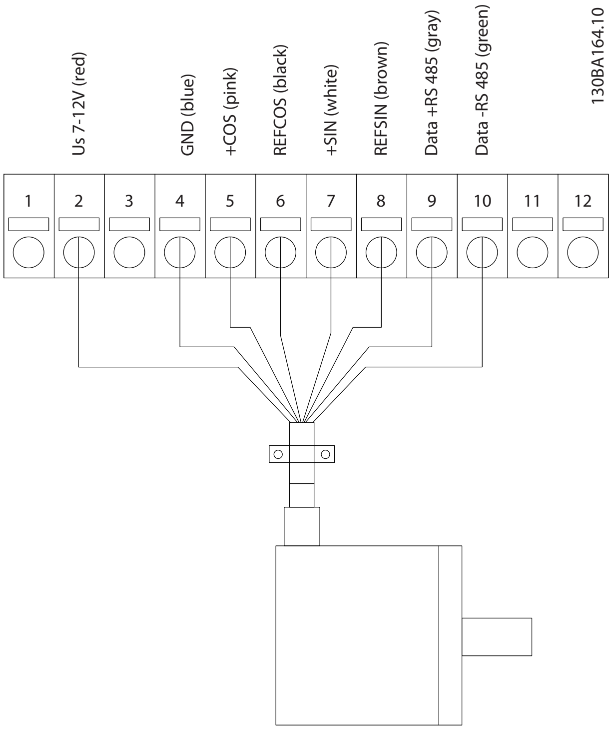


Illustration 9.13 SinCos Encoder Hiperface

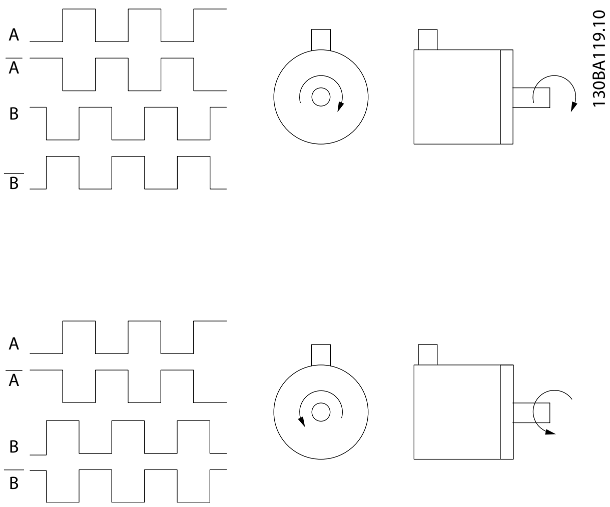


Illustration 9.14 Rotation Direction

9.5 Resolver Option MCB 103

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

MCB 103 Resolver Option supports a various number of resolver types.

Resolver Poles	*17-50 Poles*: 2 *2
Resolver Input Voltage	*17-51 Input Voltage*: 2.0 – 8.0 Vrms *7.0 Vrms
Resolver Input Frequency	*17-52 Input Frequency*: 2–15 kHz *10.0 kHz
Transformation ratio	*17-53 Transformation Ratio*: 0.1–1.1 *0.5
Secondary input voltage	Max 4 Vrms
Secondary load	App. 10 kΩ

Table 9.10 Resolver Specifications

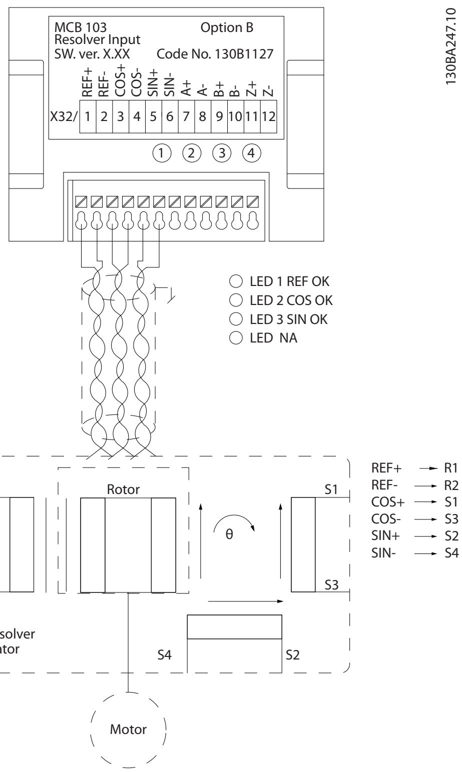


Illustration 9.15 MCB 103 Resolver Input

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 *Warning* or *Trip*.

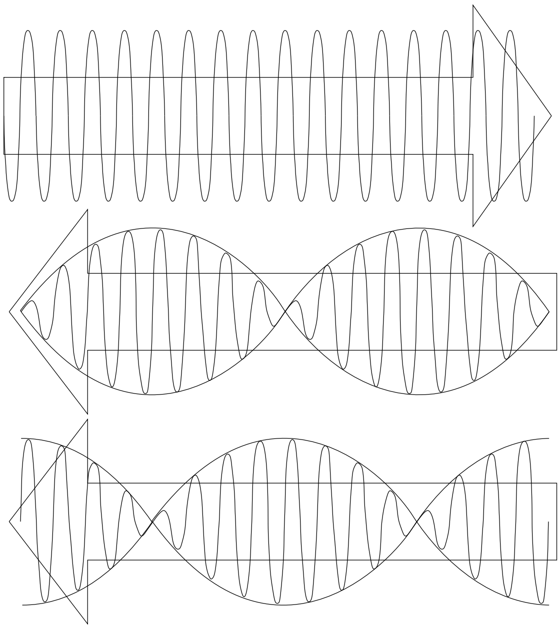

130BT102.10

Illustration 9.16 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.

NOTE

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

NOTE

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

NOTE

Always use screened motor cables and brake chopper cables.

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

Table 9.11 Parameters to Adjust

9.6 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 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

The relay option does not support FC 302 frequency converters manufactured before week 50/2004.
Min. software version: 2.03 (*15-43 Software Version*).

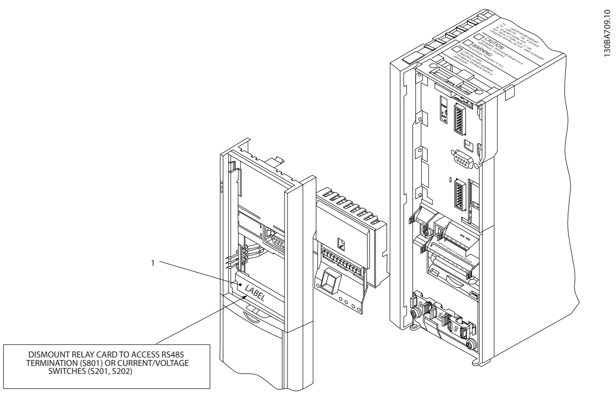


Illustration 9.17 A2-A3-B3

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

Table 9.12 Legend to *Illustration 9.17*

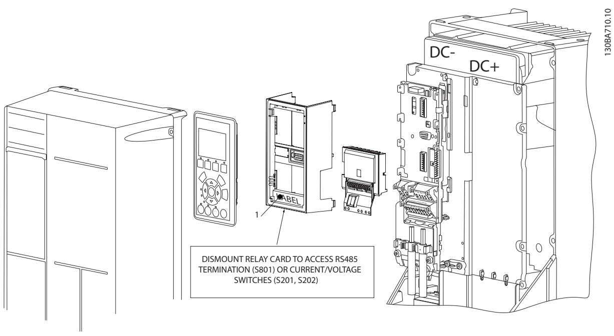


Illustration 9.18 A5-B1-B2-B4-C1-C2-C3-C4

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

Table 9.13 Legend to *Illustration 9.18*

⚠WARNING

Warning Dual supply

How to add the MCB 105 option:

- The power to the frequency converter must be disconnected.
- The power to the live part connections on relay terminals must be disconnected.
- Remove the LCP, the terminal cover and the LCP fixture from the frequency converter.
- Fit the MCB 105 option in slot B.
- Connect the control cables and fasten the cables with the enclosed cable strips.
- Make sure the length of the stripped wire is correct (see the following drawing).
- Do not mix live parts (high voltage) with control signals (PELV).
- Fit the enlarged LCP fixture and enlarged terminal cover.
- Replace the LCP.
- Connect power to the frequency converter.

- Select the relay functions in *5-40 Function Relay* [6-8], *5-41 On Delay, Relay* [6-8] and *5-42 Off Delay, Relay* [6-8].

NOTE

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

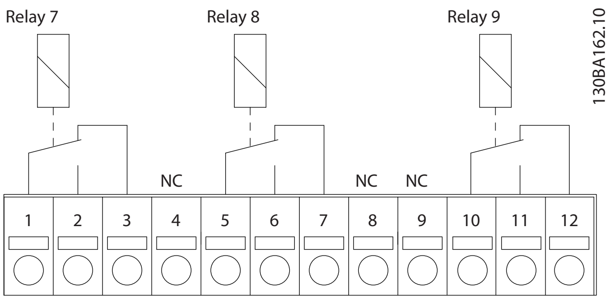


Illustration 9.19 Relays

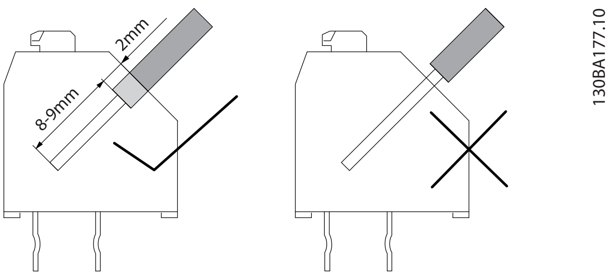


Illustration 9.20 Correct Wire Inserting

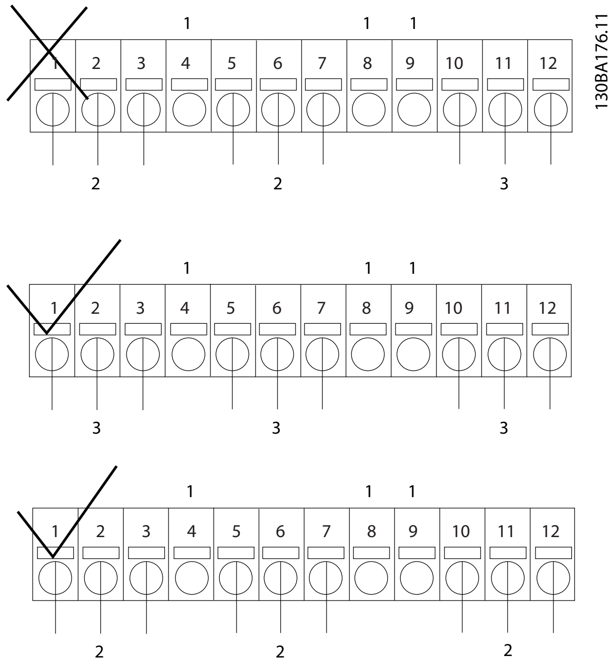


Illustration 9.21 Correct Relay Wiring

1	NC
2	Live part
3	PELV

Table 9.14 Legend to *Illustration 9.21*

WARNING

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

9.7 24 V Back-Up Option MCB 107

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) without connection to mains.

External 24 V DC supply specification	
Input voltage range	24 V DC ±15 % (max. 37 V for 10 s)
Max. input current	2.2 A
Average input current for FC 302	0.9 A
Max cable length	75 m
Input capacitance load	< 10 uF
Power-up delay	< 0.6 s

The inputs are protected.

Terminal numbers:

Terminal 35: - external 24 V DC supply.

Terminal 36: + external 24 V DC supply.

Follow these steps:

1. Remove the LCP or Blind Cover
2. Remove the Terminal Cover
3. Remove the Cable Decoupling Plate and the plastic cover underneath
4. Insert the 24 V DC Back-up External Supply Option in the Option Slot
5. Mount the Cable Decoupling Plate
6. Attach the Terminal Cover and the LCP or Blind Cover.

When MCB 107, 24 V back-up option is supplying the control circuit, the internal 24 V supply is automatically disconnected.

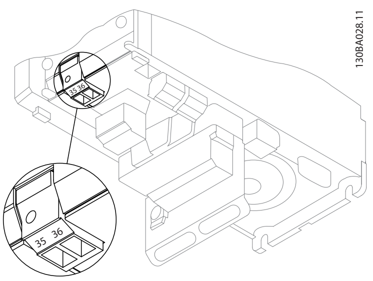


Illustration 9.22 Connection to 24 V Back-up Supply on Frame Sizes A2 and A3.

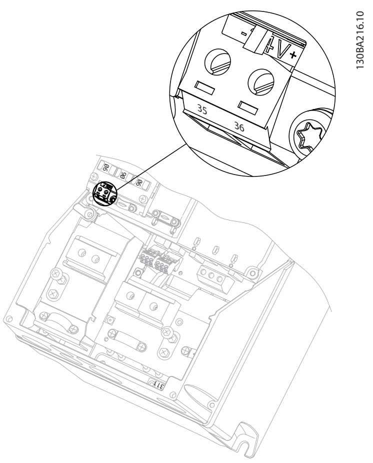


Illustration 9.23 Connection to 24 V Back-up Supply on Frame Sizes A5, B1, B2, C1 and C2.

9.8 MCB 112 PTC Thermistor Card

The MCB 112 option makes it possible to monitor the temperature of an electrical motor through a galvanically isolated PTC thermistor input. It is a B option for frequency converter with Safe Stop.

For information on mounting and installation of the option, please see *9.1.2 Mounting of Option Modules in Slot B*. See also *8 Application Examples* for different application possibilities.

X44/1 and X44/2 are the thermistor inputs, X44/12 will enable safe stop of the frequency converter (T-37) if the thermistor values make it necessary and X44/10 will inform the frequency converter that a request for Safe Stop came from the MCB 112 in order to ensure a suitable alarm handling. One of the digital inputs parameters of the frequency converter (or a digital input of a mounted option) must be set to *[80] PTC Card 1* in order to use the information from X44/10. *5-19 Terminal 37 Safe Stop* Terminal 37 Safe Stop must be configured to the desired Safe Stop functionality (default is Safe Stop Alarm).

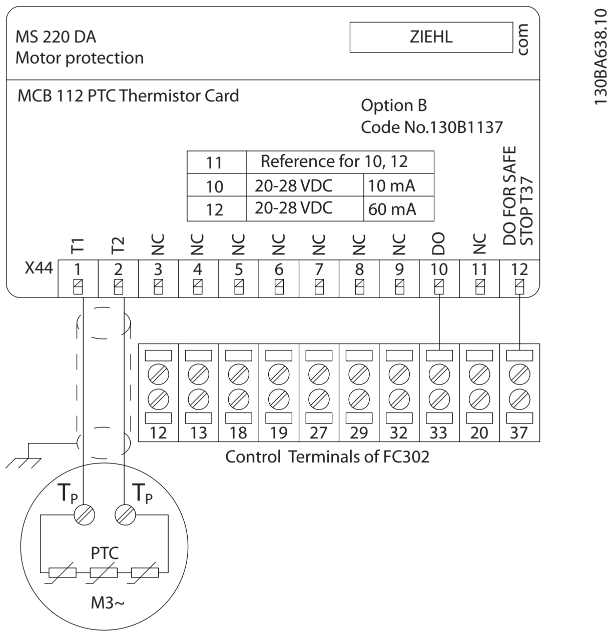


Illustration 9.24 Installation of MCB 112

ATEX Certification with FC 302

The MCB 112 has been certified for ATEX which means that the frequency converter together 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 9.25 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	

9

9.9 MCB 113 Extended Relay Card

The MCB 113 adds 7 digital inputs, 2 analog outputs and 4 SPDT relays to the standard I/O of the frequency converter for increased flexibility and to comply with the German NAMUR NE37 recommendations.

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

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

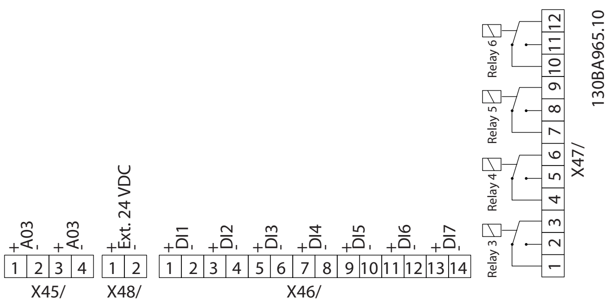


Illustration 9.26 Electrical Connections of MCB 113

MCB 113 can be connected to an external 24 V on X58/ in order 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.

NOTE

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*.

NOTE

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%

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

9.10 Brake Resistors

In applications where the motor is used as a brake, energy is generated in the motor and send back into the frequency converter. If the energy can not be transported back to the motor it will increase the voltage in the converter DC-line. In applications with frequent braking and/or high inertia loads this increase may lead to an over voltage trip in the converter and finally a shut down. Brake resistors are used to dissipate the excess energy resulting from the regenerative braking. The resistor is selected in respect to its ohmic value, its power dissipation rate and its physical size. Danfoss offers a wide variety of different resistors that are specially designed to our frequency converters. See *3.8.5 Control with Brake Function* for dimensioning of brake resistors. Code numbers can be found in *5 How to Order*.

9.11 LCP Panel Mounting Kit

The LCP can be moved to the front of a cabinet by using the remote built-in kit. The enclosure is the IP66. The fastening screws must be tightened with a torque of max. 1 Nm.

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

Table 9.15 Technical Data

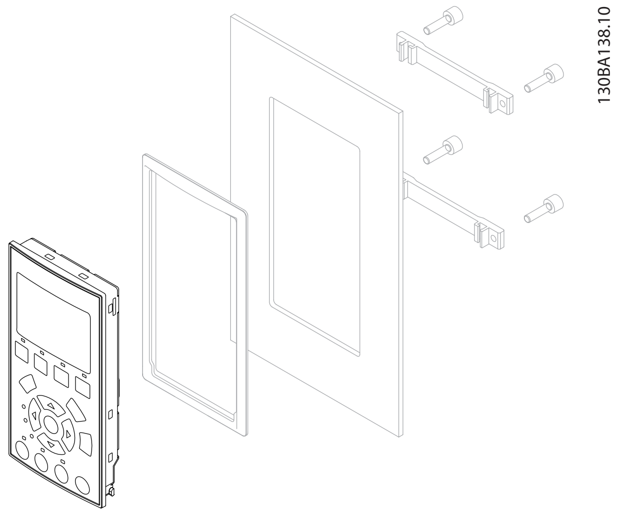


Illustration 9.27 LCP Kit with Graphical LCP, Fasteners, 3 m Cable and Gasket
Ordering No. 130B1113

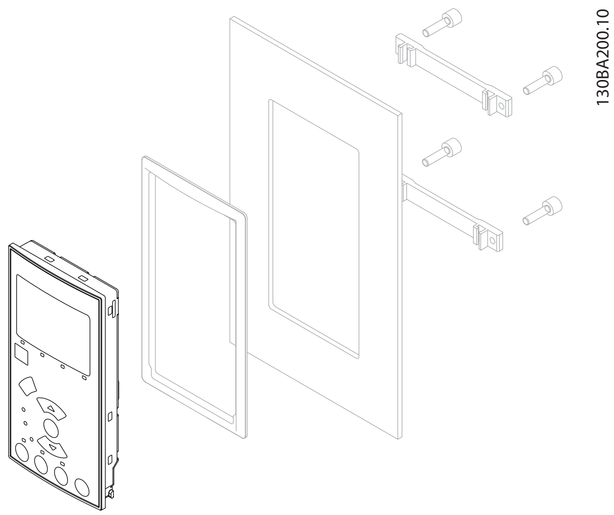


Illustration 9.28 LCP Kit with Numerical LCP, Fasteners and Gasket
Ordering no. 130B1114

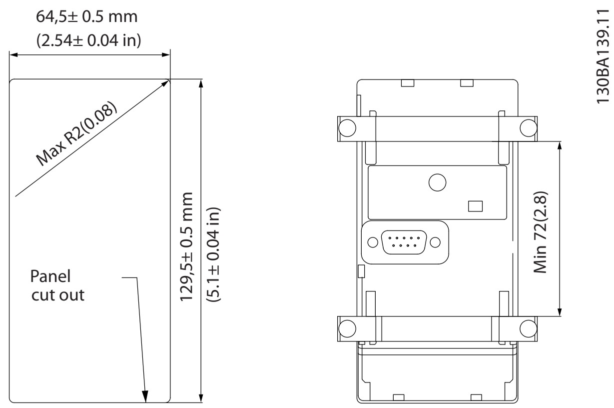


Illustration 9.29 Dimensions

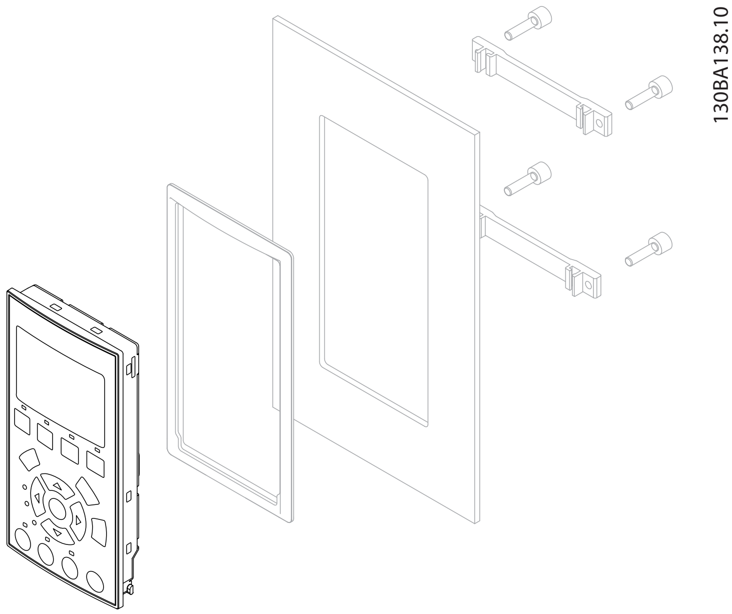


Illustration 9.30 Not for US

9.12 IP21/IP 4X/ TYPE 1 Enclosure Kit

IP20/IP 4X 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.

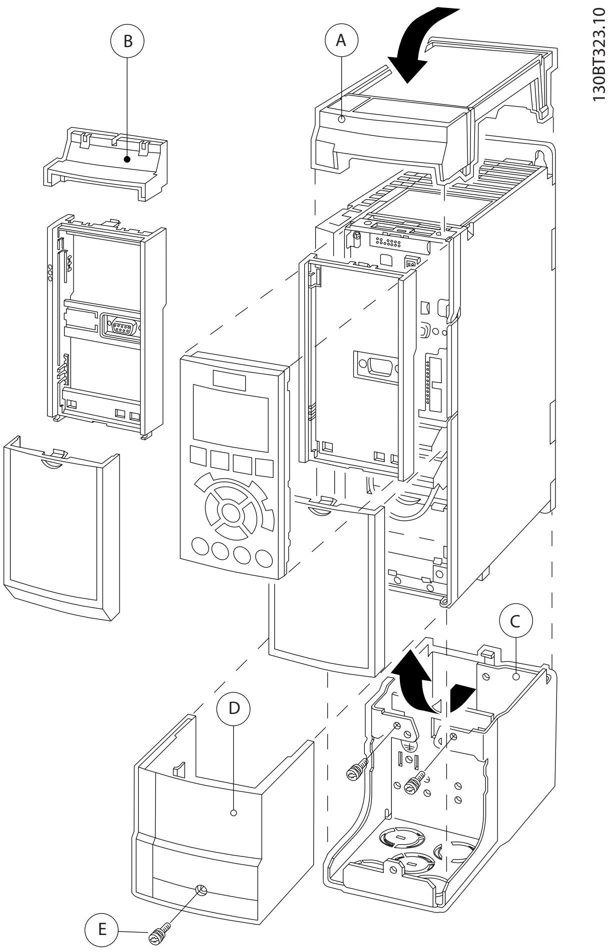


Illustration 9.31 A2 Enclosure

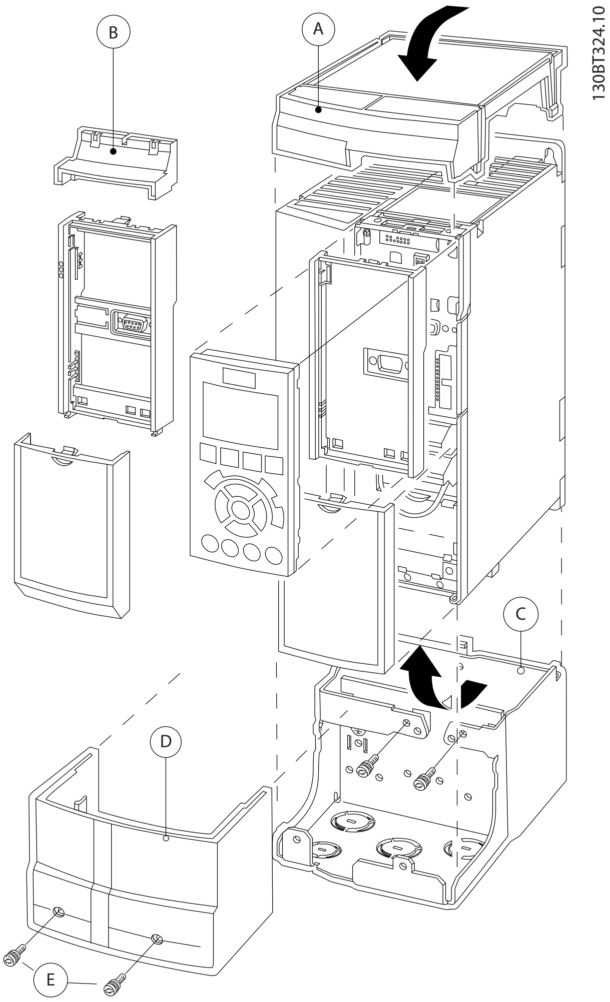


Illustration 9.32 A3 Enclosure

A	Top cover
B	Brim
C	Base part
D	Base cover
E	Screw(s)

Table 9.16 Legend to *Illustration 9.31* and *Illustration 9.32*

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

Frame size 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 9.17 Dimensions

** If option A/B is used, the depth will increase (see 6.1.2 Mechanical Dimensions for details)*

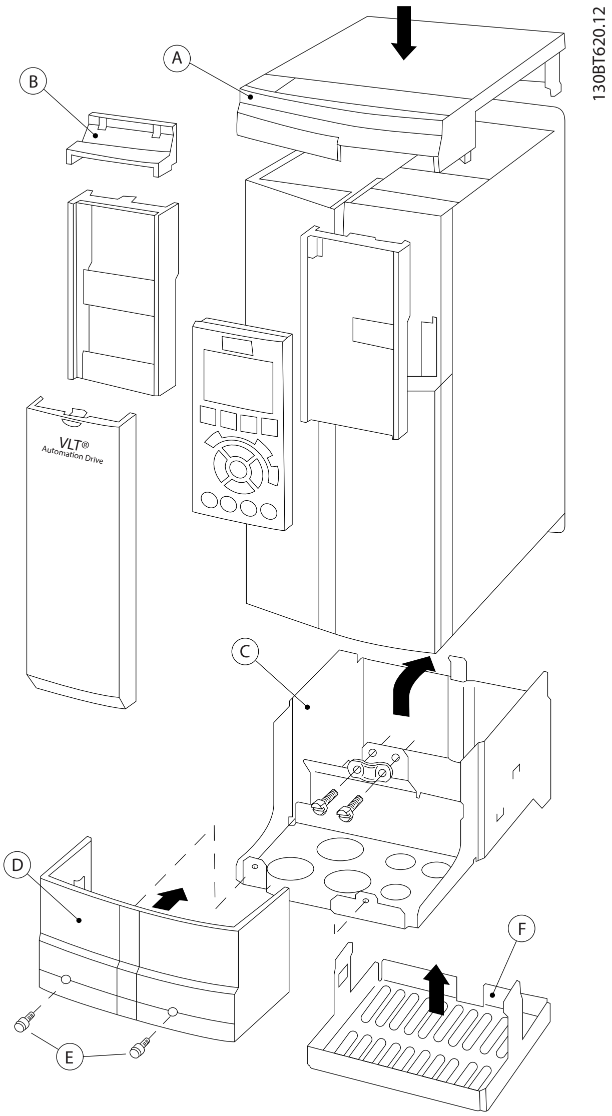


Illustration 9.33 B3 Enclosure

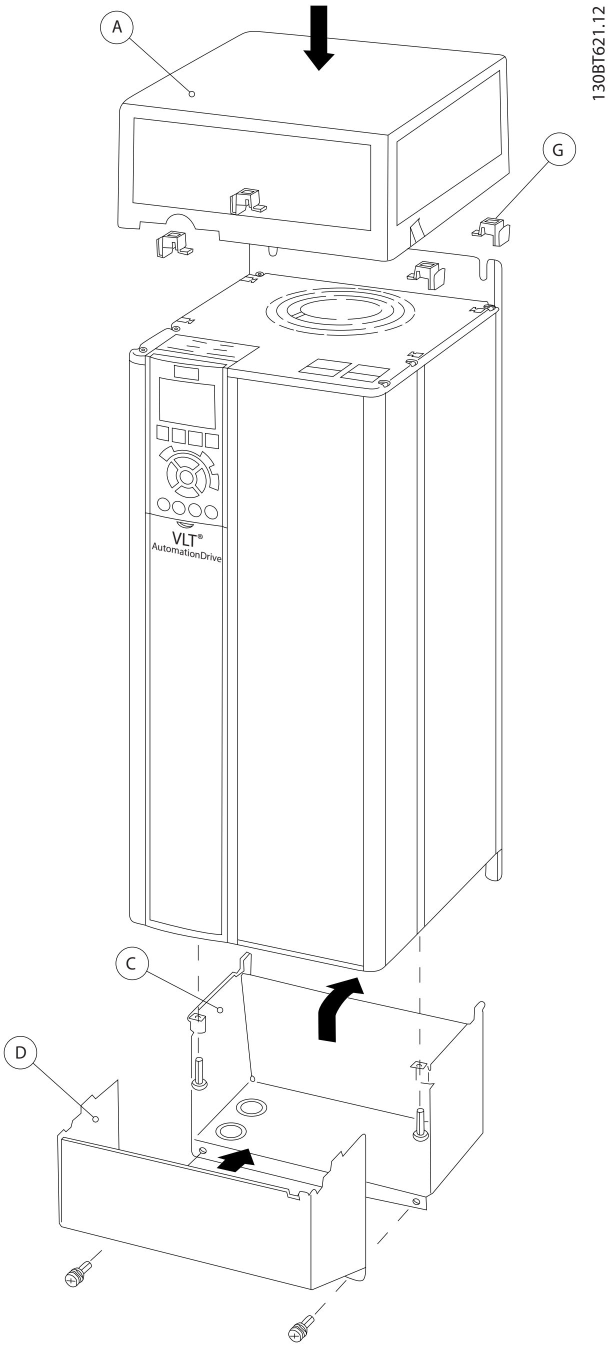


Illustration 9.34 B4 - C3 - C4 Enclosure

A	Top cover
B	Brim
C	Base part
D	Base cover
E	Screw(s)
F	Fan cover
G	Top clip

Table 9.18 Legend to *Illustration 9.33* and *Illustration 9.33*

9

When option module A and/or option module B is/are used, the brim (B) must be fitted to the top cover (A).

NOTE

Side-by-side installation is not possible when using the *IP21/IP4X/TYPE 1 Enclosure Kit*

9.13 Mounting Bracket for Frame Size A5, B1, B2, C1 and C2

Step 1

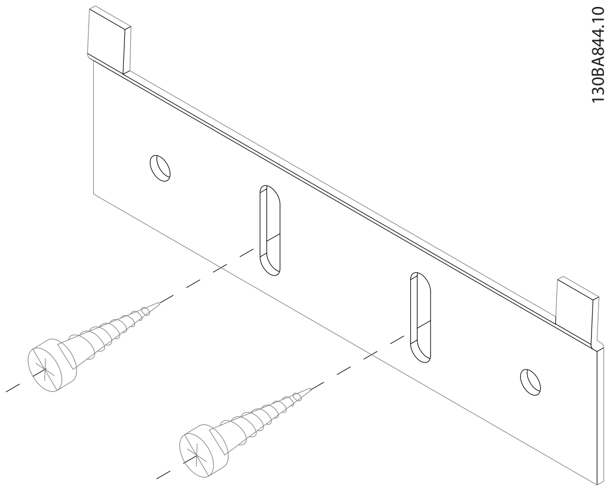


Illustration 9.35 Lower Bracket

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

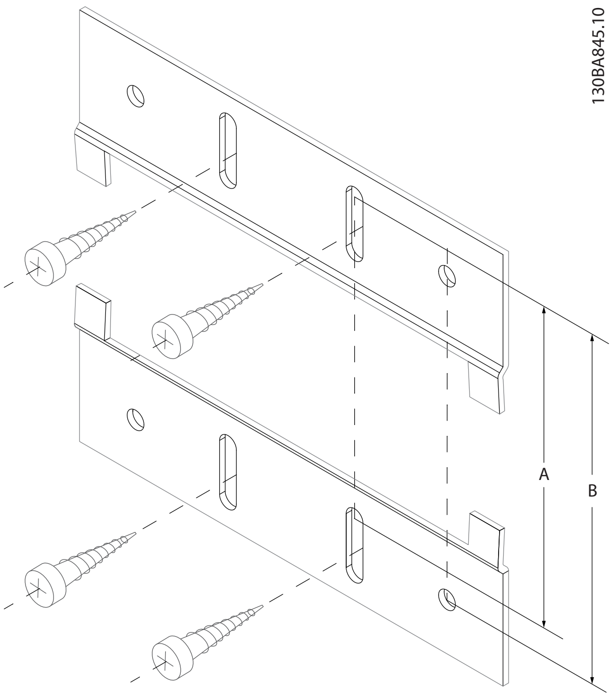


Illustration 9.36 Upper Bracket

Measure distance A or B, and position the upper bracket, but do not tighten it. See dimensions in *Table 9.19*.

Frame 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 9.19 Details

Step 3

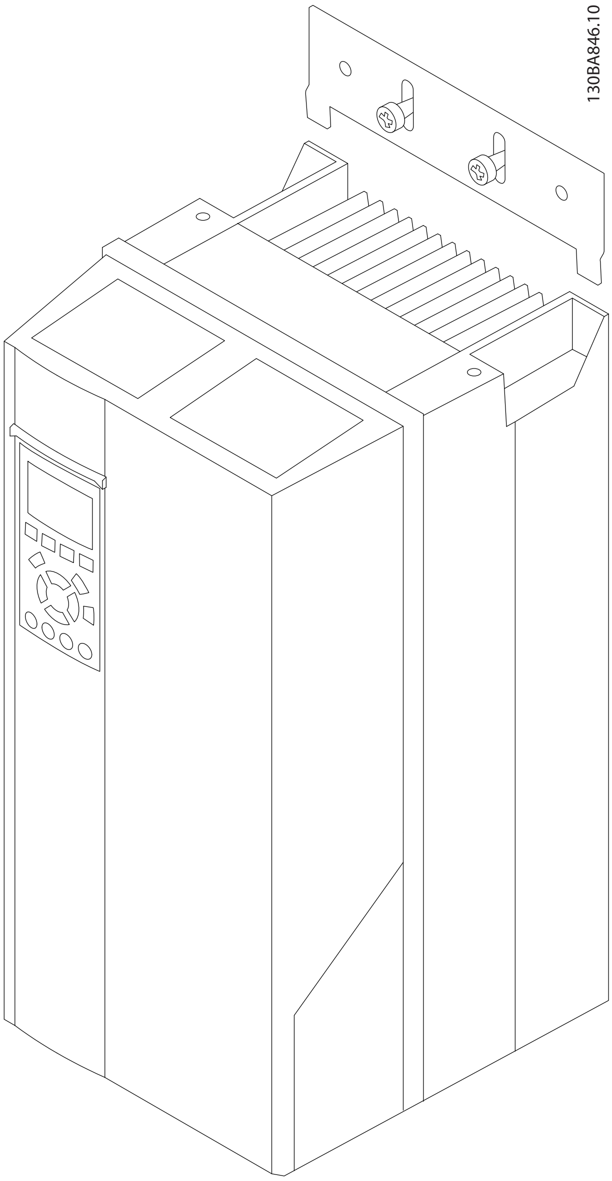


Illustration 9.37 Positioning

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

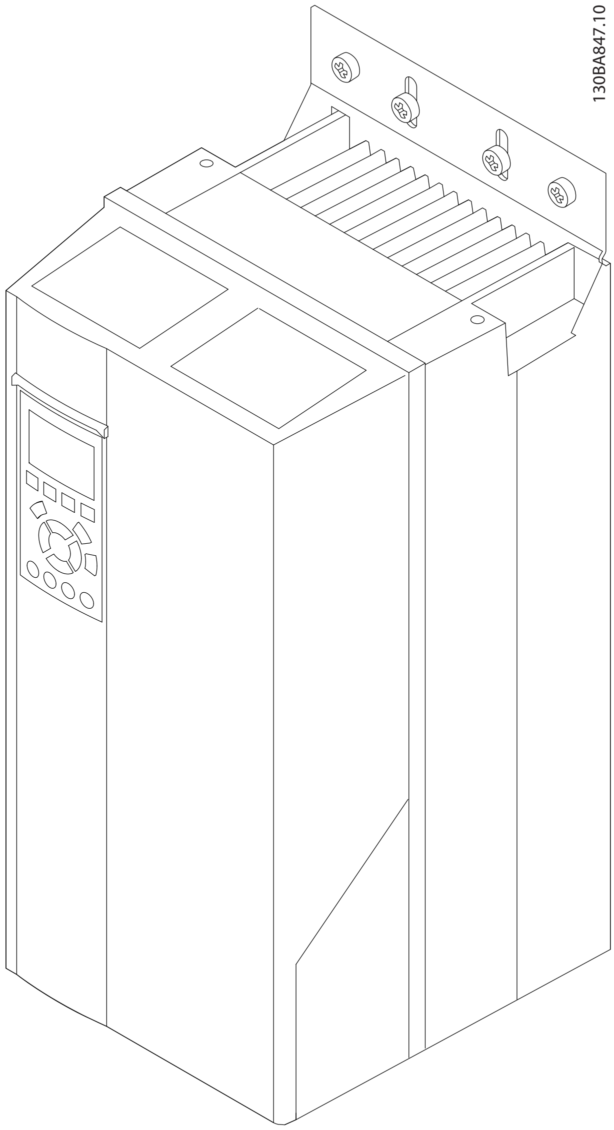


Illustration 9.38 Tightening of Screws

Now tighten the screws. For extra security, drill and mount screws in all holes.

9.14 Sine-wave Filters

When a motor is controlled by a frequency converter, resonance noise will be heard from the motor. This noise, which is the result of the design of the motor, arises every time an inverter switch in the frequency converter is activated. The frequency of the resonance noise thus corresponds to the switching frequency of the frequency converter.

For the FC 300, Danfoss can supply a Sine-wave filter to dampen the acoustic motor noise.

The filter reduces the ramp-up time of the voltage, the peak load voltage U_{PEAK} and the ripple current ΔI to the motor, which means that current and voltage become almost sinusoidal. Consequently, the acoustic motor noise is reduced to a minimum.

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

9.15 Safety Option Module MCB 15x

NOTE

For more information on MCB 15x see the *MCB 15x Safety Option Operating Instructions*.

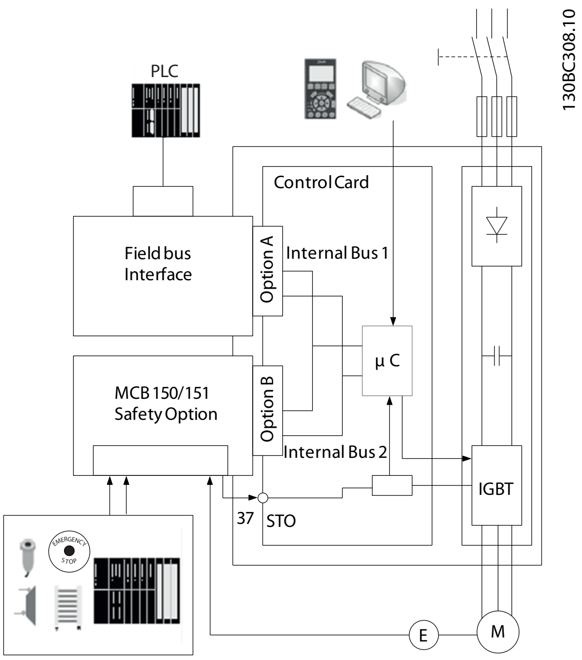


Illustration 9.39 Safe Drive System

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.

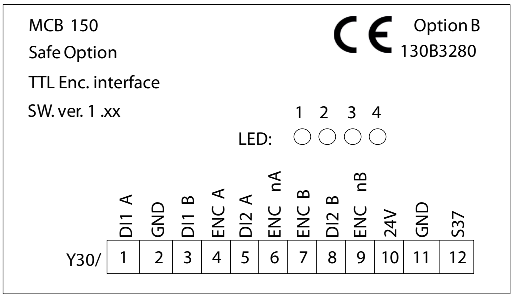
The frequency converter

- removes the power to the motor,
- switches the motor to torque-free, if Safe Torque Off is activated

The safety control system

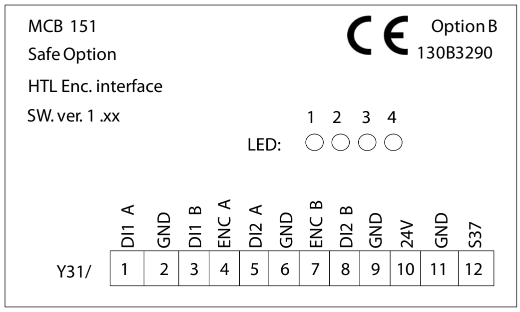
- activates the safety functions via inputs on the MCB 15x
- evaluates signals from safety devices, such as
    - E-STOP push buttons
    - Non Contact Magnetic switch
    - Interlocking switch
    - Light curtain devices
- processes the MCB 15x status function
- provides safe connection between MCB 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

Front View



130BC306.10

Illustration 9.40 MCB 150



130BC307.10

Illustration 9.41 MCB 151

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

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'	< 5V 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)

9

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 mm²/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)

10 RS-485 Installation and Set-up

10.1 Installation and Set-up

10.1.1 Overview

RS-485 is a two-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.

NOTE

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	120 Ω
Cable length	Max. 1200 m (including drop lines) Max. 500 m station-to-station

Table 10.1 Cable

10.2 Network Connection

One or more frequency converters can be connected to a control (or master) using the RS-485 standardized interface. Terminal 68 is connected to the P signal (TX+, RX+), while terminal 69 is connected to the N signal (TX-,RX-). See drawings in *7.8.3 Earthing of Screened Control Cables*.

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

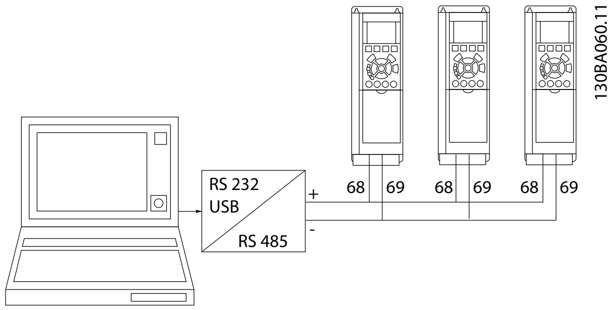


Illustration 10.1 Parallel Connections

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

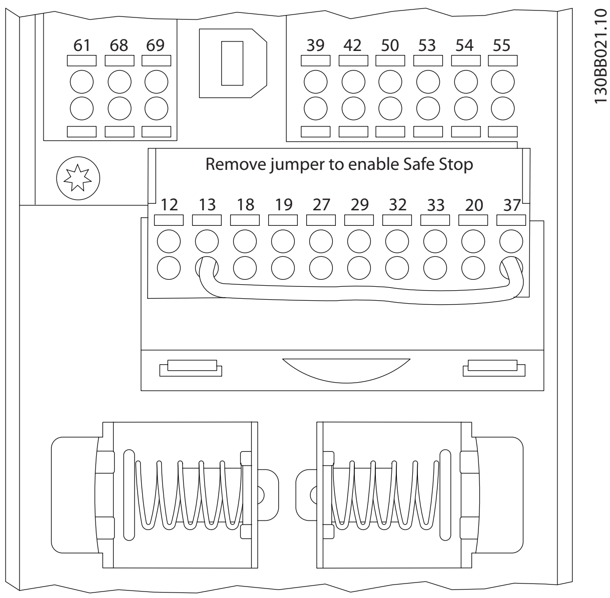


Illustration 10.2 Control Card Terminals

10.3 Bus Termination

The RS-485 bus must be terminated by a resistor network at both ends. For this purpose, set switch S801 on the control card for "ON".
For more information, see *7.5.4 Switches S201, S202, and S801* .

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

10.4 RS-485 Installation and Set-up

10.4.1 EMC Precautions

The following EMC precautions are recommended in order to achieve interference-free operation of the RS-485 network.

Relevant national and local regulations, for example regarding protective earth connection, must be observed. The RS-485 communication cable must be kept away from motor and brake resistor cables to avoid coupling of high frequency noise from one cable to another. Normally a distance of 200 mm (8 inches) is sufficient, but keeping the greatest possible distance between the cables is generally recommended, especially where cables run in parallel over long distances. When crossing is unavoidable, the RS-485 cable must cross motor and brake resistor cables at an angle of 90°.

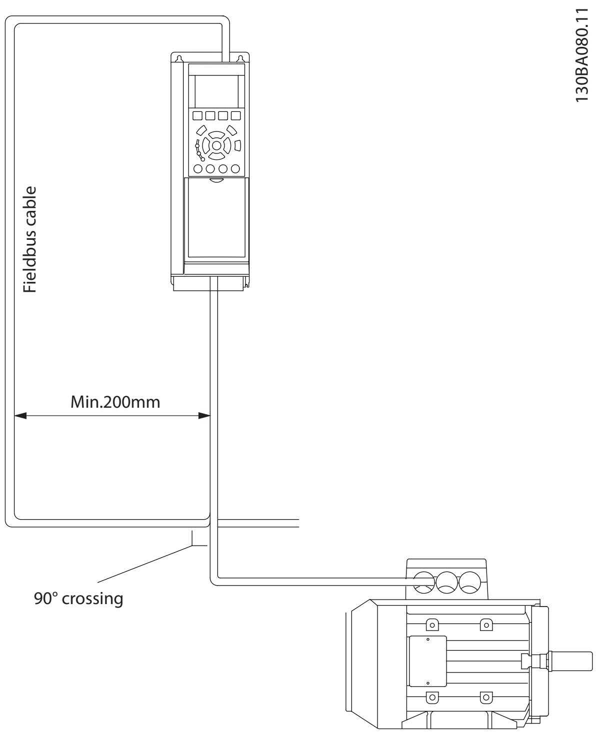


Illustration 10.3 Cable Routing

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

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

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

10.5 Network Configuration

10.5.1 Frequency Converter Set-up

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

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

Table 10.2 FC Protocol Parameters

10.6 FC Protocol Message Framing Structure

10.6.1 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.

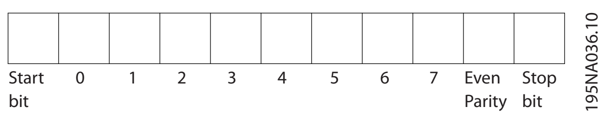


Illustration 10.4 Content of a Character

10.6.2 Telegram Structure

Each telegram has the following structure:

1. Start character (STX)=02 Hex
2. A byte denoting the telegram length (LGE)
3. A byte denoting the frequency converter address (ADR)

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

A data control byte (BCC) completes the telegram.

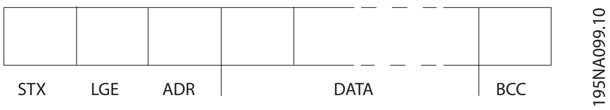


Illustration 10.5 Telegram Structure

10.6.3 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 10.3 Length of Telegrams

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

10.6.4 Frequency Converter Address (ADR)

Two different address formats are used.
The address range of the frequency converter is either 1-31 or 1-126.

1. Address format 1-31:

Bit 7 = 0 (address format 1-31 active)

Bit 6 is not used

Bit 5 = 1: Broadcast, address bits (0-4) are not used

Bit 5 = 0: No Broadcast

Bit 0-4 = frequency converter address 1-31

2. Address format 1-126:

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

Bit 0-6 = frequency converter address 1-126

Bit 0-6 = 0 Broadcast

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

10.6.5 Data Control Byte (BCC)

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

10

10.6.6 The Data Field

The structure of data blocks depends on the type of telegram. There are three 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 10.6 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.

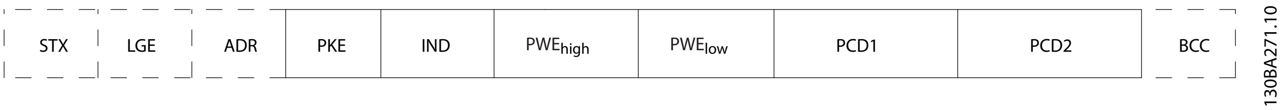


Illustration 10.7 Parameter Block

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

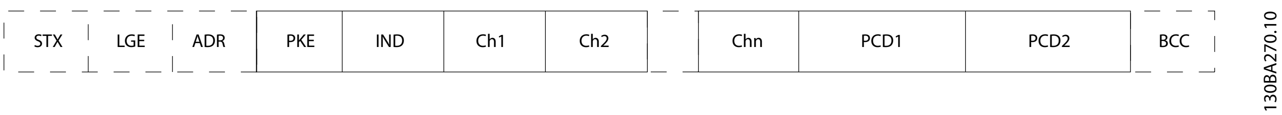


Illustration 10.8 Text Block

10.6.7 The PKE Field

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

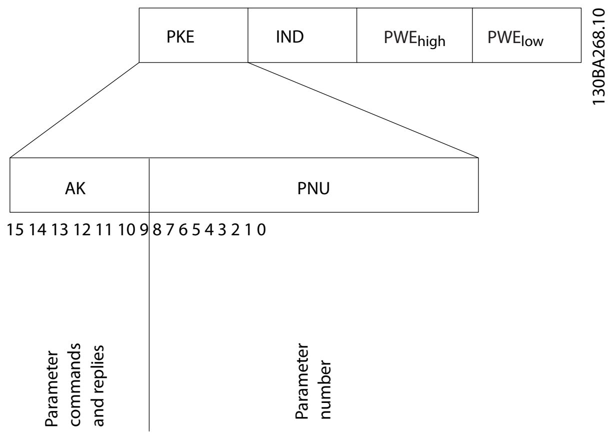


Illustration 10.9 PKE Field

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

Bit no.				Parameter command
15	14	13	12	
0	0	0	0	No command
0	0	0	1	Read parameter value
0	0	1	0	Write parameter value in RAM (word)
0	0	1	1	Write parameter value in RAM (double word)
1	1	0	1	Write parameter value in RAM and EEprom (double word)
1	1	1	0	Write parameter value in RAM and EEprom (word)
1	1	1	1	Read/write text

Table 10.4 Parameter Commands Master ⇒ Slave

Bit no.				Response
15	14	13	12	
0	0	0	0	No response
0	0	0	1	Parameter value transferred (word)
0	0	1	0	Parameter value transferred (double word)
0	1	1	1	Command cannot be performed
1	1	1	1	text transferred

Table 10.5 Response Slave ⇒ Master

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

PWE low (Hex)	Fault Report
0	The parameter number used does not 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 10.6

10.6.8 Parameter Number (PNU)

Bits no. 0-11 transfer parameter numbers. The function of the relevant parameter is defined in the parameter description in the Programming Guide.

10.6.9 Index (IND)

The index is used together with the parameter number to read/write-access parameters with an index, e.g. *15-30 Alarm Log: Error Code*. The index consists of 2 bytes, a low byte and a high byte.

Only the low byte is used as an index.

10.6.10 Parameter Value (PWE)

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

When a slave responds to a parameter request (read command), the present parameter value in the PWE block is transferred and returned to the master. If a parameter contains not a numerical value but several data options, e.g. *0-01 Language* where [0] corresponds to English, and [4] corresponds to Danish, select the data value by entering the value in the PWE block. See Example - Selecting a data value. Serial communication is only capable of reading parameters containing data type 9 (text string).

15-40 FC Type to *15-53 Power Card Serial Number* contain data type 9.
For example, read the unit size and mains voltage range in *15-40 FC Type*. When a text string is transferred (read), the length of the telegram is variable, and the texts are of different lengths. The telegram length is defined in the second byte of the telegram, LGE. When using text transfer the index character indicates whether it is a read or a write command.

To read a text via the PWE block, set the parameter command (AK) to 'F' Hex. The index character high-byte must be "4".

Some parameters contain text that can be written 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".

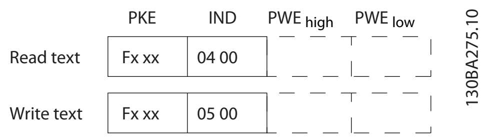


Illustration 10.10 Text via PWE Block

10.6.11 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 10.7 Supported Data Types

10.6.12 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:
0s ⇒ conversion index 0
0.00s ⇒ conversion index -2
0ms ⇒ conversion index -3
0.00ms ⇒ conversion index -5

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

Table 10.8 Conversion Table

10.6.13 Process Words (PCD)

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

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

Table 10.9 Process Words (PCD)

10.7 Examples

10.7.1 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 *10.6.12 Conversion*.

The telegram will look like this:

E19E H	0000 H	0000 H	03E8 H
PKE	IND	PWE high	PWE low

130BA092.10

Illustration 10.11 Write Data in EEPROM

NOTE

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

The response from the slave to the master will be:

119E H	0000 H	0000 H	03E8 H
PKE	IND	PWE high	PWE low

130BA093.10

Illustration 10.12 Response from Slave

10.7.2 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 10.13 Parameter Value

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

1155 H	0000 H	0000 H	03E8 H
PKE	IND	PWE high	PWE low

130BA267.10

Illustration 10.14 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*.

10.8 Modbus RTU Overview

10.8.1 Assumptions

Danfoss assumes that the installed controller supports the interfaces in this document, and strictly observe all requirements and limitations stipulated in the controller and frequency converter.

10.8.2 What the User Should Already Know

The Modbus RTU (Remote Terminal Unit) is designed to communicate with any controller that supports the interfaces defined in this document. It is assumed that the user has full knowledge of the capabilities and limitations of the controller.

10.8.3 Modbus RTU Overview

Regardless of the type of physical communication networks, the Modbus RTU Overview describes the process a controller uses to request access to another device. This process includes how the Modbus RTU responds to requests from another device, and how errors are detected and reported. It also establishes a common format for the layout and contents of message fields.
During communications over a Modbus RTU network, the protocol determines:

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

If a reply is required, the controller constructs the reply message and sends it.
Controllers communicate using a master-slave technique in which only one device (the master) can initiate transactions (called queries). The other devices (slaves) respond by supplying the requested data to the master, or by taking the action requested in the query.
The master can address individual slaves, or can initiate a broadcast message to all slaves. Slaves return a message (called a response) to queries that are addressed to them individually. No responses are returned to broadcast queries from the master. The Modbus RTU protocol establishes the format for the master's query by placing into it the device (or broadcast) address, a function code defining the requested action, any data to be sent, and an error-checking field. The slave's response message is also constructed using Modbus protocol. It contains fields confirming the action taken, any data to 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.

10.8.4 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.

10.9 Network Configuration

10.9.1 Frequency Converter with Modbus RTU

To enable Modbus RTU on the frequency converter, set the following parameters

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

Table 10.10

10.10 Modbus RTU Message Framing Structure

10.10.1 Frequency Converter with Modbus RTU

The controllers are set up to communicate on the Modbus network using RTU (Remote Terminal Unit) mode, with each byte in a message containing 2 4-bit hexadecimal characters. The format for each byte is shown in *Table 10.11*.

Start bit	Data byte								Stop/ parity	Stop

Table 10.11 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)

10.10.2 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 10.13*.

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 10.12 Typical Modbus RTU Message Structure

10.10.3 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 to 3.5 character intervals after a previous message, the receiving device will consider it a continuation of the previous message. This causes a time-out (no response from the slave), since the value in the final CRC field is not valid for the combined messages.

10.10.4 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 recognize.) A master addresses a slave by placing the slave address in the address field of the message. When the slave sends its response, it places its own address in this address field to let the master know which slave is responding.

10.10.5 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 *10.10.10 Function Codes Supported by Modbus RTU* and *10.10.11 Modbus Exception Codes*

10.10.6 Data Field

The data field is constructed using sets of two 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 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.

10.10.7 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 two values are unequal, a bus time-out results. The error-checking field contains a 16-bit binary value implemented as two 8-bit bytes. 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.

10.10.8 Coil Register Addressing

In Modbus, all data are organized in coils and holding registers. Coils hold a single bit, whereas holding registers hold a 2-byte word (i.e. 16 bits). All data addresses in Modbus messages are referenced to zero. The first occurrence of a data item is addressed as item number zero. For example: The coil known as ‘coil 1’ in a programmable controller is addressed as coil 0000 in the data address field of a Modbus message. Coil 127 decimal is addressed as coil 007EHEX (126 decimal).
Holding register 40001 is addressed as register 0000 in the data address field of the message. The function code field already specifies a ‘holding register’ operation. Therefore, the ‘4XXXX’ reference is implicit. Holding register 40108 is addressed as register 006BHEX (107 decimal).

Coil Number	Description	Signal Direction
1-16	Frequency converter control word (see)	Master to slave
17-32	Frequency converter speed or set-point reference Range 0x0 – 0xFFFF (-200% ... ~200%)	Master to slave
33-48	Frequency converter status word (see *Table 10.16*)	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 10.13 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 10.14 Frequency Converter Control Word (FC Profile)

Coil	0	1
33	Control not ready	Control ready
34	Frequency converter not ready	Frequency converter ready
35	Coasting stop	Safety closed
36	No alarm	Alarm
37	Not used	Not used
38	Not used	Not used
39	Not used	Not used
40	No warning	Warning
41	Not at reference	At reference
42	Hand mode	Auto mode
43	Out of freq. range	In frequency range
44	Stopped	Running
45	Not used	Not used
46	No voltage warning	Voltage warning
47	Not in current limit	Current limit
48	No thermal warning	Thermal warning

Table 10.15 Frequency Converter Status Word (FC Profile)

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

Table 10.16 Holding Registers

** Used to specify the index number to be used when accessing an indexed parameter.*

10.10.9 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.

10.10.10 Function Codes Supported by Modbus RTU

Modbus RTU supports use of the following function codes in the function field of a message.

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

Table 10.17 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 slave message count

Table 10.18 Function Codes

10.10.11 Modbus Exception Codes

For a full explanation of the structure of an exception code response, refer to *10.10.5 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 10.19 Modbus Exception Codes

10.11 How to Access Parameters

10.11.1 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.

10.11.2 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).

10.11.3 IND

The array index is set in Holding Register 9 and used when accessing array parameters.

10.11.4 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.

10.11.5 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.

10.11.6 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).

10.12 Danfoss FC Control Profile

10.12.1 Control Word According to FC Profile (*8-10 Control Profile* = FC profile)

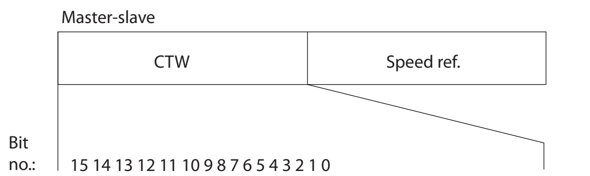


Illustration 10.15 Control Word

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 10.20 Control Word Bits

Explanation of the Control Bits

Bits 00/01
Bits 00 and 01 are used to choose between the four reference values, which are pre-programmed in *3-10 Preset Reference* according to *Table 10.22*.

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 10.21 Reference Values

NOTE

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

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 by means of the digital inputs (*5-10 Terminal 18 Digital Input* to *5-15 Terminal 33 Digital Input*) programmed to *Speed up* and *Slow down*.

NOTE

If Freeze output is active, 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. Thus, you can turn off the control word if you do not want 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* is chosen in *5-40 Function Relay*.

Bit 12, Relay 04
Bit 12 = "0": Relay 04 is not activated. Bit 12 = "1": Relay 04 is activated provided that *Control word bit 12* is chosen in *5-40 Function Relay*.

Bit 13/14, Selection of set-up
Use bits 13 and 14 to choose from the four menu set-ups according to *Table 10.23*.

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

Table 10.22 Four 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.

10.12.2 Status Word According to FC Profile (STW) (*8-10 Control Profile* = FC profile)

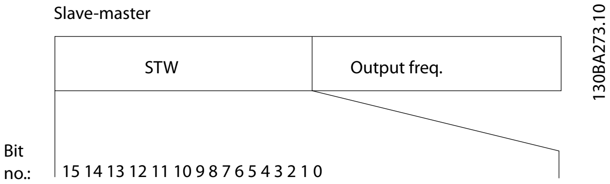


Illustration 10.16 Status Word

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 10.23 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 24V 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 activate on the control unit or *Local control* in *3-13 Reference Site* is selected. You cannot 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 *4-11 Motor Speed Low Limit [RPM]* or *4-13 Motor Speed High Limit [RPM]*. Bit 10 = "1": The output frequency is within the defined limits.

Bit 11, No operation/in operation
Bit 11 = ’0’: The motor is not running. Bit 11 = ’1’: The frequency converter has a start signal or the output frequency is greater than 0 Hz.

Bit 12, Drive OK/stopped, autostart
Bit 12 = ’0’: There is no temporary over temperature on the inverter. Bit 12 = ’1’: The inverter stops because of over temperature but the unit does not trip and will resume 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%.

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

10.12.3 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.

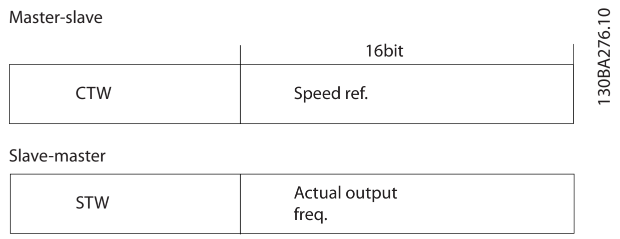


Illustration 10.17 Actual Output Frequency (MAV)

The reference and MAV are scaled as follows:

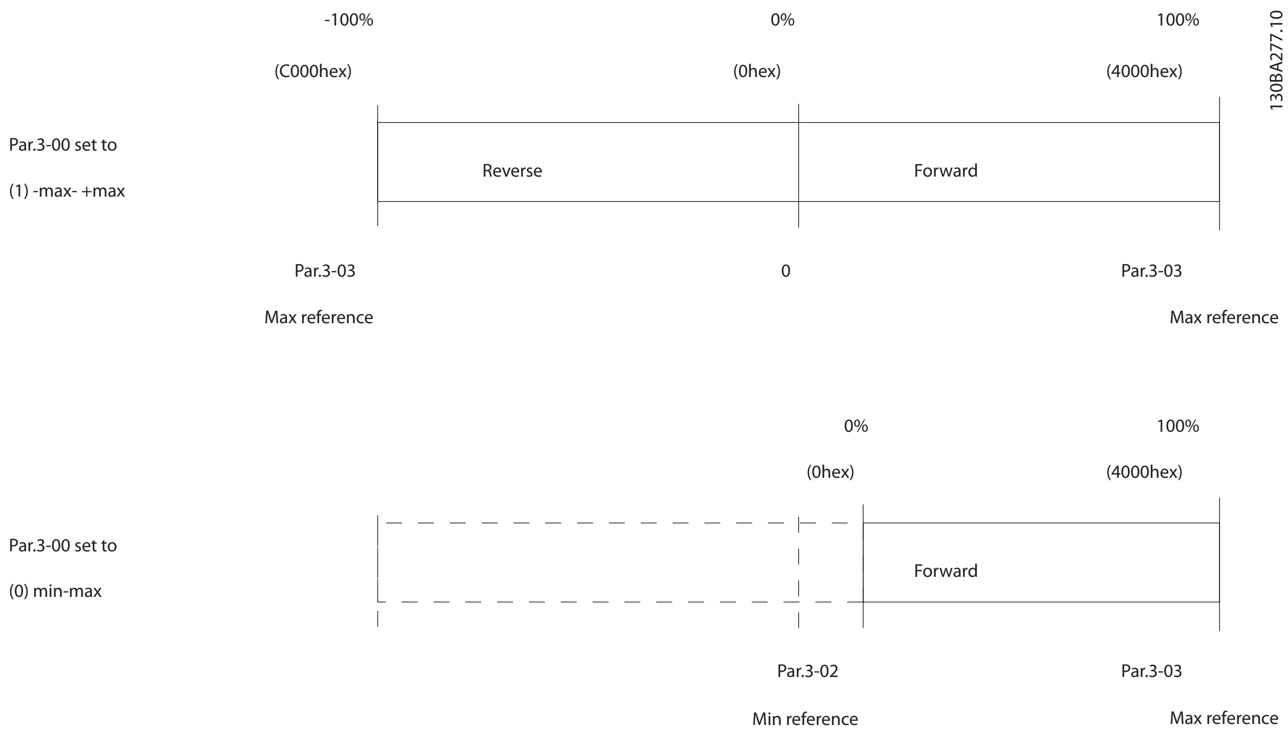


Illustration 10.18 Reference and MAV

10.12.4 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 10.24 Control Word Bits

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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”.
Refer to .

Bit 03, Coasting/No coasting
Coasting stop Bit 03="0" leads to a stop. When bit 03="1", the frequency converter can start if the other start conditions are satisfied.

NOTE

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

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

NOTE

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

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

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

NOTE

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

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

Bit 08, Jog 1 OFF/ON
Activation of the pre-programmed speed in *8-90 Bus Jog 1 Speed*. JOG 1 is only possible if bit 04="0" and bit 00-03="1".

Bit 09, Jog 2 OFF/ON
Activation of the pre-programmed speed in *8-91 Bus Jog 2 Speed*. JOG 2 is only possible if bit 04="0" and bit 00-03="1".

Bit 10, Data invalid/valid
Is used to tell the frequency converter whether the control word is to be used or ignored. Bit 10="0" causes the control word to be ignored, Bit 10="1" causes the control word to be used. This function is relevant, because the control word is always contained in the telegram, regardless of which type of telegram is used, that is, it is possible to turn off the control word if you do not wish to use it with updating or reading parameters.

Bit 11, No function/Slow down
Is used to reduce the speed reference value by the amount given in *3-12 Catch up/slow Down Value* value. When bit 11="0", no modification of the reference value occurs. When bit 11="1", the reference value is reduced.

Bit 12, No function/Catch up
Is used to increase the speed reference value by the amount given in *3-12 Catch up/slow Down Value*.
When bit 12="0", no modification of the reference value occurs.
When bit 12="1", the reference value is increased.
If both slowing down and accelerating are activated (bit 11 and 12="1"), slowing down has priority, that is, the speed reference value is reduced.

Bits 13/14, Set-up selection
Bits 13 and 14 are used to choose between the four parameter set-ups according to *Table 10.26*:

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

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

Table 10.25 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*.

NOTE

Bit 15 causes reversing only when *Ser. communication, Logic or* or *Logic and* is selected.

10.12.5 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 10.26 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 will be "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 the stop button on the LCP, or that [Linked to hand] or [Local] has been selected in *3-13 Reference Site*.
When bit 09="1", the frequency converter can be controlled through the serial interface.

Bit 10, Out of frequency limit/Frequency limit OK
When bit 10="0", the output frequency is outside the limits set in *4-52 Warning Speed Low* and *4-53 Warning Speed High*. When bit 10="1", the output frequency is within the indicated limits.

Bit 11, No operation/Operation
When bit 11="0", the motor does not turn.
When bit 11="1", the frequency converter has a start signal, or the output frequency is higher than 0 Hz.

Bit 12, Drive OK/Stopped, autostart
When bit 12="0", there is no temporary overloading of the inverter.
When bit 12="1", the inverter has stopped due to overloading. However, the frequency converter has not switched off (trip) and will start again after the overloading has ended.

Bit 13, Voltage OK/Voltage exceeded
When bit 13="0", the voltage limits of the frequency converter are not exceeded.
When bit 13="1", the direct voltage in the intermediate circuit of the frequency converter is too low or too high.

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

Bit 15, Timer OK/Timer exceeded
When bit 15="0", the timers for the thermal motor protection and thermal frequency converter protection have not exceeded 100%.
When bit 15="1", one of the timers has exceeded 100%.

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