MAKING MODERN LIVING POSSIBLE

Design Guide
VLT® AutomationDrive FC 301/302
0.25–75 kW

www.danfoss.com/drives

THE REAL DRIVE

Contents

1 Introduction

1.1 Purpose of the Design Guide

The Design Guide provides information required for integration of the adjustable frequency drive in a diversity of applications.

VLT® is a registered trademark.

1.2 Additional Resources

Other resources are available to understand advanced adjustable frequency drive operation, programming, and directives compliance.

- The *Instruction Manual* provides detailed information for the installation and start up of the adjustable frequency drive.
- The *Programming Guide* provides greater detail in how to work with parameters and many application examples.
- The *VLT® Safe Torque Off Instruction Manual* describes how to use Danfoss adjustable frequency drives in functional safety applications.
- Supplementary publications and manuals are available from Danfoss. See *danfoss.com/Product/Literature/Technical+Documentation.htm* for listings.
- Optional equipment is available that may change some of the information described in these publications. Be sure to see the instructions supplied with the options for specific requirements.

Contact a Danfoss supplier or go to *www.danfoss.com* for additional information.

1.3 Abbreviations, Symbols and Conventions

Conventions
Numbered lists indicate procedures.
Bullet lists indicate other information and description of figures.
Italicized text indicates

- cross reference
- link
- footnote
- parameter name, parameter group name, parameter option

60° AVM	60° Asynchronous Vector Modulation
A	Ampere/AMP
AC	Alternating current
AD	Air discharge
AI	Analog Input
AMA	Automatic Motor Adaptation
AWG	American wire gauge
°C	Degrees Celsius
CD	Contant discharge
CM	Common mode
CT	Constant torque
DC	Direct current
DI	Digital Input
DM	Differential mode
D-TYPE	Drive Dependent
EMC	Electro Magnetic Compatibility
ETR	Electronic Thermal Relay
f_{JOG}	Motor frequency when jog function is activated
f_M	Motor frequency
f_{MAX}	The maximum output frequency the adjustable frequency drive applies on its output.
f_{MIN}	The minimum motor frequency from adjustable frequency drive.
$f_{M,N}$	Nominal motor frequency
FC	Adjustable frequency drive
g	Gram
Hiperface®	Hiperface® is a registered trademark by Stegmann
hp	Horsepower
HTL	HTL encoder (10–30 V) pulses - High-voltage Transistor Logic
Hz	Hertz
I_{INV}	Rated Inverter Output Current
I_{LIM}	Current limit
$I_{M,N}$	Nominal motor current
$I_{VLT,MAX}$	The maximum output current
$I_{VLT,N}$	The rated output current supplied by the adjustable frequency drive
kHz	Kilohertz
LCP	Local Control Panel
lsb	Least significant bit
m	Meter
mA	Milliampere
MCM	Mille Circular Mil
MCT	Motion Control Tool
mH	Millihenry Inductance

min	Minute
ms	Millisecond
msb	Most significant bit
η_{VLT}	Efficiency of the adjustable frequency drive defined as ratio between power output and power input
nF	Nanofarad
NLCP	Numerical Local Control Panel
Nm	Newton Meters
n_s	Synchronous Motor Speed
Online/Offline Parameters	Changes to online parameters are activated immediately after the data value is changed.
$P_{br,cont.}$	Rated power of the brake resistor (average power during continuous braking)
PCB	Printed Circuit Board
PCD	Process Data
PELV	Protective Extra Low Voltage
P_m	Adjustable frequency drive nominal output power as HO
$P_{M,N}$	Nominal motor power
PM motor	Permanent Magnet motor
Process PID	The PID regulator maintains the desired speed, pressure, temperature, etc.
$R_{br,nom}$	The nominal resistor value that ensures a braking energy on motor shaft of 150/160% for 1 minute
RCD	Residual Current Device
Regen	Regenerative terminals
R_{min}	Minimum permissible brake resistor value by adjustable frequency drive
RMS	Root Mean Square
RPM	Revolutions Per Minute
R_{rec}	Resistor value and resistance of the brake resistor
s	Second
SFAVM	Stator Flux-oriented Asynchronous Vector Modulation
STW	Status Word
SMPS	Switch Mode Power Supply
THD	Total Harmonic Distortion
T_{LIM}	Torque limit
TTL	TTL encoder (5 V) pulses - Transistor Transistor Logic
$U_{M,N}$	Nominal motor voltage
V	Volts
VT	Variable Torque
VVC^{plus}	Voltage Vector Control

Table 1.1 Abbreviations

The following symbols are used in this document:

WARNING

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

CAUTION

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

NOTICE!

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

1.4 Definitions

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

Brake Resistor
The brake resistor is a module capable of absorbing the braking energy generated in regenerative braking. This regenerative braking energy 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.

Initializing
If initialization is carried out (*14-22 Operation Mode*), the adjustable frequency drive returns to the default setting.

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

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

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

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

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

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

Trip
A state entered in fault situations, e.g., if the adjustable frequency drive is subject to an overtemperature or when the adjustable frequency drive is protecting the motor, process or mechanism. Restart is prevented until the cause of the fault has disappeared and the trip state is canceled by activating reset or, 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 adjustable frequency drive is protecting itself and requiring physical intervention, e.g., if the adjustable frequency drive is subject to a short circuit on the output. A locked trip can only be canceled by cutting off line power, removing the cause of the fault, and reconnecting the adjustable frequency drive. Restart is prevented until the trip state is canceled by activating reset or, in some cases, by being programmed to reset automatically. Trip may not be used for personal safety.

VT Characteristics
Variable torque characteristics used for pumps and fans.

Power Factor
The True Power Factor (lambda) takes all the harmonics into consideration and is always smaller than the Power Factor (cos-phi) that only considers the 1st harmonics of current and voltage.

$$\cos\varphi = \frac{P\,[\text{kW}]}{P\,[\text{kVA}]} = \frac{U\lambda \ x \ I\lambda \ x \cos\varphi}{U\lambda \ x \ I\lambda}$$

Cos-phi is also known as displacement power factor.

Both lambda and cos-phi are stated for Danfoss VLT® adjustable frequency drives in *chapter 6.2.1 Line Power Supply*.

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

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

1.5 Document and Software Version

This manual is regularly reviewed and updated. All suggestions for improvement are welcome. *Table 1.2* shows the document version and the corresponding software version.

Edition	Remarks	Software version
MG33BFxx	Replaces MG33BExx	6.72

Table 1.2 Document and Software Version

1.6 Regulatory Compliance

Adjustable frequency drives are designed in compliance with the directives described in this section.

1.6.1 CE Mark

The CE mark (Communauté européenne) indicates that the product manufacturer conforms to all applicable EU directives. The three EU directives applicable to the design and manufacture of adjustable frequency drives are the directive low-voltage, the EMC directive, and (for units with an integrated safety function) the machinery directive.

The CE mark is intended to eliminate technical barriers to free trade between the EC and EFTA states inside the ECU. The CE mark does not regulate the quality of the product. Technical specifications cannot be deduced from the CE mark.

1.6.1.1 Low Voltage Directive

Adjustable frequency drives are classified as electronic components and must be CE-labelled in accordance with the low-voltage directive. The directive applies to all electrical equipment in the 50–1000 V AC and the 75–1600 V DC voltage ranges.

The directive mandates that the equipment design must ensure the safety and health of people and livestock are not endangered and the preservation of material worth so long as the equipment is properly installed, maintained, and used as intended. Danfoss CE labels comply with the low-voltage directive and provide a declaration of conformity upon request.

1.6.1.2 EMC Directive

Electromagnetic compatibility (EMC) means that electromagnetic interference between apparatus does not hinder their performance. The basic protection requirement of the EMC Directive 2004/108/EC states that devices that generate electromagnetic interference (EMI), or whose operation could be affected by EMI, must be designed to limit the generation of electromagnetic interference and shall have a suitable degree of immunity to EMI when properly installed, maintained, and used as intended.

An adjustable frequency drive can be used as stand-alone device or as part of a more complex installation. Devices used as stand alone or as part of a system must bear the CE mark. Systems must not be CE-marked but must comply with the basic protection requirements of the EMC directive.

1.6.1.3 Machinery Directive

Adjustable frequency drives are classified as electronic components subject to the low-voltage directive; however, adjustable frequency drives with an integrated safety function must comply with the machinery directive 2006/42/EC. Adjustable frequency drives without the safety function do not fall under the machinery directive. If an adjustable frequency drive is integrated into machinery system, Danfoss provides information on safety aspects relating to the adjustable frequency drive.

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

When adjustable frequency drives are used in machines with at least one moving part, the machine manufacturer must provide declaration stating compliance with all relevant statutes and safety measures. Danfoss CE labels comply with the machinery directive for adjustable frequency drives with an integrated safety function and provide a declaration of conformity upon request.

1.6.2 UL Compliance

UL-listed

c UL us

Figure 1.1 UL

NOTICE!

Adjustable frequency drives of enclosure type T7 (525–690 V) are not certified for UL.

The adjustable frequency drive complies with UL508C thermal memory retention requirements. For more information, refer to the section *Motor Thermal Protection* in the *Design Guide*.

1.6.3 C-tick Compliance

1.6.4 Marine Compliance

1.7 Disposal Instruction

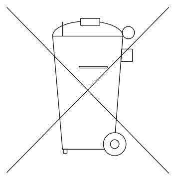
	Do not dispose of equipment containing electrical components together with domestic waste. Collect it separately in accordance with local and currently valid legislation.

Table 1.3 Disposal Instruction

1.8 Safety

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

Refer to the *Instruction Manual*, shipped with the unit and available online for:

- discharge time, and
- detailed safety instructions and warnings.

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

2 Safety

2.1 Safety Symbols

The following symbols are used in this document:

WARNING

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

CAUTION

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

NOTICE!

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

2.2 Qualified Personnel

Correct and reliable transport, storage, installation, operation and maintenance are required for the trouble-free and safe operation of the adjustable frequency drive. Only qualified personnel is allowed to install or operate this equipment.

Qualified personnel is defined as trained staff, who are authorized to install, commission, and maintain equipment, systems and circuits in accordance with pertinent laws and regulations. Additionally, the personnel must be familiar with the instructions and safety measures described in this document.

2.3 Safety Precautions

WARNING

HIGH VOLTAGE

Adjustable frequency drives contain high voltage when connected to AC line power. Failure to perform installation, start-up, and maintenance by qualified personnel could result in death or serious injury.

- **Installation, start-up, and maintenance must be performed by qualified personnel only.**

WARNING

UNINTENDED START

When the adjustable frequency drive is connected to AC line power, the motor may start at any time, causing risk of death, serious injury, equipment, or property damage. The motor can start by means of an external switch, a serial bus command, an input reference signal from the LCP, or after a cleared fault condition.

1. **Disconnect the adjustable frequency drive from line power whenever personal safety considerations make it necessary to avoid unintended motor start.**
2. **Press [Off] on the LCP before programming parameters.**
3. **The adjustable frequency drive, motor, and any driven equipment must be in operational readiness when the adjustable frequency drive is connected to AC line power.**

⚠WARNING

DISCHARGE TIME

The adjustable frequency drive contains DC link capacitors which can remain charged even when the adjustable frequency drive is not powered. Failure to wait the specified time after power has been removed before performing service or repair work could result in death or serious injury.

1. **Stop motor.**
2. **Disconnect AC line power, permanent magnet type motors, and remote DC link power supplies, including battery backups, UPS, and DC link connections to other adjustable frequency drives.**
3. **Wait for the capacitors to discharge fully before performing any service or repair work. The duration of waiting time is specified in *Table 2.1*.**

Voltage [V]	Minimum waiting time (minutes)		
	4	7	15
200–240	0.34–5 hp [0.25–3.7 kW]		7.5–50 hp [5.5–37 kW]
380–500	0.34–10 hp [0.25–7.5 kW]		15–100 hp [11–75 kW]
525–600	1–10 hp [0.75–7.5 kW]		15–100 hp [11–75 kW]
525–690		2–10 hp [1.5–7.5 kW]	15–100 hp [11–75 kW]
High voltage may be present even when the warning LED indicator lights are off.			

Table 2.1 Discharge Time

⚠WARNING

LEAKAGE CURRENT HAZARD

Leakage currents exceed 3.5 mA. Failure to ground the adjustable frequency drive properly could result in death or serious injury.

- **Ensure correct grounding of the equipment by a certified electrical installer.**

⚠WARNING

EQUIPMENT HAZARD

Contact with rotating shafts and electrical equipment can result in death or serious injury.

- **Ensure that only trained and qualified personnel perform installation, start-up, and maintenance.**
- **Ensure that electrical work conforms to national and local electrical codes.**
- **Follow the procedures in this manual.**

⚠CAUTION

WINDMILLING

Unintended rotation of permanent magnet motors causes risk of personal injury and equipment damage.

- **Ensure that permanent magnet motors are blocked to prevent unintended rotation.**

⚠CAUTION

POTENTIAL HAZARD IN THE EVENT OF INTERNAL FAILURE

Risk of personal injury when the adjustable frequency drive is not properly closed.

- **Before applying power, ensure all safety covers are in place and securely fastened.**

3 Basic Operating Principles

3.1 General

This chapter provides an overview of the adjustable frequency drive's primary assemblies and circuitry. It is intended to describe the internal electrical and signal processing functions. A description of the internal control structure is also included.

Also described are automated and optional adjustable frequency drive functions available for designing robust operating systems with sophisticated control and status reporting performance.

3.2 Description of Operation

The adjustable frequency drive supplies a regulated amount of AC line power to a standard 3-phase induction motor to control the motor speed. The adjustable frequency drive supplies variable frequency and voltage to the motor.

The adjustable frequency drive is divided into four main modules.

- Rectifier
- Intermediate circuit
- Inverter
- Control and regulation

In *chapter 3.3 Sequence of Operation*, these modules are covered in greater detail and describe how power and control signals move within the adjustable frequency drive.

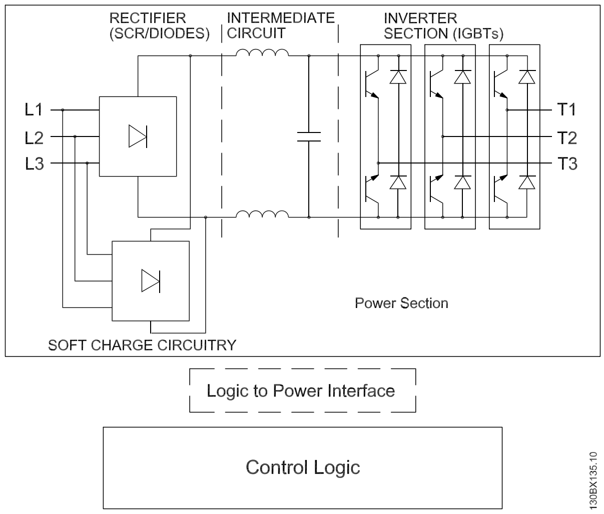


Figure 3.1 Internal Control Logic

3.3 Sequence of Operation

3.3.1 Rectifier Section

When power is first applied to the adjustable frequency drive, it enters through the input terminals (L1, L2, and L3) and on to the disconnect and/or RFI filter option, depending on the unit's configuration.

3.3.2 Intermediate Section

Following the rectifier section, voltage passes to the intermediate section. This rectified voltage is smoothed by an sine-wave filter circuit consisting of the DC bus inductor and the DC bus capacitor bank.

The DC bus inductor provides series impedance to changing current. This aids the filtering process while reducing harmonic distortion to the input AC current waveform normally inherent in rectifier circuits.

3.3.3 Inverter Section

In the inverter section, once a run command and speed reference are present, the IGBTs begin switching to create the output waveform. This waveform, as generated by the Danfoss VVC^{plus} PWM principle at the control card, provides optimal performance and minimal losses in the motor.

3.3.4 Brake Option

For adjustable frequency drives equipped with the dynamic brake option, a brake IGBT along with terminals 81(R-) and 82(R+) are included for connecting an external brake resistor.

The function of the brake IGBT is to limit the voltage in the intermediate circuit whenever the maximum voltage limit is exceeded. It does this by switching the externally mounted resistor across the DC bus to remove excess DC voltage present on the bus capacitors. Excess DC bus voltage is generally a result of an overhauling load causing regenerative energy to return to the DC bus. This occurs, for example, when the load drives the motor causing the voltage to return to the DC bus circuit.

Placing the brake resistor externally has the advantages of selecting the resistor based on application need, dissipating the energy outside of the control panel, and protecting the drive from overheating if the brake resistor is overloaded.

The brake IGBT gate signal originates on the control card and is delivered to the brake IGBT via the power card and gate drive card. Additionally, the power and control cards monitor the brake IGBT and brake resistor connection for short circuits and overloads.

3.3.5 Load Sharing

Units with the built-in load sharing option contain terminals (+) 89 DC and (–) 88 DC. Within the adjustable frequency drive, these terminals connect to the DC bus in front of the DC link reactor and bus capacitors.

The use of the load sharing terminals can take on two different configurations.

In one method, the terminals are used to tie the DC bus circuits of multiple adjustable frequency drives together. This allows one unit that is in a regenerative mode to share its excess bus voltage with another unit that is running a motor. Load sharing in this manner can reduce the need for external dynamic brake resistors while also saving energy. In theory, the number of units that can be connected in this way is infinite; however, each unit must be the same voltage rating. In addition, depending on the size and number of units, it may be necessary to install DC reactors and DC fuses in the DC link connections and AC reactors on line power. Attempting such a configuration requires specific considerations and should not be attempted without first consulting Danfoss application engineering.

In the second method, the adjustable frequency drive is powered exclusively from a DC source. This is a bit more complicated. First, a DC source is required. Second, a means to soft charge the DC bus at power-up is also required. Last, a voltage source is required to power the fans within the unit. Again such a configuration should not be attempted with out first consulting Danfoss application engineering.

3.4 Control Interface

3.4.1 Control Principle

The adjustable frequency drive receives control input from several sources.

- Local control panel (hand mode)
- Programmable analog, digital, and analog/digital control terminals (auto mode)
- The RS-485, USB, or serial communication ports (auto mode)

When wired and properly programmed, the control terminals provide feedback, reference, and other input signals to the adjustable frequency drive; output status and fault conditions from the adjustable frequency drive, relays to operate auxiliary equipment, and serial communication interface. A 24 V common is also provided. Control terminals are programmable for various functions by selecting parameter options through the local control panel (LCP) on the front of the unit or external sources. Most control wiring is customer supplied unless factory ordered.

3.5 Wiring Schematic

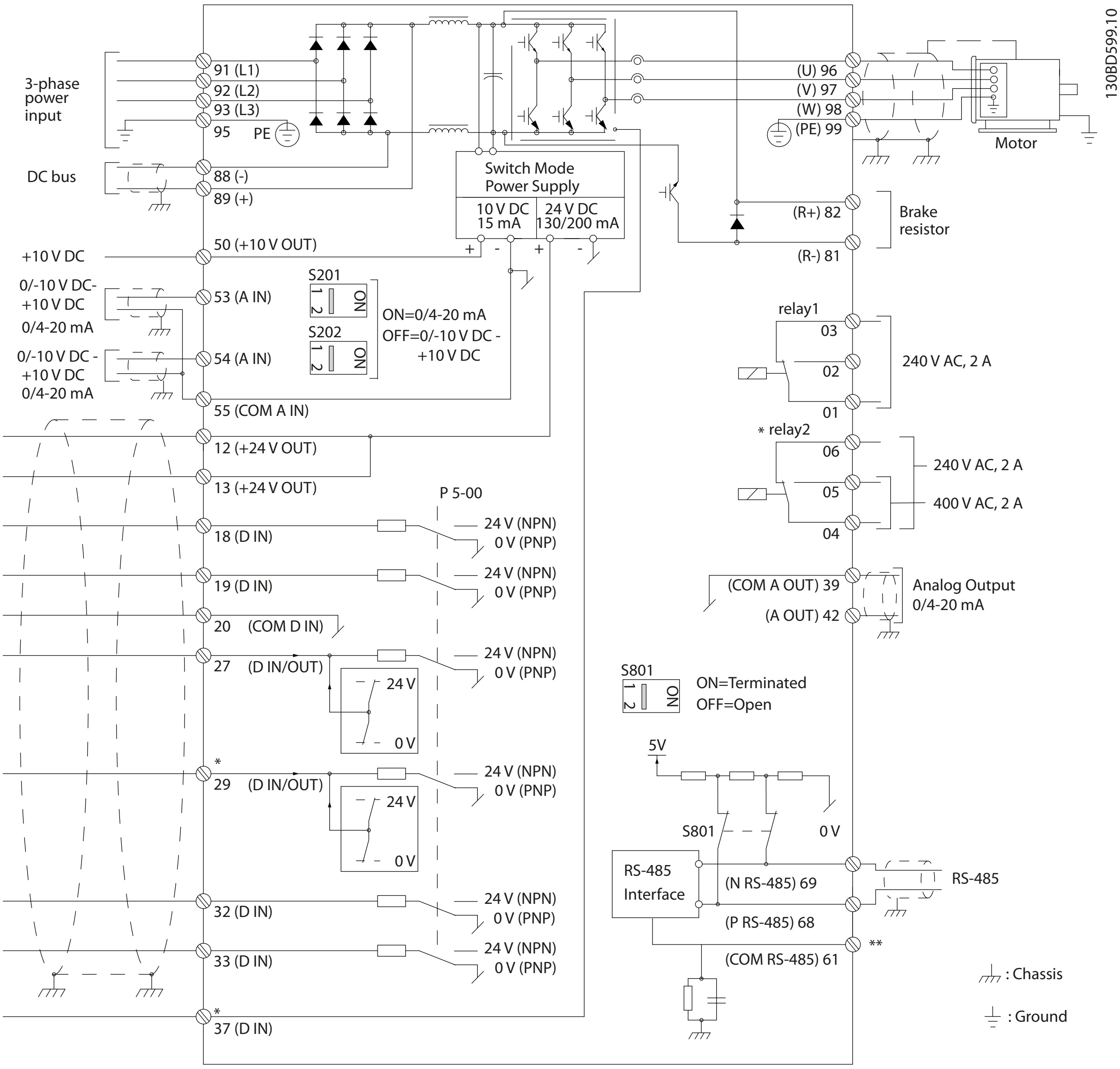


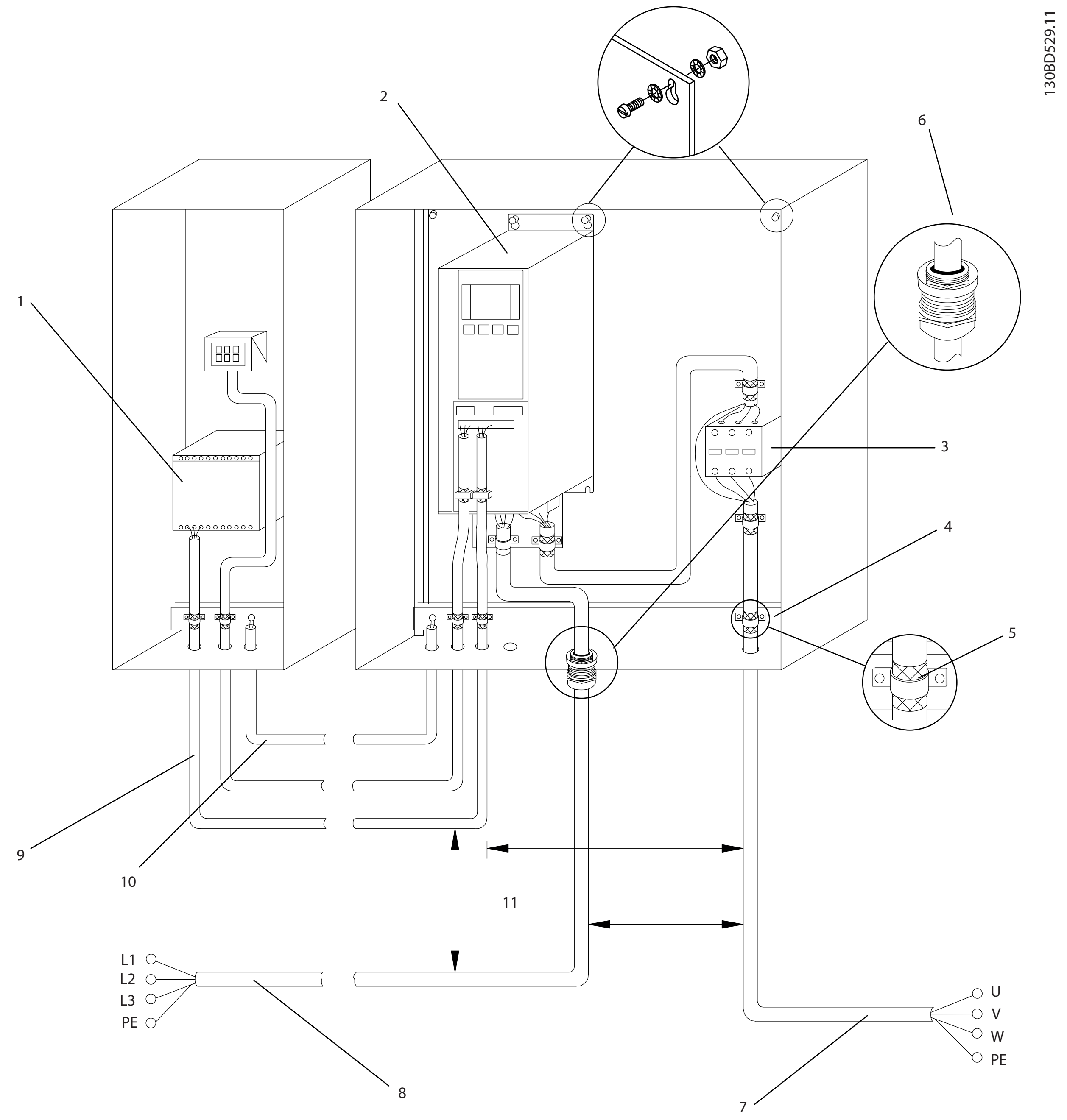
Figure 3.2 Basic Wiring Schematic

A=Analog, D=Digital

*Terminal 37 (optional) is used for Safe Torque Off. For Safe Torque Off installation instructions, refer to the *Safe Torque Off Instruction Manual for* Danfoss *VLT® Adjustable Frequency Drives*. Terminal 37 is not included in FC 301 (except enclosure type A1). Relay 2 and terminal 29 have no function in FC 301.

**Do not connect cable shield.

3



1	PLC	7	Motor, 3--phase and PE (shielded)
2	Adjustable frequency drive	8	Line power, 3--phase and reinforced PE (non-shielded)
3	Output contactor	9	Control wiring (shielded)
4	Cable clamp	10	Potential equalization min. 16 mm^2 (0.025 in^2)
5	Cable insulation (stripped)	11	Clearance between control cable, motor cable and line cable: Min. 7.9 in [200 mm]
6	Cable connector		

Figure 3.3 EMC-compliant Electrical Connection

For more information about EMC, see *chapter 4.1.15 EMC Compliance*.

NOTICE!

EMC INTERFERENCE

Run cables for input power, motor wiring and control wiring in three separate metallic conduits. Failure to isolate power, motor and control cables can result in unintended behavior or reduced performance. Minimum 7.9 in [200 mm] clearance between power, motor and control cables is required.

3.6 Controls

3.6.1 Control Principle

An adjustable frequency drive rectifies AC voltage from line power into DC voltage, after which DC voltage is converted into an AC current with a variable amplitude and frequency.

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

The adjustable frequency drive 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 the motor (sensorless).
- Speed closed-loop PID control which requires a speed feedback to an input. A properly optimized speed closed-loop control has higher accuracy than a speed open-loop control.

Selects which input to use as speed PID feedback in *7-00 Speed PID Feedback Source*.

Torque control

The torque control function is used in applications where the torque on motor output shaft is controlling the application as tension control. Torque control can be selected in *1-00 Configuration Mode*, either in VVC^{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 adjustable frequency drive.

Speed/torque reference

The reference to these controls can either be a single reference or the sum of various references including relatively scaled references. The handling of references is explained in detail in *chapter 3.7 Reference Handling*.

3

3.6.2 FC 301 vs. FC 302 Control Principle

FC 301 is a general purpose adjustable frequency drive 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 behavior on FC 301 depends on the current transducer in the positive DC link and the desaturation protection with feedback from the three lower IGBT's and the brake.

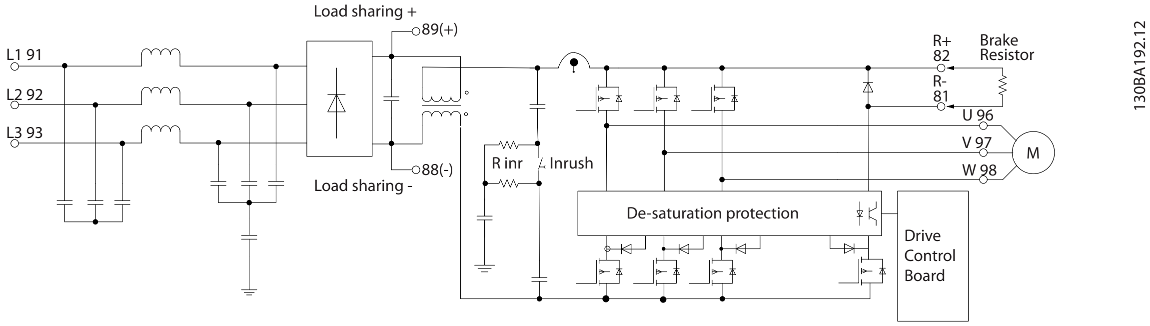


Figure 3.4 Control Principle FC 301

FC 302 is a high performance adjustable frequency drive for demanding applications. The adjustable frequency drive 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 behavior on FC 302 depends on the three current transducers in the motor phases and the desaturation protection with feedback from the brake.

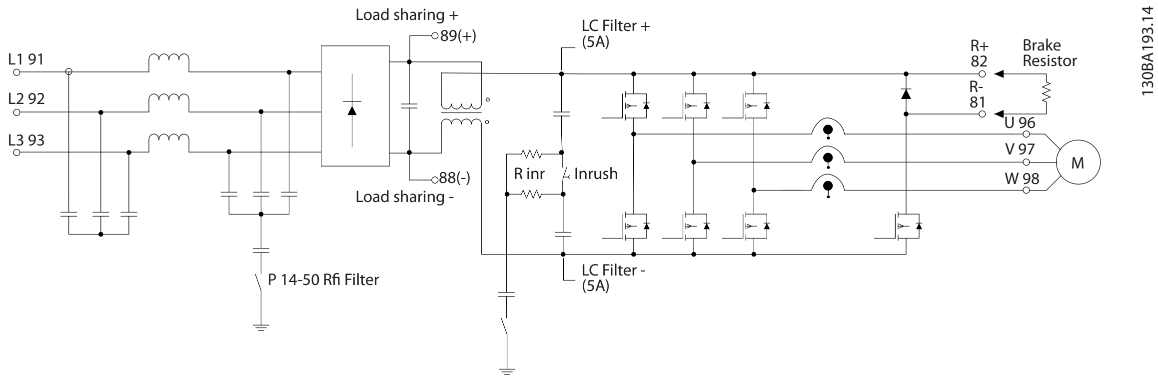


Figure 3.5 Control Principle FC 302

3.6.3 Control Structure in VVC^{plus}

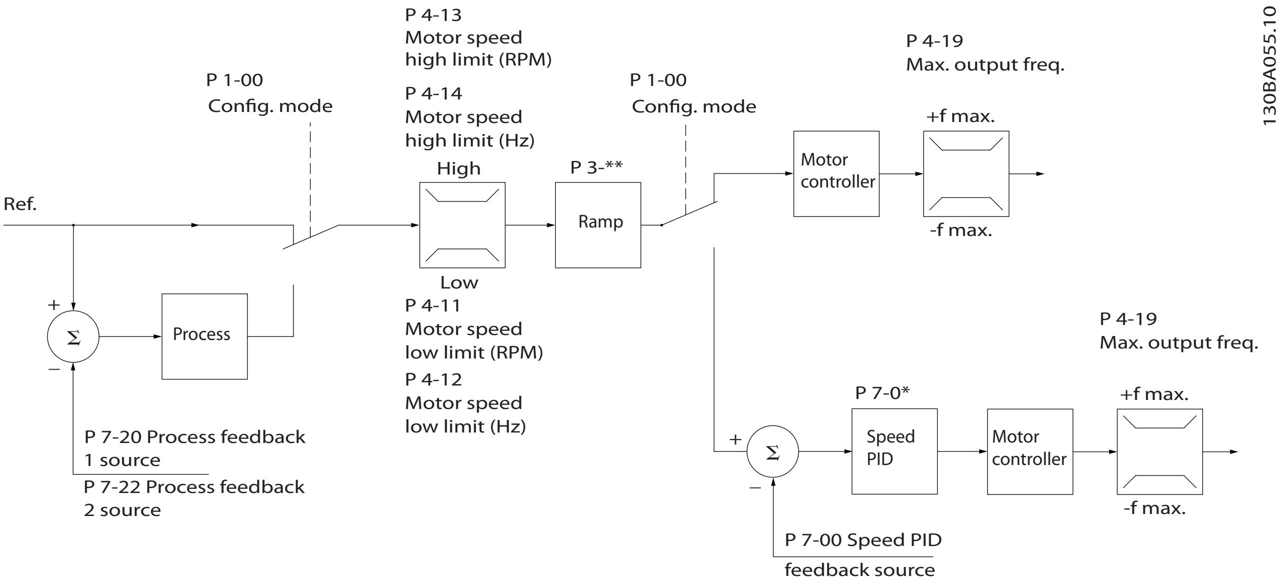


Figure 3.6 Control Structure in VVC^{plus} Open-loop and Closed-loop Configurations

See *Active/Inactive Parameters in Different Drive Control Modes* in the *Programming Guide* for an overview of which control configuration is available, depending on selection of AC motor or PM non-salient motor. In the configuration shown in *Figure 3.6*, *1-01 Motor Control Principle* is set to *[1] VVC^{plus}* and *1-00 Configuration Mode* is set to *[0] Speed open-loop*. The resulting reference from the reference handling system is received and fed through the ramp limitation and speed limitation before being sent to the motor control. The output of the motor control is then limited by the maximum frequency limit.

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

3.6.4 Control Structure in Flux Sensorless (FC 302 only)

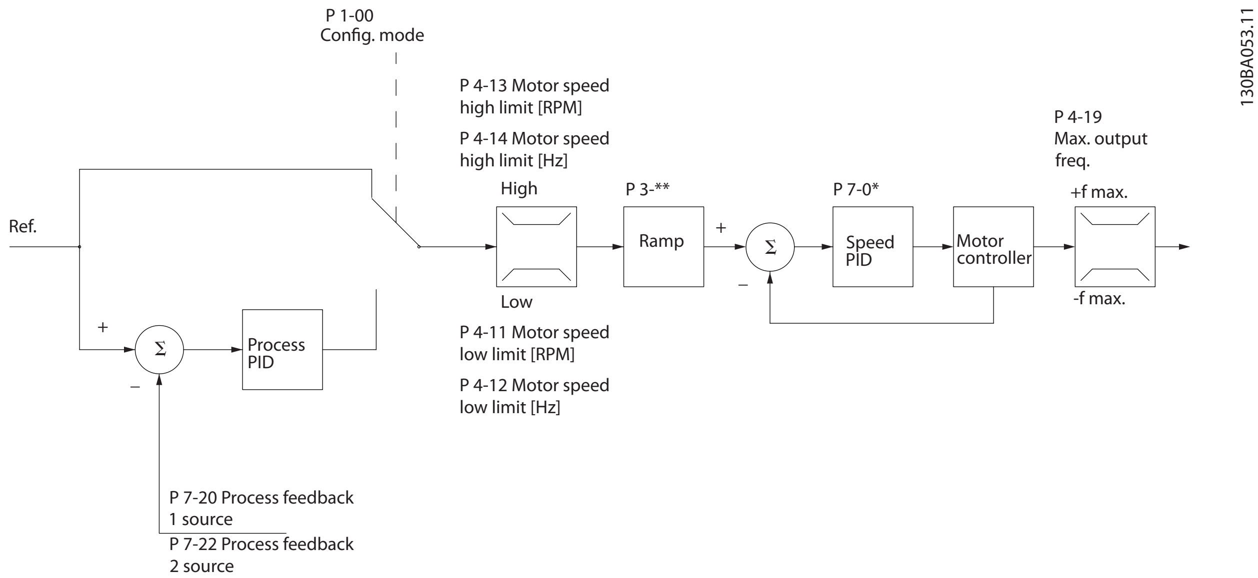


Figure 3.7 Control Structure in Flux Sensorless Open-loop and Closed-loop Configurations

See Active/Inactive Parameters in Different Drive Control Modes in the Programming Guide for an overview of which control configuration is available, depending on selection of AC motor or PM non-salient motor. In the configuration shown, *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, e.g., speed or pressure in the controlled application. The Process PID parameters are found in parameter group *7-2* Process Ctrl. Feedb* and *7-3* Process PID Ctrl*.

3.6.5 Control Structure in Flux with Motor Feedback (FC 302 only)

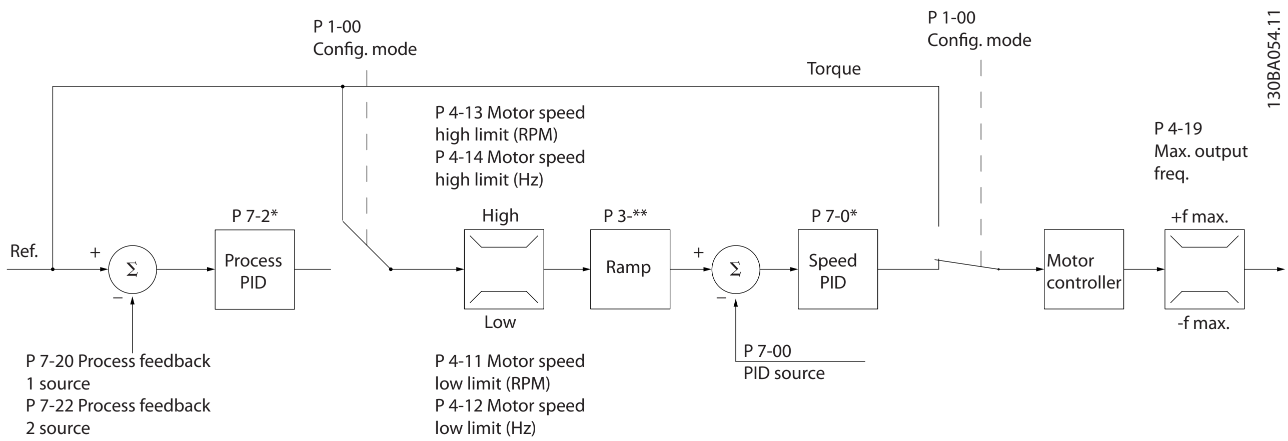


Figure 3.8 Control Structure in Flux with Motor Feedback Configuration (only available in FC 302)

See *Active/Inactive Parameters in Different Drive Control Modes* in the *Programming Guide* for an overview of which control configuration is available, depending on selection of AC motor or PM non-salient motor. In the configuration shown, *1-01 Motor Control Principle* is set to *[3] Flux w motor feedb* and *1-00 Configuration Mode* is set to *[1] Speed closed-loop*.

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

Select *[1] Speed closed-loop* in *1-00 Configuration Mode* to use the resulting reference as an input for the Speed PID control. The Speed PID control parameters are located in parameter group *7-0* Speed PID Control*.

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

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

3

3.6.6 PID

3.6.6.1 Speed PID Control

Speed PID Control maintains a constant motor speed regardless of the changing load on the motor.

1-00 Configuration Mode	1-01 Motor Control Principle			
	U/f	VVC^{plus}	Flux Sensorless	Flux w/ enc. feedb
[0] Speed open-loop	ACTIVE	ACTIVE	ACTIVE	N.A.
[1] Speed closed-loop	N.A.	Not Active	N.A.	ACTIVE
[2] Torque	N.A.	N.A.	N.A.	Not Active
[3] Process	Not Active	Not Active	Not Active	N.A.
[4] Torque open-loop	N.A.	Not Active	N.A.	N.A.
[5] Wobble	Not Active	Not Active	Not Active	Not Active
[6] Surface Winder	Not Active	Not Active	Not Active	N.A.
[7] Extend. PID Speed OL	Not Active	Not Active	Not Active	N.A.
[8] Extend. PID Speed CL	N.A.	Not Active	N.A.	Not Active

Table 3.1 Control Configurations with Active Speed Control

"N.A." means that the specific mode is not available at all. "Not Active" means that the specific mode is available but the Speed Control is not active in that mode.

NOTICE!

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

Table 3.2 sums up the characteristics that can be set-up for speed control. See *VLT® AutomationDrive FC 301/FC 302 Programming Guide* for details on programming.

<table>
<tr><th>Parameter</th><th colspan="2">Description of function</th></tr>
<tr><td>7-00 Speed PID Feedback Source</td><td colspan="2">Select from which input the speed PID should get its feedback.</td></tr>
<tr><td>7-02 Speed PID Proportional Gain</td><td colspan="2">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 colspan="2">Eliminates steady state speed error. Lower value means quick reaction. However, too high value may lead to oscillations.</td></tr>
<tr><td>7-04 Speed PID Differentiation Time</td><td colspan="2">Provides a gain proportional to the rate of change of the feedback. A setting of zero disables the differentiator.</td></tr>
<tr><td>7-05 Speed PID Diff. Gain Limit</td><td colspan="2">If there are quick changes in reference or feedback in a given application - which means that the error changes swiftly - the differentiator may soon become too dominant. This is because it reacts to changes in the error. The quicker the error changes, the stronger the differentiator gain is. The differentiator gain can thus be limited to allow setting of the reasonable differentiation time for slow changes and a suitably quick gain for quick changes.</td></tr>
<tr><td rowspan="6">7-06 Speed PID Lowpass Filter Time</td><td colspan="2">A low-pass filter that dampens oscillations on the feedback signal and improves steady state performance. However, a filter time that is too long causes the dynamic performance of the speed PID control to deteriorate.
Practical settings of parameter 7-06 taken from the number of pulses per revolution from encoder (PPR):</td></tr>
<tr><td>Encoder PPR</td><td>7-06 Speed PID Lowpass Filter Time</td></tr>
<tr><td>512</td><td>10 ms</td></tr>
<tr><td>1024</td><td>5 ms</td></tr>
<tr><td>2048</td><td>2 ms</td></tr>
<tr><td>4096</td><td>1 ms</td></tr>
<tr><td>7-07 Speed PID Feedback Gear Ratio</td><td colspan="2">The adjustable frequency drive multiplies the speed feedback by this ratio.</td></tr>
<tr><td>7-08 Speed PID Feed Forward Factor</td><td colspan="2">The reference signal bypasses the speed controller by the amount specified. This feature increases the dynamic performance of the speed control loop.</td></tr>
<tr><td>7-09 Speed PID Error Correction w/ Ramp</td><td colspan="2">The speed error between ramp and actual speed is held up against the setting in this parameter. If the speed error exceeds this parameter entry, the speed error is corrected via ramping in a controlled way.</td></tr>
</table>

Table 3.2 Relevant Parameters for Speed Control

Program in the order shown (see explanation of settings in the *Programming Guide*)

In *Table 3.3*, it is assumed that all other parameters and switches remain at their default setting.

Function	Parameter	Setting
1) Make sure the motor runs properly. Do the following:		
Set the motor parameters using nameplate data.	1-2*	As specified by motor nameplate
Perform an Automatic Motor Adaptation.	1-29 Automatic Motor Adaptation (AMA)	[1] Enable complete AMA
2) Check the motor is running and the encoder is attached properly. Do the following:		
Press [Hand On] on the LCP. Check that the motor is running and note in which direction it is turning (referred to below 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 65,535 and starts again at 0.
If *16-20 Motor Angle* is decreasing, change the encoder direction in *5-71 Term 32/33 Encoder Direction*.	5-71 Term 32/33 Encoder Direction	[1] Counter-clockwise (if *16-20 Motor Angle* is decreasing)
3) Make sure the adjustable frequency drive limits are set to safe values		

Function	Parameter	Setting
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 adjustable frequency drive capabilities and the 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 (0 V) to 1500 RPM (10 V).	6-1*	Not necessary (default)
6) Configure the 24 V HTL encoder signal as feedback for the Motor Control and the Speed Control		
Set up digital input 32 and 33 as HTL encoder inputs.	5-14 Terminal 32 Digital Input 5-15 Terminal 33 Digital Input	[0] No operation (default)
Select terminal 32/33 as motor feedback.	1-02 Flux Motor Feedback Source	Not necessary (default)
Select terminal 32/33 as Speed PID feedback.	7-00 Speed PID Feedback Source	Not necessary (default)
7) Tune the Speed Control PID parameters		
Use the tuning guidelines when relevant or tune manually.	7-0*	See the guidelines
8) Save to finish		
Save the parameter setting to the LCP for safe keeping.	0-50 LCP Copy	[1] All to LCP

Table 3.3 Programming Order

3.6.6.2 Tuning PID speed control

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

The value of *30-83 Speed PID Proportional Gain* is dependent on the combined inertia of the motor and load, and the selected bandwidth can be calculated using the following formula:

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

NOTICE!

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

A practical value for the bandwidth is 20 rad/s. Check the result of the *7-02 Speed PID Proportional Gain* calculation against the following formula (not required when using a high-resolution feedback such as a SinCos feedback):

$$Par.\ 7-02MAX=\frac{0.01\ x\ 4\ x\ Encoder\ Resolution\ x\ Par.\ 7-06}{2\ x\ \pi}\ x$$

$Max\ torque\ ripple\ [\%]$

The recommended start value for *7-06 Speed PID Lowpass Filter Time* is 5 ms (lower encoder resolution calls for a higher filter value). Typically, a max torque ripple of 3% is acceptable. For incremental encoders, the encoder resolution is found in either *5-70 Term 32/33 Pulses per Revolution* (24 V HTL on standard adjustable frequency drive) or *17-11 Resolution (PPR)* (5 V TTL on Encoder Option MCB 102).

Generally, the practical maximum limit of *7-02 Speed PID Proportional Gain* is determined by the encoder resolution and the feedback filter time, but other factors in the application might limit the *7-02 Speed PID Proportional Gain* to a lower value.

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

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

3.6.6.3 Process PID Control

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

Table 3.4 shows the control configurations where the process control is possible. When a flux vector motor control principle is used, take care also to tune the speed control PID parameters. Refer to *chapter 3.6 Controls* to see where the speed control is active.

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

Table 3.4 Control Configurations with Process Control

NOTICE!

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

3

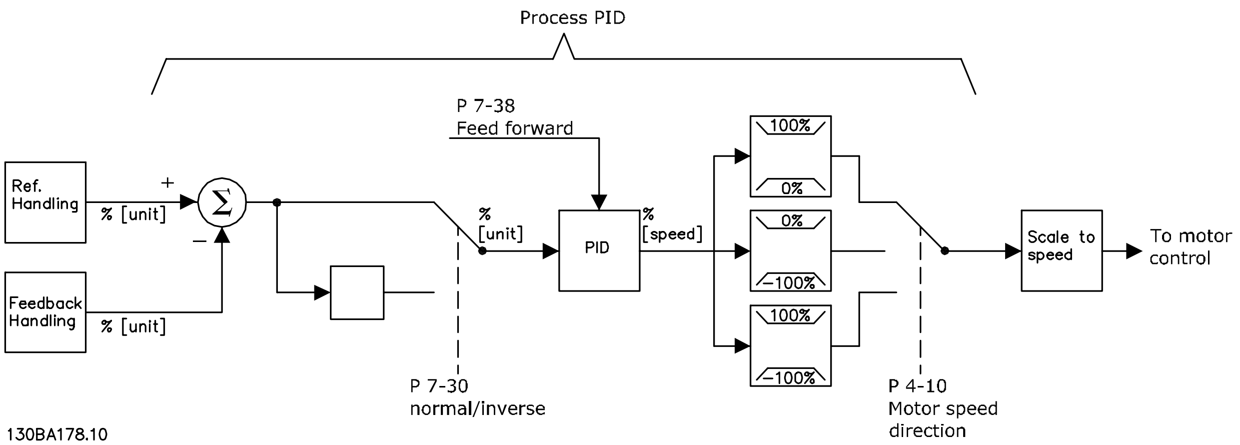


Figure 3.9 Process PID Control Diagram

Table 3.5 sums up the characteristics that can be set up for the process control.

Parameter	Description of function
7-20 Process CL Feedback 1 Resource	Select from which source (i.e., analog or pulse input) the Process PID should receive 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 are added together before being used in the Process PID control.
7-30 Process PID Normal/Inverse Control	Under *[0] Normal operation*, the Process Control responds with an increase of the motor speed if the feedback falls lower than the reference. In the same situation, but under *[1] Inverse operation*, the Process Control responds with a decreasing motor speed instead.
7-31 Process PID Anti Windup	The anti-windup function ensures that when either a frequency limit or a torque limit is reached, the integrator is set to a gain that corresponds to the actual frequency. This avoids integrating on an error that cannot in any case be compensated for with a speed change. This function can be disabled by selecting *[0] Off*.
7-32 Process PID Controller Start Value	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 adjustable frequency drive before the process control is activated. This is done by setting a Process PID Start Value (speed) in *7-32 Process PID Controller Start Value*.
7-33 Process PID Proportional Gain	The higher the value, the quicker the control. However, a value that is too large may lead to oscillations.
7-34 Process PID Integral Time	Eliminates steady state speed error. Lower value means quick reaction. However, a value that is too small 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 Differentiation Gain Limit	If there are quick changes in reference or feedback in a given application - which means that the error changes swiftly - the differentiator may soon become too dominant. This is because it reacts to changes in the error. The quicker the error changes, the stronger the differentiator gain is. The differentiator gain can thus be limited to allow setting of the reasonable differentiation time for slow changes.
7-38 Process PID Feed Forward Factor	In applications where there is a good (and approximately linear) correlation between the process reference and the motor speed necessary for obtaining that reference, the feed forward factor can be used to achieve better dynamic performance of the process PID control.

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) 6-36 Term. X30/11 Filter Time Constant 6-46 Term. X30/12 Filter Time Constant 35-46 Term. X48/2 Filter Time Constant	If there are oscillations of the current/voltage feedback signal, these can be dampened by means of a low-pass filter. This time constant represents the speed limit of the ripples occurring on the feedback signal. Example: If the low-pass filter has been set to 0.1s, the limit speed is 10 RAD/s (the reciprocal of 0.1 s), corresponding to $(10/(2 \times \pi)) = 1.6$ Hz. This means that all currents/ voltages that vary by more than 1.6 oscillations per second are damped by the filter. The control is only carried out on a feedback signal that varies by a frequency (speed) of less than 1.6 Hz. The low-pass filter improves steady state performance, but selecting a filter time that is too long causes the dynamic performance of the Process PID Control to deteriorate.

Table 3.5 Relevant Parameters for Process Control

3.6.6.4 Advanced PID Control

Consult the *VLT® AutomationDrive FC 301/FC 302 Programming Guide* for advanced PID control parameters

3.6.7 Internal Current Control in VVC^{plus} Mode

When the motor current/torque exceed the torque limits set in *4-16 Torque Limit Motor Mode*, *4-17 Torque Limit Generator Mode* and *4-18 Current Limit*, the integral current limit control is activated.
When the adjustable frequency drive is at the current limit during motor operation or regenerative operation, it tries to get below the preset torque limits as quickly as possible without losing control of the motor.

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

The adjustable frequency drive 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 adjustable frequency drive via the LCP pressing [Hand On] and [Off]. Alarms can be reset via [Reset]. After pressing [Hand On], the adjustable frequency drive goes into Hand mode and follows (as default) the local reference that can be set using the navigation keys on the LCP.

After pressing [Auto On], the adjustable frequency drive enters Auto mode and follows (as default) the remote reference. In this mode, it is possible to control the adjustable frequency drive via the digital inputs and various serial interfaces (RS-485, USB, or an optional serial communication bus). 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*.

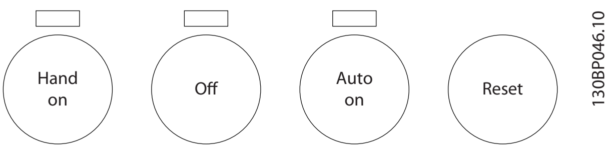


Figure 3.10 Operation Keys

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 depends on which mode is active. (Hand mode or Auto mode).

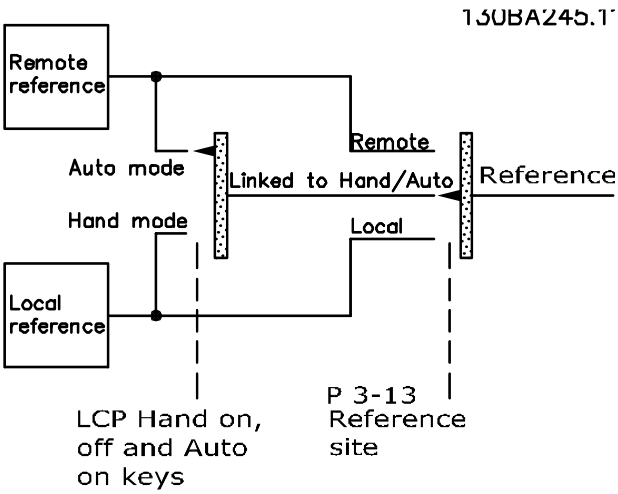


Figure 3.11 Active Reference

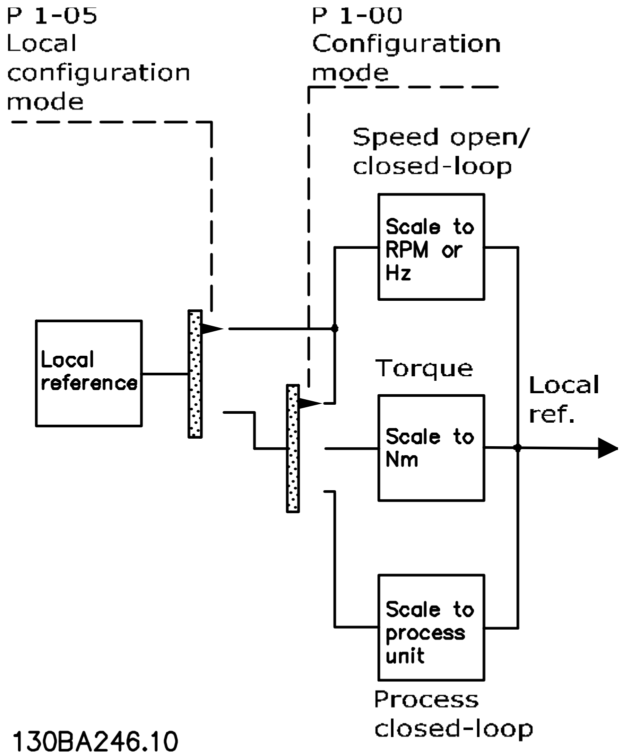


Figure 3.12 Configuration Mode

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

Table 3.6 Conditions for Local/Remote Reference Activation

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

3.7 Reference Handling

3.7.1 References

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

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

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

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

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

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

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

Remote Reference
The reference handling system for calculating the remote reference is shown in *Figure 3.13*.

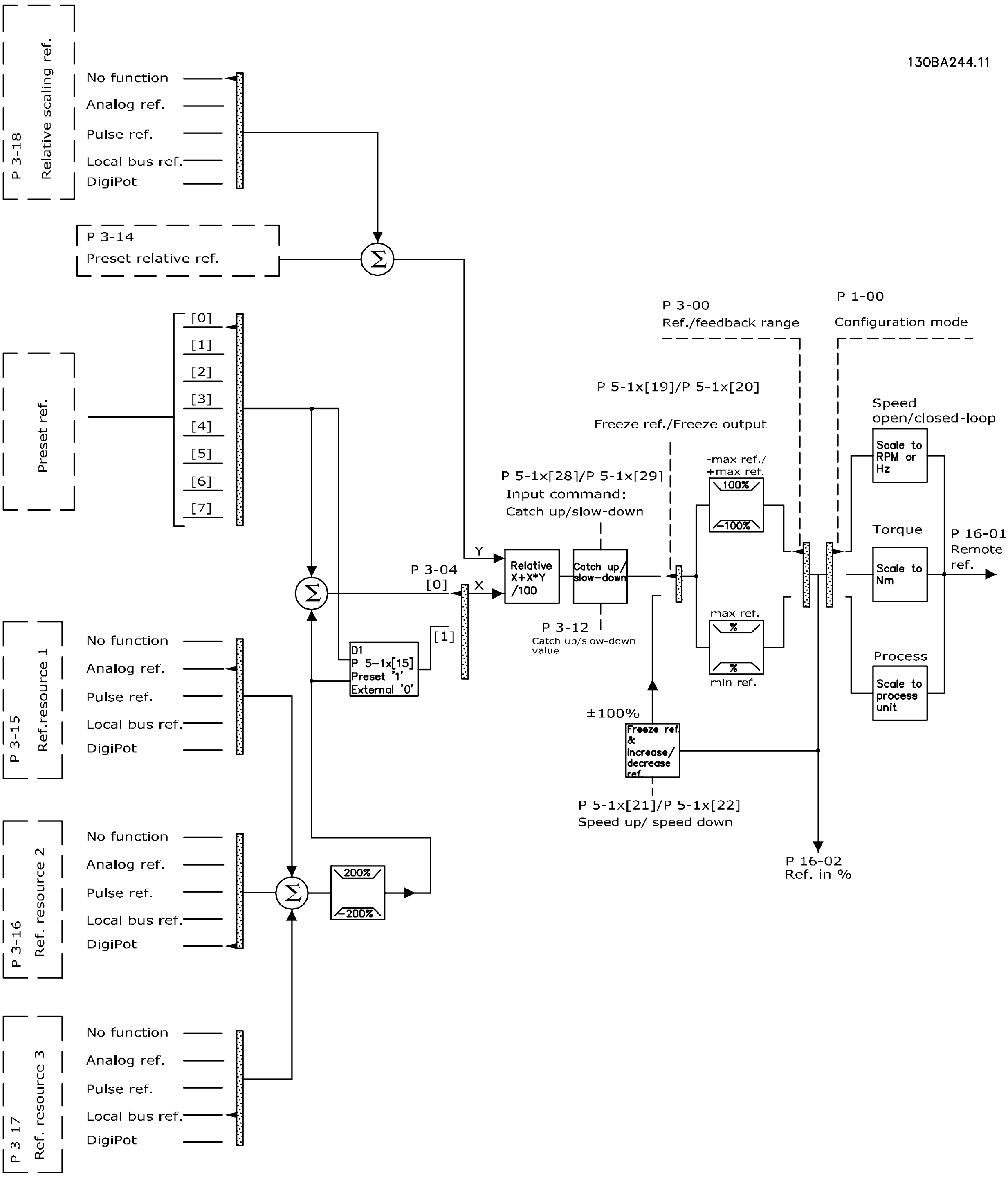


Figure 3.13 Remote Reference

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 adjustable frequency drive 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, set *3-18 Relative Scaling Reference Resource* to *[0] No function* and *3-14 Preset Relative Reference* to *0%*. The *catch up/slow-down* function and the *freeze reference* function can both be activated by digital inputs on the adjustable frequency drive. The functions and parameters are described in the *Programming Guide*.
The scaling of analog references are described in parameter groups *6-1* Analog Input 1* and *6-2* Analog Input 2*, and the scaling of digital pulse references are described in parameter group *5-5* Pulse Input*.
Reference limits and ranges are set in parameter group *3-0* Reference Limits*.

3.7.2 Reference Limits

3-00 Reference Range, *3-02 Minimum Reference* and *3-03 Maximum Reference* define the allowed range of the sum of all references. The sum of all references is clamped when necessary. The relation between the resulting reference (after clamping) and the sum of all references is shown in *Figure 3.14*.

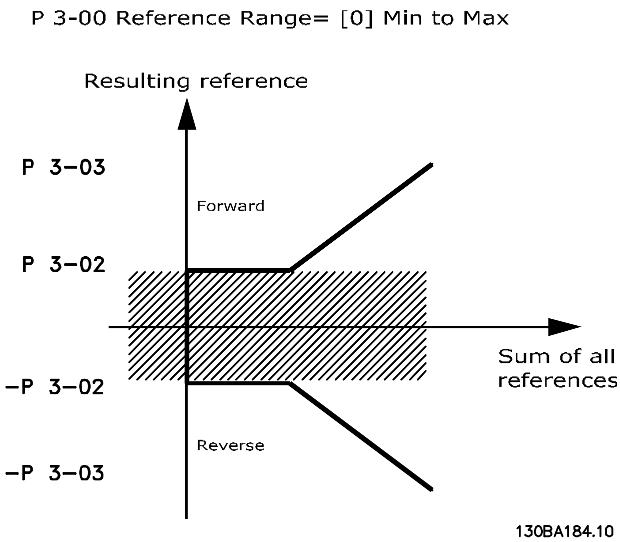


Figure 3.14 Relation between Resulting Reference and the Sum of all References

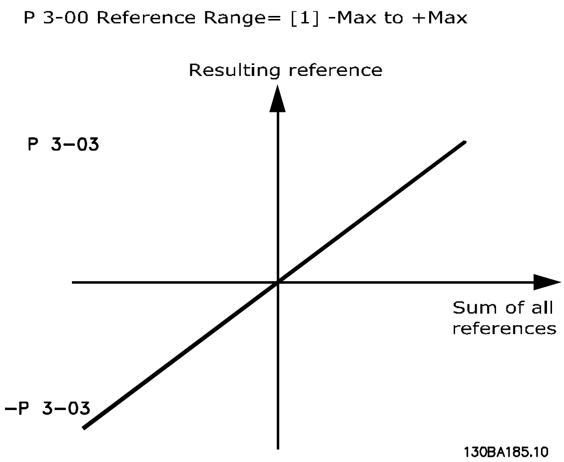


Figure 3.15 Resulting Reference

3

The value of *3-02 Minimum Reference* cannot be set to less than 0 unless *1-00 Configuration Mode* is set to *[3] Process*. In that case, the following relations between the resulting reference (after clamping) and the sum of all references is shown in *Figure 3.16*.

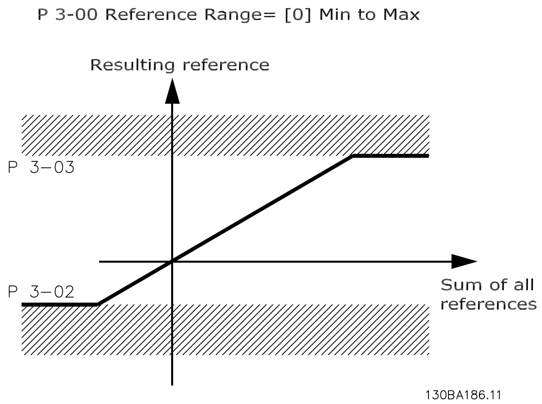


Figure 3.16 Sum of all References with *1-00 Configuration Mode* set to *[3] Process*

3.7.3 Scaling of Preset References and Bus References

Preset references are scaled according to the following rules:

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

Bus references are scaled according to the following rules:

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

3.7.4 Scaling of Analog and Pulse References and Feedback

References and feedback are scaled from analog and pulse inputs in the same way. The only difference is that a reference above or below the specified minimum and maximum “endpoints” (P1 and P2 in *Figure 3.17*) are clamped, whereas a feedback above or below is not.

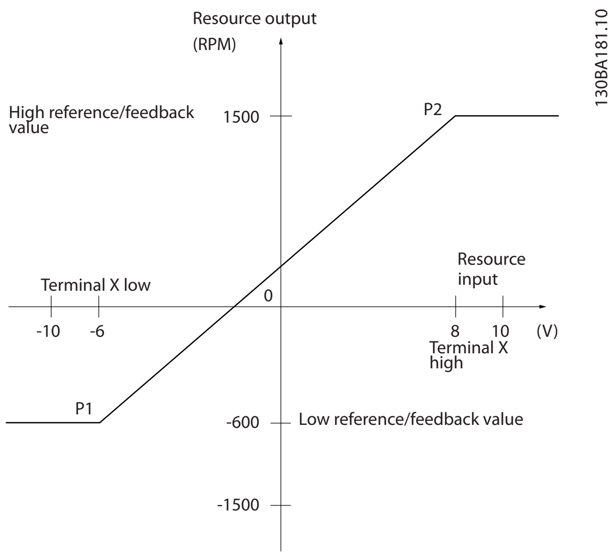


Figure 3.17 Scaling of Analog and Pulse References and Feedback

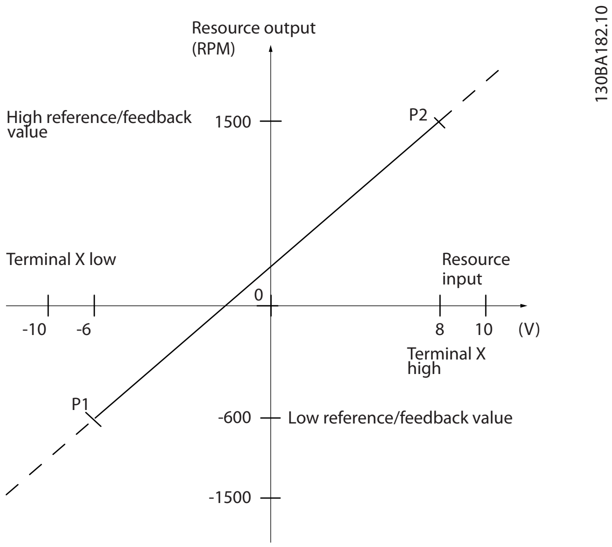


Figure 3.18 Scaling of Reference Output

3.7.5 Dead Band Around Zero

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

To activate the dead band and to set the amount of dead band, set the following:

- Either Minimum Reference Value or Maximum Reference Value must be zero. In other words, Either P1 or P2 must be on the X-axis in *Figure 3.19*.
- 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 *Figure 3.19*.

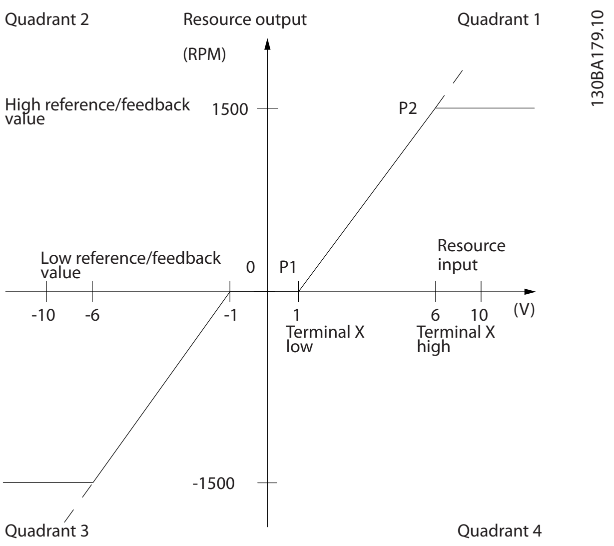


Figure 3.19 Dead Band

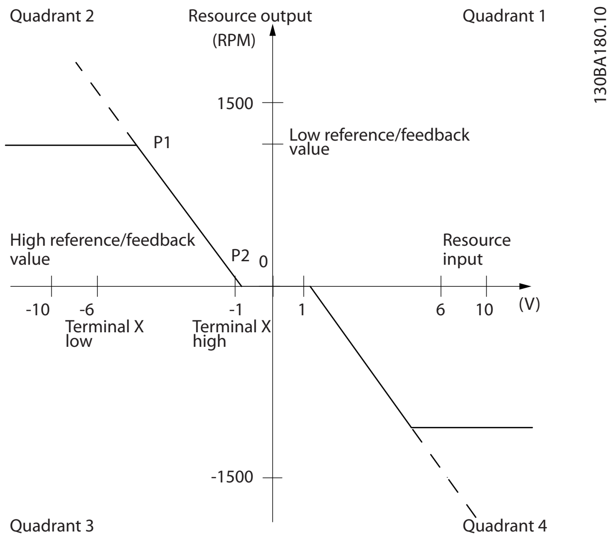


Figure 3.20 Reverse Dead Band

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

Figure 3.21 shows how reference input with limits inside Min – Max limits clamps.

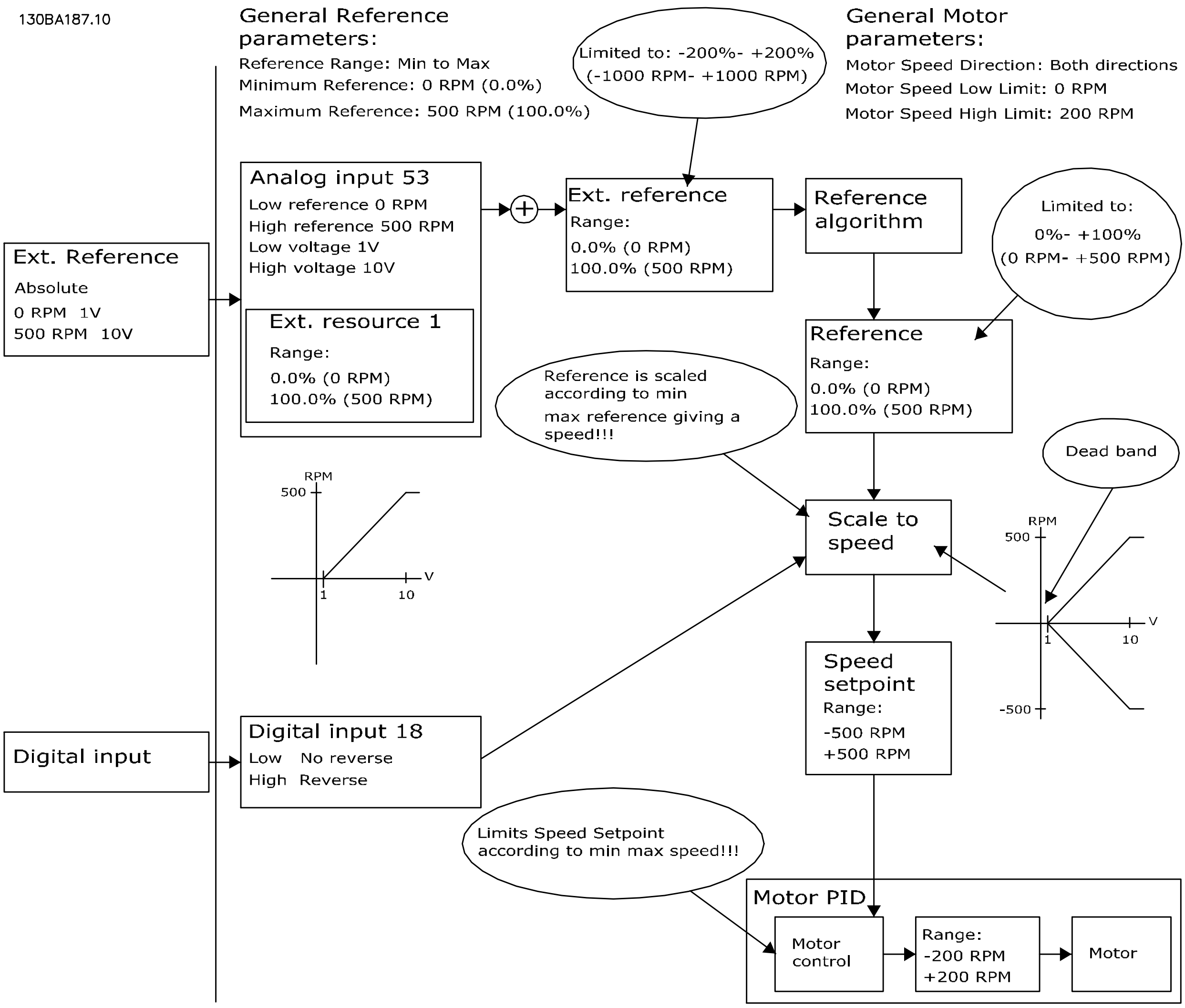


Figure 3.21 Positive Reference with Dead Band, Digital input to Trigger Reverse

Figure 3.22 shows how reference input with limits outside -Max to +Max limits clamps to the inputs low and high limits before being added to actual reference. *Figure 3.22* also shows how the actual reference is clamped to -Max to +Max by the reference algorithm.

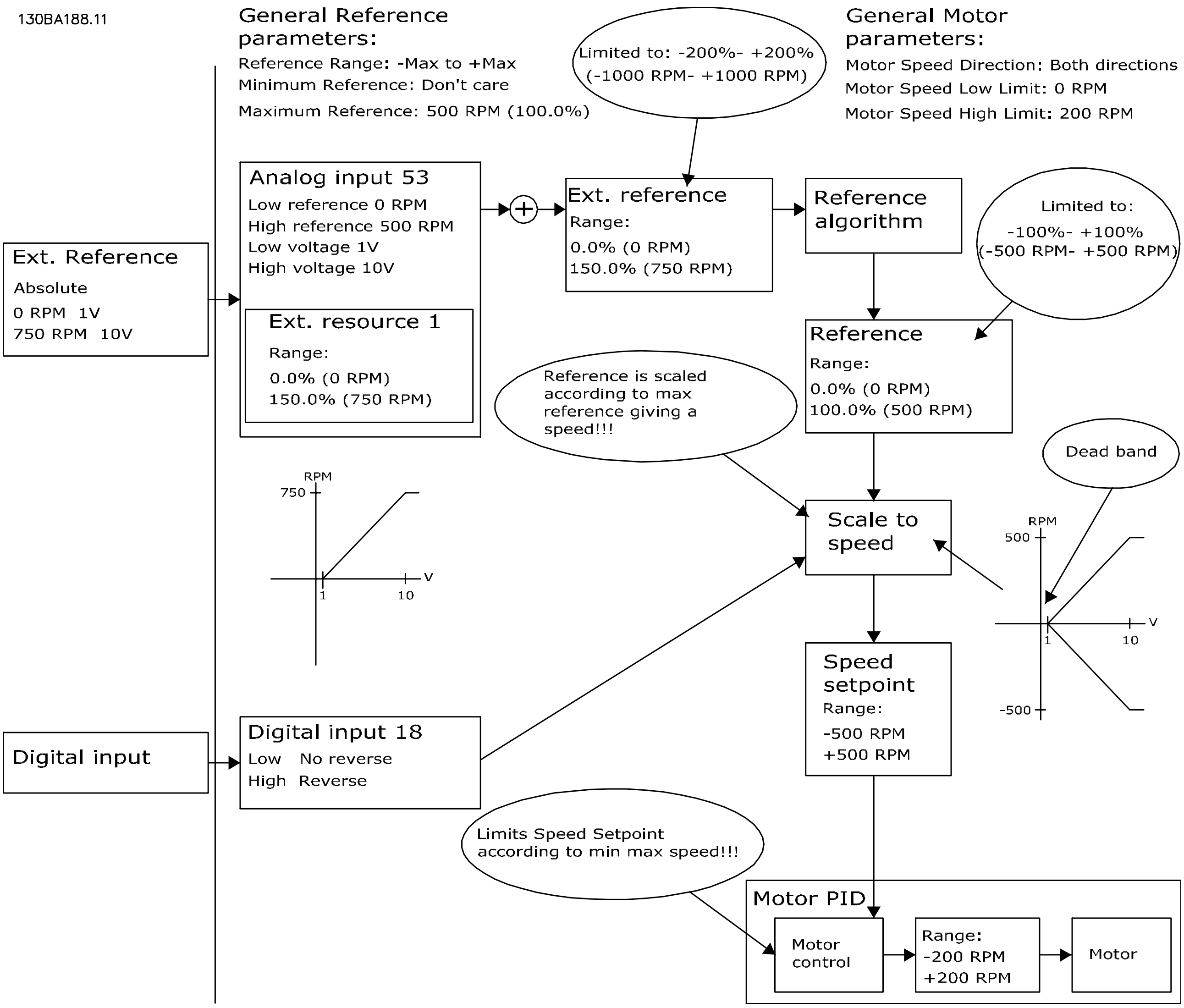


Figure 3.22 Positive Reference with Dead Band, Digital Input to Trigger Reverse. Clamping Rules

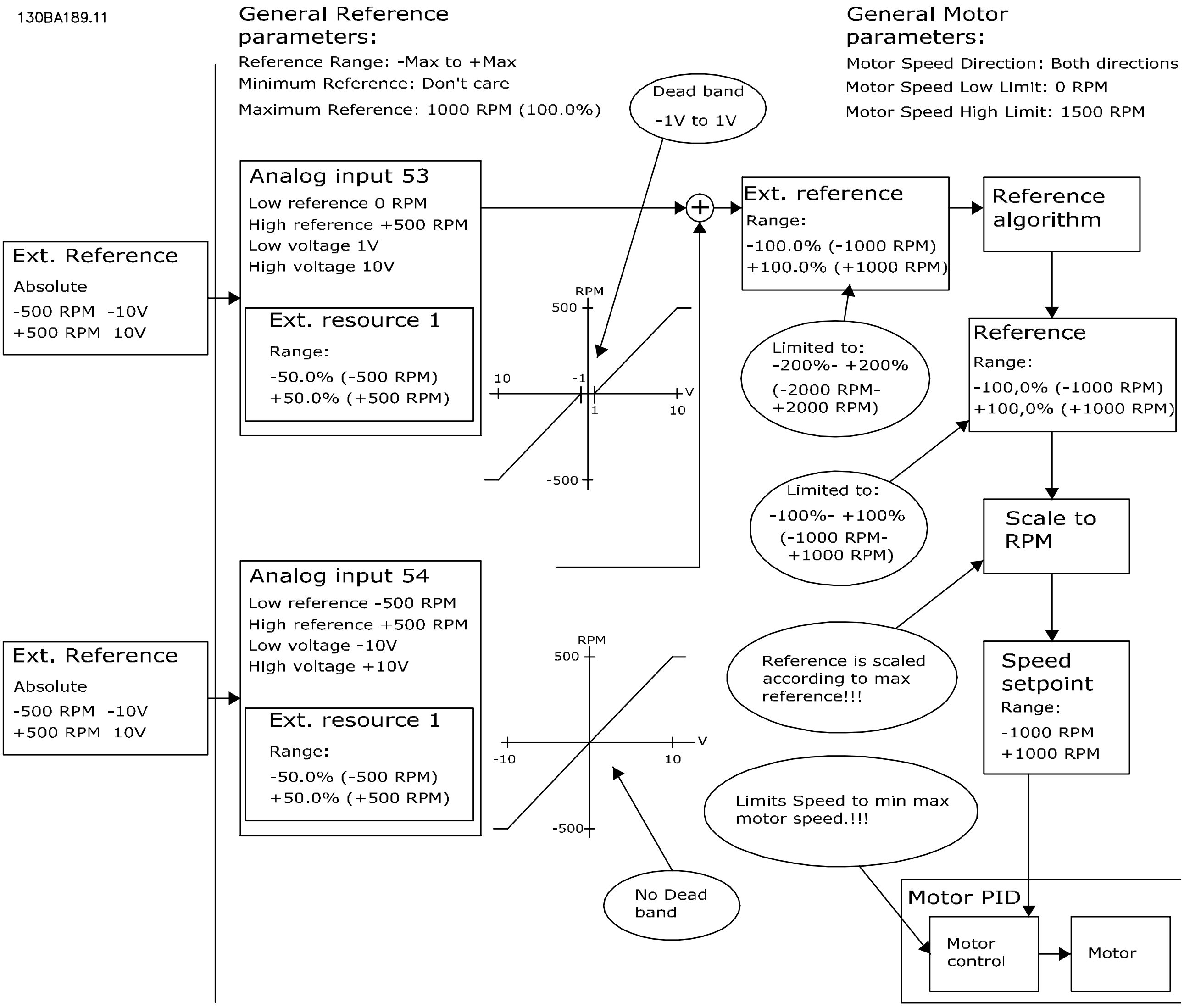


Figure 3.23 Negative to Positive Reference with Dead Band, Sign Determines the Direction, -Max to +Max

4 Product Features

4.1 Automated Operational Features

These features are active as soon as the adjustable frequency drive is operating. They require no programming or set-up. Understanding that these features are present can optimize a system design and possibly avoid introducing redundant components or functionality.

The adjustable frequency drive has a range of built-in protection functions to protect itself and the motor it is running.

4.1.1 Short Circuit Protection

Motor (phase-phase)
The adjustable frequency drive is protected against short circuits on the motor-side by current measurement in each of the three motor phases or in the DC link. A short circuit between two output phases causes an overcurrent in the inverter. The inverter is turned off when the short circuit current exceeds the permitted value (Alarm 16 Trip Lock).

Line power side
An adjustable frequency drive that works correctly limits the current it can draw from the supply. Still, it is recommended to use fuses and/or circuit breakers on the supply side as protection in case of component break-down inside the adjustable frequency drive (first fault). See *chapter 9.3 AC line input connections* for more information.

NOTICE!

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

Brake resistor
The adjustable frequency drive is protected from a short circuit in the brake resistor.

Load sharing
To protect the DC bus against short circuits and the adjustable frequency drives from overload, install DC fuses in series with the load sharing terminals of all connected units. See *chapter 9.6.3 Load Sharing* for more information.

4.1.2 Overvoltage Protection

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

- The load drives the motor (at constant output frequency from the adjustable frequency drive), i.e., the load generates energy.
- During deceleration ("ramp-down") if the moment of inertia is high, the friction is low and the ramp-down time is too short for the energy to be dissipated as a loss in the adjustable frequency drive, the motor and the installation.
- Incorrect slip compensation setting may cause higher DC link voltage.
- Back-EMF from PM motor operation. If coasted at high RPM, the PM motor back-EMF may potentially exceed the maximum voltage tolerance of the adjustable frequency drive and cause damage. To help prevent this, the value of *4-19 Max Output Frequency* is automatically limited based on an internal calculation based on the value of *1-40 Back EMF at 1000 RPM*, *1-25 Motor Nominal Speed* and *1-39 Motor Poles*.

NOTICE!

To avoid that the motor overspeeds (e.g., due to excessive windmilling effects), equip the adjustable frequency drive with a brake resistor.

The overvoltage can handled either via using a brake function (*2-10 Brake Function*) and/or using overvoltage control (*2-17 Over-voltage Control*).

Brake functions
Connect a brake resistor for dissipation of surplus brake energy. Connecting a brake resistor allows a higher DC link voltage during braking.

AC brake is an alternative to improve breaking without using a brake resistor. This function controls an overmag-netization of the motor when running generatoric. This function can improve the OVC. Increasing the electrical losses in the motor allows the OVC function to increase the breaking torque without exceeding the overvoltage limit.

NOTICE!

AC brake is not as effective as dynamic breaking with a resistor.

OverVoltage Control (OVC)
OVC reduces the risk of the adjustable frequency drive tripping due to an overvoltage on the DC link. This is managed by automatically extending the ramp-down time.

NOTICE!

OVC can be activated for PM motor with all control core, PM VVC^{plus}, Flux OL and Flux CL for PM Motors.

NOTICE!

Do not enable OVC in hoisting applications.

4.1.3 Missing Motor Phase Detection

The Missing Motor Phase Function (*4-58 Missing Motor Phase Function*) is enabled by default to avoid motor damage in the case that a motor phase is missing. The default setting is 1,000 ms, but it can be adjusted for a faster detection.

4.1.4 Line Phase Imbalance Detection

Operation under severe line imbalance conditions reduces the lifetime of the motor. Conditions are considered severe if the motor is operated continuously near nominal load. The default setting trips the adjustable frequency drive in case of line imbalance (*14-12 Function at Mains Imbalance*).

4.1.5 Switching on the Output

Adding a switch to the output between the motor and the adjustable frequency drive is permitted. Fault messages may appear. Enable flying start to catch a spinning motor.

4.1.6 Overload Protection

Torque Limit
The torque limit feature protects the motor against overload, independent of the speed. Torque limit is controlled in *4-16 Torque Limit Motor Mode* and or *4-17 Torque Limit Generator Mode* and the time before the torque limit warning trips is controlled in *14-25 Trip Delay at Torque Limit*.

Current Limit
The current limit is controlled in *4-18 Current Limit* and the time before the adjustable frequency drive trips is controlled in *14-24 Trip Delay at Current Limit*.

Speed Limit
Min. speed limit: *4-11 Motor Speed Low Limit [RPM]* or *4-12 Motor Speed Low Limit [Hz]* limit the operating speed range to for instance between 30 and 50/60 Hz.
Max. speed limit: (*4-13 Motor Speed High Limit [RPM]* or *4-19 Max Output Frequency* limit the max output speed the adjustable frequency drive can provide.

ETR
ETR is an electronic feature that simulates a bimetal relay based on internal measurements. The characteristic is shown in *Figure 4.1*.

Voltage Limit
The inverter turns off to protect the transistors and the intermediate circuit capacitors when a certain hard-coded voltage level is reached.

Overtemperature
The adjustable frequency drive has built-in temperature sensors and reacts immediately to critical values via hard-coded limits.

4.1.7 Locked Rotor Protection

There may be situations when the rotor is locked due to excessive load or some other factors (bearing, or application create locked rotor situation). This leads to overheating of motor winding (free movement of rotor is required for proper cooling). The adjustable frequency drive is able to detect the locked rotor situation with open-loop PM flux control, and PM VVC^{plus} control (*30-22 Locked Rotor Protection*).

4.1.8 Automatic Derating

The adjustable frequency drive constantly checks for critical levels:

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

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

NOTICE!

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

4.1.9 Automatic Energy Optimization

Automatic energy optimization (AEO) directs the adjustable frequency drive to continuously monitor the load on the motor and adjust the output voltage to maximize efficiency. Under light load, the voltage is reduced and the motor current is minimized. The motor benefits from increased efficiency, reduced heating, and quieter operation. There is no need to select a V/Hz curve because the adjustable frequency drive automatically adjusts motor voltage.

4.1.10 Automatic Switching Frequency Modulation

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

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

4.1.11 Automatic Derating for High Carrier Frequency

The adjustable frequency drive is designed for continuous, full load operation at carrier frequencies between 3.0 and 4.5 kHz. A carrier frequency higher than 4.5 kHz generates increased heat in the adjustable frequency drive and requires the output current to be derated.

An automatic feature of the adjustable frequency drive is load-dependent carrier frequency control. This feature allows the motor to benefit from as high a carrier frequency as the load permits.

4.1.12 Power Fluctuation Performance

The adjustable frequency drive withstands line power fluctuations such as transients, momentary dropouts, short voltage drops and surges. The adjustable frequency drive automatically compensates for input voltages ±10% from the nominal to provide full rated motor voltage and torque. With auto restart selected, the adjustable frequency drive automatically powers up after a voltage trip. And with flying start, the adjustable frequency drive synchronizes to motor rotation prior to start.

4.1.13 Resonance Damping

High frequency motor resonance noise can be eliminated through the use of resonance damping. Automatic or manually selected frequency damping is available.

4.1.14 Temperature-controlled Fans

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

4.1.15 EMC Compliance

Electromagnetic interference (EMI) or radio frequency interference (RFI, in case of radio frequency) is disturbance which can affect an electrical circuit due to electromagnetic induction or radiation from an external source. The adjustable frequency drive is designed to comply with the EMC product standard for drives IEC 61800-3 as well as the European standard EN 55011. To comply with the emission levels in EN 55011, the motor cable must be shielded and properly terminated. For more information regarding EMC performance, see *chapter 5.2.1 EMC Test Results*.

4.1.16 Galvanic Isolation of Control Terminals

All control terminals and output relay terminals are galvanically isolated from line power. This means the controller circuitry is completely protected from the input current. The output relay terminals require their own grounding. This isolations meets the stringent protective extra-low voltage (PELV) requirements for isolation.

The components that make up the galvanic isolation are

- Power supply, including signal isolation
- Gate drive for the IGBTs, the trigger transformers and optocouplers
- The output current Hall Effect transducers

4.2 Custom Application Features

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

4.2.1 Automatic Motor Adaptation

Automatic motor adaptation (AMA) is an automated test procedure used to measure the electrical characteristics of the motor. AMA provides an accurate electronic model of the motor. It allows the adjustable frequency drive to calculate optimal performance and efficiency with the motor. Running the AMA procedure also maximizes the automatic energy optimization feature of the adjustable frequency drive. AMA is performed without the motor rotating and without uncoupling the load from the motor.

4.2.2 Motor Thermal Protection

Motor thermal protection can be provided in three ways:

- Via direct temperature sensing via one of the following
  - PTC or KTY sensor in the motor windings and connected on a standard AI or DI
  - PT100 or PT1000 in the motor windings and motor bearings, connected on sensor input card MCB 114
  - PTC thermistor input on PTC thermistor card MCB 112 (ATEX approved)
- Mechanical thermal switch (Klixon type) on a DI
- Via the built-in Electronic Thermal Relay (ETR).

ETR calculates motor temperature by measuring current, frequency, and operating time. The adjustable frequency drive displays the thermal load on the motor in percentage and can issue a warning at a programmable overload setpoint.
Programmable options at the overload allow the adjustable frequency drive to stop the motor, reduce output, or ignore the condition. Even at low speeds, the adjustable frequency drive meets I2t Class 20 electronic motor overload standards.

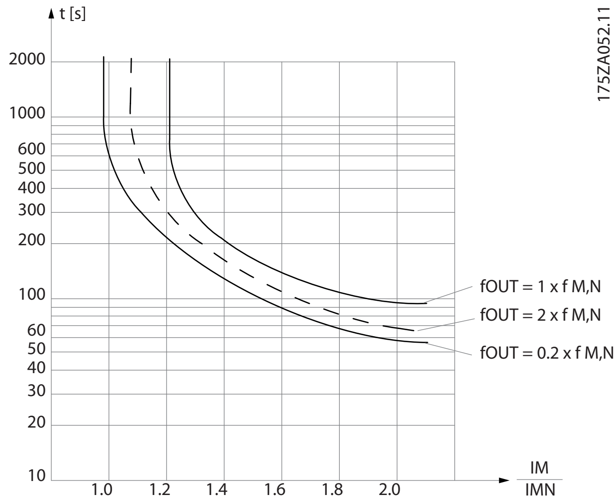


Figure 4.1 ETR Characteristics

The X-axis shows the ratio between I_{motor} and I_{motor} nominal. The Y-axis shows the time in seconds before the ETR cuts off and trips the adjustable frequency drive. The curves show the characteristic nominal speed, at twice the nominal speed and at 0.2 x the nominal speed.
At lower speed, the ETR cuts off at lower heat due to less cooling of the motor. In that way, the motor is protected from being overheated even at low speed. The ETR feature calculates the motor temperature based on the actual current and speed. The calculated temperature is visible as a readout parameter in *16-18 Motor Thermal*.
A special version of the ETR is also available for EX-e motors in ATEX areas. This function makes it possible to enter a specific curve to protect the Ex-e motor. The *Programming Guide* takes the user through the set-up.

4.2.3 Line Drop-out

During a line drop-out, the adjustable frequency drive keeps running until the intermediate circuit voltage drops below the minimum stop level, which is typically 15% below the adjustable frequency drive's lowest rated supply voltage. The AC line voltage before the drop-out and the motor load determines how long it takes for the adjustable frequency drive to coast.

The adjustable frequency drive can be configured (*14-10 Line Failure*) to different types of behavior during line drop-out, e.g:

- Trip Lock once the DC link is exhausted
- Coast with flying start whenever line power return (*1-73 Flying Start*)
- Kinetic backup
- Controlled ramp-down

Flying start
This selection makes it possible to catch a motor that is spinning freely due to a line drop-out. This option is very relevant for centrifuges and fans.

Kinetic backup
This selection ensures that the adjustable frequency drive runs as long as there is energy in the system. For short line drop-out the operation is restored upon line power return, without bringing the application to a stop or loosing control at any time. Several variants of kinetic backup can be selected.

The behavior of the adjustable frequency drive at line drop-out can be configured in *14-10 Line Failure* and *1-73 Flying Start*.

4.2.4 Built-in PID Controller

The built-in proportional, integral, derivative (PID) controller is available, eliminating the need for auxiliary control devices. The PID controller maintains constant control of closed-loop systems where regulated pressure, flow, temperature, or other system requirements must be maintained. The adjustable frequency drive can provide self-reliant control the motor speed in response to feedback signals from remote sensors.

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

4.2.5 Automatic Restart

The adjustable frequency drive can be programmed to automatically restart the motor after a minor trip, such as momentary power loss or fluctuation. This feature eliminates the need for manual resetting and enhances automated operation for remotely controlled systems. The number of restart attempts as well as the duration between attempts can be limited.

4.2.6 Flying Start

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

4.2.7 Full Torque at Reduced Speed

The adjustable frequency drive follows a variable V/Hz curve to provide full motor torque even at reduced speeds. Full output torque can coincide with the maximum designed operating speed of the motor. This is unlike variable torque drives that provide reduced motor torque at low speed, or constant torque converters that provide excess voltage, heat and motor noise at less than full speed.

4.2.8 Frequency Bypass

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

4.2.9 Motor Preheat

To preheat a motor in a cold or damp environment, a small amount of DC current can be trickled continuously into the motor to protect it from condensation and a cold start. This can eliminate the need for a space heater.

4.2.10 Four Programmable Set-ups

The adjustable frequency drive has four set-ups which can be independently programmed. Using multi-setup, it is possible to switch between independently programmed functions activated by digital inputs or a serial command. Independent set-ups are used, for example, to change references, or for day/night or summer/winter operation, or to control multiple motors. The active set-up is displayed on the LCP.

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

4.2.11 Dynamic Braking

Dynamic Brake is established by:

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

4.2.12 Open-loop Mechanical Brake Control

Parameters for controlling operation of an electro-magnetic (mechanical) brake, typically required in hoisting applications. To control a mechanical brake, a relay output (relay 01 or relay 02) or a programmed digital output (terminal 27 or 29) is required. Normally, this output must be closed during periods when the adjustable frequency drive is unable to 'hold' the motor, e.g., due to an excessive load. Select *[32] Mechanical Brake Control* for applications with an electro-magnetic brake in *5-40 Function Relay*, *5-30 Terminal 27 Digital Output*, or *5-31 Terminal 29 digital Output*. When selecting *[32] Mechanical brake control*, the mechanical brake is closed from start up until the output current is above the level selected in *2-20 Release Brake Current*. During stop, the mechanical brake activates when the speed drops below the level specified in *2-21 Activate Brake Speed [RPM]*. If the adjustable frequency drive enters an alarm condition or an overcurrent or overvoltage situation, the mechanical brake immediately cuts in. This is also the case during Safe Torque Off.

NOTICE!

Protection mode and trip delay features (*14-25 Trip Delay at Torque Limit* and *14-26 Trip Delay at Inverter Fault*) may delay the activation of the mechanical brake in an alarm condition. These features must be disabled in hoisting applications.

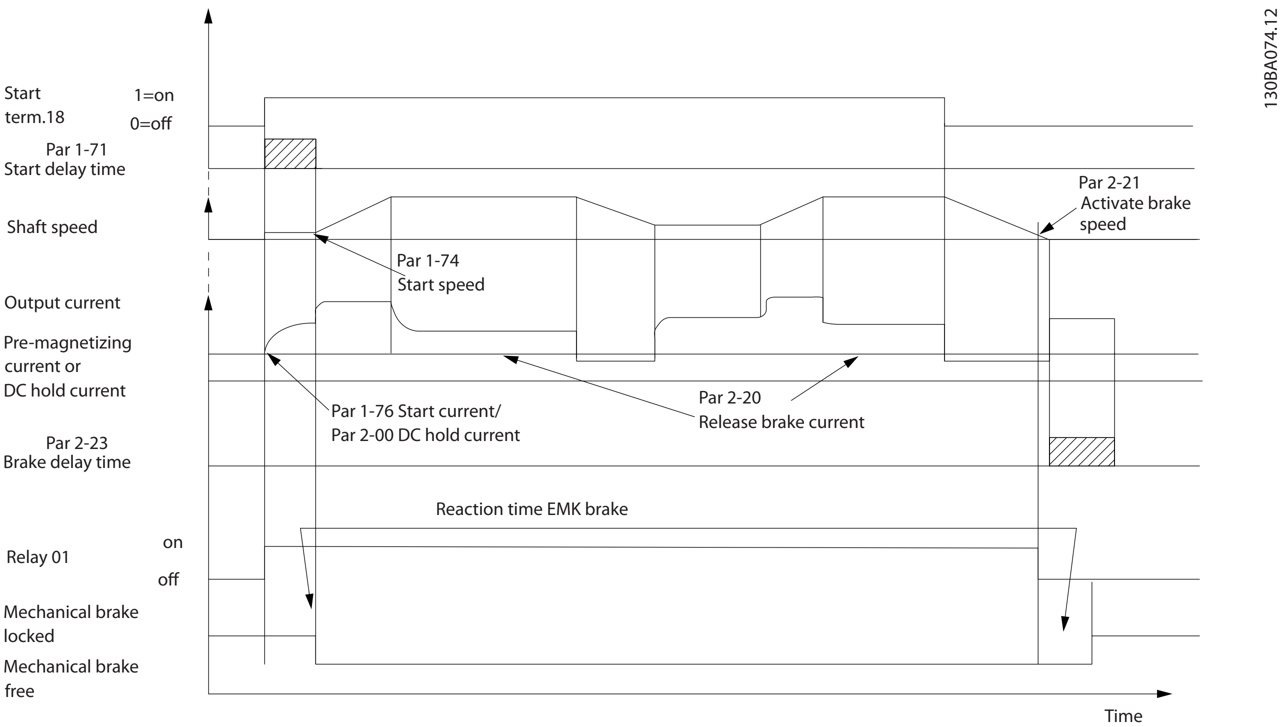


Figure 4.2 Mechanical Brake

4

4.2.13 Closed-loop Mechanical Brake Control/Hoist Mechanical Brake

The hoist mechanical break control supports the following functions:

- Two channels for mechanical brake feedback to offer further protection against unintended behavior resulting from broken cable.
- Monitoring of mechanical brake feedback throughout the complete cycle. This helps protect the mechanical brake - especially if more adjustable frequency drives are connected to the same shaft.
- No ramp up until feedback confirms mechanical brake is open.
- Improved load control at stop. If *2-23 Activate Brake Delay* is set too short, W22 is activated and the torque is not allowed to ramp down.
- The transition when motor takes over the load from the brake can be configured. *2-28 Gain Boost Factor* can be increased to minimize the movement. For very smooth transition, change the setting from the speed control to the position control during the change-over.
    - Set *2-28 Gain Boost Factor* to 0 to enable Position Control during *2-25 Brake Release Time*. This enables parameters *2-30 Position P Start Proportional Gain* to *2-33 Speed PID Start Lowpass Filter Time* which are PID parameters for the Position Control.

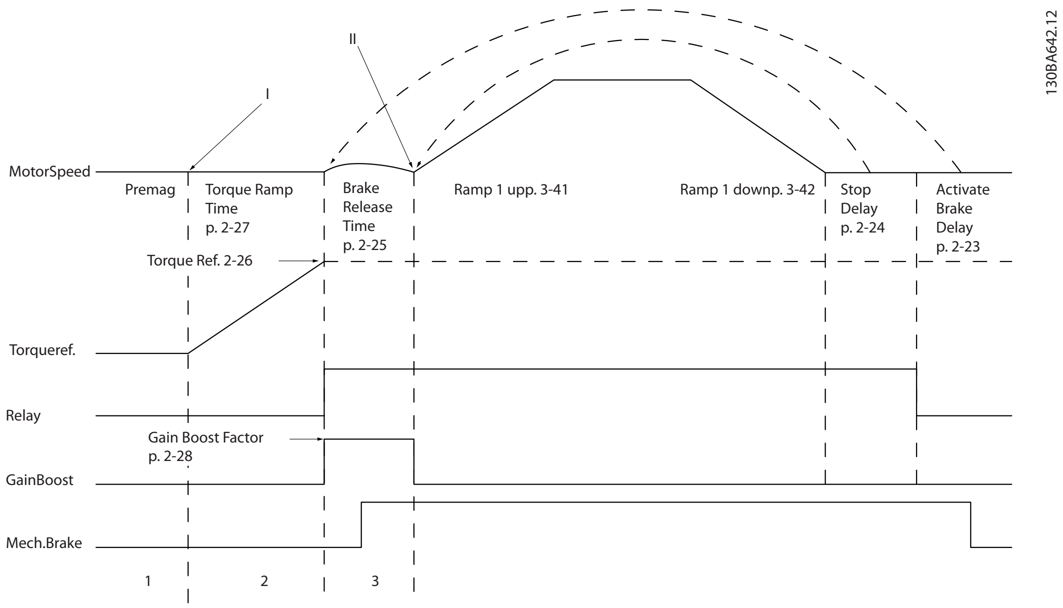


Figure 4.3 Brake release sequence for hoist mechanical brake control. This brake control is available in FLUX with motor feedback only, available for asynchronous and non-salient PM motors.

2-26 Torque Ref to *2-33 Speed PID Start Lowpass Filter Time* are only available for the hoist mechanical brake control (FLUX with motor feedback). *2-30 Position P Start Proportional Gain* to *2-33 Speed PID Start Lowpass Filter Time* can be set up for very smooth transition change from speed control to position control during *2-25 Brake Release Time* - the time when the load is transferred from the mechanical brake to the adjustable frequency drive.
2-30 Position P Start Proportional Gain to *2-33 Speed PID Start Lowpass Filter Time* are activated when *2-28 Gain Boost Factor* is set to 0. See *Figure 4.3* for more information.

NOTICE!

For an example of advanced mechanical brake control for hoisting applications, see *chapter 10 Application Examples*.

4.2.14 Smart Logic Control (SLC)

Smart Logic Control (SLC) is a sequence of user-defined actions (see *13-52 SL Controller Action* [x]) executed by the SLC when the associated user-defined *event* (see *13-51 SL Controller Event* [x]) is evaluated as TRUE by the SLC.
The condition for an event can be a particular status or that the output from a logic rule or a comparator operand becomes TRUE. That leads to an associated Action as shown in *Figure 4.4*.

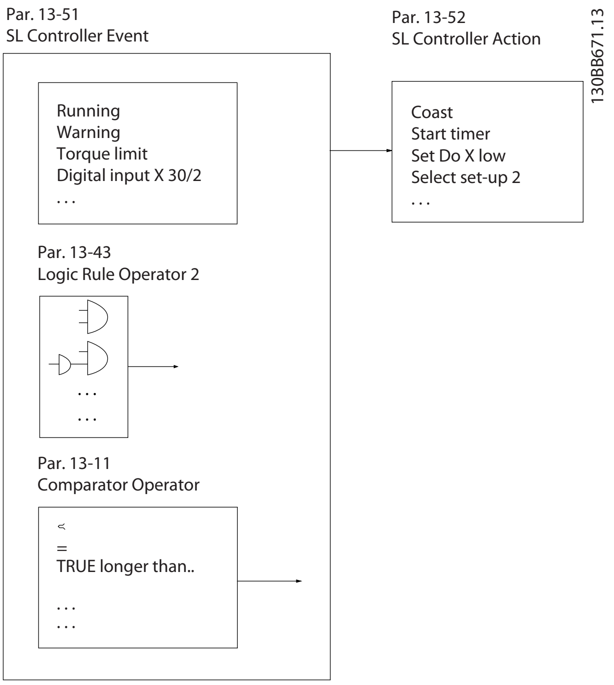


Figure 4.4 SCL Event and Action

Events and actions are each numbered and linked in pairs (states). This means that when *event* [0] is fulfilled (attains the value TRUE), *action* [0] is executed. After this, the conditions of *event* [1] is evaluated and if evaluated TRUE, *action* [1] is executed and so on. Only one *event* is evaluated at any time. If an *event* is evaluated as FALSE, nothing happens (in the SLC) during the current scan interval and no other *events* are evaluated. This means that when the SLC starts, it evaluates *event* [0] (and only *event* [0]) each scan interval. Only when *event* [0] is evaluated TRUE, the SLC executes *action* [0] and starts evaluating *event* [1]. It is possible to program 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]. *Figure 4.5* shows an example with four event/actions:

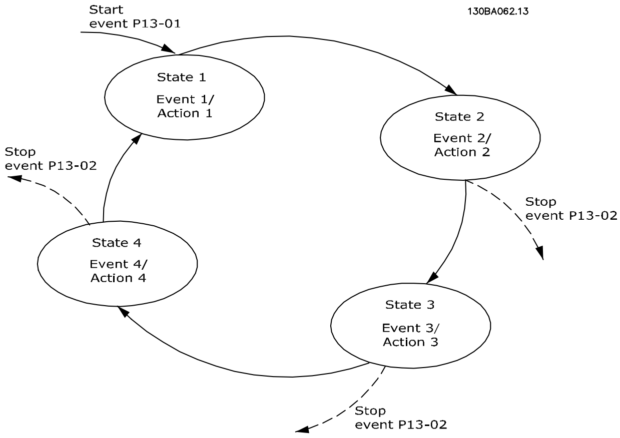


Figure 4.5 Order of Execution when Four Events/Actions are Programmed

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

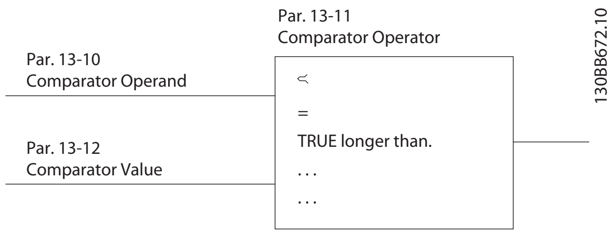


Figure 4.6 Comparators

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.

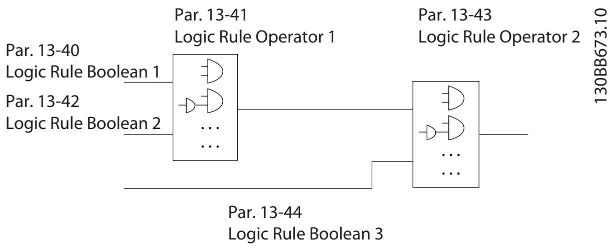


Figure 4.7 Logic Rules

4

4.2.15 Safe Torque Off

For information about Safe Torque Off, refer to the *VLT® FC Series Safe Torque Off Instruction Manual*.

4.3 Danfoss VLT® FlexConcept®

Danfoss VLT® FlexConcept® is an energy efficient, flexible and cost-efficient adjustable frequency drive solution, mainly for conveyors. The concept consists of the VLT® OneGearDrive® driven by the VLT® AutomationDrive FC 302 or VLT® Decentral Drive FCD 302.

OneGearDrive is basically a permanent magnet motor with a bevel gear. The bevel gear can be delivered with different gear ratios.

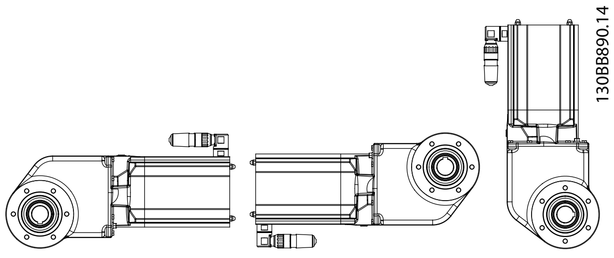


Figure 4.8 OneGearDrive

The OneGearDrive can be driven by VLT® AutomationDrive FC 302 and VLT® Decentral Drive FCD 302 in the following power sizes dependent on demands of the actual application:

- 0.75 kW
- 1.1 kW
- 1.5 kW
- 2.2 kW
- 3.0 kW

When *[1] PM, non-salient SPM* has been selected in in either FC 302 or FCD 302, the OneGearDrive can be selected in *1-11 Motor Model*, and the recommended parameters are set automatically.

For further information, refer to the *VLT® AutomationDrive FC 301/FC 302 Programming Guide*, the *VLT® OneGearDrive Selection Guide*, and *www.danfoss.com/BusinessAreas/Drives-Solutions/VLTFlexConcept/*

5 System Integration

5.1 Ambient Operating Conditions

5.1.1 Humidity

Although the adjustable frequency drive can operate properly at high humidity (up to 95% relative humidity), condensation must always be avoided. There is a specific risk of condensation when the adjustable frequency drive is colder than moist ambient air. Moisture in the air can also condense on the electronic components and cause short circuits. Condensation occurs to units without power. It is advisable to install a cabinet heater when condensation is possible due to ambient conditions. Avoid installation in areas subject to frost.

Alternatively, operating the adjustable frequency drive in stand-by mode (with the unit connected to line power) reduces the risk of condensation. However, ensure the power dissipation is sufficient to keep the adjustable frequency drive circuitry free of moisture.

5.1.2 Temperature

Minimum and maximum ambient temperature limits are specified for all adjustable frequency drives. Avoiding extreme ambient temperatures prolongs the life of the equipment and maximizes overall system reliability. Follow the recommendations listed for maximum performance and equipment longevity.

- Although drives can operate at temperatures down to 14°F [-10°C], proper operation at rated load is only guaranteed at 32°F [0°C] or higher.
- Do not exceed the maximum temperature limit.
- The lifetime of electronic components decreases by 50% for every 17°F [10°C] when operated above its design temperature.
- Even devices with IP54, IP55, or IP66 protection ratings must adhere to the specified ambient temperature ranges.
- Additional air conditioning of the cabinet or installation site may be required.

5.1.3 Temperature and Cooling

The adjustable frequency drives have built-in fans to ensure optimum cooling. The main fan forces the air flow along the cooling fins on the heatsink, ensuring a cooling of the internal air. Some power sizes have a small secondary fan close to the control card, ensuring that the internal air is circulated to avoid hot spots. The main fan is controlled by the internal temperature in the adjustable frequency drive and the speed gradually increases along with temperature, reducing noise and energy consumption when the need is low, and ensuring maximum cooling when the need is there. The fan control can be adapted via *14-52 Fan Control* to accommodate any application, also to protect against negative effects of cooling in very cold climates. In case of overtemperature inside the adjustable frequency drive, it derates the switching frequency and pattern, see *chapter 5.1.4 Manual Derating* for more info.

Minimum and maximum ambient temperature limits are specified for all adjustable frequency drives. Avoiding extreme ambient temperatures prolongs the life of the equipment and maximizes overall system reliability. Follow the recommendations listed for maximum performance and equipment longevity.

- Although adjustable frequency drives can operate at temperatures down to 14°F [-10°C], proper operation at rated load is only guaranteed at 32°F [0°C] or higher.
- Do not exceed the maximum temperature limit.
- Do not exceed the maximum 24-hour average temperature.
  (The 24-hour average temperature is the max. ambient temperature minus 9°F [5°C].
  Example: Max. temperature is 122°F [50°C], maximum 24-hour avg. temperature is 113°F [45°C]).
- Observe the minimum top and bottom clearance requirements (*chapter 8.2.1.1 Clearance*).
- As a rule of thumb, the lifetime of electronic components decreases by 50% for every 17°F [10°C] when operated above its design temperature.

- Even devices with high protection ratings must adhere to the specified ambient temperature ranges.
- Additional air conditioning of the cabinet or installation site may be required.

5.1.4 Manual Derating

Consider derating when any of the following conditions are present.

- Operating above 3,300 ft [1,000 m] (low air pressure)
- Low speed operation
- Long motor cables
- Cables with a large cross-section
- High ambient temperature

For more information, refer to *chapter 6.2.6 Derating for Ambient Temperature*.

5.1.4.1 Derating for Running at Low Speed

When a motor is connected to an adjustable frequency drive, it is necessary to make sure that the cooling of the motor is adequate.
The level of heating depends on the load on the motor as well as the operating speed and time.

Constant torque applications (CT mode)

A problem may occur at low RPM values in constant torque applications. In a constant torque application, a motor may overheat at low speeds due to less cooling air from the motor integral fan.
Therefore, if the motor is to be run continuously at an RPM value lower than half of the rated value, the motor must be supplied with additional air-cooling (or a motor designed for this type of operation may be used).

An alternative is to reduce the load level of the motor by selecting a larger motor. However, the design of the adjustable frequency drive limits the motor size.

Variable (quadratic) torque applications (VT)
In VT applications such as centrifugal pumps and fans, where the torque is proportional to the square of the speed and the power is proportional to the cube of the speed, there is no need for additional cooling or derating of the motor.

5.1.4.2 Derating for Low Air Pressure

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

Below 1,000 m altitude, no derating is necessary but above 1,000 m the ambient temperature (TAMB) or max. output current (Iout) should be derated in accordance with *Figure 5.1*.

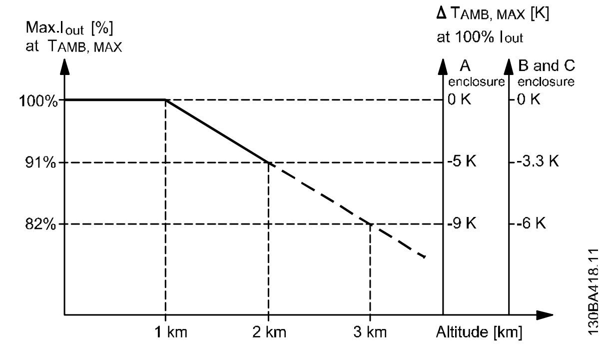


Figure 5.1 Derating of output current versus altitude at $T_{AMB, MAX}$ for frame sizes A, B and C. At altitudes above 6,600 ft [2,000 m], contact Danfoss regarding PELV.

An alternative is to lower the ambient temperature at high altitudes and thereby ensure 100% output current at high altitudes. As an example of how to read the graph, the situation at 6,600 ft [2,000 m] is elaborated for an enclosure type B with $T_{AMB, MAX}$ = 122°F [50°C]. At a temperature of 113°F [45°C] ($T_{AMB, MAX}$ - 3.3 K), 91% of the rated output current is available. At a temperature of 107°F [41.7°C], 100% of the rated output current is available.

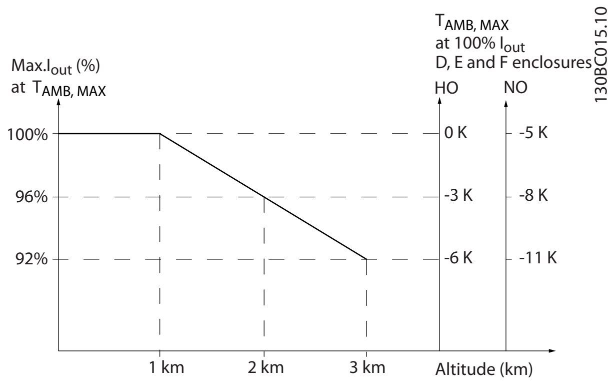


Figure 5.2 Derating of output current versus altitude at $T_{AMB, MAX}$ for enclosure types D3h.

5.1.5 Acoustic Noise

Acoustic noise from the adjustable frequency drive comes from three sources

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

See *chapter 6.2.9 Acoustic Noise* for acoustic noise ratings.

5.1.6 Vibration and Shock

The adjustable frequency drive tested according to a procedure based on the IEC 68-2-6/34/35 and 36. These tests subject the unit to 0.7 g forces, over the range of 18 to 1,000 Hz random, in three directions for two hours. All Danfoss adjustable frequency drives comply with requirements that correspond to these conditions when the unit is wall or floor mounted, as well as when mounted within panels bolted to walls or floors.

5.1.7 Aggressive Atmospheres

5.1.7.1 Gases

Aggressive gases, such as hydrogen sulfide, chlorine, or ammonia can damage adjustable frequency drive electrical and mechanical components. Contamination of the cooling air can also cause the gradual decomposition of PCB tracks and door seals. Aggressive contaminants are often present in sewage treatment plants or swimming pools. A clear sign of an aggressive atmosphere is corroded copper.

In aggressive atmospheres, restricted IP enclosures are recommended along with conformal-coated circuit boards. See *Table 5.1* for conformal-coating values.

NOTICE!

The adjustable frequency drive comes standard with class 3C2 coating. On request, class 3C3 coating is available.

Gas type	Unit	Class				
		3C1	3C2		3C3	
			Average value	Max. value	Average value	Max. value
Sea salt	n/a	None	Salt mist		Salt mist	
Sulfur oxides	mg/m³	0.1	0.3	1.0	5.0	10
Hydrogen sulfide	mg/m³	0.01	0.1	0.5	3.0	10
Chlorine	mg/m³	0.01	0.1	0.03	0.3	1.0
Hydrogen chloride	mg/m³	0.01	0.1	0.5	1.0	5.0
Hydrogen fluoride	mg/m³	0.003	0.01	0.03	0.1	3.0
Ammonia	mg/m³	0.3	1.0	3.0	10	35
Ozone	mg/m³	0.01	0.05	0.1	0.1	0.3
Nitrogen	mg/m³	0.1	0.5	1.0	3.0	9.0

Table 5.1 Conformal-coating Class Ratings

Maximum values are transient peak values not to exceed 30 minutes per day.

5.1.7.2 Dust Exposure

Installation of adjustable frequency drives in environments with high dust exposure is often unavoidable. Dust affects wall or frame mounted units with IP55 or IP66 protection rating, and also cabinet mounted devices with IP21 or IP20 protection rating. Take the three aspects described below into account when adjustable frequency drives are installed in such environments.

Reduced Cooling
Dust forms deposits on the surface of the device and inside on circuit boards and the electronic components. These deposits act as insulation layers and hamper heat transfer to the ambient air, reducing the cooling capacity. The components become warmer. This causes accelerated aging of the electronic components, and the service life of the unit decreases. Dust deposits on the heatsink in the back of the unit also decrease the service life of the unit.

Cooling Fans
The airflow for cooling the unit is produced by cooling fans, usually located on the back of the device. The fan rotors have small bearings into which dust can penetrate and act as an abrasive. This leads to bearing damage and fan failure.

Filters
High-power adjustable frequency drives are equipped with cooling fans that expel hot air from the interior of the device. Above a certain size, these fans are fitted with filter mats. These filters can become quickly clogged when used in very dusty environments. Preventative measures are necessary under these conditions.

Periodic Maintenance

Under the conditions described above, it is advisable to clean the adjustable frequency drive during periodic maintenance. Remove dust off the heatsink and fans and clean the filter mats.

5.1.7.3 Potentially Explosive Atmospheres

Systems operated in potentially explosive atmospheres must fulfill special conditions. EU Directive 94/9/EC describes the operation of electronic devices in potentially explosive atmospheres.

Motors controlled by adjustable frequency drives in potentially explosive atmospheres must be monitored for temperature using a PTC temperature sensor. Motors with ignition protection class d or e are approved for this environment.

- e classification consists of preventing any occurrence of a spark. The FC 302 with firmware version V6.3x or higher is equipped with an "ATEX ETR thermal monitoring" function for operation of specially approved Ex-e motors. When combined with an ATEX approved PTC monitoring device like the PTC Thermistor Card MCB 112 the installation does not need an individual approval from an approbated organization, i.e., no need for matched pairs.
- d classification consists of ensuring that if a spark occurs, it is contained in a protected area. While not requiring approval, special wiring and containment are required.
- d/e combination is the most often used in potentially explosive atmospheres. The motor itself has a e ignition protection class, while the motor cabling and connection environment is in compliance with the e classification. The restriction on the e connection space consists of the maximum voltage allowed in this space. The output voltage of an adjustable frequency drive is usually limited to the AC line voltage. The modulation of the output voltage may generate unallowable high peak voltage for e classification. In practice, using a sine-wave filter at the adjustable frequency drive output has proven to be an effective means to attenuate the high peak voltage.

NOTICE!

Do not install an adjustable frequency drive in a potentially explosive atmosphere. Install the adjustable frequency drive in a cabinet outside of this area. Using a sine-wave filter at the output of the adjustable frequency drive is also recommended to attenuate the dU/dt voltage rise and peak voltage. Keep the motor cables as short as possible.

NOTICE!

VLT® AutomationDrive units with the MCB 112 option have PTB-certified motor thermistor sensor monitoring capability for potentially explosive atmospheres. Shielded motor cables are not necessary when adjustable frequency drives are operated with sine-wave output filters.

5.1.8 Maintenance

Danfoss adjustable frequency drive models up to 90 kW are maintenance free. High power adjustable frequency drives (rated at 110 kW or higher) have built-in filter mats which require periodic cleaning by the operator, depending on the exposure to dust and contaminants. Maintenance intervals for the cooling fans (approximately 3 years) and capacitors (approximately 5 years) are recommended in most environments.

5.1.9 Storage

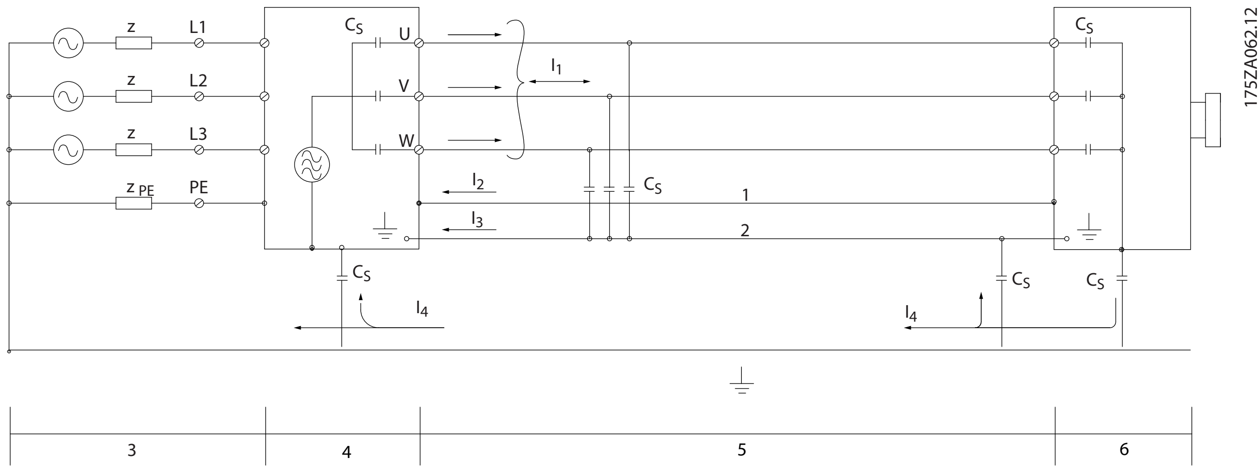
Like all electronic equipment, adjustable frequency drives must be stored in a dry location. Periodic forming (capacitor charging) is not necessary during storage.

It is recommended to keep the equipment sealed in its packaging until installation.

5.2 General Aspects of EMC

Electrical interference is usually conducted at frequencies in the range 150 kHz to 30 MHz. Airborne interference from the adjustable frequency drive system in the range 30 MHz to 1 GHz is generated from the inverter, motor cable, and the motor.
As shown in *Figure 5.3*, capacitance in the motor cable coupled with a high dU/dt from the motor voltage generate leakage currents.
The use of a shielded motor cable increases the leakage current (see *Figure 5.3*) because shielded cables have higher capacitance to ground than non-shielded cables. If the leakage current is not filtered, it causes greater interference on the line power in the radio frequency range below approximately 5 MHz. Since the leakage current (I_1) is carried back to the unit through the shield (I_3), there is in principle only a small electro-magnetic field (I_4) from the shielded motor cable according to *Figure 5.3*.

The shield reduces the radiated interference, but increases the low-frequency interference in the line power supply. Connect the motor cable shield to the adjustable frequency drive enclosure as well as on the motor enclosure. This is best done by using integrated shield clamps so as to avoid twisted shield ends (pigtails) Pigtails increase the shield impedance at higher frequencies, which reduces the shield effect and increases the leakage current (I_4).
If a shielded cable is used for relay, control cable, signal interface and brake, mount the shield on the enclosure at both ends. In some situations, however, it is necessary to break the shield to avoid current loops.



1	Ground wire	4	Adjustable frequency drive
2	Shield	5	Shielded motor cable
3	AC line power supply	6	Motor

Figure 5.3 Situation that Generates Leakage Currents

If the shield is to be placed on a mounting plate for the adjustable frequency drive, the mounting plate must be made of metal, to convey the shield currents back to the unit. Moreover, ensure good electrical contact from the mounting plate through the mounting screws to the adjustable frequency driver chassis.

When non-shielded cables are used, some emission requirements are not complied with, although most immunity requirements are observed.

To reduce the interference level from the entire system (unit+installation), make motor and brake cables as short as possible. Avoid placing cables with a sensitive signal level alongside motor and brake cables. Radio interference higher than 50 MHz (airborne) is especially generated by the control electronics.

5.2.1 EMC Test Results

The following test results have been obtained using a system with an adjustable frequency drive, a shielded control cable, a control box with potentiometer, as well as a single motor and screened motor cable (Ölflex Classic 100 CY) at nominal switching frequency. *Table 5.2* states the maximum motor cable lengths for compliance.

NOTICE!

Conditions may change significantly for other set-ups.

NOTICE!

Consult *Table 9.19* for parallel motor cables.

RFI filter type		Conducted emission			Radiated emission		
		Cable length [m]					
Standards and requirements	EN 55011/CISPR 11	Class B	Class A Group 1	Class A Group 2	Class B	Class A Group 1	Class A Group 2
	EN/IEC 61800-3	Category C1	Category C2	Category C3	Category C1	Category C2	Category C3
H1							
FC 301	0–50 hp [0–37 kW] 200–240 V	10	50	50	No	Yes	Yes
	0–100 hp [0–75 kW] 380–480 V	10	50	50	No	Yes	Yes
FC 302	0–50 hp [0–37 kW] 200–240 V	50	150	150	No	Yes	Yes
	0–100 hp [0–75 kW] 380–480 V	50	150	150	No	Yes	Yes
H2/H5							
FC 301	0–5 hp [0–3.7 kW] 200–240 V	No	No	5	No	No	Yes
FC 302	7.5–50 hp [5.5–37 kW] 200–240 V[2)]	No	No	25	No	No	Yes
	0–10 HP (0–7.5 kW) 380–500 V	No	No	5	No	No	Yes
	15–100 hp [11–75 kW] 380–500 V[2)]	No	No	25	No	No	Yes
	15–30 hp [11–22 kW] 525–690 V[2)]	No	No	25	No	No	Yes
	40–100 hp [30–75 kW] 525–690 V[2)]	No	No	25	No	No	Yes
H3							
FC 301	0–2 hp [0–1.5 kW] 200–240 V	2.5	25	25	No	Yes	Yes
	0–2 hp [0–1.5 kW] 380–480 V	2.5	25	25	No	Yes	Yes
H4							
FC 302	1.5–10 hp [1.1–7.5 kW] 525–690 V	No	100	100	No	Yes	Yes
	15–30 hp [11–22 kW] 525–690 V	No	100	100	No	Yes	Yes
	15–50 hp [11–37 kW] 525–690 V[3]	No	150	150	No	Yes	Yes
	40–100 hp [30–75 kW] 525–690 V	No	150	150	No	Yes	Yes
Hx[1)]							
FC 302	1–100 hp [0.75–75 kW] 525–600 V	No	No	No	No	No	No

Table 5.2 EMC Test Results (Emission) Maximum Motor Cable Length

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

2) T5, 30–60 hp [22–45 kW] and T7, 30–100 hp [22–75 kW] comply with class A group 1 with 25 m motor cable. Some restrictions for the installation apply (contact Danfoss for details).

Hx, H1, H2, H3, H4 or H5 is defined in the type code pos. 16-17 for EMC filters, see Table 7.1.

3) IP20

5.2.2 Emission Requirements

The EMC product standard for adjustable frequency drives defines four categories (C1, C2, C3 and C4) with specified requirements for emission and immunity. *Table 5.3* states the definition of the four categories and the equivalent classification from EN 55011.

Category	Definition	Equivalent emission class in EN 55011
C1	Adjustable frequency drives installed in the first environment (home and office) with a supply voltage less than 1000 V.	Class B
C2	Adjustable frequency drives 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	Adjustable frequency drives installed in the second environment (industrial) with a supply voltage lower than 1000 V.	Class A Group 2
C4	Adjustable frequency drives installed in the second environment with a supply voltage equal to or above 1000 V or rated current equal to or above 400 A or intended for use in complex systems.	No limit line. An EMC plan should be made.

Table 5.3 Correlation between IEC 61800-3 and EN 55011

When the generic (conducted) emission standards are used, the adjustable frequency drives are required to comply with the limits in *Table 5.4*.

Environment	Generic emission standard	Equivalent emission class in EN 55011
First environment (home and office)	EN/IEC 61000-6-3 Emission standard for residential, commercial and light industrial environments.	Class B
Second environment (industrial environment)	EN/IEC 61000-6-4 Emission standard for industrial environments.	Class A Group 1

Table 5.4 Correlation between Generic Emission Standards and EN 55011

5.2.3 Immunity Requirements

The immunity requirements for adjustable frequency drives 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 adjustable frequency drives comply with the requirements for the industrial environment and consequently comply also with the lower requirements for home and office environment with a large safety margin.

To document immunity against electrical interference from electrical phenomena, the following immunity tests have been made in accordance with following basic standards:

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

See *Table 5.5*.

Basic standard	Electrical interference IEC 61000-4-4	Surge IEC 61000-4-5	ESD IEC 61000-4-2	Radiated electromagnetic field IEC 61000-4-3	RF common mode voltage IEC 61000-4-6
Acceptance criterion	B	B	B	A	A
Voltage range: 200–240 V, 380–500 V, 525–600 V, 525–690 V					
Line	4 kV CM	2 kV/2 Ω DM 4 kV/12 Ω CM	—	—	10 V_{RMS}
Motor	4 kV CM	4 kV/2 Ω[1)]	—	—	10 V_{RMS}
Brake	4 kV CM	4 kV/2 Ω[1)]	—	—	10 V_{RMS}
Load sharing	4 kV CM	4 kV/2 Ω[1)]	—	—	10 V_{RMS}
Control wires	2 kV CM	2 kV/2 Ω[1)]	—	—	10 V_{RMS}
Standard bus	2 kV CM	2 kV/2 Ω[1)]	—	—	10 V_{RMS}
Relay wires	2 kV CM	2 kV/2 Ω[1)]	—	—	10 V_{RMS}
Application and Serial Communication options	2 kV CM	2 kV/2 Ω[1)]	—	—	10 V_{RMS}
LCP cable	2 kV CM	2 kV/2 Ω[1)]	—	—	10 V_{RMS}
External 24 V DC	2 V CM	0.5 kV/2 Ω DM 1 kV/12 Ω CM	—	—	10 V_{RMS}
Enclosure	—	—	8 kV AD 6 kV CD	10 V/m	—

Table 5.5 EMC Immunity Form

[1)] *Injection on cable shield*

5.2.4 Motor Insulation

Modern design of motors for use with adjustable frequency drives have a high degree of insulation to account for new generation high-efficiency IGBTs with high dU/dt. For retrofit in old motors, it is necessary to confirm the motor insulation or to mitigate with dU/dt filter or if necessary a sine-wave filter. dU/dt

For motor cable lengths ≤ the maximum cable length listed in *chapter 6.2 General Specifications*, the motor insulation ratings listed in *Table 5.6* are recommended. If a motor has lower insulation rating, it is recommended to use a dU/dt or sine-wave filter.

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

Table 5.6 Motor Insulation

5.2.5 Motor Bearing Currents

To minimize bearing and shaft currents, ground the following to the driven machine:

- adjustable frequency drive
- motor
- driven machine
- motor

Standard Mitigation Strategies

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

5.3 Line Power Supply Interference/ Harmonics

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

Harmonic currents	I_1	I_5	I_7
Hz	50	250	350

Table 5.7 Transformed Non-sinusoidal Current

The harmonics do not affect the power consumption directly, but they do 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 prevent an overload of the transformer and high temperature in the cables.

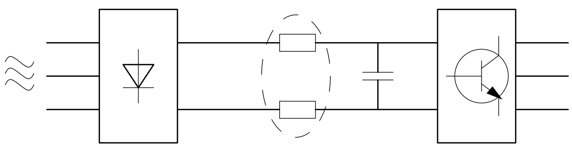


Figure 5.4 Intermediate Circuit Coils

NOTICE!

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

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

Table 5.8 Harmonic Currents Compared to the RMS Input Current

To ensure low harmonic currents, the adjustable frequency drive is equipped with intermediate circuit coils as standard. DC coils reduce the total harmonic distortion (THD) to 40%.

5.3.1 The Effect of Harmonics in a Power Distribution System

In *Figure 5.5*, a transformer is connected on the primary side to a point of common coupling PCC1, on the medium voltage supply. The transformer has an impedance of 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 of Z_1, Z_2, Z_3.

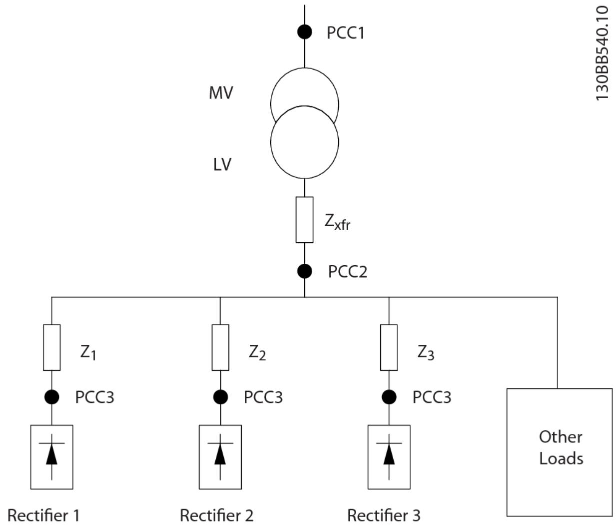


Figure 5.5 Small Distribution System

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

Current distortion relates to apparatus performance, which in turn relates to the individual load. Voltage distortion relates to system performance. It is not possible to determine the voltage distortion in the PCC knowing only the load's harmonic performance. To predict the distortion in the PCC, the configuration of the distribution system and relevant impedances must be known.

5

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

$$Rsce = \frac{Sce}{Sequ}$$

where $Ssc = \frac{U^2}{Zsupply}$ and $Sequ = U \times Iequ$

The negative effect of harmonics is two-fold

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

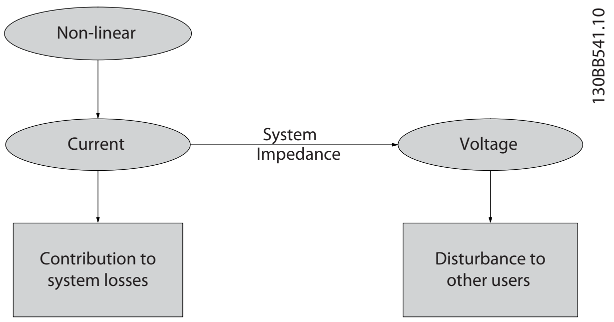


Figure 5.6 Negative Effects of Harmonics

5.3.2 Harmonic Limitation Standards and Requirements

The requirements for harmonic limitation can be

- application specific requirements
- standards that must be observed

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

Example

A 250 kVA transformer with two 110 kW motors connected is sufficient if one of the motors is connected directly online and the other is supplied through an adjustable frequency drive. However, the transformer is undersized if both motors are supplied by an adjustable frequency drive. Using additional means of harmonic reduction within the installation or selecting low harmonic drive variants makes it possible for both motors to run with adjustable frequency drives.

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

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

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

In Europe, the maximum THVD is 8% if the plant is connected via the public grid. If the plant has its own transformer, the limit is 10% THVD. The VLT® AutomationDrive is designed to withstand 10% THVD.

5.3.3 Harmonic Mitigation

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

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

The choice of the right solution depends on several factors:

- The grid (background distortion, line power unbalance, resonance and type of supply (transformer/generator)
- Application (load profile, number of loads and load size)
- Local/national requirements/regulations (IEEE519, IEC, G5/4, etc.)
- Total cost of ownership (initial cost, efficiency, maintenance, etc.)

Always consider harmonic mitigation if the transformer load has a non-linear contribution of 40% or more.

5.3.4 Harmonic Calculation

Danfoss offers tools for calculation of harmonics, see *chapter 9.6.5 PC Software*.

5.4 Galvanic Isolation (PELV)

5.4.1 PELV - Protective Extra Low Voltage

PELV offers protection by way of extra low voltage. Protection against electric shock is ensured when the electrical supply is of the PELV type and the installation is made as described in local/national regulations on PELV supplies.
All control terminals and relay terminals 01-03/04-06 comply with PELV (Protective Extra Low Voltage), with the exception of the 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 *Figure 5.7*):

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

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

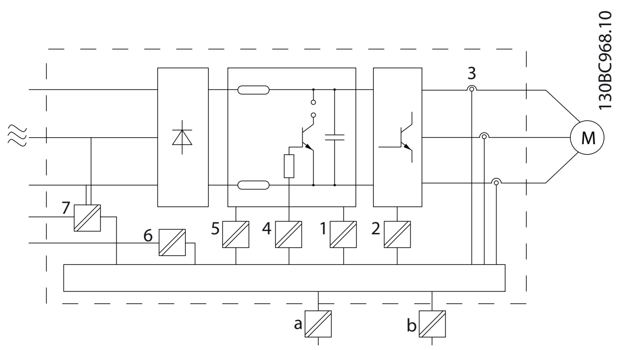


Figure 5.7 Galvanic Isolation

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

⚠WARNING

Installation at high altitude:
At altitudes above 6,600 ft [2,000 m], contact Danfoss regarding PELV.

⚠WARNING

Touching the electrical parts could be fatal - even after the equipment has been disconnected from line power.
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 backup.
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.

5.5 Brake Functions

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

5.5.1 Selection of Brake Resistor

The brake resistor ensures that the energy is absorbed in the brake resistor and not in the adjustable frequency drive. 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. *Figure 5.8* shows a typical braking cycle.

NOTICE!

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

5

5

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)

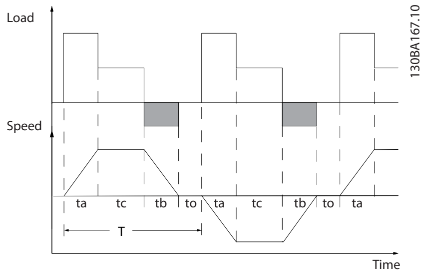


Figure 5.8 Typical Braking Cycle

	Cycle time (s)	Braking duty cycle at 100% torque	Braking duty cycle at over torque (150/160%)
200–240 V			
PK25-P11K	120	Continuous	40%
P15K-P37K	300	10%	10%
380–500 V			
PK37-P75K	120	Continuous	40%
P90K-P160	600	Continuous	10%
P200-P800	600	40%	10%
525–600 V			
PK75-P75K	120	Continuous	40%
525–690 V			
P37K-P400	600	40%	10%
P500-P560	600	40% 1)	10% 2)
P630-P1M0	600	40%	10%

Table 5.9 Braking at High Overload Torque Level

1) 650 hp [500 kW] at 86% braking torque/750 hp [560 kW] at 76% braking torque
2) 650 hp [500 kW] at 130% braking torque/750 hp [560 kW] at 115% braking torque

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

NOTICE!

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

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

$$ED\,(duty\ cycle) = \frac{tb}{T\ cycle}$$

where tb is the braking time in seconds and T cycle is the total cycle time.

The brake resistance is calculated as shown:

$$Rbr\,[\Omega] = \frac{U_{dc}^2}{Ppeak}$$

where

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

The brake resistance depends on the intermediate circuit voltage (U_{dc}).
The FC 301 and FC 302 brake function is settled in four areas of line power.

Size	Brake active	Warning before cut-out	Cut-out (trip)
FC 301/FC 302 200–240 V	390 V	405 V	410 V
FC 301 380–480 V	778 V	810 V	820 V
FC 302 380–500 V	810 V	840 V	850 V
FC 302 525–600 V	943 V	965 V	975 V
FC 302 525–690 V	1084 V	1109 V	1130 V

Table 5.10 Brake Limits [UDC]

NOTICE!

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

Danfoss recommends the brake resistance R_{rec}, i.e., one that guarantees that the adjustable frequency drive is able to brake at the highest braking torque ($M_{br(\%)}$) of 160%. The formula can be written as:

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

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

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

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

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

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

$500V: Rrec = \frac{464923}{Pmotor}$ [Ω]

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

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

1) *For adjustable frequency drives ≤ 10 hp [7.5 kW] shaft output*

2) *For adjustable frequency drives 15–100 hp [11–75 kW] shaft output*

NOTICE!

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

NOTICE!

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

CAUTION

The brake resistor gets hot during and after braking.

- **To avoid personal injury, do not touch the brake resistor.**
- **Place the brake resistor in a secure environment to avoid fire risk.**

CAUTION

Enclosure types D-F adjustable frequency drives contain more than one brake chopper. Consequently, use one brake resistor per brake chopper for those enclosure types.

5.5.2 Brake Resistor Cabling

EMC (twisted cables/shielding)
To meet the specified EMC performance of the adjustable frequency drive, use shielded cables/wires. If non-shielded wires are used, it is recommended to twist the wires to reduce the electrical noise from the wires between the brake resistor and the adjustable frequency drive.

For enhanced EMC performance, use a metal shield.

5.5.3 Control with Brake Function

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

NOTICE!

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

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

NOTICE!

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

6 Product Specifications

6.1 Electrical Data

6.1.1 Line Power Supply 200–240 V

Type Designation	PK25	PK37	PK55	PK75	P1K1	P1K5	P2K2	P3K0	P3K7
Typical Shaft Output [kW]	0.25	0.37	0.55	0.75	1.1	1.5	2.2	3.0	3.7
Enclosure IP20 (FC 301 only)	A1	A1	A1	A1	A1	A1	-	-	-
Enclosure IP20/IP21	A2	A2	A2	A2	A2	A2	A2	A3	A3
Enclosure IP55, IP66	A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A5	A5
Output current									
Continuous (200–240 V) [A]	1.8	2.4	3.5	4.6	6.6	7.5	10.6	12.5	16.7
Intermittent (200–240 V) [A]	2.9	3.8	5.6	7.4	10.6	12.0	17.0	20.0	26.7
Continuous kVA (208 V) [kVA]	0.65	0.86	1.26	1.66	2.38	2.70	3.82	4.50	6.00
Max. input current									
Continuous (200–240 V) [A]	1.6	2.2	3.2	4.1	5.9	6.8	9.5	11.3	15.0
Intermittent (200–240 V) [A]	2.6	3.5	5.1	6.6	9.4	10.9	15.2	18.1	24.0
Additional Specifications									
Max. cable cross-section[4)] for line power, motor, brake and load sharing [mm^2] ([AWG])	4,4,4 (12,12,12) (min. 0.2 (24))								
Max. cable cross-section[4)] for disconnect [mm^2] ([AWG])	6,4,4 (10,12,12)								
Estimated power loss at rated max. load hp [W][3)]	21	29	42	54	63	82	116	155	185
Efficiency[2)]	0.94	0.94	0.95	0.95	0.96	0.96	0.96	0.96	0.96

Table 6.1 Line Power Supply 200–240 V, PK25-P3K7

Type Designation	P5K5		P7K5		P11K	
High/Normal Overload[1]	HO	NO	HO	NO	HO	NO
Typical Shaft Output [kW]	5.5	7.5	7.5	11	11	15
Enclosure IP20	B3		B3		B4	
Enclosure IP21, IP55, IP66	B1		B1		B2	
Output current						
Continuous (200–240 V) [A]	24.2	30.8	30.8	46.2	46.2	59.4
Intermittent (60 s overload) (200–240 V) [A]	38.7	33.9	49.3	50.8	73.9	65.3
Continuous kVA (208 V) [kVA]	8.7	11.1	11.1	16.6	16.6	21.4
Max. input current						
Continuous (200–240 V) [A]	22.0	28.0	28.0	42.0	42.0	54.0
Intermittent (60 s overload) (200–240 V) [A]	35.2	30.8	44.8	46.2	67.2	59.4
Additional Specifications						
IP20 max. cable cross-section[4] for line power, brake, motor and load sharing [mm²] ([AWG])	10,10,- (8,8,-)		10,10,- (8,8,-)		35,-,- (2,-,-)	
IP21 max. cable cross-section[4] for line power, brake and load sharing [mm²] ([AWG])	16,10,16 (6,8,6)		16,10,16 (6,8,6)		35,-,- (2,-,-)	
IP21 max. cable cross-section[4] for motor [mm²] ([AWG])	10,10,- (8,8,-)		10,10,- (8,8,-)		35,25,25 (2,4,4)	
Max. cable cross-section[4] for Disconnect [mm²] ([AWG])	16,10,10 (6,8,8)					
Estimated power loss at rated max. load hp [W][3]	239	310	371	514	463	602
Efficiency[2]	0.96		0.96		0.96	

Table 6.2 Line Power Supply 200–240 V, P5K5-P11K

Type Designation	P15K		P18K		P22K		P30K		P37K	
High/Normal Overload[1]	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft Output [kW]	15	18.5	18.5	22	22	30	30	37	37	45
Enclosure IP20	B4		C3		C3		C4		C4	
Enclosure IP21, IP55, IP66	C1		C1		C1		C2		C2	
Output current										
Continuous (200–240 V) [A]	59.4	74.8	74.8	88.0	88.0	115	115	143	143	170
Intermittent (60 s overload) (200–240 V) [A]	89.1	82.3	112	96.8	132	127	173	157	215	187
Continuous kVA (208 V) [kVA]	21.4	26.9	26.9	31.7	31.7	41.4	41.4	51.5	51.5	61.2
Max. input current										
Continuous (200–240 V) [A]	54.0	68.0	68.0	80.0	80.0	104	104	130	130	154
Intermittent (60 s overload) (200–240 V) [A]	81.0	74.8	102	88.0	120	114	156	143	195	169
Additional Specifications										
IP20 max. cable cross-section for line power, brake, motor and load sharing [mm²] ([AWG])	35 (2)		50 (1)		50 (1)		150 (300MCM)		150 (300MCM)	
IP21, IP55, IP66 max. cable cross-section for line power and motor [mm²] ([AWG])	50 (1)		50 (1)		50 (1)		150 (300MCM)		150 (300MCM)	
IP21, IP55, IP66 max. cable cross-section for brake and load sharing [mm²] ([AWG])	50 (1)		50 (1)		50 (1)		95 (3/0)		95 (3/0)	
Max. cable cross-section[4] for Disconnect [mm²] ([AWG])	50, 35, 35 (1, 2, 2)						95, 70, 70 (3/0, 2/0, 2/0)		185, 150, 120 (350MCM, 300MCM, 4/0)	
Estimated power loss at rated max. load hp [W][3]	624	737	740	845	874	1140	1143	1353	1400	1636
Efficiency[2]	0.96		0.97		0.97		0.97		0.97	

Table 6.3 Line Power Supply 200–240 V, P15K-P37K

6.1.2 Line Power Supply 380–500 V

Type Designation	PK37	PK55	PK75	P1K1	P1K5	P2K2	P3K0	P4K0	P5K5	P7K5
Typical Shaft Output [kW]	0.37	0.55	0.75	1.1	1.5	2.2	3.0	4.0	5.5	7.5
Enclosure IP20 (FC 301 only)	A1	A1	A1	A1	A1	-	-	-	-	-
Enclosure IP20/IP21	A2	A2	A2	A2	A2	A2	A2	A2	A3	A3
Enclosure IP55, IP66	A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A5	A5
Output Current High Overload 160% for 1 min										
Shaft output [kW]	0.37	0.55	0.75	1.1	1.5	2.2	3	4	5.5	7.5
Continuous (380–440 V) [A]	1.3	1.8	2.4	3.0	4.1	5.6	7.2	10	13	16
Intermittent (380–440 V) [A]	2.1	2.9	3.8	4.8	6.6	9.0	11.5	16	20.8	25.6
Continuous (441–500 V) [A]	1.2	1.6	2.1	2.7	3.4	4.8	6.3	8.2	11	14.5
Intermittent (441–500 V) [A]	1.9	2.6	3.4	4.3	5.4	7.7	10.1	13.1	17.6	23.2
Continuous kVA (400 V) [kVA]	0.9	1.3	1.7	2.1	2.8	3.9	5.0	6.9	9.0	11
Continuous kVA (460 V) [kVA]	0.9	1.3	1.7	2.4	2.7	3.8	5.0	6.5	8.8	11.6
Max. input current										
Continuous (380–440 V) [A]	1.2	1.6	2.2	2.7	3.7	5.0	6.5	9.0	11.7	14.4
Intermittent (380–440 V) [A]	1.9	2.6	3.5	4.3	5.9	8.0	10.4	14.4	18.7	23
Continuous (441–500 V) [A]	1.0	1.4	1.9	2.7	3.1	4.3	5.7	7.4	9.9	13
Intermittent (441–500 V) [A]	1.6	2.2	3.0	4.3	5.0	6.9	9.1	11.8	15.8	20.8
Additional Specifications										
IP20, IP21 max. cable cross-section[4)] for line power, motor, brake and load sharing [mm^2] ([AWG])	4,4,4 (12,12,12) (min. 0.2(24))									
IP55, IP66 max. cable cross-section[4)] for line power, motor, brake and load sharing [mm^2] ([AWG])	4,4,4 (12,12,12)									
Max. cable cross-section[4)] for disconnect [mm^2] ([AWG])	6,4,4 (10,12,12)									
Estimated power loss at rated max. load hp [W][3)]	35	42	46	58	62	88	116	124	187	255
Efficiency[2)]	0.93	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.97

Table 6.4 Line Power Supply 380–500 V (FC 302), 380–480 V (FC 301), PK37-P7K5

Type Designation	P11K		P15K		P18K		P22K	
High/Normal Overload[1)]	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft output [kW]	11	15	15	18.5	18.5	22.0	22.0	30.0
Enclosure IP20	B3		B3		B4		B4	
Enclosure IP21	B1		B1		B2		B2	
Enclosure IP55, IP66	B1		B1		B2		B2	
Output current								
Continuous (380–440 V) [A]	24	32	32	37.5	37.5	44	44	61
Intermittent (60 s overload) (380–440 V) [A]	38.4	35.2	51.2	41.3	60	48.4	70.4	67.1
Continuous (441–500 V) [A]	21	27	27	34	34	40	40	52
Intermittent (60 s overload) (441–500 V) [A]	33.6	29.7	43.2	37.4	54.4	44	64	57.2
Continuous kVA (400 V) [kVA]	16.6	22.2	22.2	26	26	30.5	30.5	42.3
Continuous kVA (460 V) [kVA]		21.5		27.1		31.9		41.4
Max. input current								
Continuous (380–440 V) [A]	22	29	29	34	34	40	40	55
Intermittent (60 s overload) (380–440 V) [A]	35.2	31.9	46.4	37.4	54.4	44	64	60.5
Continuous (441–500 V) [A]	19	25	25	31	31	36	36	47
Intermittent (60 s overload) (441–500 V) [A]	30.4	27.5	40	34.1	49.6	39.6	57.6	51.7
Additional specifications								
IP21, IP55, IP66 max. cable cross-section[4)] for line power, brake and load sharing [mm^2] ([AWG])	16, 10, 16 (6, 8, 6)		16, 10, 16 (6, 8, 6)		35,-,-(2,-,-)		35,-,-(2,-,-)	
IP21, IP55, IP66 max. cable cross-section[4)] for motor [mm^2] ([AWG])	10, 10,- (8, 8,-)		10, 10,- (8, 8,-)		35, 25, 25 (2, 4, 4)		35, 25, 25 (2, 4, 4)	
IP20 max. cable cross-section[4)] for line power, brake, motor and load sharing [mm^2] ([AWG])	10, 10,- (8, 8,-)		10, 10,- (8, 8,-)		35,-,-(2,-,-)		35,-,-(2,-,-)	
Max. cable cross-section[4)] for Disconnect [mm^2] ([AWG])	16, 10, 10 (6, 8, 8)							
Estimated power loss at rated max. load hp [W][3)]	291	392	379	465	444	525	547	739
Efficiency[2)]	0.98		0.98		0.98		0.98	

Table 6.5 Line Power Supply 380–500 V (FC 302), 380–480 V (FC 301), P11K-P22K

Type Designation	P30K		P37K		P45K		P55K		P75K	
High/Normal Overload[1)]	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft output [kW]	30	37	37	45	45	55	55	75	75	90
Enclosure IP21	C1		C1		C1		C2		C2	
Enclosure IP20	B4		C3		C3		C4		C4	
Enclosure IP55, IP66	C1		C1		C1		C2		C2	
Output current										
Continuous (380–440 V) [A]	61	73	73	90	90	106	106	147	147	177
Intermittent (60 s overload) (380–440 V) [A]	91.5	80.3	110	99	135	117	159	162	221	195
Continuous (441–500 V) [A]	52	65	65	80	80	105	105	130	130	160
Intermittent (60 s overload) (441–500 V) [A]	78	71.5	97.5	88	120	116	158	143	195	176
Continuous kVA (400 V) [kVA]	42.3	50.6	50.6	62.4	62.4	73.4	73.4	102	102	123
Continuous kVA (460 V) [kVA]		51.8		63.7		83.7		104		128
Max. input current										
Continuous (380–440 V) [A]	55	66	66	82	82	96	96	133	133	161
Intermittent (60 s overload) (380–440 V) [A]	82.5	72.6	99	90.2	123	106	144	146	200	177
Continuous (441–500 V) [A]	47	59	59	73	73	95	95	118	118	145
Intermittent (60 s overload) (441–500 V) [A]	70.5	64.9	88.5	80.3	110	105	143	130	177	160
Additional specifications										
IP20 max. cable cross-section for line power and motor [mm^2] ([AWG])	35 (2)		50 (1)		50 (1)		150 (300 MCM)		150 (300 MCM)	
IP20 max. cable cross-section for brake and load sharing [mm^2] ([AWG])	35 (2)		50 (1)		50 (1)		95 (4/0)		95 (4/0)	
IP21, IP55, IP66 max. cable cross-section for line power and motor [mm^2] ([AWG])	50 (1)		50 (1)		50 (1)		150 (300 MCM)		150 (300MCM)	
IP21, IP55, IP66 max. cable cross-section for brake and load sharing [mm^2] ([AWG])	50 (1)		50 (1)		50 (1)		95 (3/0)		95 (3/0)	
Max cable cross-section[4)] for line power disconnect [mm^2] ([AWG])	50, 35, 35 (1, 2, 2)						95, 70, 70 (3/0, 2/0, 2/0)		185, 150, 120 (350 MCM, 300 MCM, 4/0)	
Estimated power loss at rated max. load hp [W][3)]	570	698	697	843	891	1083	1022	1384	1232	1474
Efficiency[2)]	0.98		0.98		0.98		0.98		0.99	

Table 6.6 Line Power Supply 380–500 V (FC 302), 380–480 V (FC 301), P30K-P75K

6.1.3 Line Power Supply 525–600 V (FC 302 only)

Type Designation	PK75	P1K1	P1K5	P2K2	P3K0	P4K0	P5K5	P7K5
Typical Shaft Output [kW]	0.75	1.1	1.5	2.2	3	4	5.5	7.5
Enclosure IP20, IP21	A3	A3	A3	A3	A3	A3	A3	A3
Enclosure IP55	A5	A5	A5	A5	A5	A5	A5	A5
Output current								
Continuous (525–550 V) [A]	1.8	2.6	2.9	4.1	5.2	6.4	9.5	11.5
Intermittent (525–550 V) [A]	2.9	4.2	4.6	6.6	8.3	10.2	15.2	18.4
Continuous (551–600 V) [A]	1.7	2.4	2.7	3.9	4.9	6.1	9.0	11.0
Intermittent (551–600 V) [A]	2.7	3.8	4.3	6.2	7.8	9.8	14.4	17.6
Continuous kVA (525 V) [kVA]	1.7	2.5	2.8	3.9	5.0	6.1	9.0	11.0
Continuous kVA (575 V) [kVA]	1.7	2.4	2.7	3.9	4.9	6.1	9.0	11.0
Max. input current								
Continuous (525–600 V) [A]	1.7	2.4	2.7	4.1	5.2	5.8	8.6	10.4
Intermittent (525–600 V) [A]	2.7	3.8	4.3	6.6	8.3	9.3	13.8	16.6
Additional specifications								
Max. cable cross-section4) for line power, motor, brake and load sharing [mm^2] ([AWG])	4,4,4 (12,12,12) (min. 0.2 (24))							
Max. cable cross-section4) for disconnect [mm^2] ([AWG])	6,4,4 (10,12,12)							
Estimated power loss at rated max. load hp [W]3)	35	50	65	92	122	145	195	261
Efficiency2)	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97

Table 6.7 Line Power Supply 525–600 V (FC 302 only), PK75-P7K5

Type Designation	P11K		P15K		P18K		P22K		P30K	
High/Normal Overload[1)]	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft Output [kW]	11	15	15	18.5	18.5	22	22	30	30	37
Enclosure IP20	B3		B3		B4		B4		B4	
Enclosure IP21, IP55, IP66	B1		B1		B2		B2		C1	
Output current										
Continuous (525–550 V) [A]	19	23	23	28	28	36	36	43	43	54
Intermittent (525–550 V) [A]	30	25	37	31	45	40	58	47	65	59
Continuous (551–600 V) [A]	18	22	22	27	27	34	34	41	41	52
Intermittent (551–600 V) [A]	29	24	35	30	43	37	54	45	62	57
Continuous kVA (550 V) [kVA]	18.1	21.9	21.9	26.7	26.7	34.3	34.3	41.0	41.0	51.4
Continuous kVA (575 V) [kVA]	17.9	21.9	21.9	26.9	26.9	33.9	33.9	40.8	40.8	51.8
Max. input current										
Continuous at 550 V [A]	17.2	20.9	20.9	25.4	25.4	32.7	32.7	39	39	49
Intermittent at 550 V [A]	28	23	33	28	41	36	52	43	59	54
Continuous at 575 V [A]	16	20	20	24	24	31	31	37	37	47
Intermittent at 575 V [A]	26	22	32	27	39	34	50	41	56	52
Additional specifications										
IP20 max. cable cross-section[4)] for line power, brake, motor and load sharing [mm^2] ([AWG])	10, 10,- (8, 8,-)		10, 10,- (8, 8,-)		35,-,-(2,-,-)		35,-,-(2,-,-)		35,-,-(2,-,-)	
IP21, IP55, IP66 max. cable cross-section[4)] for line power, brake and load sharing [mm^2] ([AWG])	16, 10, 10 (6, 8, 8)		16, 10, 10 (6, 8, 8)		35,-,-(2,-,-)		35,-,-(2,-,-)		50,-,- (1,-,-)	
IP21, IP55, IP66 max. cable cross-section[4)] for motor [mm^2] ([AWG])	10, 10,- (8, 8,-)		10, 10,- (8, 8,-)		35, 25, 25 (2, 4, 4)		35, 25, 25 (2, 4, 4)		50,-,- (1,-,-)	
Max. cable cross-section[4)] for Disconnect [mm^2] ([AWG])	16, 10, 10 (6, 8, 8)								50, 35, 35 (1, 2, 2)	
Estimated power loss at rated max. load hp [W][3)]	220	300	300	370	370	440	440	600	600	740
Efficiency[2)]	0.98		0.98		0.98		0.98		0.98	

Table 6.8 Line Power Supply 525–600 V (FC 302 only), P11K-P30K

Type Designation	P37K		P45K		P55K		P75K	
High/Normal Overload[1]	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft Output [kW]	37	45	45	55	55	75	75	90
Enclosure IP20	C3	C3	C3		C4		C4	
Enclosure IP21, IP55, IP66	C1	C1	C1		C2		C2	
Output current								
Continuous (525–550 V) [A]	54	65	65	87	87	105	105	137
Intermittent (525–550 V) [A]	81	72	98	96	131	116	158	151
Continuous (551–600 V) [A]	52	62	62	83	83	100	100	131
Intermittent (551–600 V) [A]	78	68	93	91	125	110	150	144
Continuous kVA (550 V) [kVA]	51.4	61.9	61.9	82.9	82.9	100.0	100.0	130.5
Continuous kVA (575 V) [kVA]	51.8	61.7	61.7	82.7	82.7	99.6	99.6	130.5
Max. input current								
Continuous at 550 V [A]	49	59	59	78.9	78.9	95.3	95.3	124.3
Intermittent at 550 V [A]	74	65	89	87	118	105	143	137
Continuous at 575 V [A]	47	56	56	75	75	91	91	119
Intermittent at 575 V [A]	70	62	85	83	113	100	137	131
Additional specifications								
IP20 max. cable cross-section for line power and motor [mm^2] ([AWG])	50 (1)				150 (300 MCM)			
IP20 max. cable cross-section for brake and load sharing [mm^2] ([AWG])	50 (1)				95 (4/0)			
IP21, IP55, IP66 max. cable cross-section for line power and motor [mm^2] ([AWG])	50 (1)				150 (300 MCM)			
IP21, IP55, IP66 max. cable cross-section for brake and load sharing [mm^2] ([AWG])	50 (1)				95 (4/0)			
Max cable cross-section[4] for line power disconnect [mm^2] ([AWG])	50, 35, 35 (1, 2, 2)				95, 70, 70 (3/0, 2/0, 2/0)		185, 150, 120 (350MCM, 300MCM, 4/0)	
Estimated power loss at rated max. load hp [W][3]	740	900	900	1100	1100	1500	1500	1800
Efficiency[2]	0.98		0.98		0.98		0.98	

Table 6.9 Line Power Supply 525–600 V (FC 302 only), P37K-P75K

6

6.1.4 Line Power Supply 525–690 V (FC 302 only)

Type Designation	P1K1	P1K5	P2K2	P3K0	P4K0	P5K5	P7K5
High/Normal Overload[1]	HO/NO	HO/NO	HO/NO	HO/NO	HO/NO	HO/NO	HO/NO
Typical Shaft output (kW)	1.1	1.5	2.2	3.0	4.0	5.5	7.5
Enclosure IP20	A3	A3	A3	A3	A3	A3	A3
Output current							
Continuous (525–550 V) [A]	2.1	2.7	3.9	4.9	6.1	9.0	11.0
Intermittent (525–550 V) [A]	3.4	4.3	6.2	7.8	9.8	14.4	17.6
Continuous (551–690 V) [A]	1.6	2.2	3.2	4.5	5.5	7.5	10.0
Intermittent (551–690 V) [A]	2.6	3.5	5.1	7.2	8.8	12.0	16.0
Continuous KVA 525 V	1.9	2.5	3.5	4.5	5.5	8.2	10.0
Continuous KVA 690 V	1.9	2.6	3.8	5.4	6.6	9.0	12.0
Max. input current							
Continuous (525–550 V) [A]	1.9	2.4	3.5	4.4	5.5	8.1	9.9
Intermittent (525–550 V) [A]	3.0	3.9	5.6	7.0	8.8	12.9	15.8
Continuous (551–690 V) [A]	1.4	2.0	2.9	4.0	4.9	6.7	9.0
Intermittent (551–690 V) [A]	2.3	3.2	4.6	6.5	7.9	10.8	14.4
Additional specifications							
Max. cable cross-section[4] for line power, motor, brake and load sharing [mm^2] ([AWG])	4, 4, 4 (12, 12, 12) (min. 0.2 (24)						
Max. Cable cross-section[4] for disconnect [mm^2] ([AWG])	6, 4, 4 (10, 12, 12)						
Estimated power loss at rated max. load hp (W)[3]	44	60	88	120	160	220	300
Efficiency[2]	0.96	0.96	0.96	0.96	0.96	0.96	0.96

Table 6.10 A3 Enclosure, Line Power Supply 525–690 V IP20/Protected Chassis, P1K1-P7K5

Type Designation	P11K		P15K		P18K		P22K	
High/Normal Overload[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 690 V [kW]	11	15	15	18.5	18.5	22	22	30
Enclosure IP20	B4		B4		B4		B4	
Enclosure IP21, IP55	B2		B2		B2		B2	
Output current								
Continuous (525–550 V) [A]	14.0	19.0	19.0	23.0	23.0	28.0	28.0	36.0
Intermittent (60 s overload) (525–550 V) [A]	22.4	20.9	30.4	25.3	36.8	30.8	44.8	39.6
Continuous (551–690 V) [A]	13.0	18.0	18.0	22.0	22.0	27.0	27.0	34.0
Intermittent (60 s overload) (551-690V) [A]	20.8	19.8	28.8	24.2	35.2	29.7	43.2	37.4
continuous KVA (at 550 V) [KVA]	13.3	18.1	18.1	21.9	21.9	26.7	26.7	34.3
continuous KVA (at 690 V) [KVA]	15.5	21.5	21.5	26.3	26.3	32.3	32.3	40.6
Max. input current								
Continuous (at 550 V) (A)	15.0	19.5	19.5	24.0	24.0	29.0	29.0	36.0
Intermittent (60 s overload) (at 550 V) (A)	23.2	21.5	31.2	26.4	38.4	31.9	46.4	39.6
Continuous (at 690 V) (A)	14.5	19.5	19.5	24.0	24.0	29.0	29.0	36.0
Intermittent (60 s overload) (at 690 V) (A)	23.2	21.5	31.2	26.4	38.4	31.9	46.4	39.6
Additional specifications								
Max. cable cross-section[4)] for line power/motor, load share and brake [mm^2] ([AWG])	35, 25, 25 (2, 4, 4)							
Max cable cross-section[4)] for line power disconnect [mm^2] ([AWG])	16,10,10 (6, 8, 8)							
Estimated power loss at rated max. load hp (W)[3)]	150	220	220	300	300	370	370	440
Efficiency[2)]	0.98		0.98		0.98		0.98	

Table 6.11 B2/B4 Enclosure, Line Power Supply 525–690 V IP20/IP21/IP55 - Chassis/NEMA 1/NEMA 12 (FC 302 only), P11K-P22K

6

Type Designation	P30K		P37K		P45K		P55K		P75K	
High/Normal Overload[1]	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft output at 550 V hp [kW]	22	30	30	37	37	45	45	55	50	75
Typical Shaft output at 690 V [kW]	30	37	37	45	45	55	55	75	75	90
Enclosure IP20	B4		C3		C3		D3h		D3h	
Enclosure IP21, IP55	C2		C2		C2		C2		C2	
Output current										
Continuous (525–550 V) [A]	36.0	43.0	43.0	54.0	54.0	65.0	65.0	87.0	87.0	105
Intermittent (60 s overload) (525–550 V) [A]	54.0	47.3	64.5	59.4	81.0	71.5	97.5	95.7	130.5	115.5
Continuous (551–690 V) [A]	34.0	41.0	41.0	52.0	52.0	62.0	62.0	83.0	83.0	100
Intermittent (60 s overload) (551-690V) [A]	51.0	45.1	61.5	57.2	78.0	68.2	93.0	91.3	124.5	110
continuous KVA (at 550 V) [KVA]	34.3	41.0	41.0	51.4	51.4	61.9	61.9	82.9	82.9	100
continuous KVA (at 690 V) [KVA]	40.6	49.0	49.0	62.1	62.1	74.1	74.1	99.2	99.2	119.5
Max. input current										
Continuous (at 550 V) [A]	36.0	49.0	49.0	59.0	59.0	71.0	71.0	87.0	87.0	99.0
Intermittent (60 s overload) (at 550 V) [A]	54.0	53.9	72.0	64.9	87.0	78.1	105.0	95.7	129	108.9
Continuous (at 690 V) [A]	36.0	48.0	48.0	58.0	58.0	70.0	70.0	86.0	-	-
Intermittent (60 s overload) (at 690 V) [A]	54.0	52.8	72.0	63.8	87.0	77.0	105	94.6	-	-
Additional specifications										
Max. cable - cross-section for line power and motor [mm^2] ([AWG])	150 (300 MCM)									
Max. cable - cross-section for load share and brake [mm^2] ([AWG])	95 (3/0)									
Max cable cross-section[4] for line power disconnect [mm^2] ([AWG])	95, 70, 70 (3/0, 2/0, 2/0)						185, 150, 120 (350 MCM, 300 MCM, 4/0)		-	
Estimated power loss at rated max. load hp [W][3]	600	740	740	900	900	1100	1100	1500	1500	1800
Efficiency[2]	0.98		0.98		0.98		0.98		0.98	

Table 6.12 B4, C2, C3 Enclosure, Line Power Supply 525–690 V IP20/IP21/IP55 - Chassis/NEMA1/NEMA 12 (FC 302 only), P30K-P75K

For fuse ratings, see chapter 9.3.1 Fuses and Circuit Breakers.

1) High overload=150% or 160% torque during 60 s. Normal overload=110% torque during 60 s.

2) Measured using 16.5 ft. [5 m] shielded motor cables at rated load and rated frequency.

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

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

6.2 General Specifications

6.2.1 Line Power Supply

Line power supply	
Supply Terminals (6-pulse)	L1, L2, L3
Supply voltage	200–240 V ±10%
Supply voltage	FC 301: 380–480 V/FC 302: 380–500 V ±10%
Supply voltage	FC 302: 525–600 V ±10%
Supply voltage	FC 302: 525–690 V ±10%

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

Supply frequency	50/60 Hz ±5%
Max. temporary imbalance between line 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) ≤ 10 hp [7.5 kW]	maximum 2 times/min.
Switching on input supply L1, L2, L3 (power-ups) 11–75 kW	maximum 1 time/min.
Switching on input supply L1, L2, L3 (power-ups) ≥ 90 kW	Maximum 1 time/2 min.
Environment according to EN60664-1	Overvoltage category III/pollution degree 2

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

6.2.2 Motor Output and Motor Data

Motor output (U, V, W)	
Output voltage	0–100% of supply voltage
Output frequency	0–590 Hz[3)]
Output frequency in flux mode	0–300 Hz
Switching on output	Unlimited
Ramp times	0.01–3600 s

Torque characteristics	
Starting torque (constant torque)	maximum 160% for 60 s[1)] once in 10 min.
Starting/overload torque (variable torque)	maximum 110% up to 0.5 s[1)] once in 10 min.
Torque rise time in FLUX (for 5 kHz fsw)	1 ms
Torque rise time in VVC^{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.
[3)] Special customer versions with output frequency 0–1000 Hz are available.

6.2.3 Ambient Conditions

Environment	
Enclosure	IP20/Chassis, IP21/Type 1, IP55/ Type 12, IP66/ Type 4X
Vibration test	1.0 g
Max. THVD	10%
Max. relative humidity	5%–93% (IEC 721-3-3; Class 3K3 (non-condensing) during operation
Aggressive environment (IEC 60068-2-43) H_2S test	class Kd
Ambient temperature	Max. 122°F [50°C] (24-hour average maximum 113°F [45°C])
Minimum ambient temperature during full-scale operation	32°F [0°C]
Minimum ambient temperature at reduced performance	14°F [10°C]
Temperature during storage/transport	-13–+149/158°F [-25–+65/70 °C]
Maximum altitude above sea level without derating	3,300 ft [1,000 m]
EMC standards, Emission	EN 61800-3, EN 55011[1)]
EMC standards, Immunity	EN61800-3, EN 61000-6-1/2

[1)] *See chapter 5.2.1 EMC Test Results*

6.2.4 Cable Specifications

Cable lengths and cross-sections for control cables[1)]	
Max. motor cable length, shielded	500 ft [150 m]
Max. motor cable length, non-shielded	1,000 ft [300 m]
Maximum cross-section to control terminals, flexible/rigid wire without cable end sleeves	1.5 mm^2/16 AWG
Maximum cross-section to control terminals, flexible wire with cable end sleeves	1 mm^2/18 AWG
Maximum cross-section to control terminals, flexible wire with cable end sleeves with collar	0.5 mm^2/20 AWG
Minimum cross-section to control terminals	0.25 mm^2/24 AWG

[1)] *For power cables, see electrical tables in chapter 6.1 Electrical Data.*

6.2.5 Control Input/Output and Control Data

6.2.5.1 Digital Inputs

Digital inputs	
Programmable digital inputs	FC 301: 4 (5)[1]/FC 302: 4 (6)[1]
Terminal number	18, 19, 27[1], 29[1], 32, 33
Logic	PNP or NPN
Voltage level	0–24 V DC
Voltage level, logic'0' PNP	< 5 V DC
Voltage level, logic'1' PNP	> 10 V DC
Voltage level, logic '0' NPN[2]	> 19 V DC
Voltage level, logic '1' NPN[2]	< 14 V DC
Maximum voltage on input	28 V DC
Pulse frequency ranges	0–110 kHz
(Duty cycle) Min. pulse width	4.5 ms
Input resistance, R_i	Approx. 4 kΩ

Safe stop Terminal 37[3, 4] (Terminal 37 is fixed PNP logic)	
Voltage level	0–24 V DC
Voltage level, logic'0' PNP	<4 V DC
Voltage level, logic'1' PNP	>20 V DC
Maximum voltage on input	28 V DC
Typical input current at 24 V	50 mA rms
Typical input current at 20 V	60 mA rms
Input capacitance	400 nF

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

1) Terminals 27 and 29 can also be programmed as output.

2) Except safe stop input Terminal 37.

3) See VLT® Adjustable Frequency Drives - Safe Torque Off Instruction Manual 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.

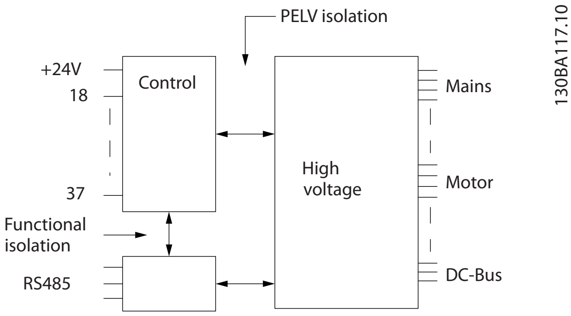


Figure 6.1 PELV Isolation

Pulse/encoder inputs	
Programmable pulse/encoder inputs	2/1
Terminal number pulse/encoder	29[1)], 33[2)] / 32[3)], 33[3)]
Max. frequency at terminal 29, 32, 33	110 kHz (push-pull driven)
Max. frequency at terminal 29, 32, 33	5 kHz (open collector)
Min. frequency at terminal 29, 32, 33	4 Hz
Voltage level	see section on Digital input
Maximum voltage on input	28 V DC
Input resistance, R_i	approx. 4 kΩ
Pulse input accuracy (0.1–1 kHz)	Max. error: 0.1% of full scale
Encoder input accuracy (1–11 kHz)	Max. error: 0.05% of full scale

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

[1)] FC 302 only

[2)] Pulse inputs are 29 and 33

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

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 ground. Use only an isolated laptop as PC connection to the USB connector on the adjustable frequency drive.

Relay outputs

Programmable relay outputs	FC 301 all kW: 1/FC 302 all kW: 2
Relay 01 Terminal number	1-3 (break), 1-2 (make)
Max. terminal load (AC-1)[1] on 1-3 (NC), 1-2 (NO) (Resistive load)	240 V AC, 2 A
Max. terminal load (AC-15)[1] (Inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Max. terminal load (DC-1)[1] on 1-2 (NO), 1-3 (NC) (Resistive load)	60 V DC, 1 A
Max. terminal load (DC-13)[1] (Inductive load)	24 V DC, 0.1 A
Relay 02 (FC 302 only) Terminal number	4-6 (break), 4-5 (make)
Max. terminal load (AC-1)[1] on 4-5 (NO) (Resistive load)[2][3] Overvoltage cat. II	400 V AC, 2 A
Max. terminal load (AC-15)[1] on 4-5 (NO) (Inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Max. terminal load (DC-1)[1] on 4-5 (NO) (Resistive load)	80 V DC, 2 A
Max. terminal load (DC-13)[1] on 4-5 (NO) (Inductive load)	24 V DC, 0.1 A
Max. terminal load (AC-1)[1] on 4-6 (NC) (Resistive load)	240 V AC, 2 A
Max. terminal load (AC-15)[1] on 4-6 (NC) (Inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Max. terminal load (DC-1)[1] on 4-6 (NC) (Resistive load)	50 V DC, 2 A
Max. terminal load (DC-13)[1] on 4-6 (NC) (Inductive load)	24 V DC, 0.1 A
Min. terminal load on 1-3 (NC), 1-2 (NO), 4-6 (NC), 4-5 (NO)	24 V DC 10 mA, 24 V AC 20 mA
Environment according to EN 60664-1	Overvoltage category III/pollution degree 2

[1] IEC 60947 part 4 and 5

The relay contacts are galvanically isolated from the rest of the circuit by reinforced isolation (PELV).

[2] Overvoltage Category II

[3] UL applications 300 V AC 2A

Control card performance

Scan interval	1 ms

Control characteristics

Resolution of output frequency at 0–590 Hz	±0.003 Hz
Repeat accuracy of Precise start/stop (terminals 18, 19)	≤±0.1 ms
System response time (terminals 18, 19, 27, 29, 32, 33)	≤ 2 ms
Speed control range (open-loop)	1:100 of synchronous speed
Speed control range (closed-loop)	1:1000 of synchronous speed
Speed accuracy (open-loop)	30–4000 rpm: error ±8 rpm
Speed accuracy (closed-loop), depending on resolution of feedback device	0–6000 rpm: error ±0.15 rpm
Torque control accuracy (speed feedback)	max error ±5% of rated torque

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

6.2.6 Derating for Ambient Temperature

6.2.6.1 Derating for Ambient Temperature, Enclosure Type A

60° AVM - Pulse Width Modulation

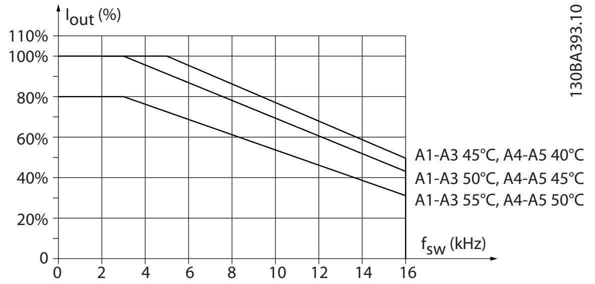


Figure 6.2 Derating of I_{out} for Different $T_{AMB, MAX}$ for Enclosure Type A, using 60° AVM

SFAVM - Stator Frequency Asyncron Vector Modulation

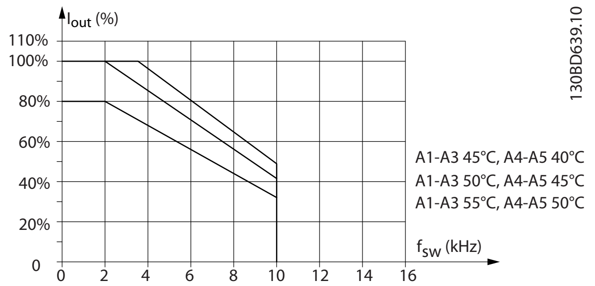


Figure 6.3 Derating of I_{out} for Different $T_{AMB, MAX}$ for Enclosures Type A, using SFAVM

When using only 33 ft [10 m] motor cable or less in enclosure size A, less derating is necessary. This is due to the fact that the length of the motor cable has a relatively high impact on the recommended derating.

60° AVM

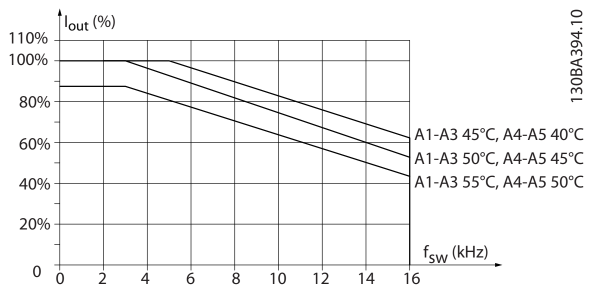


Figure 6.4 Derating of I_{out} for Different $T_{AMB, MAX}$ for Enclosures Type A, using 60° AVM and maximum 33 ft [10 m] motor cable

SFAVM

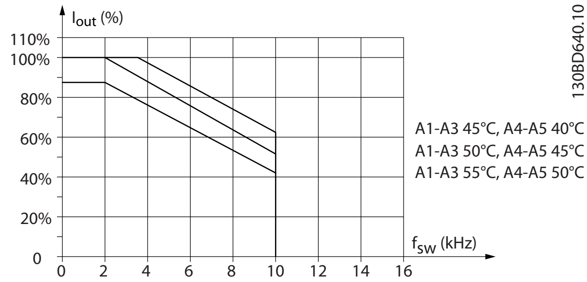


Figure 6.5 Derating of I_{out} for Different $T_{AMB, MAX}$ for Enclosures Type A, using SFAVM and maximum 33 ft [10 m] motor cable

6.2.6.2 Derating for Ambient Temperature, Enclosure Types B

Enclosure B, T2, T4 and T5

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

60° AVM - Pulse Width Modulation

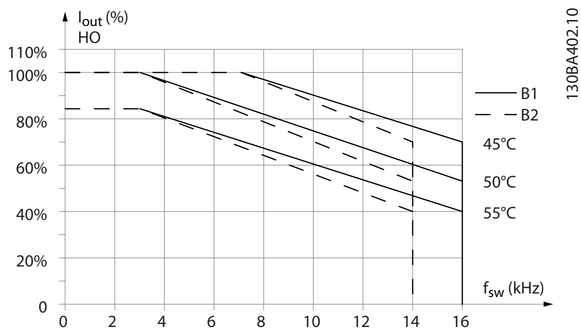


Figure 6.6 Derating of I_{out} for different $T_{AMB, MAX}$ for Enclosure Types B1 and B2, using 60° AVM in High overload mode (160% overtorque)

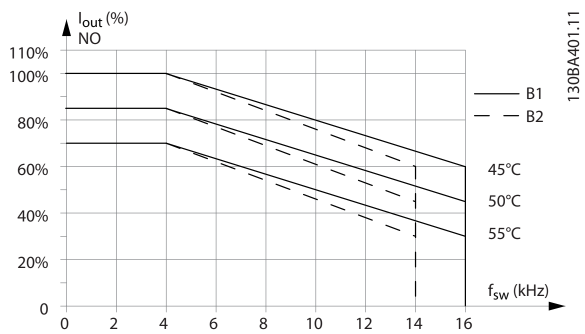


Figure 6.7 Derating of I_{out} for different $T_{AMB, MAX}$ for Enclosure Types B1 and B2, using 60° AVM in Normal overload mode (110% overtorque)

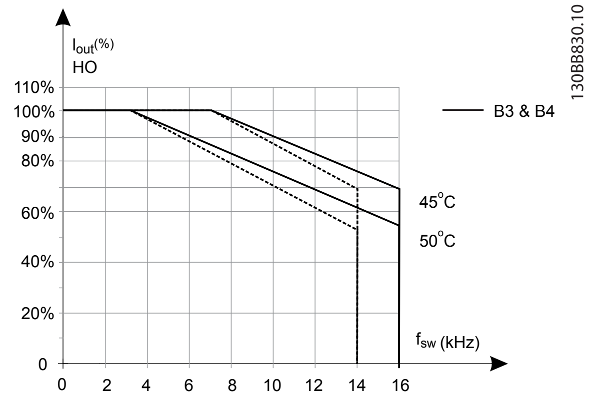


Figure 6.8 Derating of I_{out} for different $T_{AMB, MAX}$ for Enclosure Types B3 and B4, using 60° AVM in High overload mode (160% overtorque)

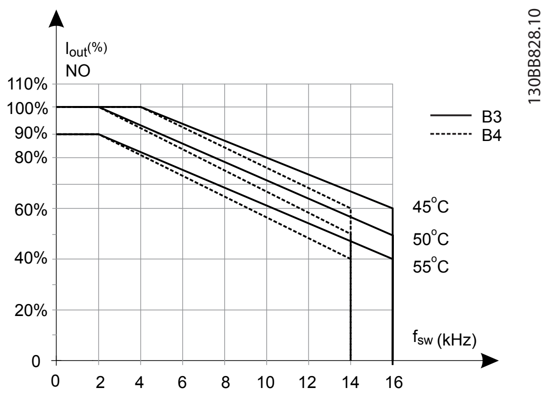


Figure 6.9 Derating of I_{out} for different $T_{AMB, MAX}$ for Enclosure Types B3 and B4, using 60° AVM in Normal overload mode (110% overtorque)

SFAVM - Stator Frequency Asyncron Vector Modulation

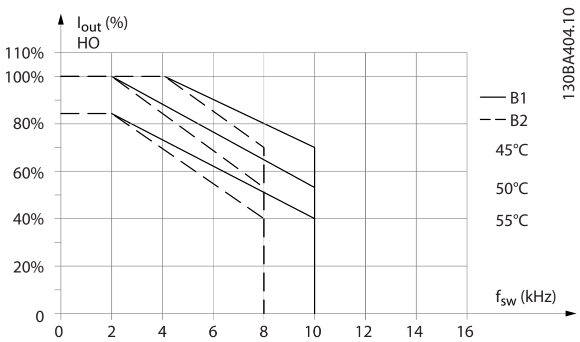


Figure 6.10 Derating of I_{out} for different $T_{AMB, MAX}$ for Enclosure Types B1 and B2, using SFAVM in High overload mode (160% overtorque)

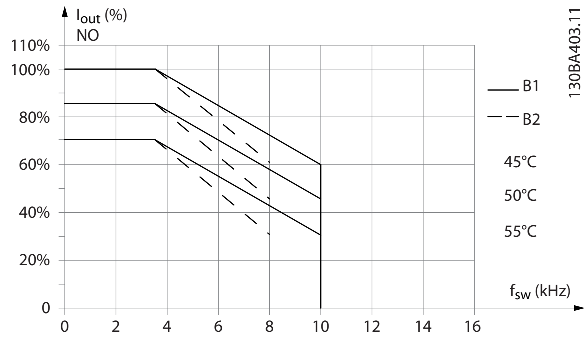


Figure 6.11 Derating of I_{out} for different $T_{AMB, MAX}$ for Enclosure Types B1 and B2, using SFAVM in Normal overload mode (110% overtorque)

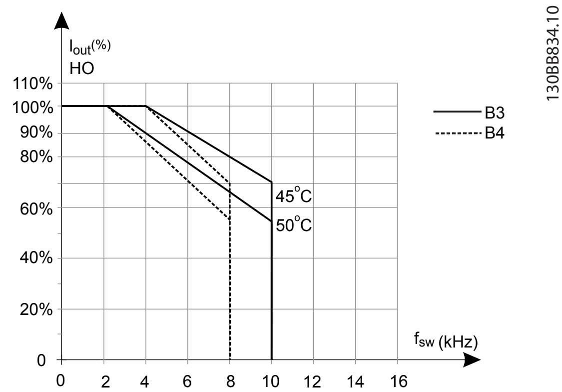


Figure 6.12 Derating of I_{out} for different $T_{AMB, MAX}$ for Enclosure Types B3 and B4, using SFAVM in High overload mode (160% overtorque)

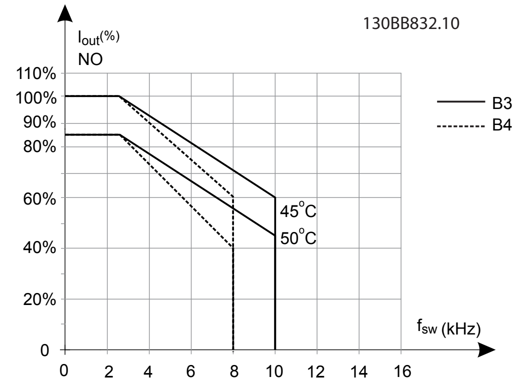


Figure 6.13 Derating of I_{out} for different $T_{AMB, MAX}$ for Enclosure Types B3 and B4, using SFAVM in Normal overload mode (110% overtorque)

Enclosures B, T6

60° AVM - Pulse Width Modulation

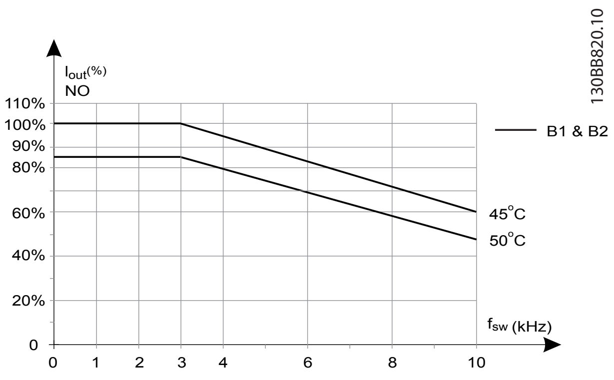


Figure 6.14 Output current derating with switching frequency and ambient temperature for 600 V adjustable frequency drives, enclosure type B, 60° AVM, NO

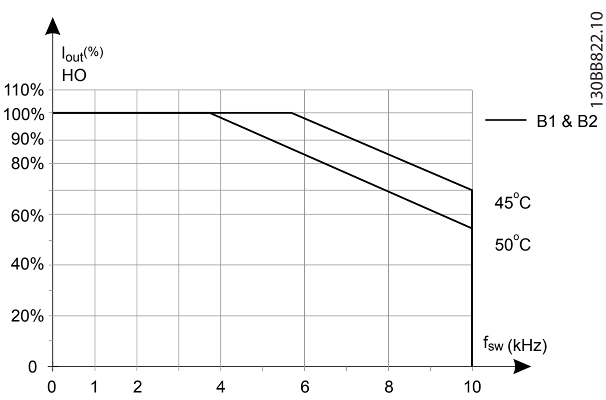


Figure 6.15 Output current derating with switching frequency and ambient temperature for 600 V adjustable frequency drives, enclosure type B, 60° AVM, HO

SFAVM - Stator Frequency Asyncron Vector Modulation

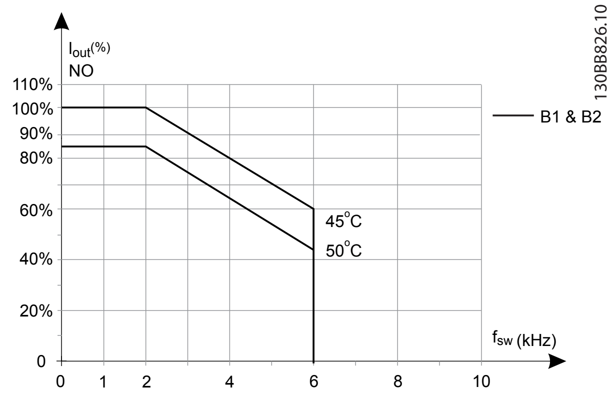


Figure 6.16 Output current derating with switching frequency and ambient temperature for 600 V adjustable frequency drives, enclosure type B; SFAVM, NO

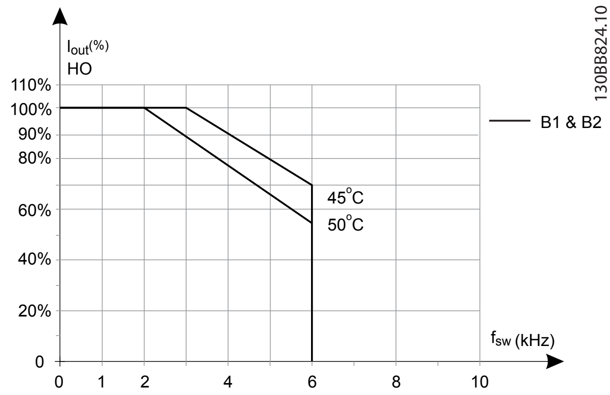


Figure 6.17 Output current derating with switching frequency and ambient temperature for 600 V adjustable frequency drives, enclosure type B; SFAVM, HO

6

Enclosures B, T7
Enclosures B2 and B4, 525–690 V
60° AVM - Pulse Width Modulation

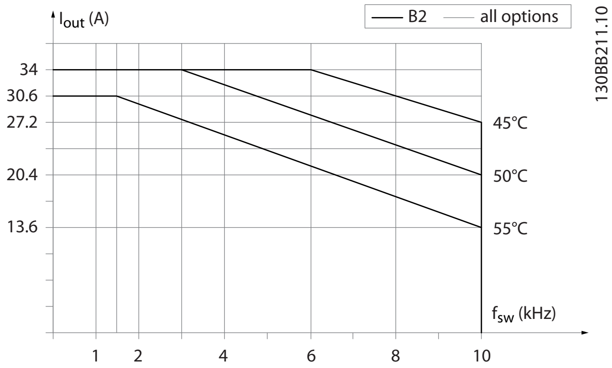


Figure 6.18 Output current derating with switching frequency and ambient temperature for enclosure types B2 and B4, 60° AVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.

SFAVM - Stator Frequency Asyncron Vector Modulation

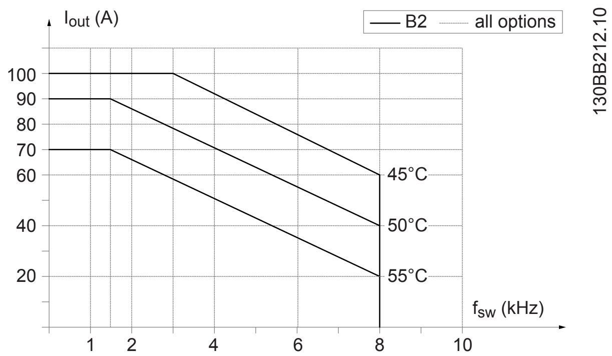


Figure 6.19 Output current derating with switching frequency and ambient temperature for enclosure types B2 and B4, SFAVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.

6.2.6.3 Derating for Ambient Temperature, Enclosure Types C

Enclosures C, T2, T4 and T5
60° AVM - Pulse Width Modulation

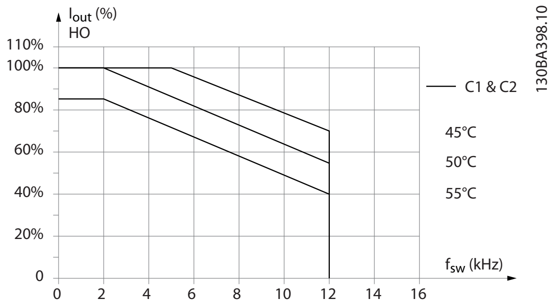


Figure 6.20 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types C1 and C2, using 60° AVM in High overload mode (160% overtorque)

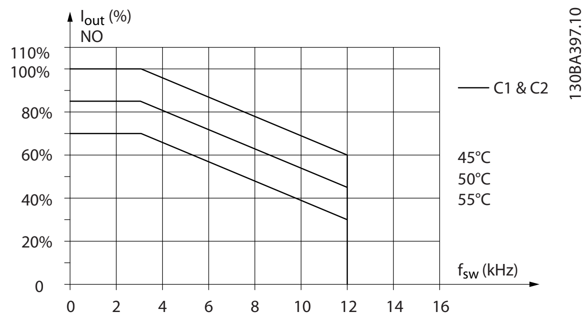


Figure 6.21 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types C1 and C2, using 60° AVM in Normal overload mode (110% overtorque)

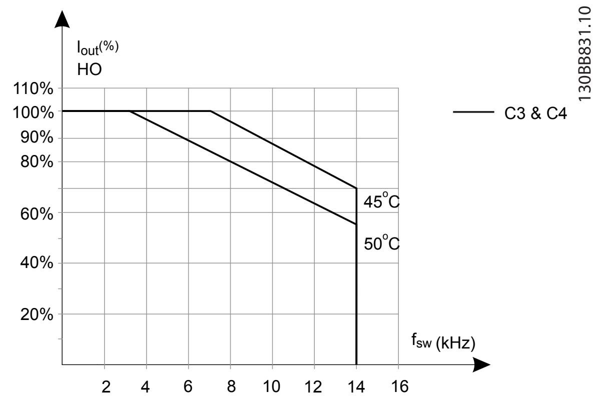


Figure 6.22 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types C3 and C4, using 60° AVM in High overload mode (160% overtorque)

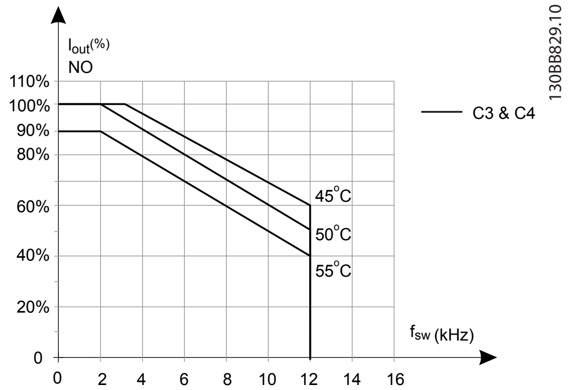


Figure 6.23 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types C3 and C4, using 60° AVM in Normal overload mode (110% overtorque)

SFAVM - Stator Frequency Asyncron Vector Modulation

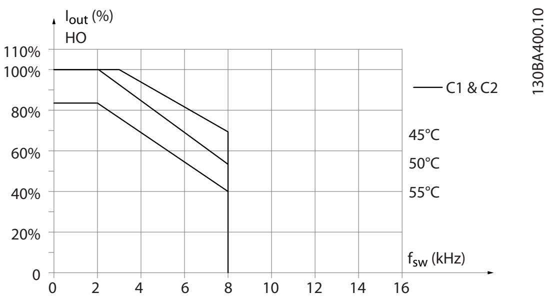


Figure 6.24 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types C1 and C2, using SFAVM in High overload mode (160% overtorque)

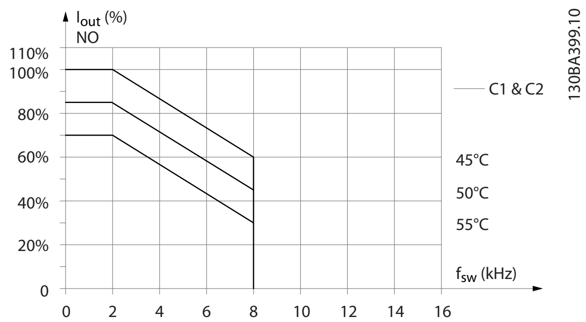


Figure 6.25 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types C1 and C2, using SFAVM in Normal overload mode (110% overtorque)

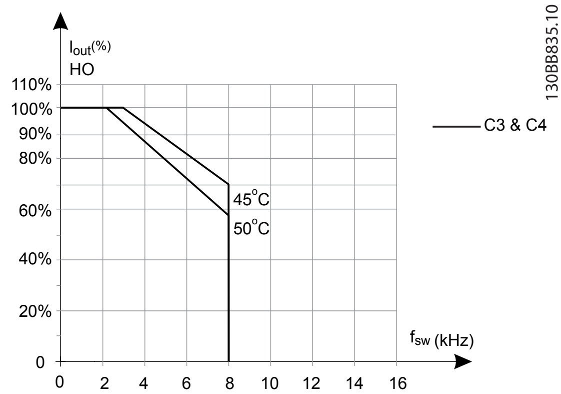


Figure 6.26 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types C3 and C4, using SFAVM in High overload mode (160% overtorque)

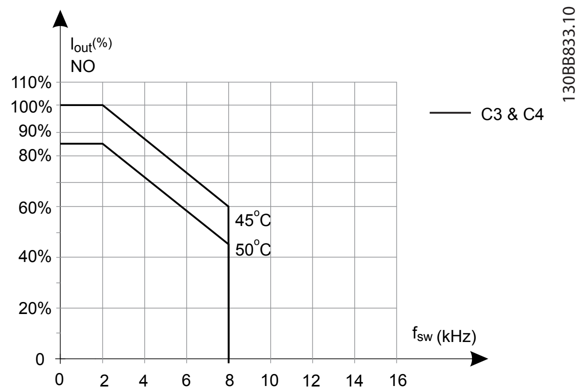


Figure 6.27 Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure types C3 and C4, using SFAVM in Normal overload mode (110% overtorque)

6

Enclosure Types C, T6
60° AVM - Pulse Width Modulation

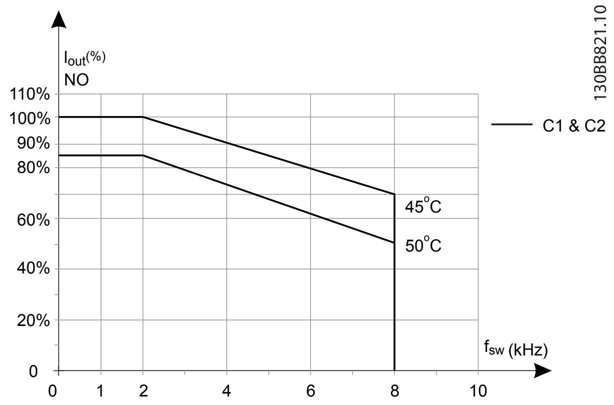


Figure 6.28 Output current derating with switching frequency and ambient temperature for 600 V adjustable frequency drives, enclosure type C, 60° AVM, NO

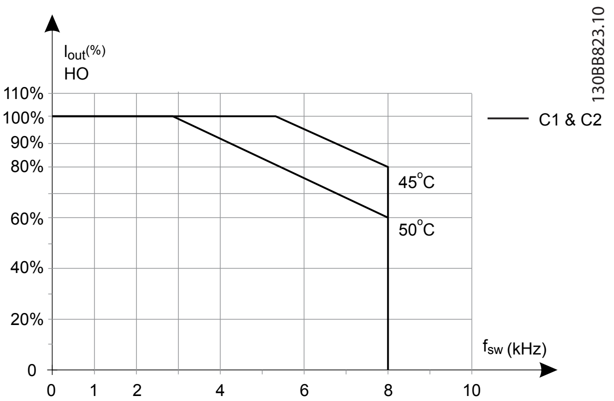


Figure 6.29 Output current derating with switching frequency and ambient temperature for 600 V adjustable frequency drives, enclosure types C, 60° AVM, HO

SFAVM - Stator Frequency Asyncron Vector Modulation

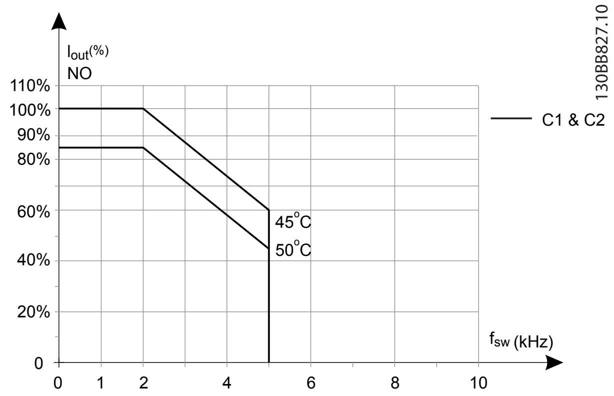


Figure 6.30 Output current derating with switching frequency and ambient temperature for 600 V adjustable frequency drives, enclosure types C; SFAVM, NO

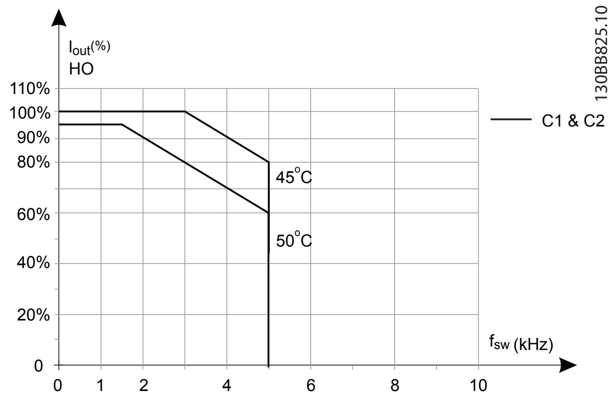


Figure 6.31 Output current derating with switching frequency and ambient temperature for 600 V adjustable frequency drives, enclosure types C; SFAVM, HO

Enclosure Type C, T7

60° AVM - Pulse Width Modulation

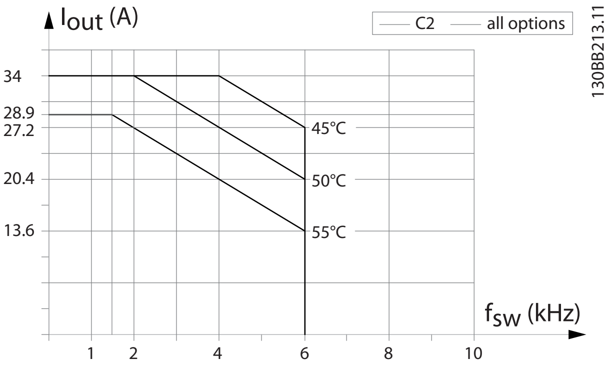


Figure 6.32 Output current derating with switching frequency and ambient temperature for enclosure type C2, 60° AVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.

SFAVM - Stator Frequency Asyncron Vector Modulation

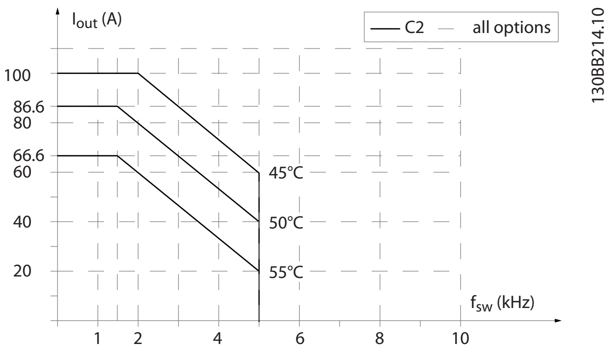


Figure 6.33 Output current derating with switching frequency and ambient temperature for enclosure type C2, SFAVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.

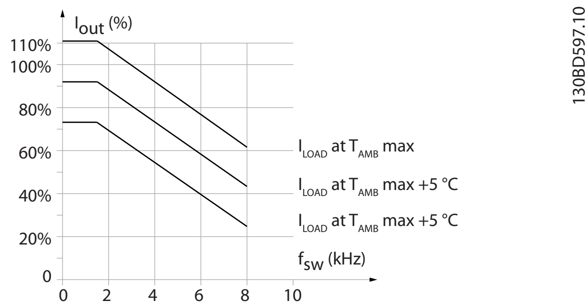


Figure 6.34 Output current derating with switching frequency and ambient temperature for enclosure type C3

6.2.7 Measured Values for dU/dt Testing

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

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, shielded, or non-shielded)

The natural induction causes an overshoot voltage peak in the motor voltage before it stabilizes. The level depends on the voltage in the DC link.

Peak voltage on the motor terminals is caused by the switching of the IGBTs. The rise time and the peak voltage affect the service life of the motor. If the peak voltage is too high, motors without phase coil insulation can be adversely affected over time.

With short motor cables (several feet or meters), the rise time and peak voltage are lower. The rise time and peak voltage increase with cable length (330 ft [100 m]).

The adjustable frequency drive complies with IEC 60034-25 and IEC 60034-17 for motor design.

200–240 V (T2)

Cable length [m]	AC line voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
5	240	0.13	0.510	3.090
50	240	0.23		2.034
100	240	0.54	0.580	0.865
150	240	0.66	0.560	0.674

Table 6.13 P5K5T2

Cable length [m]	AC line voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
36	240	0.264	0.624	1.890
136	240	0.536	0.596	0.889
150	240	0.568	0.568	0.800

Table 6.14 P7K5T2

6

Cable length [m]	AC line voltage [V]	Rise time [µs]	Upeak [kV]	dU/dt [kV/µs]
30	240	0.556	0.650	0.935
100	240	0.592	0.594	0.802
150	240	0.708	0.587	0.663

Table 6.15 P11KT2

Cable length [m]	AC line voltage [V]	Rise time [µs]	Upeak [kV]	dU/dt [kV/µs]
36	240	0.244	0.608	1.993
136	240	0.568	0.580	0.816
150	240	0.720	0.574	0.637

Table 6.16 P15KT2

Cable length [m]	AC line voltage [V]	Rise time [µs]	Upeak [kV]	dU/dt [kV/µs]
36	240	0.244	0.608	1.993
136	240	0.568	0.580	0.816
150	240	0.720	0.574	0.637

Table 6.17 P18KT2

Cable length [m]	AC line voltage [V]	Rise time [µs]	Upeak [kV]	dU/dt [kV/µs]
15	240	0.194	0.626	2.581
50	240	0.252	0.574	1.822
150	240	0.488	0.538	0.882

Table 6.18 P22KT2

Cable length [m]	AC line voltage [V]	Rise time [µs]	Upeak [kV]	dU/dt [kV/µs]
30	240	0.300	0.598	1.594
100	240	0.536	0.566	0.844
150	240	0.776	0.546	0.562

Table 6.19 P30KT2

Cable length [m]	AC line voltage [V]	Rise time [µs]	Upeak [kV]	dU/dt [kV/µs]
30	240	0.300	0.598	1.594
100	240	0.536	0.566	0.844
150	240	0.776	0.546	0.562

Table 6.20 P37KT2

380–500 V (T4)

Cable length [m]	AC line voltage [V]	Rise time [µs]	Upeak [kV]	dU/dt [kV/µs]
5	480	0.640	0.690	0.862
50	480	0.470	0.985	0.985
150	480	0.760	1.045	0.947

Table 6.21 P1K5T4

Cable length [m]	AC line voltage [V]	Rise time [µs]	Upeak [kV]	dU/dt [kV/µs]
5	480	0.172	0.890	4.156
50	480	0.310		2.564
150	480	0.370	1.190	1.770

Table 6.22 P4K0T4

Cable length [m]	AC line voltage [V]	Rise time [µs]	Upeak [kV]	dU/dt [kV/µs]
5	480	0.04755	0.739	8.035
50	480	0.207		4.548
150	480	0.6742	1.030	2.828

Table 6.23 P7K5T4

Cable length [m]	AC line voltage [V]	Rise time [µs]	Upeak [kV]	dU/dt [kV/µs]
36	480	0.396	1.210	2.444
100	480	0.844	1.230	1.165
150	480	0.696	1.160	1.333

Table 6.24 P11KT4

Cable length [m]	AC line voltage [V]	Rise time [µs]	Upeak [kV]	dU/dt [kV/µs]
36	480	0.396	1.210	2.444
100	480	0.844	1.230	1.165
150	480	0.696	1.160	1.333

Table 6.25 P15KT4

Cable length [m]	AC line voltage [V]	Rise time [µs]	Upeak [kV]	dU/dt [kV/µs]
36	480	0.312		2.846
100	480	0.556	1.250	1.798
150	480	0.608	1.230	1.618

Table 6.26 P18KT4

Cable length [m]	AC line voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
15	480	0.288		3.083
100	480	0.492	1.230	2.000
150	480	0.468	1.190	2.034

Table 6.27 P22KT4

Cable length [m]	AC line voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
5	480	0.368	1.270	2.853
50	480	0.536	1.260	1.978
100	480	0.680	1.240	1.426
150	480	0.712	1.200	1.334

Table 6.28 P30KT4

Cable length [m]	AC line voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
5	480	0.368	1.270	2.853
50	480	0.536	1.260	1.978
100	480	0.680	1.240	1.426
150	480	0.712	1.200	1.334

Table 6.29 P37KT4

Cable length [m]	AC line voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
15	480	0.256	1.230	3.847
50	480	0.328	1.200	2.957
100	480	0.456	1.200	2.127
150	480	0.960	1.150	1.052

Table 6.30 P45KT4

380–500 V (T5)

Cable length [m]	AC line voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
5	480	0.371	1.170	2.523

Table 6.31 P55KT5

Cable length [m]	AC line voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
5	480	0.371	1.170	2.523

Table 6.32 P75KT5

600 V (T6)

Cable length [m]	AC line voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
36	600	0.304	1.560	4.105
50	600	0.300	1.550	4.133
100	600	0.536	1.640	2.448
150	600	0.576	1.640	2.278

Table 6.33 P15KT6

Cable length [m]	AC line voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
36	600	0.084	1.560	7.962
50	600	0.120	1.540	5.467
100	600	0.165	1.472	3.976
150	600	0.190	1.530	3.432

Table 6.34 P30KT6

Cable length [m]	AC line voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
15	600	0.276	1.184	4.290

Table 6.35 P75KT6

525–690 V (T7)

Cable length [m]	AC line voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
80	690	0.58	1.728	2369
130	690	0.93	1.824	1569
180	690	0.925	1.818	1570

Table 6.36 P7K5T7

Cable length [m]	AC line voltage [V]	Rise time [μs]	Upeak [kV]	dU/dt [kV/μs]
6	690	0.238	1416	4739
50	690	0.358	1764	3922
150	690	0.465	1872	3252

Table 6.37 P45KT7

6

6.2.8 Efficiency

Efficiency of the adjustable frequency drive
The load on the adjustable frequency drive has little effect on its efficiency.

This also means that the adjustable frequency drive efficiency does not change when other U/f characteristics are chosen. However, the U/f characteristics do influence the efficiency of the motor.

The efficiency declines a little when the switching frequency is set to a value above 5 kHz. The efficiency is also slightly reduced when the motor cable is longer than 100 ft [30 m].

Efficiency calculation
Calculate the efficiency of the adjustable frequency drive at different loads based on *Figure 6.35*. Multiply the factor in this graph with the specific efficiency factor listed in *chapter 6.2 General Specifications*.

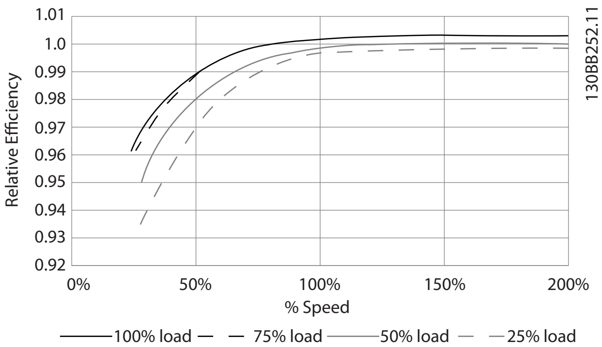


Figure 6.35 Typical Efficiency Curves

Example: Assume a 75 hp [55 kW], 380–480 V AC adjustable frequency drive with 25% load at 50% speed. The graph is showing 0.97 rated efficiency for a 75 hp [55 kW] adjustable frequency drive is 0.98. The actual efficiency is then: 0.97 x 0.98=0.95.

Motor efficiency
The efficiency of a motor connected to the adjustable frequency drive depends on magnetizing level. The efficiency of the motor depends on the type of motor.

- In the range of 75–100% of the rated torque, the efficiency of the motor is practically constant, both when it is controlled by the adjustable frequency drive, and when it runs directly on line power.
- The influence from the U/f characteristic on small motors is marginal. However, in motors from 15 hp [11 kW] and up, the efficiency advantage is significant.
- The switching frequency does not affect the efficiency of small motors. Motors from 15 hp [11 kW] and up have their efficiency improved 1–2%. This is because the sine shape of the motor current is almost perfect at high switching frequency.

System efficiency
To calculate the system efficiency, the efficiency of the adjustable frequency drive is multiplied by the efficiency of the motor.

6.2.9 Acoustic Noise

Acoustic noise from the adjustable frequency drive comes from three sources

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

See *Table 6.38* for acoustic noise ratings.

Enclosure type	50% fan speed [dBA]	Full fan speed [dBA]
A1	51	60
A2	51	60
A3	51	60
A4	51	60
A5	54	63
B1	61	67
B2	58	70
B4	52	62
C1	52	62
C2	55	65
C4	56	71
D3h	58	71

Table 6.38 Acoustic Noise Ratings

Values are measured 3.3 ft [1 m] from the unit.

7 How to Order

7.1 Drive Configurator

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

130BB836.10

Figure 7.1 Type Code Example

Configure the right adjustable frequency drive for the right application from the Internet based Drive Configurator and generate the type code string. The Drive Configurator automatically generates an 8-digit sales number to be delivered to the local sales office.
Furthermore, it is possible to establish a project list with several products and send it to a Danfoss sales representative.

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

7.1.1 Type Code

An example of the type code is:

FC-302PK75T5E20H1BGCXXXSXXXXA0BXCXXXXD0

The meaning of the characters in the string can be found in *Table 7.1* and *Table 7.2*. In the example above, a Profibus DP V1 and a 24 V backup option is built-in.

Description	Pos	Possible choices
Product group	1-3	FC 30x
Drive series	4-6	301: FC 301 302: FC 302
Power rating	8-10	0.25–75 kW
Phases	11	Three phases (T)
AC line voltage	11-12	T2: 200–240 V T4: 380–480 V T5: 380–500 V T6: 525–600 V T7: 525–690 V
Enclosure	13-15	E20: IP20 E55: IP 55/NEMA Type 12 P20: IP20 (with backplate) P21: IP21/ NEMA Type 1 (with backplate) P55: IP55/ NEMA Type 12 (with backplate) Z20: IP 20[1)] E66: IP 66

7

Description	Pos	Possible choices
RFI filter	16-17	Hx: No EMC filters built in the adjustable frequency drive (600 V units only) H1: Integrated EMC filter. Fulfill EN 55011 Class A1/B and EN/IEC 61800-3 Category 1/2 H2: No additional EMC filter. Fulfill EN 55011 Class A2 and EN/IEC 61800-3 Category 3 H3: H3 - Integrated EMC filter. Fulfil EN 55011 class A1/B and EN/IEC 61800-3 Category 1/2 (Enclosure type A1 only)[1)] H4: Integrated EMC filter. Fulfill EN 55011 class A1 and EN/IEC 61800-3 Category 2 H5: Marine versions. Fulfill same emissions levels as H2 versions
Brake	18	B: Brake chopper included X: No brake chopper included T: Safe Stop No brake[1)] U: Safe stop brake chopper[1)]
Display	19	G: Graphical Local Control Panel (LCP) N: Numerical Local Control Panel (LCP) X: No Local Control Panel
Coating PCB	20	C: Coated PCB R: Ruggedized X: No coated PCB
Line power option	21	X: No line power option 1: Line power disconnect 3: Line power disconnect and Fuse[2)] 5: Line power disconnect, fuse and load sharing2,[3)] 7: Fuse[2)] 8: Line power 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/enclosure type A1 only [2)] US Market only [3)]: A and B3 frames have load sharing built-in by default		

Table 7.1 Ordering Type Code Enclosure types A, B and C

Description	Pos	Possible choices
A options	29-30	AX: No A option A0: MCA 101 Profibus DP V1 (standard) A4: MCA 104 DeviceNet (standard) A6: CANOpen MCA 105 (standard) AN: MCA 121 Ethernet IP AL: MCA 120 ProfiNet AQ: MCA 122 Modbus TCP AT: MCA 113 Profibus Drive VLT 3000 AU: MCA 114 Profibus Drive VLT 5000 AY: MCA 123 Powerlink A8: MCA 124 EtherCAT
B options	31-32	BX: No option BK: MCB 101 General purpose I/O option BR: MCB 102 Encoder option BU: MCB 103 Resolver option BP: MCB 105 Relay option BZ: MCB 108 Safety PLC Interface B2: MCB 112 PTC Thermistor Card B4: MCB 114 VLT Sensor Input B6: MCB 150 Safe Option TTL B7: MCB 151 Safe Option HTL
C0 options	33-34	CX: No option C4: MCO 305, Programmable Motion Controller
C1 options	35	X: No option R: MCB 113 Ext. Relay Card Z: MCA 140 Modbus RTU OEM option
C option software/E1 options	36-37	XX: Standard controller 10: MCO 350 Synchronizing control 11: MCO 351 Positioning control
D options	38-39	DX: No option D0: MCB 107 Ext. 24 V DC backup

Table 7.2 Ordering Type Code, Options

NOTICE!

For power sizes over 100 hp [75 kW], see the *VLT® AutomationDrive FC 300 90–1400 kW Design Guide*.

7.1.2 Language

Adjustable Frequency Drives are automatically 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	Language package 2	Language package 3	Language package 4
English	English	English	English
German	German	German	German
French	Chinese	Slovenian	Spanish
Danish	Korean	Bulgarian	English US
Dutch	Japanese	Serbian	Greek
Spanish	Thai	Romanian	Brazilian Portuguese
Swedish	Traditional Chinese	Hungarian	Turkish
Italian	Bahasa Indonesian	Czech	Polish
Finnish		Russian	

Table 7.3 Language Packages

To order adjustable frequency drives with a different language package, contact the local sales office.

7.2 Ordering Numbers

7.2.1 Options and Accessories

Description	Ordering no.	
	Uncoated	Coated
Miscellaneous hardware		
VLT® Panel through kit enclosure type A5	130B1028	
VLT® Panel through kit enclosure type B1	130B1046	
VLT® Panel through kit enclosure type B2	130B1047	
VLT® Panel through kit enclosure type C1	130B1048	
VLT® Panel through kit enclosure type C2	130B1049	
VLT® Mounting brackets for enclosure type A5	130B1080	
VLT® Mounting brackets for enclosure type B1	130B1081	
VLT® Mounting brackets for enclosure type B2	130B1082	
VLT® Mounting brackets for enclosure type C1	130B1083	
VLT® Mounting brackets for enclosure type C2	130B1084	
VLT® IP 21/Type 1 Kit, enclosure type A1	130B1121	
VLT® IP 21/Type 1 Kit, enclosure type A2	130B1122	
VLT® IP 21/Type 1 Kit, enclosure type A3	130B1123	
VLT® IP 21/Type 1 Top Kit, enclosure type A2	130B1132	
VLT® IP 21/Type 1 Top Kit, enclosure type A3	130B1133	
VLT® Backplate IP55/Type12, enclosure type A5	130B1098	
VLT® Backplate IP21/Type 1, IP55/Type 12, enclosure type B1	130B3383	
VLT® Backplate IP21/Type 1, IP55/Type 12, enclosure type B2	130B3397	
VLT® Backplate IP20/Type 1, enclosure type B4	130B4172	
VLT® Backplate IP21/Type 1, IP55/Type 12, enclosure type C1	130B3910	
VLT® Backplate IP21/Type 1, IP55/Type 12, enclosure type C2	130B3911	
VLT® Backplate IP20/Type 1, enclosure type C3	130B4170	
VLT® Backplate IP20/Type 1, enclosure type C4	130B4171	
VLT® Backplate IP66/Type 4X, enclosure type A5	130B3242	
VLT® Backplate in stainless steel IP66/Type 4X, enclosure type B1	130B3434	
VLT® Backplate in stainless steel IP66/Type 4X, enclosure type B2	130B3465	
VLT® Backplate in stainless steel IP66/Type 4X, enclosure type C1	130B3468	
VLT® Backplate in stainless steel IP66/Type 4X, enclosure type C2	130B3491	
VLT® Profibus Adapter Sub-D9 Connector	130B1112	
Profibus shield plate kit for IP20, enclosure types A1, A2 and A3	130B0524	
Terminal block for DC link connection on enclosure types A2/A3	130B1064	
VLT® Screw terminals	130B1116	
VLT® USB extension, 350 mm cable	130B1155	
VLT® USB extension, 650 mm cable	130B1156	
VLT® Back frame A2 for 1 brake resistor	175U0085	
VLT® Back frame A3 for 1 brake resistor	175U0088	
VLT® Back frame A2 for 2 brake resistors	175U0087	
VLT® Back A3 for 2 brake resistors	175U0086	
Local Control Panel		
VLT® LCP 101 Numeric Local Control Pad	130B1124	
VLT® LCP 102 Graphical Local Control Pad	130B1107	
VLT® Cable for LCP 2, 3 m	175Z0929	

Description	Ordering no.	
	Uncoated	Coated
VLT® Panel Mounting Kit for all LCP types	130B1170	
VLT® Panel Mounting Kit, graphical LCP	130B1113	
VLT® Panel Mounting Kit, numerical LCP	130B1114	
VLT® LCP Mounting Kit, w/ no LCP	130B1117	
VLT® LCP Mounting Kit Blind Cover IP55/66, 8 m	130B1129	
VLT® Control Panel LCP 102, graphical	130B1078	
VLT® Blindcover, w/ Danfoss logo, IP55/66	130B1077	
Options for slot A		
VLT® Profibus DP V1 MCA 101	130B1100	130B1200
VLT® DeviceNet MCA 104	130B1102	130B1202
VLT® CAN Open MCA 105	130B1103	130B1205
VLT® PROFIBUS Drive MCA 113	130B1245	
VLT® PROFIBUS Drive MCA 114		130B1246
VLT® PROFINET MCA 120	130B1135	130B1235
VLT® EtherNet/IP MCA 121	130B1119	130B1219
VLT® Modbus TCP MCA 122	130B1196	130B1296
POWERLINK	130B1489	130B1490
EtherCAT	130B5546	130B5646
VLT® DeviceNet MCA 104	130B1102	130B1202
Options for slot B		
VLT® General Purpose I/O MCB 101	130B1125	130B1212
VLT® Encoder Input MCB 102	130B1115	130B1203
VLT® Resolver Input MCB 103	130B1127	130B1227
VLT® Relay Option MCB 105	130B1110	130B1210
VLT® Safe PLC I/O MCB 108	130B1120	130B1220
VLT® PTC Thermistor Card MCB 112		130B1137
VLT® Safe Option MCB 140	130B6443	
VLT® Safe Option MCB 141	130B6447	
VLT® Safe option MCB 150		130B3280
VLT® Safe option MCB 151		130B3290
Mounting Kits for C options		
VLT® Mounting Kit for C Option, 40 mm, enclosure types A2/A3	130B7530	
VLT® Mounting Kit for C Option, 60 mm, enclosure types A2/A3	130B7531	
VLT® Mounting Kit for C Option, enclosure type A5	130B7532	
VLT® Mounting Kit for C Option, enclosure types B/C/D/E/F (except B3)	130B7533	
VLT® Mounting Kit for C Option, 40 mm, enclosure type B3	130B1413	
VLT® Mounting Kit for C Option, 60 mm, enclosure type B3	130B1414	
Options for Slot C		
VLT® Motion Control MCO 305	130B1134	130B1234
VLT® Synchronizing Contr. MCO 350	130B1152	130B1252
VLT® Position. Controller MCO 351	130B1153	120B1253
Center Winder Controller	130B1165	130B1166
VLT® Extended Relay Card MCB 113	130B1164	130B1264
VLT® C Option Adapter MCF 106		130B1230
Option for Slot D		
VLT® 24 V DC Supply MCB 107	130B1108	130B1208

Description	Ordering no.	
	Uncoated	Coated
VLT® EtherNet/IP MCA 121	175N2584	
VLT® Leakage Current Monitor Kit, enclosure types A2/A3	130B5645	
VLT® Leakage Current Monitor Kit, enclosure type B3	130B5764	
VLT® Leakage Current Monitor Kit, enclosure type B4	130B5765	
VLT® Leakage Current Monitor Kit, enclosure type C3	130B6226	
VLT® Leakage Current Monitor Kit, enclosure type C4	130B5647	
PC Software		
VLT® Motion Ctrl Tool MCT 10, 1 license	130B1000	
VLT® Motion Ctrl Tool MCT 10, 5 licenses	130B1001	
VLT® Motion Ctrl Tool MCT 10, 10 licenses	130B1002	
VLT® Motion Ctrl Tool MCT 10, 25 licenses	130B1003	
VLT® Motion Ctrl Tool MCT 10, 50 licenses	130B1004	
VLT® Motion Ctrl Tool MCT 10, 100 licenses	130B1005	
VLT® Motion Ctrl Tool MCT 10, >100 licenses	130B1006	
Options can be ordered as factory built-in options, see ordering information, *chapter 7.1 Drive Configurator*.		

Table 7.4 Ordering Numbers for Options and Accessories

7.2.2 Spare Parts

Consult the VLT shop or the configurator for spare parts available for your specification, *VLTShop.danfoss.com*.

7.2.3 Accessory Bags

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

Table 7.5 Ordering Numbers for Accessory Bags

7.2.4 VLT AutomationDrive FC 301

T2, Horizontal Braking 10% Duty Cycle

FC 301				Horizontal braking 10% duty cycle							
Adjustable frequency drive data				Brake resistor data						Installation	
						Danfoss part number					
Line power type	P_m (hp [kW])	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20	Cable cross-section [mm²]	Thermo relay [A]
T2	0.34 [0.25]	368	415.9	410	0.100	175u3004	-	-	-	1.5	0.5
T2	0.5 [0.37]	248	280.7	300	0.100	175u3006	-	-	-	1.5	0.6
T2	0.75 [0.55]	166	188.7	200	0.100	175u3011	-	-	-	1.5	0.7
T2	1.0 [0.75]	121	138.4	145	0.100	175u3016	-	-	-	1.5	0.8
T2	1.5 [1.1]	81.0	92.0	100	0.100	175u3021	-	-	-	1.5	0.9
T2	2 [1.5]	58.5	66.5	70	0.200	175u3026	-	-	-	1.5	1.6
T2	3 [2.2]	40.2	44.6	48	0.200	175u3031	-	-	-	1.5	1.9
T2	4 [3]	29.1	32.3	35	0.300	175u3325	-	-	-	1.5	2.7
T2	5 [3.7]	22.5	25.9	27	0.360	175u3326	175u3477	175u3478	-	1.5	3.5
T2	7.5 [5.5]	17.7	19.7	18	0.570	175u3327	175u3442	175u3441	-	1.5	5.3
T2	10 [7.5]	12.6	14.3	13	0.680	175u3328	175u3059	175u3060	-	1.5	6.8
T2	15 [11]	8.7	9.7	9	1.130	175u3329	175u3068	175u3069	-	2.5	10.5
T2	20 [15]	5.3	7.5	5.7	1.400	175u3330	175u3073	175u3074	-	4	15
T2	25 [18.5]	5.1	6.0	5.7	1.700	175u3331	175u3483	175u3484	-	4	16
T2	30 [22]	3.2	5.0	3.5	2.200	175u3332	175u3080	175u3081	-	6	24
T2	40 [30]	3.0	3.7	3.5	2.800	175u3333	175u3448	175u3447	-	10	27
T2	50 [37]	2.4	3.0	2.8	3.200	175u3334	175u3086	175u3087	-	16	32

Table 7.6 T2, Horizontal Braking 10% Duty Cycle

FC 301				Vertical braking 40% duty cycle							
Adjustable frequency drive data				Brake resistor data						Installation	
						Danfoss part number					
Line power type	P_m (hp [kW])	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20	Cable cross-section [mm²]	Thermo relay [A]
T2	0.37 [0.25]	368	415.9	410	0.100	175u3004	-	-	-	1.5	0.5
T2	0.5 [0.37]	248	280.7	300	0.200	175u3096	-	-	-	1.5	0.8
T2	0.75 [0.55]	166	188.7	200	0.200	175u3008	-	-	-	1.5	0.9
T2	1.0 [0.75]	121	138.4	145	0.300	175u3300	-	-	-	1.5	1.3
T2	1.5 [1.1]	81.0	92.0	100	0.450	175u3301	175u3402	175u3401	-	1.5	2
T2	2 [1.5]	58.5	66.5	70	0.570	175u3302	175u3404	175u3403	-	1.5	2.7
T2	3 [2.2]	40.2	44.6	48	0.960	175u3303	175u3406	175u3405	-	1.5	4.2
T2	4 [3]	29.1	32.3	35	1.130	175u3304	175u3408	175u3407	-	1.5	5.4
T2	5 [3.7]	22.5	25.9	27	1.400	175u3305	175u3410	175u3409	-	1.5	6.8
T2	7.5 [5.5]	17.7	19.7	18	2.200	175u3306	175u3412	175u3411	-	1.5	10.4
T2	10 [7.5]	12.6	14.3	13	3.200	175u3307	175u3414	175u3413	-	2.5	14.7
T2	15 [11]	8.7	9.7	9	5.500	-	175u3176	175u3177	-	4	23
T2	20 [15]	5.3	7.5	5.7	6.000	-	-	-	175u3233	10	33
T2	25 [18.5]	5.1	6.0	5.7	8.000	-	-	-	175u3234	10	38
T2	30 [22]	3.2	5.0	3.5	9.000	-	-	-	175u3235	16	51
T2	40 [30]	3.0	3.7	3.5	14.000	-	-	-	175u3224	25	63
T2	50 [37]	2.4	3.0	2.8	17.000	-	-	-	175u3227	35	78

Table 7.7 T2, Vertical Braking 40% Duty Cycle

FC 301				Horizontal braking 10% duty cycle							
Adjustable frequency drive data				Brake resistor data						Installation	
						Danfoss part number					
Line power type	P_m (hp [kW])	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20	Cable cross-section [mm²]	Thermo relay [A]
T4	0.5 [0.37]	1000	1121.4	1200	0.100	175u3000	-	-	-	1.5	0.3
T4	0.75 [0.55]	620	749.8	850	0.100	175u3001	-	-	-	1.5	0.4
T4	1.0 [0.75]	485	547.6	630	0.100	175u3002	-	-	-	1.5	0.4
T4	1.5 [1.1]	329	365.3	410	0.100	175u3004	-	-	-	1.5	0.5
T4	2 [1.5]	240	263.0	270	0.200	175u3007	-	-	-	1.5	0.8
T4	3 [2.2]	161	176.5	200	0.200	175u3008	-	-	-	1.5	0.9
T4	4 [3]	117	127.9	145	0.300	175u3300	-	-	-	1.5	1.3
T4	5 [4]	86.9	94.6	110	0.450	175u3335	175u3450	175u3449	-	1.5	1.9
T4	7.5 [5.5]	62.5	68.2	80	0.570	175u3336	175u3452	175u3451	-	1.5	2.5
T4	10 [7.5]	45.3	49.6	56	0.680	175u3337	175u3027	175u3028	-	1.5	3.3
T4	15 [11]	34.9	38.0	38	1.130	175u3338	175u3034	175u3035	-	1.5	5.2
T4	20 [15]	25.3	27.7	28	1.400	175u3339	175u3039	175u3040	-	1.5	6.7
T4	25 [18.5]	20.3	22.3	22	1.700	175u3340	175u3047	175u3048	-	1.5	8.3
T4	30 [22]	16.9	18.7	19	2.200	175u3357	175u3049	175u3050	-	1.5	10.1
T4	40 [30]	13.2	14.5	14	2.800	175u3341	175u3055	175u3056	-	2.5	13.3
T4	50 [37]	10.6	11.7	12	3.200	175u3359	175u3061	175u3062	-	2.5	15.3
T4	60 [45]	8.7	9.6	9.5	4.200	-	175u3065	175u3066	-	4	20
T4	75 [55]	6.6	7.8	7.0	5.500	-	175u3070	175u3071	-	6	26
T4	100 [75]	4.2	5.7	5.5	7.000	-	-	-	175u3231	10	36

Table 7.8 T4, Horizontal Braking 10% Duty Cycle

FC 301				Vertical braking 40% duty cycle							
Adjustable frequency drive data				Brake resistor data						Installation	
						Danfoss part number					
Line power type	P_m (hp [kW])	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20	Cable cross-section [mm^2]	Thermo relay [A]
T4	0.5 [0.37]	1000	1121.4	1200	0.200	175u3101	-	-	-	1.5	0.4
T4	0.75 [0.55]	620	749.8	850	0.200	175u3308	-	-	-	1.5	0.5
T4	1.0 [0.75]	485	547.6	630	0.300	175u3309	-	-	-	1.5	0.7
T4	1.5 [1.1]	329	365.3	410	0.450	175u3310	175u3416	175u3415	-	1.5	1
T4	2 [1.5]	240	263.0	270	0.570	175u3311	175u3418	175u3417	-	1.5	1.4
T4	3 [2.2]	161	176.5	200	0.960	175u3312	175u3420	175u3419	-	1.5	2.1
T4	4 [3]	117	127.9	145	1.130	175u3313	175u3422	175u3421	-	1.5	2.7
T4	5 [4]	86.9	94.6	110	1.700	175u3314	175u3424	175u3423	-	1.5	3.7
T4	7.5 [5.5]	62.5	68.2	80	2.200	175u3315	175u3138	175u3139	-	1.5	5
T4	10 [7.5]	45.3	49.6	56	3.200	175u3316	175u3428	175u3427	-	1.5	7.1
T4	15 [11]	34.9	38.0	38	5.000	-	-	-	175u3236	1.5	11.5
T4	20 [15]	25.3	27.7	28	6.000	-	-	-	175u3237	2.5	14.7
T4	25 [18.5]	20.3	22.3	22	8.000	-	-	-	175u3238	4	19
T4	30 [22]	16.9	18.7	19	10.000	-	-	-	175u3203	4	23
T4	40 [30]	13.2	14.5	14	14.000	-	-	-	175u3206	10	32
T4	50 [37]	10.6	11.7	12	17.000	-	-	-	175u3210	10	38
T4	60 [45]	8.7	9.6	9.5	21.000	-	-	-	175u3213	16	47
T4	75 [55]	6.6	7.8	7.0	26.000	-	-	-	175u3216	25	61
T4	100 [75]	4.2	5.7	5.5	36.000	-	-	-	175u3219	35	81

Table 7.9 T4, Vertical Braking 40% Duty Cycle

7

7.2.5 Brake Resistors for FC 302

FC 302				Horizontal braking 10% duty cycle							
Adjustable frequency drive data				Brake resistor data						Installation	
						Danfoss part number					
Line power type	P_m (hp [kW])	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20	Cable cross-section [mm²]	Thermo relay [A]
T2	0.34 [0.25]	380	475.3	410	0.100	175u3004	-	-	-	1.5	0.5
T2	0.5 [0.37]	275	320.8	300	0.100	175u3006	-	-	-	1.5	0.6
T2	0.75 [0.55]	188	215.7	200	0.100	175u3011	-	-	-	1.5	0.7
T2	1.0 [0.75]	130	158.1	145	0.100	175u3016	-	-	-	1.5	0.8
T2	1.5 [1.1]	81.0	105.1	100	0.100	175u3021	-	-	-	1.5	0.9
T2	2 [1.5]	58.5	76.0	70	0.200	175u3026	-	-	-	1.5	1.6
T2	3 [2.2]	45.0	51.0	48	0.200	175u3031	-	-	-	1.5	1.9
T2	4 [3]	31.5	37.0	35	0.300	175u3325	-	-	-	1.5	2.7
T2	5 [3.7]	22.5	29.7	27	0.360	175u3326	175u3477	175u3478	-	1.5	3.5
T2	7.5 [5.5]	17.7	19.7	18	0.570	175u3327	175u3442	175u3441	-	1.5	5.3
T2	10 [7.5]	12.6	14.3	13.0	0.680	175u3328	175u3059	175u3060	-	1.5	6.8
T2	15 [11]	8.7	9.7	9.0	1.130	175u3329	175u3068	175u3069	-	2.5	10.5
T2	20 [15]	5.3	7.5	5.7	1.400	175u3330	175u3073	175u3074	-	4	14.7
T2	25 [18.5]	5.1	6.0	5.7	1.700	175u3331	175u3483	175u3484	-	4	16
T2	30 [22]	3.2	5.0	3.5	2.200	175u3332	175u3080	175u3081	-	6	24
T2	40 [30]	3.0	3.7	3.5	2.800	175u3333	175u3448	175u3447	-	10	27
T2	50 [37]	2.4	3.0	2.8	3.200	175u3334	175u3086	175u3087	-	16	32

Table 7.10 T2, Horizontal Braking 10% Duty Cycle

FC 302				Vertical braking 40% duty cycle							
Adjustable frequency drive data				Brake resistor data						Installation	
						Danfoss part number					
Line power type	P_m (hp [kW])	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20	Cable cross-section [mm^2]	Thermo relay [A]
T2	0.34 [0.25]	380	475.3	410	0.100	175u3004	-	-	-	1.5	0.5
T2	0.5 [0.37]	275	320.8	300	0.200	175u3096	-	-	-	1.5	0.8
T2	0.75 [0.55]	188	215.7	200	0.200	175u3008	-	-	-	1.5	0.9
T2	1.0 [0.75]	130	158.1	145	0.300	175u3300	-	-	-	1.5	1.3
T2	1.5 [1.1]	81.0	105.1	100	0.450	175u3301	175u3402	175u3401	-	1.5	2
T2	2 [1.5]	58.5	76.0	70	0.570	175u3302	175u3404	175u3403	-	1.5	2.7
T2	3 [2.2]	45.0	51.0	48	0.960	175u3303	175u3406	175u3405	-	1.5	4.2
T2	4 [3]	31.5	37.0	35	1.130	175u3304	175u3408	175u3407	-	1.5	5.4
T2	5 [3.7]	22.5	29.7	27	1.400	175u3305	175u3410	175u3409	-	1.5	6.8
T2	7.5 [5.5]	17.7	19.7	18	2.200	175u3306	175u3412	175u3411	-	1.5	10.4
T2	10 [7.5]	12.6	14.3	13.0	3.200	175u3307	175u3414	175u3413	-	2.5	14.7
T2	15 [11]	8.7	9.7	9.0	5.500	-	175u3176	175u3177	-	4	23
T2	20 [15]	5.3	7.5	5.7	6.000	-	-	-	175u3233	10	33
T2	25 [18.5]	5.1	6.0	5.7	8.000	-	-	-	175u3234	10	38
T2	30 [22]	3.2	5.0	3.5	9.000	-	-	-	175u3235	16	51
T2	40 [30]	3.0	3.7	3.5	14.000	-	-	-	175u3224	25	63
T2	50 [37]	2.4	3.0	2.8	17.000	-	-	-	175u3227	35	78

Table 7.11 T2, Vertical Braking 40% Duty Cycle

FC 302				Horizontal braking 10% duty cycle							
Adjustable frequency drive data				Brake resistor data						Installation	
						Danfoss part number				Cable cross-section $[mm^2]$	Thermo relay [A]
Line power type	P_m (hp [kW])	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20		
T5	0.5 [0.37]	1000	1389.2	1200	0.100	175u3000	-	-	-	1.5	0.3
T5	0.75 [0.55]	620	928.8	850	0.100	175u3001	-	-	-	1.5	0.4
T5	1.0 [0.75]	558	678.3	630	0.100	175u3002	-	-	-	1.5	0.4
T5	1.5 [1.1]	382	452.5	410	0.100	175u3004	-	-	-	1.5	0.5
T5	2 [1.5]	260	325.9	270	0.200	175u3007	-	-	-	1.5	0.8
T5	3 [2.2]	189	218.6	200	0.200	175u3008	-	-	-	1.5	0.9
T5	4 [3]	135	158.5	145	0.300	175u3300	-	-	-	1.5	1.3
T5	5 [4]	99.0	117.2	110	0.450	175u3335	175u3450	175u3449	-	1.5	1.9
T5	7.5 [5.5]	72.0	84.4	80	0.570	175u3336	175u3452	175u3451	-	1.5	2.5
T5	10 [7.5]	50.0	61.4	56	0.680	175u3337	175u3027	175u3028	-	1.5	3.3
T5	15 [11]	36.0	41.2	38	1.130	175u3338	175u3034	175u3035	-	1.5	5.2
T5	20 [15]	27.0	30.0	28	1.400	175u3339	175u3039	175u3040	-	1.5	6.7
T5	25 [18.5]	20.3	24.2	22	1.700	175u3340	175u3047	175u3048	-	1.5	8.3
T5	30 [22]	18.0	20.3	19	2.200	175u3357	175u3049	175u3050	-	1.5	10.1
T5	40 [30]	13.4	15.8	14	2.800	175u3341	175u3055	175u3056	-	2.5	13.3
T5	50 [37]	10.8	12.7	12	3.200	175u3359	175u3061	175u3062	-	2.5	15.3
T5	60 [45]	8.8	10.4	9.5	4.200	-	175u3065	175u3066	-	4	20
T5	75 [55]	6.5	8.5	7.0	5.500	-	175u3070	175u3071	-	6	26
T5	100 [75]	4.2	6.2	5.5	7.000	-	-	-	175u3231	10	36

Table 7.12 T5, Horizontal Braking 10% Duty Cycle

FC 302				Vertical braking 40% duty cycle							
Adjustable frequency drive data				Brake resistor data						Installation	
						Danfoss part number				Cable cross-section $[mm^2]$	Thermo relay [A]
Line power type	P_m (hp [kW])	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20		
T5	0.5 [0.37]	1000	1389.2	1200	0.200	175u3101	-	-	-	1.5	0.4
T5	0.75 [0.55]	620	928.8	850	0.200	175u3308	-	-	-	1.5	0.5
T5	1.0 [0.75]	558	678.3	630	0.300	175u3309	-	-	-	1.5	0.7
T5	1.5 [1.1]	382	452.5	410	0.450	175u3310	175u3416	175u3415	-	1.5	1
T5	2 [1.5]	260	325.9	270	0.570	175u3311	175u3418	175u3417	-	1.5	1.4
T5	3 [2.2]	189	218.6	200	0.960	175u3312	175u3420	175u3419	-	1.5	2.1
T5	4 [3]	135	158.5	145	1.130	175u3313	175u3422	175u3421	-	1.5	2.7
T5	5 [4]	99.0	117.2	110	1.700	175u3314	175u3424	175u3423	-	1.5	3.7
T5	7.5 [5.5]	72.0	84.4	80	2.200	175u3315	175u3138	175u3139	-	1.5	5
T5	10 [7.5]	50.0	61.4	56	3.200	175u3316	175u3428	175u3427	-	1.5	7.1
T5	15 [11]	36.0	41.2	38	5.000	-	-	-	175u3236	1.5	11.5
T5	20 [15]	27.0	30.0	28	6.000	-	-	-	175u3237	2.5	14.7
T5	25 [18.5]	20.3	24.2	22	8.000	-	-	-	175u3238	4	19
T5	30 [22]	18.0	20.3	19	10.000	-	-	-	175u3203	4	23
T5	40 [30]	13.4	15.8	14	14.000	-	-	-	175u3206	10	32
T5	50 [37]	10.8	12.7	12	17.000	-	-	-	175u3210	10	38
T5	60 [45]	8.8	10.4	9.5	21.000	-	-	-	175u3213	16	47
T5	75 [55]	6.5	8.5	7.0	26.000	-	-	-	175u3216	25	61
T5	100 [75]	4.2	6.2	5.5	36.000	-	-	-	175u3219	35	81

Table 7.13 T5, Vertical Braking 40% Duty Cycle

FC 302				Horizontal braking 10% duty cycle							
Adjustable frequency drive data				Brake resistor data						Installation	
				R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Danfoss part number				Cable cross-section [mm²]	Thermo relay [A]
Line power type	P_m (hp [kW])	R_{min} [Ω]	$R_{br.nom}$ [Ω]			Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20		
T6	1.0 [0.75]	620	914.2	850	0.100	175u3001	-	-	-	1.5	0.4
T6	1.5 [1.1]	550	611.3	570	0.100	175u3003	-	-	-	1.5	0.4
T6	2 [1.5]	380	441.9	415	0.200	175u3005	-	-	-	1.5	0.7
T6	3 [2.2]	260	296.4	270	0.200	175u3007	-	-	-	1.5	0.8
T6	4 [3]	189	214.8	200	0.300	175u3342	-	-	-	1.5	1.1
T6	5 [4]	135	159.2	145	0.450	175u3343	175u3012	175u3013	-	1.5	1.7
T6	7.5 [5.5]	99.0	114.5	100	0.570	175u3344	175u3136	175u3137	-	1.5	2.3
T6	10 [7.5]	69.0	83.2	72	0.680	175u3345	175u3456	175u3455	-	1.5	2.9
T6	15 [11]	48.6	56.1	52	1.130	175u3346	175u3458	175u3457	-	1.5	4.4
T6	20 [15]	35.1	40.8	38	1.400	175u3347	175u3460	175u3459	-	1.5	5.7
T6	25 [18.5]	27.0	32.9	31	1.700	175u3348	175u3037	175u3038	-	1.5	7
T6	30 [22]	22.5	27.6	27	2.200	175u3349	175u3043	175u3044	-	1.5	8.5
T6	40 [30]	17.1	21.4	19	2.800	175u3350	175u3462	175u3461	-	2.5	11.4
T6	50 [37]	13.5	17.3	14	3.200	175u3358	175u3464	175u3463	-	2.5	14.2
T6	60 [45]	10.8	14.2	13.5	4.200	-	175u3057	175u3058	-	4	17
T6	75 [55]	8.8	11.6	11	5.500	-	175u3063	175u3064	-	6	21
T6	100 [75]	6.6	8.4	7.0	7.000	-	-	-	175u3245	10	32

Table 7.14 T6, Horizontal Braking 10% Duty Cycle

FC 302				Vertical braking 40% duty cycle							
Adjustable frequency drive data				Brake resistor data						Installation	
						Danfoss part number				Cable cross-section [mm²]	Thermo relay [A]
Line power type	P_m (hp [kW])	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20		
T6	1.0 [0.75]	620	914.2	850	0.280	175u3317	175u3104	175u3105	-	1.5	0.6
T6	1.5 [1.1]	550	611.3	570	0.450	175u3318	175u3430	175u3429	-	1.5	0.9
T6	2 [1.5]	380	441.9	415	0.570	175u3319	175u3432	175u3431	-	1.5	1.1
T6	3 [2.2]	260	296.4	270	0.960	175u3320	175u3434	175u3433	-	1.5	1.8
T6	4 [3]	189	214.8	200	1.130	175u3321	175u3436	175u3435	-	1.5	2.3
T6	5 [4]	135	159.2	145	1.700	175u3322	175u3126	175u3127	-	1.5	3.3
T6	7.5 [5.5]	99.0	114.5	100	2.200	175u3323	175u3438	175u3437	-	1.5	4.4
T6	10 [7.5]	69.0	83.2	72	3.200	175u3324	175u3440	175u3439	-	1.5	6.3
T6	15 [11]	48.6	56.1	52	5.500	-	175u3148	175u3149	-	1.5	9.7
T6	20 [15]	35.1	40.8	38	6.000	-	-	-	175u3239	2.5	12.6
T6	25 [18.5]	27.0	32.9	31	8.000	-	-	-	175u3240	4	16
T6	30 [22]	22.5	27.6	27	10.000	-	-	-	175u3200	4	19
T6	40 [30]	17.1	21.4	19	14.000	-	-	-	175u3204	10	27
T6	50 [37]	13.5	17.3	14	17.000	-	-	-	175u3207	10	35
T6	60 [45]	10.8	14.2	13.5	21.000	-	-	-	175u3208	16	40
T6	75 [55]	8.8	11.6	11	26.000	-	-	-	175u3211	25	49
T6	100 [75]	6.6	8.4	7.0	30.000	-	-	-	175u3241	35	66

Table 7.15 T6, Vertical Braking 40% Duty Cycle

FC 302				Vertical braking 40% duty cycle							
Adjustable frequency drive data				Brake resistor data						Installation	
						Danfoss part number					
Line power type	P_m (hp [kW])	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont.}$ [kW]	Wire IP54	Screw terminal IP21	Screw terminal IP65	Bolt connection IP20	Cable cross-section [mm^2]	Thermo relay [A]
T7	1.5 [1.1]	620	830	630	0.360	-	175u3108	175u3109	-	1.5	0.8
T7	2 [1.5]	513	600	570	0.570	-	175u3110	175u3111	-	1.5	1
T7	3 [2.2]	340	403	415	0.790	-	175u3112	175u3113	-	1.5	1.3
T7	4 [3]	243	292	270	1.130	-	175u3118	175u3119	-	1.5	2
T7	5 [4]	180	216	200	1.700	-	175u3122	175u3123	-	1.5	2.8
T7	7.5 [5.5]	130	156	145	2.200	-	175u3106	175u3107	-	1.5	3.7
T7	10 [7.5]	94	113	105	3.200	-	175u3132	175u3133	-	1.5	5.2
T7	15 [11]	69.7	76.2	72	4.200	-	175u3142	175u3143	-	1.5	7.2
T7	20 [15]	46.8	55.5	52	6.000	-	-	-	175u3242	2.5	10.8
T7	25 [18.5]	36.0	44.7	42	8.000	-	-	-	175u3243	2.5	13.9
T7	30 [22]	29.0	37.5	31	10.000	-	-	-	175u3244	4	18
T7	40 [30]	22.5	29.1	27	14.000	-	-	-	175u3201	10	23
T7	50 [37]	18.0	23.5	22	17.000	-	-	-	175u3202	10	28
T7	60 [45]	13.5	19.3	15.5	21.000	-	-	-	175u3205	16	37
T7	75 [55]	13.5	15.7	13.5	26.000	-	-	-	175u3209	16	44
T7	100 [75]	8.8	11.5	11	36.000	-	-	-	175u3212	25	57

Table 7.16 T7, Vertical Braking 40% Duty Cycle

Horizontal braking: Duty cycle 10% and maximum 120 s repetition rates according the reference brake profile. Average power corresponds to 6%.
Vertical braking: Duty cycle 40% and maximum 120 s repetition rates according the reference brake profile. Average power corresponds to 27%.
Cable cross-section: Recommended min. value based upon PVC-insulated copper cable, 86°F [30 °C] ambient temperature with normal heat dissipation.
All cabling must comply with national and local regulations on cable cross-sections and ambient temperature.
Thermal relay: Brake current setting of external thermal relay. All resistors have a built-in thermal relay switch N.C.
The IP54 is equipped with a 39 in [1,000 mm] fixed non-shielded cable. Vertical and horizontal mounting. Derating required by horizontal mounting.
IP21 & IP65 are with screw terminal for cable termination. Vertical and horizontal mounting. Derating required by horizontal mounting.
The IP20 is with bolt connection for cable termination. Floor mounting.

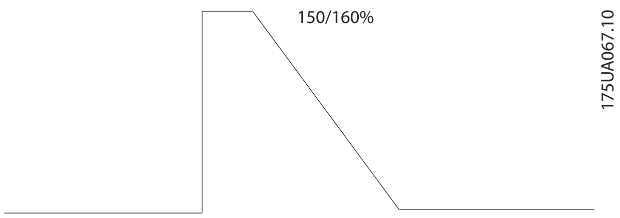


Figure 7.2 Horizontal Loads

Figure 7.3 Vertical Loads

7.2.6 Other Flat Pack Brake Resistors

FC 301	P_m	R_{min}	$R_{br, nom}$	Flat pack IP65 for horizontal conveyors		
				R_{rec} per item	Duty cycle	Ordering no.
T2	(hp [kW])	[Ω]	[Ω]	[Ω//W]	[%]	175Uxxxx
PK25	0.37 [0.25]	368	416	430/100	40	1002
PK37	0.5 [0.37]	248	281	330/100 or 310/200	27 or 55	1003 or 0984
PK55	0.75 [0.55]	166	189	220/100 or 210/200	20 or 37	1004 or 0987
PK75	1.0 [0.75]	121	138	150/100 or 150/200	14 or 27	1005 or 0989
P1K1	1.5 [1.1]	81.0	92	100/100 or 100/200	10 or 19	1006 or 0991
P1K5	2 [1.5]	58.5	66.5	72/200	14	0992
P2K2	3 [2.2]	40.2	44.6	50/200	10	0993
P3K0	4 [3]	29.1	32.3	35/200 or 72/200	7 14	0994 or 2 x 0992
P3K7	5 [3.7]	22.5	25.9	60/200	11	2 x 0996

Table 7.17 Other Flat Packs for Adjustable Frequency Drives with Line Power Supply FC 301 Line Power: 200–240 V (T2)

FC 302	P_m	R_{min}	$R_{br. nom}$	Flat pack IP65 for horizontal conveyors		
				R_{rec} per item	Duty cycle	Ordering no.
T2	(hp [kW])	[Ω]	[Ω]	[Ω/W]	[%]	175Uxxxx
PK25	0.37 [0.25]	380	475	430/100	40	1002
PK37	5 [0.37]	275	321	330/100 or 310/200	27 or 55	1003 or 0984
PK55	0.75 [0.55]	188	216	220/100 or 210/200	20 or 37	1004 or 0987
PK75	1 [0.75]	130	158	150/100 or 150/200	14 or 27	1005 or 0989
P1K1	1.5 [1.1]	81.0	105.1	100/100 or 100/200	10 or 19	1006 or 0991
P1K5	2 [1.5]	58.5	76.0	72/200	14	0992
P2K2	3 [2.2]	45.0	51.0	50/200	10	0993
P3K0	4 [3]	31.5	37.0	35/200 or 72/200	7 or 14	0994 or 2 x 0992
P3K7	5 [3.7]	22.5	29.7	60/200	11	2 x 0996

Table 7.18 Other Flat Packs for Adjustable Frequency Drives with Line Power Supply FC 302 Line Power: 200–240 V (T2)

FC 301	P_m	R_{min}	$R_{br. nom}$	Flat pack IP65 for horizontal conveyors		
				R_{rec} per item	Duty cycle	Ordering no.
T4	(hp [kW])	[Ω]	[Ω]	[Ω/W]	[%]	175Uxxxx
PK37	0.37	620	1121	830/100	30	1000
PK55	0.75 [0.55]	620	750	830/100	20	1000
PK75	1 [0.75]	485	548	620/100 or 620/200	14 or 27	1001 or 0982
P1K1	1.5 [1.1]	329	365	430/100 or 430/200	10 or 20	1002 or 0983
P1K5	2 [1.5]	240.0	263.0	310/200	14	0984
P2K2	3 [2.2]	161.0	176.5	210/200	10	0987
P3K0	4 [3]	117.0	127.9	150/200 or 300/200	7 or 14	0989 or 2 x 0985
P4K0	5 [4]	87	95	240/200	10	2 x 0986
P5K5	7.5 [5.5]	63	68	160/200	8	2 x 0988
P7K5	10 [7.5]	45	50	130/200	6	2 x 0990
P11K	15 [11]	34.9	38.0	80/240	5	2 x 0090
P15K	20 [15]	25.3	27.7	72/240	4	2 x 0091

Table 7.19 Other Flat Packs for Adjustable Frequency Drives with Line Power Supply FC 301 Line Power: 380–480 V (T4)

FC 302	P_m	R_{min}	$R_{br. nom}$	Flat pack IP65 for horizontal conveyors		
				R_{rec} per item	Duty cycle	Ordering no.
T5	(hp [kW])	[Ω]	[Ω]	[Ω/W]	[%]	175Uxxxx
PK37	5 [0.37]	620	1389	830/100	30	1000
PK55	0.75 [0.55]	620	929	830/100	20	1000
PK75	1 [0.75]	558	678	620/100 or 620/200	14 or 27	1001 or 0982
P1K1	1.5 [1.1]	382	453	430/100 or 430/200	10 or 20	1002 or 0983
P1K5	2 [1.5]	260.0	325.9	310/200	14	0984
P2K2	3 [2.2]	189.0	218.6	210/200	10	0987
P3K0	4 [3]	135.0	158.5	150/200 or 300/200	7 or 14	0989 or 2 x 0985
P4K0	5 [4]	99	117	240/200	10	2 x 0986
P5K5	7.5 [5.5]	72	84	160/200	8	2 x 0988
P7K5	10 [7.5]	50	61	130/200	6	2 x 0990
P11K	15 [11]	36.0	41.2	80/240	5	2 x 0090
P15K	20 [15]	27.0	30.0	72/240	4	2 x 0091

Table 7.20 Other Flat Packs for Adjustable Frequency Drives with Line Power Supply FC 302 Line Power: 380–500 V (T5)

IP65 is a flat-pack type with fixed cable.

7.2.7 Harmonic Filters

Harmonic filters are used to reduce line harmonics.

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

Cooling and ventilation
IP20: Cooled by natural convection or with built-in fans. IP00: Additional forced cooling is required. Secure sufficient airflow through the filter during installation to prevent overheating of the filter. Airflow of minimum 2 m/s is required through the filter.

Power and current ratings		Typical motor	Filter current rating 50 Hz	Ordering no. AHF 005		Ordering no. AHF 010	
[kW]	[A]	(hp [kW])	[A]	IP00	IP20	IP00	IP20
PK37-P4K0	1.2–9	4 [3]	10	130B1392	130B1229	130B1262	130B1027
P5K5-P7K5	14.4	10 [7.5]	14	130B1393	130B1231	130B1263	130B1058
P11K	22	15 [11]	22	130B1394	130B1232	130B1268	130B1059
P15K	29	20 [15]	29	130B1395	130B1233	130B1270	130B1089
P18K	34	25 [18.5]	34	130B1396	130B1238	130B1273	130B1094
P22K	40	30 [22]	40	130B1397	130B1239	130B1274	130B1111
P30K	55	40 [30]	55	130B1398	130B1240	130B1275	130B1176
P37K	66	50 [37]	66	130B1399	130B1241	130B1281	130B1180
P45K	82	60 [45]	82	130B1442	130B1247	130B1291	130B1201
P55K	96	75 [55]	96	130B1443	130B1248	130B1292	130B1204
P75K	133	100 [75]	133	130B1444	130B1249	130B1293	130B1207

Table 7.21 Harmonic Filters for 380–415 V, 50 Hz

Power and current ratings		Typical motor	Filter current rating 60 Hz	Ordering no. AHF 005		Ordering no. AHF 010	
[kW]	[A]	(hp [kW])	[A]	IP00	IP20	IP00	IP20
PK37-P4K0	1.2–9	4 [3]	10	130B3095	130B2857	130B2874	130B2262
P5K5-P7K5	14.4	10 [7.5]	14	130B3096	130B2858	130B2875	130B2265
P11K	22	15 [11]	22	130B3097	130B2859	130B2876	130B2268
P15K	29	20 [15]	29	130B3098	130B2860	130B2877	130B2294
P18K	34	25 [18.5]	34	130B3099	130B2861	130B3000	130B2297
P22K	40	30 [22]	40	130B3124	130B2862	130B3083	130B2303
P30K	55	40 [30]	55	130B3125	130B2863	130B3084	130B2445
P37K	66	50 [37]	66	130B3026	130B2864	130B3085	130B2459
P45K	82	60 [45]	82	130B3127	130B2865	130B3086	130B2488
P55K	96	75 [55]	96	130B3128	130B2866	130B3087	130B2489
P75K	133	100 [75]	133	130B3129	130B2867	130B3088	130B2498

Table 7.22 Harmonic Filters for 380–415 V, 60 Hz

Power and current ratings		Typical motor	Filter current rating 60 Hz	Ordering no. AHF 005		Ordering no. AHF 010	
[kW]	[A]	(hp [kW])	[A]	IP00	IP20	IP00	IP20
PK37-P4K0	1–7.4	4 [3]	10	130B1787	130B1752	130B1770	130B1482
P5K5-P7K5	9.9+13	10 [7.5]	14	130B1788	130B1753	130B1771	130B1483
P11K	19	15 [11]	19	130B1789	130B1754	130B1772	130B1484
P15K	25	20 [15]	25	130B1790	130B1755	130B1773	130B1485
P18K	31	25 [18.5]	31	130B1791	130B1756	130B1774	130B1486
P22K	36	30 [22]	36	130B1792	130B1757	130B1775	130B1487
P30K	47	40 [30]	48	130B1793	130B1758	130B1776	130B1488
P37K	59	50 [37]	60	130B1794	130B1759	130B1777	130B1491
P45K	73	60 [45]	73	130B1795	130B1760	130B1778	130B1492
P55K	95	75 [55]	95	130B1796	130B1761	130B1779	130B1493
P75K	118	100 [75]	118	130B1797	130B1762	130B1780	130B1494

Table 7.23 Harmonic Filters for 440–480 V, 60 Hz

7

Power and current ratings		Typical motor	Filter current rating 60 Hz	Ordering no. AHF 005		Ordering no. AHF 010	
[kW]	[A]	(hp [kW])	[A]	IP00	IP20	IP00	IP20
P11K	15	13.5 [10]	15	130B5261	130B5246	130B5229	130B5212
P15K	19	22 [16.4]	20	130B5262	130B5247	130B5230	130B5213
P18K	24	27 [20]	24	130B5263	130B5248	130B5231	130B5214
P22K	29	32 [24]	29	130B5263	130B5248	130B5231	130B5214
P30K	36	44 [33]	36	130B5265	130B5250	130B5233	130B5216
P37K	49	54 [40]	50	130B5266	130B5251	130B5234	130B5217
P45K	58	67 [50]	58	130B5267	130B5252	130B5235	130B5218
P55K	74	80 [60]	77	130B5268	130B5253	130B5236	130B5219
P75K	85	100 [75]	87	130B5269	130B5254	130B5237	130B5220

Table 7.24 Harmonic Filters for 600 V, 60 Hz

Power and current ratings 500–550 V		Typical motor	Power and Current Ratings 551–690 V		Typical motor	Filter current rating 50 Hz	Ordering no. AHF 005		Ordering no. AHF 010	
[kW]	[A]	(hp [kW])	[kW]	[A]	(hp [kW])	[A]	IP00	IP20	IP00	IP20
P11K	15	10 [7.5]	P15K	16	20 [15]	15	130B5000	130B5088	130B5297	130B5280
P15K	19.5	15 [11]	P18K	20	25 [18.5]	20	130B5017	130B5089	130B5298	130B5281
P18K	24	20 [15]	P22K	25	30 [22]	24	130B5018	130B5090	130B5299	130B5282
P22K	29	25 [18.5]	P30K	31	40 [30]	29	130B5019	130B5092	130B5302	130B5283
P30K	36	30 [22]	P37K	38	50 [37]	36	130B5021	130B5125	130B5404	130B5284
P37K	49	40 [30]	P45K	48	60 [45]	50	130B5022	130B5144	130B5310	130B5285
P45K	59	50 [37]	P55K	57	75 [55]	58	130B5023	130B5168	130B5324	130B5286
P55K	71	60 [45]	P75K	76	100 [75]	77	130B5024	130B5169	130B5325	130B5287
P75K	89	75 [55]				87	130B5025	130B5170	130B5326	130B5288

Table 7.25 Harmonic Filters for 500–690 V, 50 Hz

7.2.8 Sine-Wave Filters

Adjustable frequency drive power and current ratings						Filter current rating			Switching frequency	Ordering no.	
200–240 V		380–440 V		441–500 V		50 Hz	60 Hz	100 Hz		IP00	IP20/23[1)]
(hp [kW])	[A]	(hp [kW])	[A]	(hp [kW])	[A]	[A]	[A]	[A]	[kHz]		
-	-	0.5 [0.37]	1.3	0.5 [0.37]	1.1	2.5	2.5	2	5	130B2404	130B2439
0.34 [0.25]	1.8	0.75 [0.55]	1.8	0.75 [0.55]	1.6						
0.5 [0.37]	2.4	1 [0.75]	2.4	1 [0.75]	2.1						
		1.5 [1.1]	3	1.5 [1.1]	3	4.5	4	3.5	5	130B2406	130B2441
0.75 [0.55]	3.5	2 [1.5]	4.1	2 [1.5]	3.4						
1 [0.75]	4.6	3 [2.2]	5.6	3 [2.2]	4.8	8	7.5	5.5	5	130B2408	130B2443
1.5 [1.1]	6.6	4 [3]	7.2	4 [3]	6.3						
2 [1.5]	7.5	-	-	-	-						
-	-	5 [4]	10	5 [4]	8.2	10	9.5	7.5	5	130B2409	130B2444
3 [2.2]	10.6	7.5 [5.5]	13	7.5 [5.5]	11	17	16	13	5	130B2411	130B2446
4 [3]	12.5	10 [7.5]	16	10 [7.5]	14.5						
5 [3.7]	16.7	-	-	-	-						
7.5 [5.5]	24.2	15 [11]	24	15 [11]	21	24	23	18	4	130B2412	130B2447
10 [7.5]	30.8	20 [15]	32	20 [15]	27	38	36	28.5	4	130B2413	130B2448
		25 [18.5]	37.5	25 [18.5]	34						
15 [11]	46.2	30 [22]	44	30 [22]	40	48	45.5	36	4	130B2281	130B2307
20 [15]	59.4	40 [30]	61	40 [30]	52	62	59	46.5	3	130B2282	130B2308
25 [18.5]	74.8	50 [37]	73	50 [37]	65	75	71	56	3	130B2283	130B2309
30 [22]	88	60 [45]	90	75 [55]	80	115	109	86	3	130B3179	130B3181*
40 [30]	115	75 [55]	106	100 [75]	105						
50 [37]	143	100 [75]	147	125 [90]	130	180	170	135	3	130B3182	130B3183*
60 [45]	170	125 [90]	177								

Table 7.26 Sine-Wave Filters for Adjustable Frequency Drives with 380–500 V

*1) Ordering numbers marked with * are IP23.*

Adjustable frequency drive power and current ratings						Filter current rating			Switching frequency	Ordering no.	
525–600 V		690 V		525–550 V		50 Hz	60 Hz	100 Hz		IP00	IP20/23[1]
(hp [kW])	[A]	(hp [kW])	[A]	(hp [kW])	[A]	[A]	[A]	[A]	kHz		
1 [0.75]	1.7	1.5 [1.1]	1.6	-	-	4.5	4	3	4	130B7335	130B7356
1.5 [1.1]	2.4	2 [1.5]	2.2								
2 [1.5]	2.7	3 [2.2]	3.2								
3 [2.2]	3.9	4 [3.0]	4.5								
4 [3]	4.9	5 [4.0]	5.5	-	-	10	9	7	4	130B7289	130B7324
5 [4]	6.1	7.5 [5.5]	7.5								
7.5 [5.5]	9	10 [7.5]	10								
10 [7.5]	11	15 [11]	13	10 [7.5]	14	13	12	9	3	130B3195	130B3196
15 [11]	18	20 [15]	18	15 [11]	19	28	26	21	3	130B4112	130B4113
20 [15]	22	25 [18.5]	22	20 [15]	23						
25 [18.5]	27	30 [22]	27	24 [18]	28						
30 [22]	34	40 [30]	34	30 [22]	36	45	42	33	3	130B4114	130B4115
40 [30]	41	50 [37]	41	40 [30]	48						
50 [37]	52	60 [45]	52	50 [37]	54	76	72	57	3	130B4116	130B4117*
60 [45]	62	75 [55]	62	60 [45]	65						
75 [55]	83	60 [45]	83	75 [55]	87	115	109	86	3	130B4118	130B4119*
100 [75]	100	125 [90]	100	100 [75]	105						
125 [90]	131	-	-	125 [90]	137	165	156	124	2	130B4121	130B4124*

Table 7.27 Sine-Wave Filters for Adjustable Frequency Drives with 525–690 V

*1) Ordering numbers marked with * are IP23.*

Parameter	Setting
14-00 Switching Pattern	[1] SFAVM
14-01 Switching Frequency	Set according the individual filter. Listed at filter product label and in output filter manual. Sine-wave filters do not allow lower switching frequency than specified by the individual filter.
14-55 Output Filter	[2] Sine-Wave Filter Fixed
14-56 Capacitance Output Filter	Set according to the individual filter. Listed at filter product label and in output filter manual (only required for FLUX operation).
14-57 Inductance Output Filter	Set according to the individual filter. Listed at filter product label and in output filter manual (only required for FLUX operation).

Table 7.28 Parameter Settings for Sine-Wave Filter Operation

7.2.9 dU/dt Filters

Adjustable frequency drive ratings [V]										Filter current rating [V]				Ordering no.		
200–240		380–440		441–500		525–550		551–690		380@60 Hz 200–400/ 440@50 Hz	460/480 @60 Hz 500/525 @50 Hz	575/600 @60 Hz	690 @50 Hz	IP00	IP20*	IP54
(hp [kW])	[A]	(hp [kW])	[A]	(hp [kW])	[A]	(hp [kW])	[A]	(hp [kW])	[A]	[A]	[A]	[A]	[A]			
4 [3]	12.5	7.5 [5.5]	13	7.5 [5.5]	11	7.5 [5.5]	9.5	1.5 [1.1]	1.6	17	15	13	10	N/A	130B7367*	N/A
5 [3.7]	16	10 [7.5]	16	10 [7.5]	14.5	10 [7.5]	11.5	2 [1.5]	2.2							
-	-	-	-	-	-	-	-	3 [2.2]	3.2							
								4 [3]	4.5							
								5 [4]	5.5							
								7.5 [5.5]	7.5							
								10 [7.5]	10							
7.5 [5.5]	24.2	15 [11]	24	15 [11]	21	10 [7.5]	14	15 [11]	13	44	40	32	27	130B2835	130B2836	130B2837
10 [7.5]	30.8	20 [15]	32	20 [15]	27	15 [11]	19	20 [15]	18							
-	-	25 [18.5]	37.5	25 [18.5]	34	20 [15]	23	25 [18.5]	22							
-	-	30 [22]	44	30 [22]	40	25 [18.5]	28	30 [22]	27							
15 [11]	46.2	40 [30]	61	40 [30]	52	40 [30]	43	40 [30]	34	90	80	58	54	130B2838	130B2839	130B2840
20 [15]	59.4	50 [37]	73	50 [37]	65	50 [37]	54	50 [37]	41							
25 [18.5]	74.8	60 [45]	90	7.5 [55]	80	60 [45]	65	60 [45]	52							
30 [22]	88	-	-	-	-	-	-	-	-							
-	-	75 [55]	106	100 [75]	105	75 [55]	87	75 [55]	62	106	105	94	86	103B2841	103B2842	103B2843
-	-							75 [55]	83							
40 [30]	115	75 [55]	147	125 [90]	130	75 [55]	113	125 [90]	108	177	160	131	108	130B2844	130B2845	130B2846
50 [37]	143	125 [90]	177	-	-	125 [90]	137	-	-							
45	170	-	-	-	-	-	-	-	-							

* Dedicated A3 enclosure types supporting foot print mounting and book style mounting. Fixed shielded cable connection to adjustable frequency drive.

Table 7.29 dU/dt Filters for 200–690 V

7

Parameter	Setting
14-01 Switching Frequency	Higher operating switching frequency than specified by the individual filter is not recommended.
14-55 Output Filter	[0] No Filter
14-56 Capacitance Output Filter	Not used
14-57 Inductance Output Filter	Not used

Table 7.30 Parameter Settings for dU/dt Filter Operation

8 Mechanical Installation

8.1 Safety

See *chapter 2 Safety* for general safety instructions.

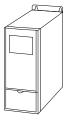
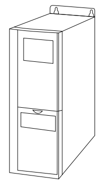
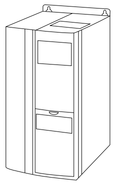
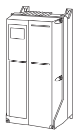
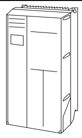
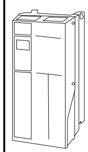
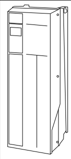
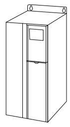
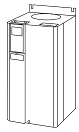
WARNING

Pay attention to the requirements that apply to integration and the field mounting kit. Observe the information in the list to avoid serious injury or equipment damage, especially when installing large units.

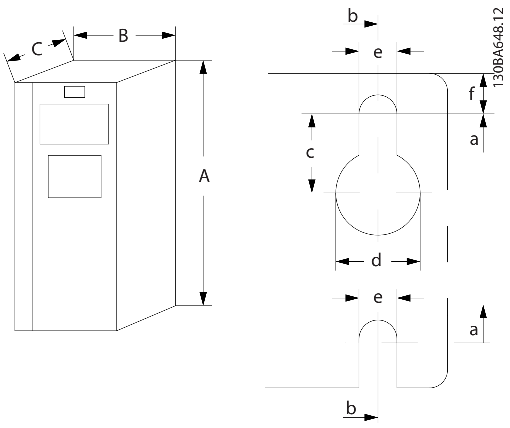
NOTICE!

The adjustable frequency drive is cooled by 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 adjustable frequency drive and that the 24-hour average temperature is NOT exceeded. Locate the maximum temperature in *chapter 6.2.3 Ambient Conditions*.
The 24-hour average temperature 9°F is [5°C] below the maximum temperature.

8.2 Mechanical Dimensions

Enclosure Type			A1	A2		A3		A4	A5	B1	B2	B3	B4
Power [kW]	**200–240 V**		**0.25–1.5**	**0.25–2.2**		**3–3.7**		**0.25–2.2**	**0.25–3.7**	**5.5–7.5**	**11**	**5.5–7.5**	**11–15**
	380–480/ 500 V		**0.37–1.5**	**0.37–4.0**		**5.5–7.5**		**0.37–4**	**0.37–7.5**	**11–15**	**18.5–22**	**11–15**	**18.5–30**
	525–600 V					**0.75–7.5**			**0.75–7.5**	**11–15**	**18.5–22**	**11–15**	**18.5–30**
	525–690 V					**1.1–7.5**					**11–22**		**11–30**
Figures			 130BA870.10	 130BA809.10		 130BA810.10		 130BB458.10	 130BA811.10	 130BA812.10	 130BA813.10	 130BA826.10	 130BA827.10
IP			20	20	21	20	21	55/66	55/66	21/55/66	21/55/66	20	20
NEMA			Chassis	Chassis	Type 1	Chassis	Type 1	Type 12/4X	Type 12/4X	Type 1/12/4X	Type 1/12/4X	Chassis	Chassis
Height (in [mm])													
Height of backplate		A	7.87 [200]	10.55 [268]	14.76 [375]	10.55 [268]	14.76 [375]	15.35 [390]	16.54 [420]	18.9 [480]	15.59 [650]	15.71 [399]	20.47 [520]
Height with decoupling plate for serial communication bus cables		A	12.44 [316]	14.72 [374]	-	14.72 [374]	-	-	-	-	-	16.54 [420]	23.43 [595]
Distance between mounting holes		a	7.48 [190]	10.12 [257]	13.78 [350]	10.12 [257]	13.78 [350]	15.79 [401]	15.83 [402]	17.87 [454]	24.57 [624]	14.96 [380]	19.49 [495]
Width (in [mm])													
Width of backplate		B	2.95 [75]	3.54 [90]	3.54 [90]	5.12 [130]	5.12 [130]	7.87 [200]	9.53 [242]	9.53 [242]	9.53 [242]	6.5 [165]	9.06 [230]
Width of backplate with one C option		B	-	5.12 [130]	5.12 [130]	6.69 [170]	6.69 [170]	-	9.53 [242]	9.53 [242]	9.53 [242]	8.07 [205]	9.06 [230]
Width of backplate with two C options		B	-	5.91 [150]	5.91 [150]	7.48 [190]	7.48 [190]	-	9.53 [242]	9.53 [242]	9.53 [242]	8.86 [225]	9.06 [230]
Distance between mounting holes		b	2.36 [60]	2.76 [70]	2.76 [70]	4.33 [110]	4.33 [110]	6.73 [171]	8.47 [215]	8.27 [210]	8.27 [210]	5.51 [140]	7.87 [200]
Depth (in [mm])													
Depth without option A/B		C	8.15 [207]	8.07 [205]	8.15 [207]	8.07 [205]	8.15 [207]	6.89 [175]	7.87 [200]	10.24 [260]	10.24 [260]	9.8 [249]	9.53 [242]
With option A/B		C	8.74 [222]	8.66 [220]	8.74 [222]	8.66 [220]	8.74 [222]	6.89 [175]	7.87 [200]	10.24 [260]	10.24 [260]	10.32 [262]	9.53 [242]
Screw holes (in [mm])													
		c	0.24 [6.0]	0.32 [8.0]	0.32 [8.0]	0.32 [8.0]	0.32 [8.0]	0.33 [8.25]	0.33 [8.25]	0.47 [12]	0.47 [12]	0.32 [8]	-
		d	ø0.32 [ø8]	ø0.43 [ø11]	ø0.43 [ø11]	ø0.43 [ø11]	ø0.43 [ø11]	ø0.47 [ø12]	ø0.47 [ø12]	ø0.75 [ø19]	ø0.75 [ø19]	0.47 [12]	-
		e	ø0.2 [ø5]	ø0.22 [ø5.5]	ø0.22 [ø5.5]	ø0.22 [ø5.5]	ø0.22 [ø5.5]	ø0.26 [ø6.5]	ø0.26 [ø6.5]	ø0.35 [ø9]	ø0.35 [ø9]	0.27 [6.8]	0.34 [8.5]
		f	0.2 [5]	0.35 [9]	0.35 [9]	0.26 [6.5]	0.26 [6.5]	0.24 [6]	0.35 [9]	0.35 [9]	0.35 [9]	0.31 [7.9]	0.59 [15]
Max weight (lbs [kg])			6 [2.7]	10.8 [4.9]	11.7 [5.3]	14.6 [6.6]	15.4 [7.0]	21.4 [9.7]	29.8/31.3 [13.5/ 14.2]	50.7 [23]	59.5 [27]	26.5 [12]	51.8 [23.5]

Enclosure Type		A1	A2	A3	A4	A5	B1	B2	B3	B4
Power [kW]	**200–240 V**	**0.25–1.5**	**0.25–2.2**	**3–3.7**	**0.25–2.2**	**0.25–3.7**	**5.5–7.5**	**11**	**5.5–7.5**	**11–15**
	380–480/ 500 V	**0.37–1.5**	**0.37–4.0**	**5.5–7.5**	**0.37–4**	**0.37–7.5**	**11–15**	**18.5–22**	**11–15**	**18.5–30**
	525–600 V			**0.75–7.5**		**0.75–7.5**	**11–15**	**18.5–22**	**11–15**	**18.5–30**
	525–690 V			**1.1–7.5**				**11–22**		**11–30**
Front cover tightening torque [Nm]										
Plastic cover (low IP)		Click	Click	Click	-	-	Click	Click	Click	Click
Metal cover (IP55/66)		-	-	-	1.5	1.5	2.2	2.2	-	-



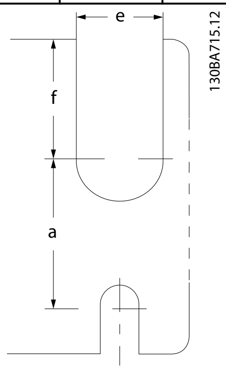
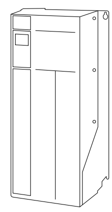
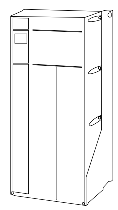
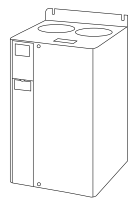
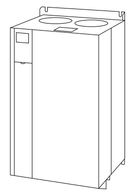
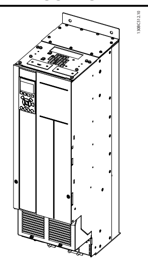
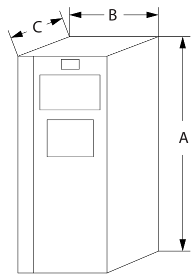


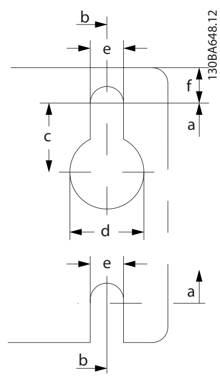
Figure 8.1 Top and Bottom Mounting Holes (B4, C3 and C4 only)

Table 8.1 Mechanical Dimensions, Enclosure Types A and B

8

Enclosure Type			C1	C2	C3	C4	D3h
Power [kW]	200–240 V		15–22	30–37	18.5–22	30–37	-
	380–480/500 V		30–45	55–75	37–45	55–75	-
	525–600 V		30–45	55–90	37–45	55–90	-
	525–690 V			30–75	37–45		55–75
Figures			 	 	 	 	
IP			21/55/66	21/55/66	20	20	20
NEMA			Type 1/12/4X	Type 1/12/4X	Chassis	Chassis	Chassis
Height (in [mm])							
Height of backplate		A	26.77 [680]	30.32 [770]	21.65 [550]	25.98 [660]	35.79 [909]
Height with decoupling plate for serial communication bus cables		A	-	-	24.8 [630]	31.5 [800]	-
Distance between mounting holes		a	25.5 [648]	29.1 [739]	20.51 [521]	24.84 [631]	-
Width (in [mm])							
Width of backplate		B	12.13 [308]	14.57 [370]	12.13 [308]	14.57 [370]	9.84 [250]
Width of backplate with one C option		B	12.13 [308]	14.57 [370]	12.13 [308]	14.57 [370]	-
Width of backplate with two C options		B	12.13 [308]	14.57 [370]	12.13 [308]	14.57 [370]	-
Distance between mounting holes		b	10.71 [272]	13.15 [334]	10.63 [270]	13 [330]	-
Depth (in [mm])							
Depth without option A/B		C	13 [310]	13.19 [335]	13.11 [333]	13.11 [333]	10.83 [275]
With option A/B		C	13 [310]	13.19 [335]	13.11 [333]	13.11 [333]	10.83 [275]
Screw holes (in [mm])							
		c	0.49 [12.5]	0.49 [12.5]	-	-	-
		d	ø0.75 [ø19]	ø0.75 [ø19]	-	-	-
		e	ø0.35 [ø9]	ø0.35 [ø9]	0.34 [8.5]	0.34 [8.5]	-
		f	0.39 [9.8]	0.39 [9.8]	0.67 [17]	0.67 [17]	-
Max weight (lbs [kg])			99.2 [45]	143.3 [65]	77.2 [35]	110.2 [50]	136.7 [62]
Front cover tightening torque [Nm]							
Plastic cover (low IP)			Click	Click	2.0	2.0	-
Metal cover (IP55/66)			2.2	2.2	2.0	2.0	-





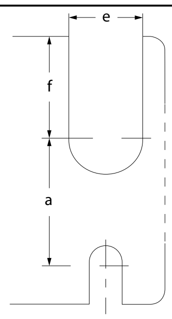


Figure 8.1 Top and Bottom Mounting Holes (B4, C3 and C4 only)

Table 8.2 Mechanical Dimensions, Enclosure Types C and D

NOTICE!

Accessory bags containing necessary brackets, screws and connectors are shipped with the adjustable frequency drives upon delivery.

8.2.1 Mechanical Mounting

8.2.1.1 Clearance

All enclosure types allow side-by-side installation except when an IP21/IP4X/TYPE 1 enclosure kit is used (see *chapter 11 Options and Accessories*).

Side-by-side mounting
IP20 A and B enclosure types can be arranged side-by-side with no clearance required between them, but the mounting order is important. *Figure 8.1* shows how to mount the frames correctly.

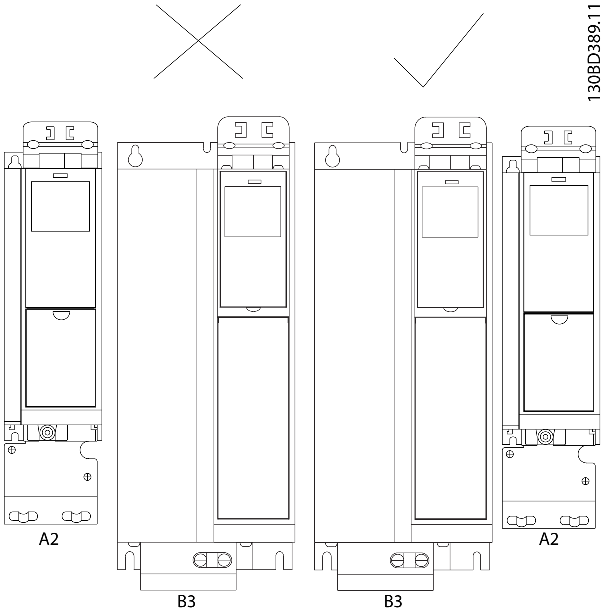


Figure 8.1 Correct Side-by-side Mounting

If the IP21 enclosure kit is used on enclosure types A1, A2 or A3, there must be a clearance between the adjustable frequency drives of min. 2 in [50 mm].

For optimal cooling conditions allow a free air passage above and below the adjustable frequency drive. See *Table 8.3*.

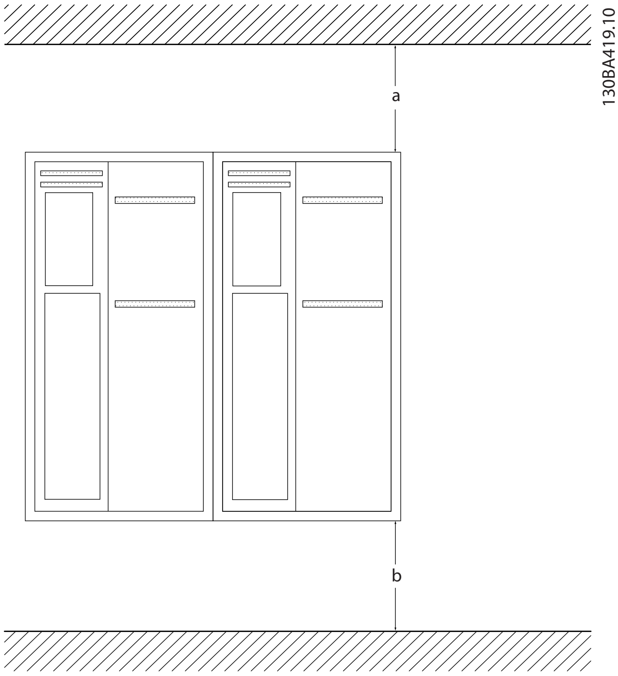


Figure 8.2 Clearance

Enclosure Type	A1*/A2/A3/A4/ A5/B1	B2/B3/B4/ C1/C3	C2/C4
a (ins [mm])	3.94 [100]	7.87 [200]	8.86 [225]
b (ins [mm])	3.94 [100]	7.87 [200]	8.86 [225]

Table 8.3 Air Passage for Different Enclosure Types

8.2.1.2 Wall Mounting

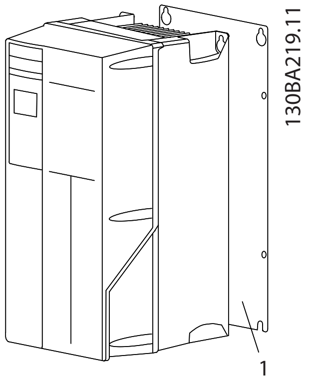
When mounting on a solid back wall, the installation is straight forward.

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

If the adjustable frequency drive is to be mounted on a non-solid back wall, provide the adjustable frequency drive with a backplate, “1”, due to insufficient cooling air over the heatsink.

NOTICE!

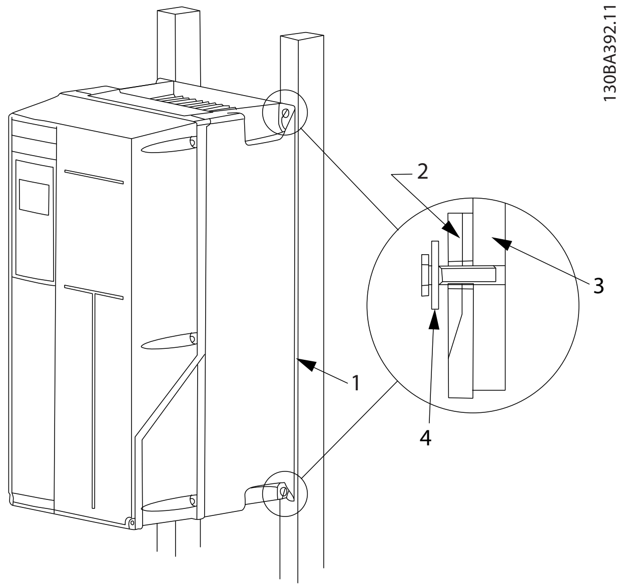
The backplate is relevant for A4, A5, B1, B2, C1 and C2 only.



1	Backplate

Figure 8.3 Mounting on a non-solid backwall requires a backplate

For adjustable frequency drives with IP66, take extra care to maintain the corrosive-resistant surface. A fiber washer or a nylon washer may be used to protect the epoxy coating.



1	Backplate
2	IP66 adjustable frequency drive
3	Base plate
4	Fiber washer

Figure 8.4 Mounting on a Non-solid Back Wall

9 Electrical Installation

9.1 Safety

See *chapter 2 Safety* for general safety instructions.

⚠WARNING

INDUCED VOLTAGE

Induced voltage from output motor cables that run together can charge equipment capacitors even with the equipment turned off and locked out. Failure to run output motor cables separately or use shielded cables or metal conduits could result in death or serious injury.

- **run output motor cables separately, or**
- **use shielded cables or metal conduits**

⚠CAUTION

SHOCK HAZARD

The adjustable frequency drive can cause a DC current in the PE conductor.

- **When a residual current-operated protective device (RCD) is used for protection against electrical shock, only an RCD of Type B is permitted on the supply side.**

Failure to follow the recommendation means the RCD may not provide the intended protection.

⚠WARNING

LEAKAGE CURRENT HAZARD

Leakage currents exceed 3.5 mA. Failure to ground the adjustable frequency drive properly could result in death or serious injury.

- **Ensure correct grounding of the equipment by a certified electrical installer.**

For electrical safety

- Ground the adjustable frequency drive in accordance with applicable standards and directives.
- Use a dedicated ground wire for input power, motor power and control wiring.
- Do not ground one adjustable frequency drive to another in a “daisy chain” fashion.
- Keep the ground wire connections as short as possible.
- Follow the motor manufacturer wiring requirements.
- Minimum cable cross-section: 10 mm^2 (or 2 rated ground wires terminated separately).

For EMC-compliant installation

- Establish electrical contact between cable shield and adjustable frequency drive enclosure by using metal cable connectors or by using the clamps provided on the equipment (see *chapter 9.4 Motor Connection*).
- Use high-strand wire to reduce electrical interference.
- Do not use pigtails.

NOTICE!

POTENTIAL EQUALIZATION

Risk of electrical interference, when the ground potential between the adjustable frequency drive and the system is different. Install equalizing cables between the system components. Recommended cable cross-section: 16 mm^2.

⚠WARNING

LEAKAGE CURRENT HAZARD

Leakage currents exceed 3.5 mA. Failure to ground the adjustable frequency drive properly could result in death or serious injury.

- **Ensure correct grounding of the equipment by a certified electrical installer.**

9

9.2 Cables

NOTICE!

Cables General

All cabling must comply with national and local regulations on cable cross-sections and ambient temperature. Copper (167 °F [75 °C]) conductors are recommended.

Aluminum Conductors

Terminals can accept aluminum conductors, but the conductor surface must 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 aluminum. It is crucial to keep the connection a gas-tight joint; otherwise, the aluminum surface will oxidize again.

9.2.1 Tightening Torque

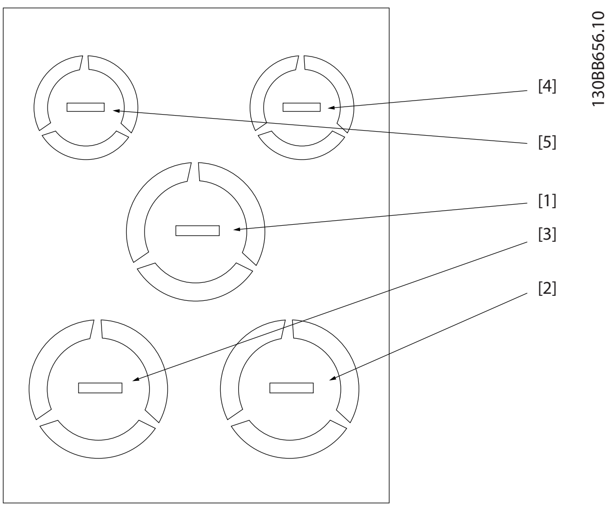
Enclosure Type	200–240 V (hp [kW])	380–500 V [kW]	525–690 V (hp [kW])	Cable for	Tightening-up torque [Nm]
A1	0.34–2 [0.25–1.5]	0.5–2 [0.37–1.5]	-	Line power, brake resistor, load sharing, motor cables	0.5–0.6
A2	0.34–3 [0.25–2.2]	0.5–5 [0.37–4]	-		
A3	4–5 [3–3.7]	7.5–10 [5.5–7.5]	1.5–10 [1.1–7.5]		
A4	0.34–3 [0.25–2.2]	0.5–5 [0.37–4]			
A5	4–5 [3–3.7]	7.5–10 [5.5–7.5]	-		
B1	7.5–10 [5.5–7.5]	15–20 [11–15]	-	Line power, brake resistor, load sharing, motor cables	1.8
				Relay	0.5–0.6
				Ground	2–3
B2	11	18.5–22	11–22	Line power, brake resistor, load sharing cables	4.5
				Motor cables	4.5
				Relay	0.5–0.6
				Ground	2–3
B3	7.5–10 [5.5–7.5]	15–20 [11–15]	-	Line power, brake resistor, load sharing, motor cables	1.8
				Relay	0.5–0.6
				Ground	2–3
B4	15–20 [11–15]	25–40 [18.5–30]	15–40 [11–30]	Line power, brake resistor, load sharing, motor cables	4.5
				Relay	0.5–0.6
				Ground	2–3
C1	20–30 [15–22]	40–60 [30–45]	-	Line power, brake resistor, load sharing cables	10
				Motor cables	10
				Relay	0.5–0.6
				Ground	2–3
C2	40–50 [30–37]	75–100 [55–75]	40–100 [30–75]	Line power, motor cables	14 (up to 95 mm^2) 24 (over 95 mm^2)
				Load sharing, brake cables	14
				Relay	0.5–0.6
				Ground	2–3
C3	25–30 [18.5–22]	40–50 [30–37]	50–60 [37–45]	Line power, brake resistor, load sharing, motor cables	10
				Relay	0.5–0.6
				Ground	2–3
C4	50–60 [37–45]	75–100 [55–75]	-	Line power, motor cables	14 (up to 95 mm^2) 24 (over 95 mm^2)
				Load sharing, brake cables	14
				Relay	0.5–0.6
				Ground	2–3

Table 9.1 Tightening Torque for Cables

9.2.2 Entry Holes

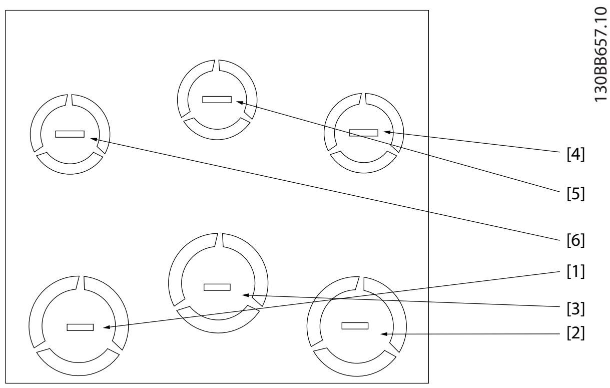
1. Remove the cable entry from the adjustable frequency drive (this prevents foreign parts from falling into the adjustable frequency drive when removing knockouts).
2. Cable entry has to be supported around the knockout to be removed.
3. The knockout can now be removed with a strong mandrel and a hammer.
4. Remove burrs from the hole.
5. Mount the cable entry on the adjustable frequency drive.

The suggested use of the holes are recommendations, but other solutions are possible. Unused cable entry holes can be sealed with rubber grommets (for IP21).



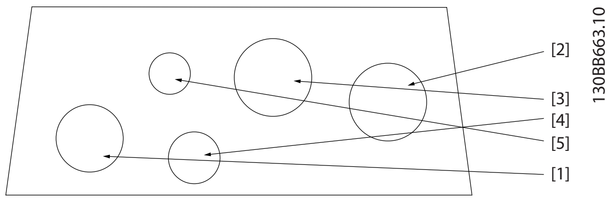
Hole number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Line power	3/4	28.4	M25
2) Motor	3/4	28.4	M25
3) Brake/load sharing	3/4	28.4	M25
4) Control cable	1/2	22.5	M20
5) Control cable	1/2	22.5	M20
[1] Tolerance ± 0.2 mm			

Figure 9.1 A2 - IP21



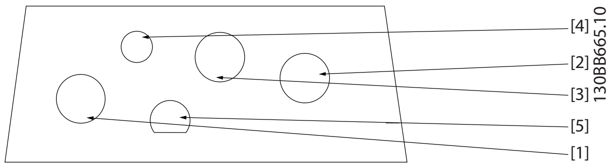
Hole number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Line power	3/4	28.4	M25
2) Motor	3/4	28.4	M25
3) Brake/load sharing	3/4	28.4	M25
4) Control cable	1/2	22.5	M20
5) Control cable	1/2	22.5	M20
6) Control cable	1/2	22.5	M20
[1] Tolerance ± 0.2 mm			

Figure 9.2 A3 - IP21



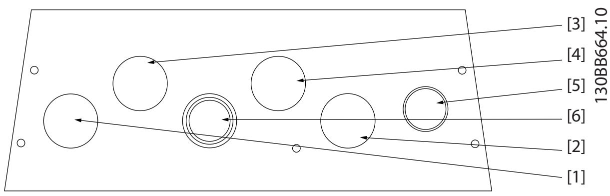
Hole number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Line power	3/4	28.4	M25
2) Motor	3/4	28.4	M25
3) Brake/load sharing	3/4	28.4	M25
4) Control cable	1/2	22.5	M20
5) Removed	-	-	-
[1] Tolerance ± 0.2 mm			

Figure 9.3 A4 - IP55



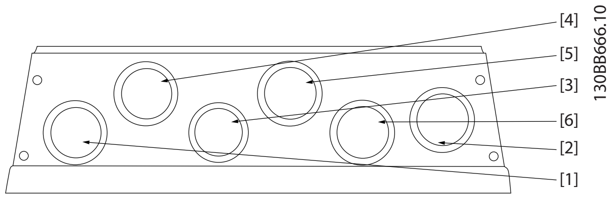
Hole number and recommended use	Nearest metric
1) Line power	M25
2) Motor	M25
3) Brake/load sharing	M25
4) Control cable	M16
5) Control cable	M20

Figure 9.4 A4 - IP55 Threaded Connector Holes



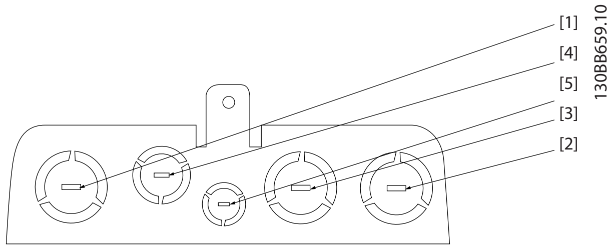
Hole number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Line power	3/4	28.4	M25
2) Motor	3/4	28.4	M25
3) Brake/load sharing	3/4	28.4	M25
4) Control cable	3/4	28.4	M25
5) Control cable[2]	3/4	28.4	M25
6) Control cable[2]	3/4	28.4	M25
[1] Tolerance ± 0.2 mm [2] Knockout hole			

Figure 9.5 A5 - IP55



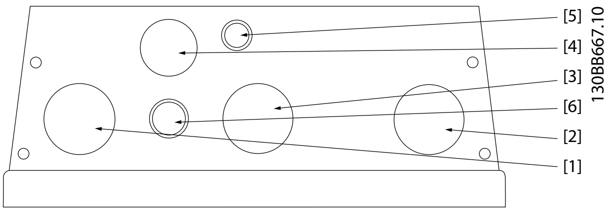
Hole number and recommended use	Nearest metric
1) Line power	M25
2) Motor	M25
3) Brake/load sharing	1.12 in [28.4 mm][1]
4) Control cable	M25
5) Control cable	M25
6) Control cable	M25
[1] Knockout hole	

Figure 9.6 A5- IP55 Threaded Connector Holes



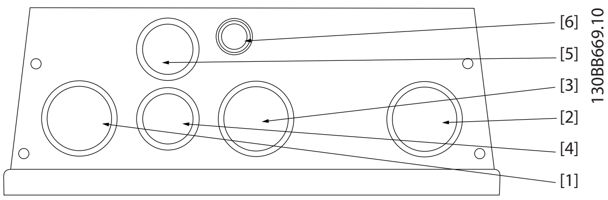
Hole number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Line power	1	34.7	M32
2) Motor	1	34.7	M32
3) Brake/load sharing	1	34.7	M32
4) Control cable	1	34.7	M32
5) Control cable	1/2	22.5	M20
[1] Tolerance ± 0.2 mm			

Figure 9.7 B1 - IP21



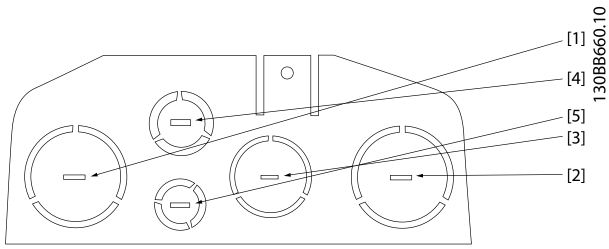
Hole number and recommended use	Dimensions1)		Nearest metric
	UL [in]	[mm]	
1) Line power	1	34.7	M32
2) Motor	1	34.7	M32
3) Brake/load sharing	1	34.7	M32
4) Control cable	3/4	28.4	M25
5) Control cable	1/2	22.5	M20
5) Control cable2)	1/2	22.5	M20
1) Tolerance ± 0.2 mm 2) Knockout hole			

Figure 9.8 B1 - IP55



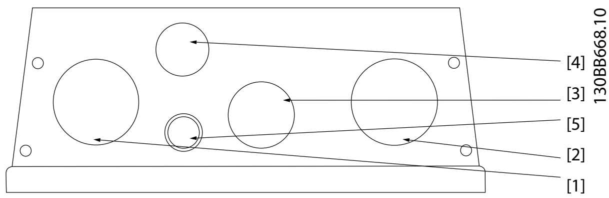
Hole number and recommended use	Nearest metric
1) Line power	M32
2) Motor	M32
3) Brake/load sharing	M32
4) Control cable	M25
5) Control cable	M25
6) Control cable	22.5 mm1)
1) Knockout hole	

Figure 9.9 B1 - IP55 Threaded Connector Holes



Hole number and recommended use	Dimensions1)		Nearest metric
	UL [in]	[mm]	
1) Line power	1 1/4	44.2	M40
2) Motor	1 1/4	44.2	M40
3) Brake/load sharing	1	34.7	M32
4) Control cable	3/4	28.4	M25
5) Control cable	1/2	22.5	M20
1) Tolerance ± 0.2 mm			

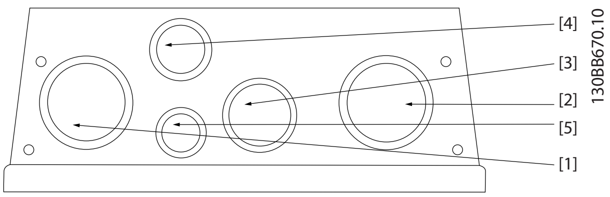
Figure 9.10 B2 - IP21



Hole number and recommended use	Dimensions1)		Nearest metric
	UL [in]	[mm]	
1) Line power	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 cable2)	1/2	22.5	M20
1) Tolerance ± 0.2 mm 2) Knockout hole			

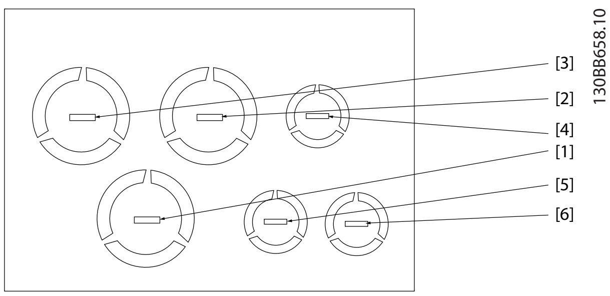
Figure 9.11 B2 - IP55

9



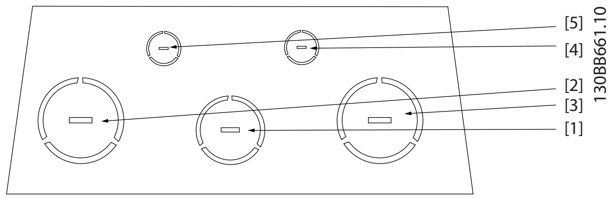
Hole number and recommended use	Nearest metric
1) Line power	M40
2) Motor	M40
3) Brake/load sharing	M32
4) Control cable	M25
5) Control cable	M20

Figure 9.12 B2 - IP55 Threaded Connector Holes



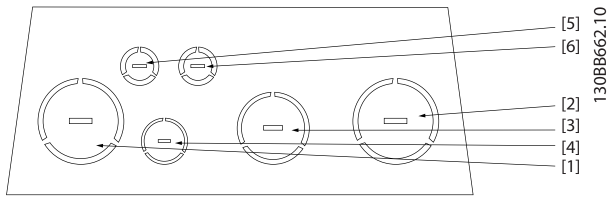
Hole number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Line power	1	34.7	M32
2) Motor	1	34.7	M32
3) Brake/load sharing	1	34.7	M32
4) Control cable	1/2	22.5	M20
5) Control cable	1/2	22.5	M20
6) Control cable	1/2	22.5	M20
[1] Tolerance ± 0.2 mm			

Figure 9.13 B3 - IP21



Hole number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Line power	2	63.3	M63
2) Motor	2	63.3	M63
3) Brake/load sharing	1 1/2	50.2	M50
4) Control cable	3/4	28.4	M25
5) Control cable	1/2	22.5	M20
[1] Tolerance ± 0.2 mm			

Figure 9.14 C1 - IP21



Hole number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	[mm]	
1) Line power	2	63.3	M63
2) Motor	2	63.3	M63
3) Brake/load sharing	1 1/2	50.2	M50
4) Control cable	3/4	28.4	M25
5) Control cable	1/2	22.5	M20
6) Control cable	1/2	22.5	M20
[1] Tolerance ±0.2 mm			

Figure 9.15 C2 - IP21

9.2.3 Tightening of the Cover after Connections are Made

Enclosure Type	IP20	IP21	IP55	IP66
A1	*	-	-	-
A2	*	*	-	-
A3	*	*	-	-
A4/A5	-	-	2	2
B1	-	*	2.2	2.2
B2	-	*	2.2	2.2
B3	*	-	-	-
B4	*	-	-	-
C1	-	*	2.2	2.2
C2	-	*	2.2	2.2
C3	2	-	-	-
C4	2	-	-	-
* = No screws to tighten - = Does not exist				

Table 9.2 Tightening of the Cover (Nm)

9.3 AC line input connections

It is mandatory to ground the AC line input connection properly using terminal 95 of the adjustable frequency drive, see *chapter 9.1.1 Grounding*.

The ground connection cable cross-section must be at least 10 mm^2 or 2 x rated line power wires terminated separately according to EN 50178.
Use non-shielded cable.

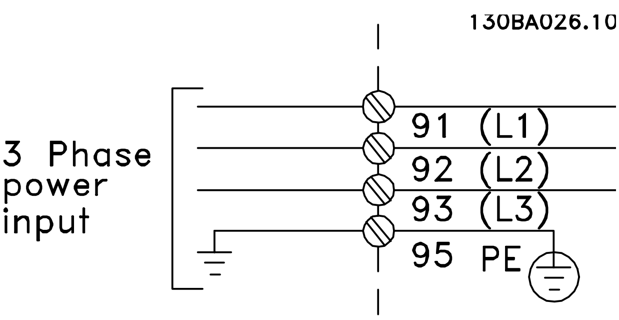


Figure 9.16 AC line input connections

NOTICE!

Using fuses and/or circuit breakers on the supply side is mandatory to ensure compliance with IEC 60364 for CE or NEC 2009 for UL, see *chapter 9.3.1.4 UL Compliance*.

NOTICE!

Exceeding 480 V RMS

RISK OF DAMAGE TO THE ADJUSTABLE FREQUENCY DRIVE WITH RFI FILTER INSTALLED

When installed on a delta-grounded grid or an IT grid (including ground fault condition), line input voltage in the range of 380–500 V (T4,T5) must not exceed 480 V RMS between line power and ground.

For some enclosures, the mounting is different if the adjustable frequency drive is configured from factory with a line power switch. The various scenarios are illustrated in the following.

AC line input connection for enclosures A1, A2 and A3:

NOTICE!

The power plug connector can be used on adjustable frequency drives 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 adjustable frequency drive is properly grounded. Connect to ground connection (terminal 95). Use screw from the accessory bag.
3. Place plug connector 91 (L1), 92 (L2), 93 (L3) from the accessory bag onto the terminals labeled MAINS at the bottom of the adjustable frequency drive.
4. Attach the line wires to the line power plug connector.
5. Support the cable with the enclosed supporting brackets.

9

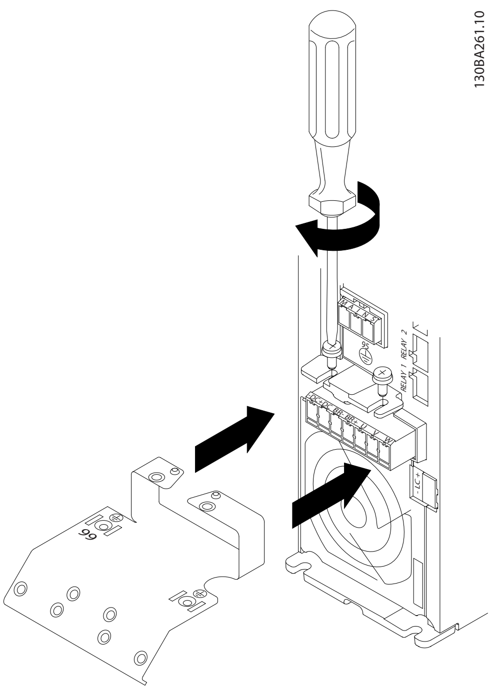


Figure 9.17 Support Plate

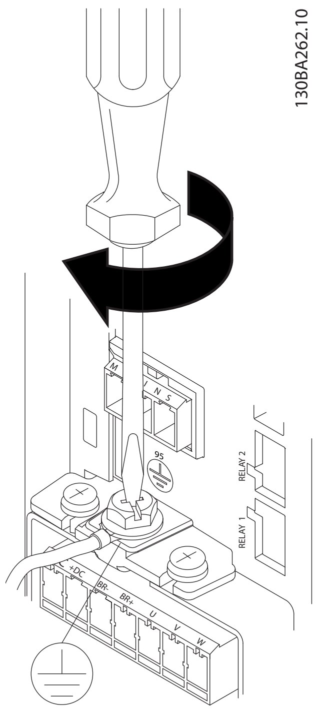


Figure 9.18 Tightening the Ground Cable

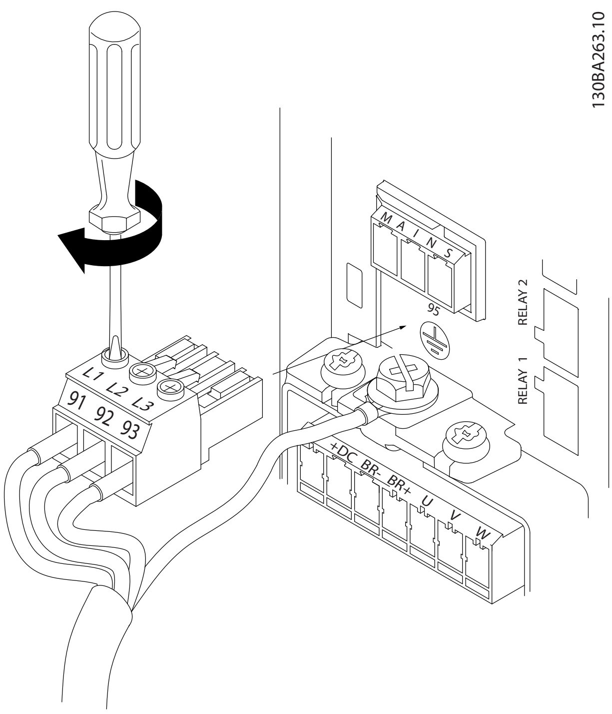


Figure 9.19 Mounting Line Power Plug and Tightening Wires

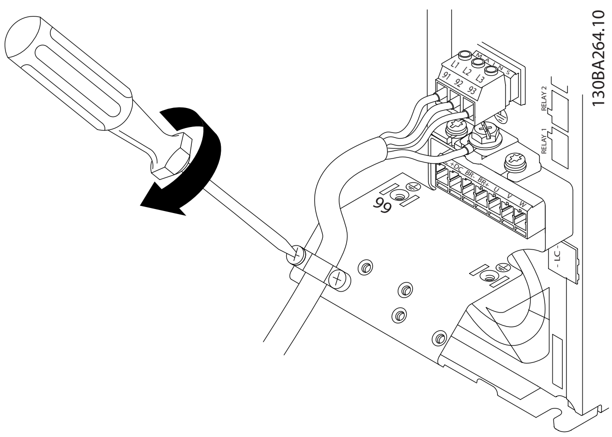


Figure 9.20 Tighten Support Bracket

AC line input connector enclosures A4/A5

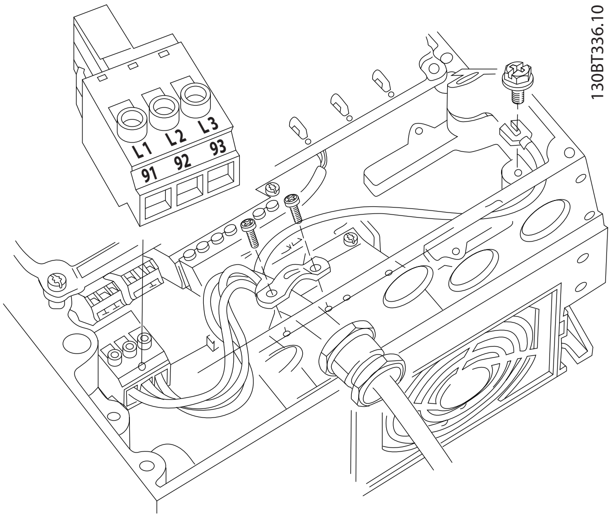


Figure 9.21 Connecting to Line Power and Grounding without Disconnector

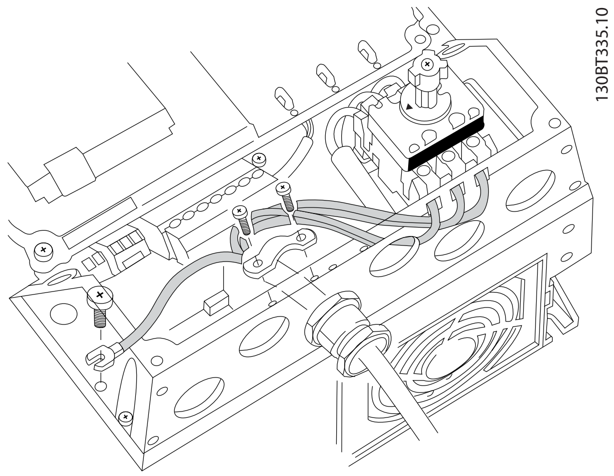


Figure 9.22 Connecting to Line Power and Grounding with Disconnector

adjustable frequency driveWhen disconnector is used (enclosures A4/A5), mount the PE on the left side of the adjustable frequency drive.

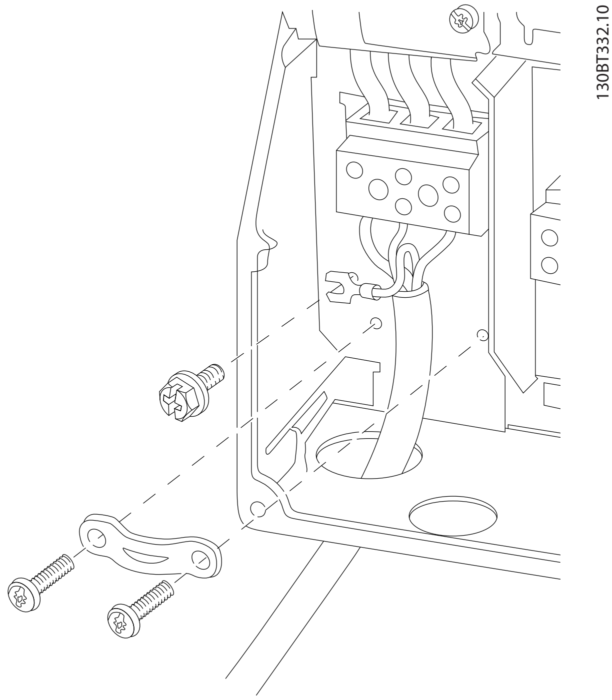


Figure 9.23 AC Line Input Connection Enclosures B1 and B2

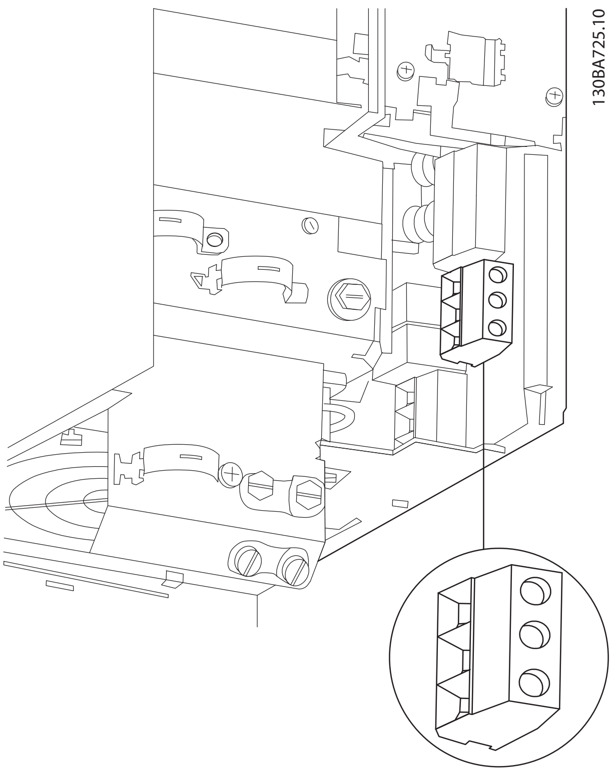


Figure 9.24 AC Line Input Connection Enclosure B3

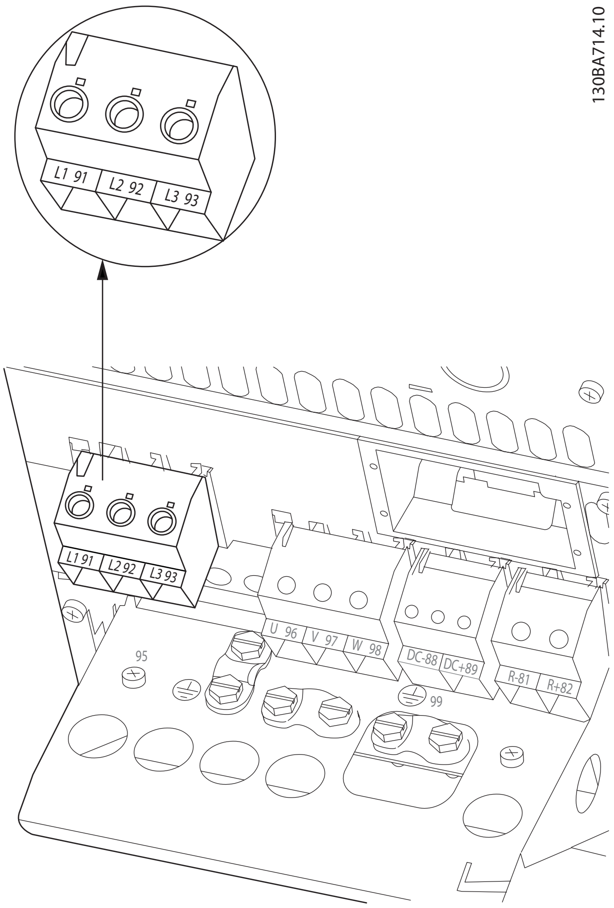


Figure 9.25 AC Line Input Connection Enclosure B4

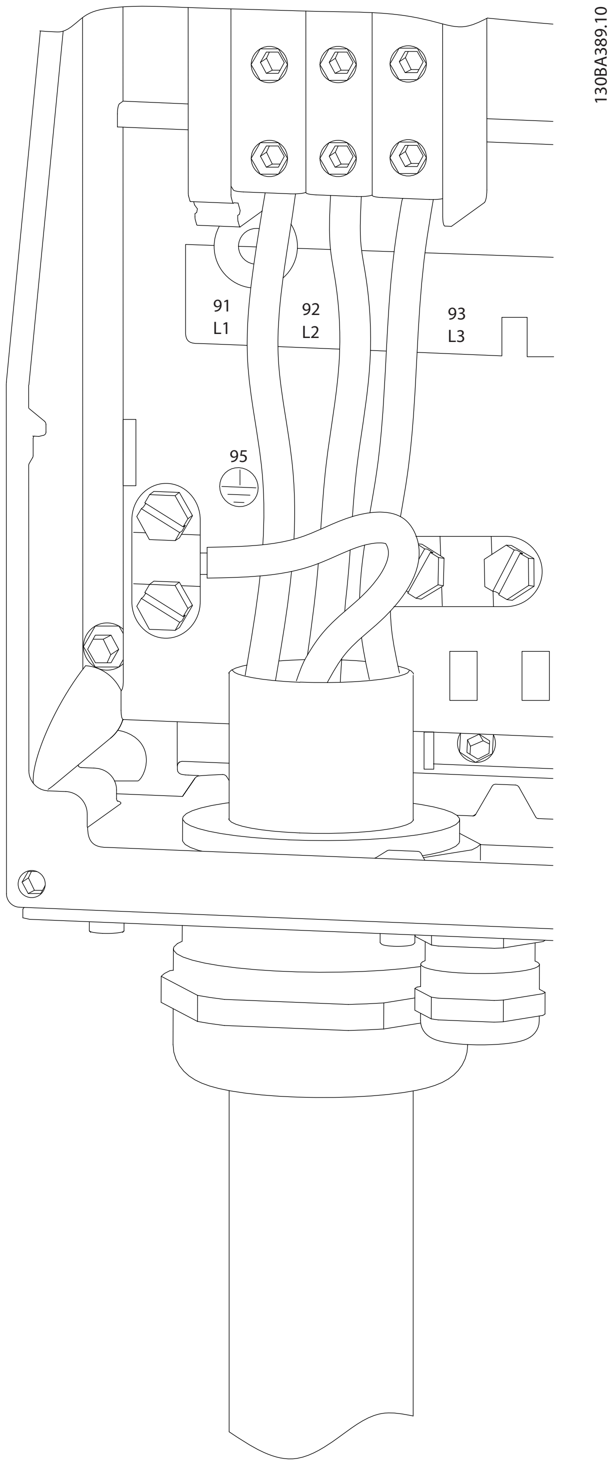


Figure 9.26 AC Line Input Connection Enclosures C1 and C2 (IP21/NEMA Type 1 and IP55/66/NEMA Type 12).

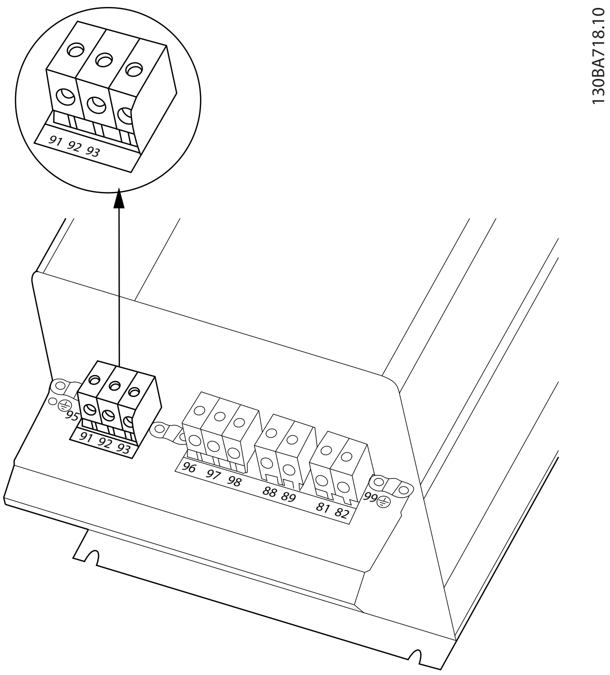


Figure 9.27 AC Line Input Connection Enclosures C3 (IP20).

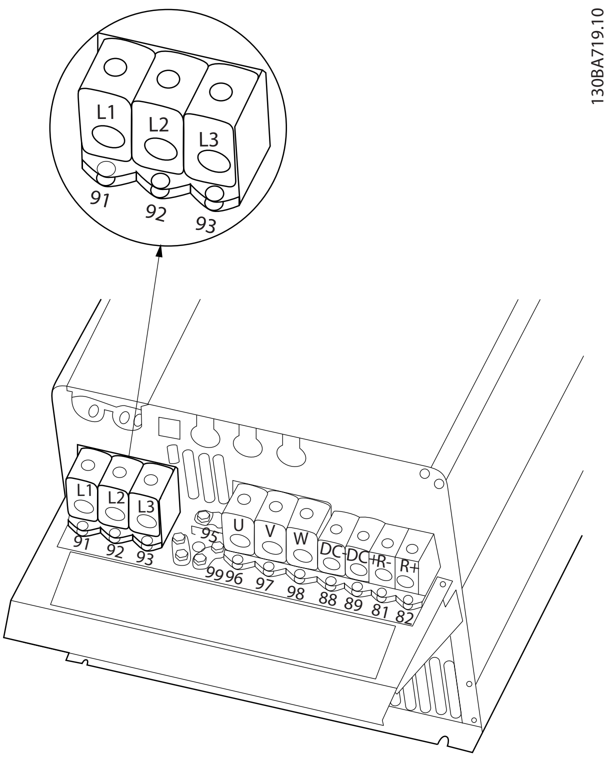


Figure 9.28 AC Line Input Connection Enclosures C4 (IP20).

9.3.1 Fuses and Circuit Breakers

9.3.1.1 Fuses

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

NOTICE!

Using fuses and/or circuit breakers on the supply side is mandatory to ensure compliance with IEC 60364 for CE or NEC 2009 for UL.

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

NOTICE!

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

Short-circuit protection
Danfoss recommends using the fuses/circuit breakers mentioned below to protect service personnel and property in case of component breakdown in the adjustable frequency drive.

9.3.1.2 Recommendations

The tables in *chapter 9.3.1 Fuses and Circuit Breakers* list the recommended rated current. Recommended fuses are of the type gG for small to medium power sizes. For larger power sizes, aR fuses are recommended. For circuit breakers, Moeller types are recommended. Other types of circuit breakers may be used provided they limit the energy into the adjustable frequency drive to a level equal to or lower than the Moeller types.

If fuses/circuit breakers according to recommendations are selected, possible damage on the adjustable frequency drive is mainly limited to damages inside the unit.

For further information see *Application Note Fuses and Circuit Breakers, MN90T*.

9

9.3.1.3 CE Compliance

Fuses or circuit breakers are mandatory to comply with IEC 60364. Danfoss recommend using a selection of the following.

The fuses below are suitable for use on a circuit capable of delivering 100,000 A_{rms} (symmetrical), 240 V, 500 V, 600 V, or 690 V depending on the adjustable frequency drive voltage rating. With the proper fusing the adjustable frequency drive short circuit current rating (SCCR) is 100,000 A_{rms}.

The following UL-listed fuses are suitable:

- UL248-4 class CC fuses
- UL248-8 class J fuses
- UL248-12 class R fuses (RK1)
- UL248-15 class T fuses

The following max. fuse size and type have been tested:

Enclosure	Power (hp [kW])	Recommended fuse size	Recommended max. fuse	Recommended circuit breaker Moeller	Max trip level [A]
A1	0.34–2 [0.25–1.5]	gG-10	gG-25	PKZM0-10	10
A2	0.34–3 [0.25–2.2]	gG-10 (0.25–1.5) gG-16 (2.2)	gG-25	PKZM0-16	16
A3	4–5 [3.0–3.7]	gG-16 (3) gG-20 (3.7)	gG-32	PKZM0-25	25
A4	0.34–3 [0.25–2.2]	gG-10 (0.25–1.5) gG-16 (2.2)	gG-32	PKZM0-25	25
A5	0.34–5 [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	7.5–10 [5.5–7.5]	gG-25 (5.5) gG-32 (7.5)	gG-80	PKZM4-63	63
B2	15 [11]	gG-50	gG-100	NZMB1-A100	100
B3	7.5 [5.5]	gG-25	gG-63	PKZM4-50	50
B4	10–20 [7.5–15]	gG-32 (7.5) gG-50 (11) gG-63 (15)	gG-125	NZMB1-A100	100
C1	20–30 [15–2]	gG-63 (15) gG-80 (18.5) gG-100 (22)	gG-160 (15–18.5) aR-160 (22)	NZMB2-A200	160
C2	40–50 [30–37]	aR-160 (30) aR-200 (37)	aR-200 (30) aR-250 (37)	NZMB2-A250	250
C3	25–30 [18.5–22]	gG-80 (18.5) aR-125 (22)	gG-150 (18.5) aR-160 (22)	NZMB2-A200	150
C4	40–50 [30–37]	aR-160 (30) aR-200 (37)	aR-200 (30) aR-250 (37)	NZMB2-A250	250

Table 9.3 200–240 V, Enclosure Types A, B and C

Enclosure	Power (hp [kW])	Recommended fuse size	Recommended max. fuse	Recommended circuit breaker Moeller	Max trip level [A]
A1	0.37–1.5	gG-10	gG-25	PKZM0-10	10
A2	0.37–4.0	gG-10 (0.37–3) gG-16 (4)	gG-25	PKZM0-16	16
A3	7.5–10 [5.5–7.5]	gG-16	gG-32	PKZM0-25	25
A4	0.5–4 [0.37–4]	gG-10 (0.37–3) gG-16 (4)	gG-32	PKZM0-25	25
A5	0.5–10 [0.37–7.5]	gG-10 (0.37–3) gG-16 (4–7.5)	gG-32	PKZM0-25	25
B1	15–20 [11–15]	gG-40	gG-80	PKZM4-63	63
B2	25–30 [18.5–22]	gG-50 (18.5) gG-63 (22)	gG-100	NZMB1-A100	100
B3	15–20 [11–15]	gG-40	gG-63	PKZM4-50	50
B4	25–40 [18.5–30]	gG-50 (18.5) gG-63 (22) gG-80 (30)	gG-125	NZMB1-A100	100
C1	40–60 [30–45]	gG-80 (30) gG-100 (37) gG-160 (45)	gG-160	NZMB2-A200	160
C2	75–100 [55–75]	aR-200 (55) aR-250 (75)	aR-250	NZMB2-A250	250
C3	40–60 [37–45]	gG-100 (37) gG-160 (45)	gG-150 (37) gG-160 (45)	NZMB2-A200	150
C4	75–100 [55–75]	aR-200 (55) aR-250 (75)	aR-250	NZMB2-A250	250

Table 9.4 380–500 V, Enclosure Types A, B and C

Enclosure	Power (hp [kW])	Recommended fuse size	Recommended max. fuse	Recommended circuit breaker Moeller	Max trip level [A]
A2	1–5 [0.75–4.0]	gG-10	gG-25	PKZM0-16	16
A3	7.5–10 [5.5–7.5]	gG-10 (5.5) gG-16 (7.5)	gG-32	PKZM0-25	25
A5	1–10 [0.75–7.5]	gG-10 (0.75–5.5) gG-16 (7.5)	gG-32	PKZM0-25	25
B1	15–24 [11–18]	gG-25 (11) gG-32 (15) gG-40 (18.5)	gG-80	PKZM4-63	63
B2	30–40 [22–30]	gG-50 (22) gG-63 (30)	gG-100	NZMB1-A100	100
B3	15–20 [11–15]	gG-25 (11) gG-32 (15)	gG-63	PKZM4-50	50
B4	25–40 [18.5–30]	gG-40 (18.5) gG-50 (22) gG-63 (30)	gG-125	NZMB1-A100	100
C1	50–75 [37–55]	gG-63 (37) gG-100 (45) aR-160 (55)	gG-160 (37–45) aR-250 (55)	NZMB2-A200	160
C2	100 [75]	aR-200 (75)	aR-250	NZMB2-A250	250
C3	50–60 [37–45]	gG-63 (37) gG-100 (45)	gG-150	NZMB2-A200	150
C4	75–100 [55–75]	aR-160 (55) aR-200 (75)	aR-250	NZMB2-A250	250

Table 9.5 525–600 V, Enclosure Types A, B and C

Enclosure	Power (hp [kW])	Recommended fuse size	Recommended max. fuse	Recommended circuit breaker Moeller	Max trip level [A]
A3	1.5 [1.1] 20 [1.5] 3 [2.2] 4 [3] 5 [4] 7.5 [5.5] 10 [7.5]	gG-6 gG-6 gG-6 gG-10 gG-10 gG-16 gG-16	gG-25 gG-25 gG-25 gG-25 gG-25 gG-25 gG-25	PKZM0-16	16
B2/B4	15 [11] 20 [15] 24 [18] 30 [22]	gG-25 (11) gG-32 (15) gG-32 (18) gG-40 (22)	gG-63	-	-
B4/C2	40 [30]	gG-63 (30)	gG-80 (30)	-	-
C2/C3	50 [37] 60 [45]	gG-63 (37) gG-80 (45)	gG-100 (37) gG-125 (45)		
C2	75 [55] 100 [75]	gG-100 (55) gG-125 (75)	gG-160 (55–75)		

Table 9.6 525–690 V, Enclosure Types A, B and C

9.3.1.4 UL Compliance

The fuses below are suitable for use on a circuit capable of delivering 100,000 A_{rms} (symmetrical), 240 V, or 500 V, or 600 V depending on the adjustable frequency drive voltage rating. With the proper fusing, the adjustable frequency drive Short Circuit Current Rating (SCCR) is 100,000 A_{rms}.

Fuses or circuit breakers are mandatory to comply with NEC 2009. Danfoss recommends using a selection of the following:

	Recommended max. fuse					
Power [kW]	**Bussmann Type RK1[1)]**	**Bussmann Type J**	**Bussmann Type T**	**Bussmann Type CC**	**Bussmann Type CC**	**Bussmann Type CC**
0.34–0.5 [0.25–0.37]	KTN-R-05	JKS-05	JJN-05	FNQ-R-5	KTK-R-5	LP-CC-5
0.75–1.5 [0.55–1.1]	KTN-R-10	JKS-10	JJN-10	FNQ-R-10	KTK-R-10	LP-CC-10
2 [1.5]	KTN-R-15	JKS-15	JJN-15	FNQ-R-15	KTK-R-15	LP-CC-15
3 [2.2]	KTN-R-20	JKS-20	JJN-20	FNQ-R-20	KTK-R-20	LP-CC-20
4 [3.0]	KTN-R-25	JKS-25	JJN-25	FNQ-R-25	KTK-R-25	LP-CC-25
5 [3.7]	KTN-R-30	JKS-30	JJN-30	FNQ-R-30	KTK-R-30	LP-CC-30
7.5 [5.5]	KTN-R-50	KS-50	JJN-50	-	-	-
10 [7.5]	KTN-R-60	JKS-60	JJN-60	-	-	-
15 [11]	KTN-R-80	JKS-80	JJN-80	-	-	-
20–25 [15–18.5]	KTN-R-125	JKS-125	JJN-125	-	-	-
30 [22]	KTN-R-150	JKS-150	JJN-150	-	-	-
40 [30]	KTN-R-200	JKS-200	JJN-200	-	-	-
50 [37]	KTN-R-250	JKS-250	JJN-250	-	-	-

Table 9.7 200–240 V, Enclosure Types A, B and C

	Recommended max. fuse			
Power [kW]	**SIBA Type RK1**	**Littelfuse Type RK1**	**Ferraz-Shawmut Type CC**	**Ferraz-Shawmut Type RK1[3)]**
0.34–0.5 [0.25–0.37]	5017906-005	KLN-R-05	ATM-R-05	A2K-05-R
0.75–1.5 [0.55–1.1]	5017906-010	KLN-R-10	ATM-R-10	A2K-10-R
2 [1.5]	5017906-016	KLN-R-15	ATM-R-15	A2K-15-R
3 [2.2]	5017906-020	KLN-R-20	ATM-R-20	A2K-20-R
4 [3.0]	5017906-025	KLN-R-25	ATM-R-25	A2K-25-R
5 [3.7]	5012406-032	KLN-R-30	ATM-R-30	A2K-30-R
7.5 [5.5]	5014006-050	KLN-R-50	-	A2K-50-R
10 [7.5]	5014006-063	KLN-R-60	-	A2K-60-R
15 [11]	5014006-080	KLN-R-80	-	A2K-80-R
20–25 [15–18.5]	2028220-125	KLN-R-125	-	A2K-125-R
30 [22]	2028220-150	KLN-R-150	-	A2K-150-R
40 [30]	2028220-200	KLN-R-200	-	A2K-200-R
50 [37]	2028220-250	KLN-R-250	-	A2K-250-R

Table 9.8 200–240 V, Enclosure Types A, B and C

	Recommended max. fuse			
Power [kW]	Bussmann Type JFHR2[2)]	Littelfuse JFHR2	Ferraz-Shawmut JFHR2[4)]	Ferraz-Shawmut J
0.34–0.5 [0.25–0.37]	FWX-5	-	-	HSJ-6
0.75–1.5 [0.55–1.1]	FWX-10	-	-	HSJ-10
2 [1.5]	FWX-15	-	-	HSJ-15
3 [2.2]	FWX-20	-	-	HSJ-20
4 [3.0]	FWX-25	-	-	HSJ-25
5 [3.7]	FWX-30	-	-	HSJ-30
7.5 [5.5]	FWX-50	-	-	HSJ-50
10 [7.5]	FWX-60	-	-	HSJ-60
15 [11]	FWX-80	-	-	HSJ-80
20–25 [15–18.5]	FWX-125	-	-	HSJ-125
30 [22]	FWX-150	L25S-150	A25X-150	HSJ-150
40 [30]	FWX-200	L25S-200	A25X-200	HSJ-200
50 [37]	FWX-250	L25S-250	A25X-250	HSJ-250

Table 9.9 200–240 V, Enclosure Types A, B and C

1) KTS fuses from Bussmann may substitute KTN for 240 V adjustable frequency drives.

2) FWH fuses from Bussmann may substitute FWX for 240 V adjustable frequency drives.

3) A6KR fuses from FERRAZ SHAWMUT may substitute A2KR for 240 V adjustable frequency drives.

4) A50X fuses from FERRAZ SHAWMUT may substitute A25X for 240 V adjustable frequency drives.

	Recommended max. fuse					
Power [kW]	Bussmann Type RK1	Bussmann Type J	Bussmann Type T	Bussmann Type CC	Bussmann Type CC	Bussmann Type CC
0.5–1.5 [0.37–1.1]	KTS-R-6	JKS-6	JJS-6	FNQ-R-6	KTK-R-6	LP-CC-6
2–3 [1.5–2.2]	KTS-R-10	JKS-10	JJS-10	FNQ-R-10	KTK-R-10	LP-CC-10
4 [3]	KTS-R-15	JKS-15	JJS-15	FNQ-R-15	KTK-R-15	LP-CC-15
5 [4]	KTS-R-20	JKS-20	JJS-20	FNQ-R-20	KTK-R-20	LP-CC-20
7.5 [5.5]	KTS-R-25	JKS-25	JJS-25	FNQ-R-25	KTK-R-25	LP-CC-25
10 [7.5]	KTS-R-30	JKS-30	JJS-30	FNQ-R-30	KTK-R-30	LP-CC-30
15 [11]	KTS-R-40	JKS-40	JJS-40	-	-	-
20 [15]	KTS-R-50	JKS-50	JJS-50	-	-	-
24 [18]	KTS-R-60	JKS-60	JJS-60	-	-	-
30 [22]	KTS-R-80	JKS-80	JJS-80	-	-	-
40 [30]	KTS-R-100	JKS-100	JJS-100	-	-	-
50 [37]	KTS-R-125	JKS-125	JJS-125	-	-	-
60 [45]	KTS-R-150	JKS-150	JJS-150	-	-	-
75 [55]	KTS-R-200	JKS-200	JJS-200	-	-	-
100 [75]	KTS-R-250	JKS-250	JJS-250	-	-	-

Table 9.10 380–500 V, Enclosure Types A, B and C

	Recommended max. fuse			
Power [kW]	SIBA Type RK1	Littelfuse Type RK1	Ferraz-Shawmut Type CC	Ferraz-Shawmut Type RK1
0.5–1.5 [0.37–1.1]	5017906-006	KLS-R-6	ATM-R-6	A6K-6-R
2–3 [1.5–2.2]	5017906-010	KLS-R-10	ATM-R-10	A6K-10-R
4 [3]	5017906-016	KLS-R-15	ATM-R-15	A6K-15-R
5 [4]	5017906-020	KLS-R-20	ATM-R-20	A6K-20-R
7.5 [5.5]	5017906-025	KLS-R-25	ATM-R-25	A6K-25-R
10 [7.5]	5012406-032	KLS-R-30	ATM-R-30	A6K-30-R
15 [11]	5014006-040	KLS-R-40	-	A6K-40-R
20 [15]	5014006-050	KLS-R-50	-	A6K-50-R
24 [18]	5014006-063	KLS-R-60	-	A6K-60-R
30 [22]	2028220-100	KLS-R-80	-	A6K-80-R
40 [30]	2028220-125	KLS-R-100	-	A6K-100-R
50 [37]	2028220-125	KLS-R-125	-	A6K-125-R
60 [45]	2028220-160	KLS-R-150	-	A6K-150-R
75 [55]	2028220-200	KLS-R-200	-	A6K-200-R
100 [75]	2028220-250	KLS-R-250	-	A6K-250-R

Table 9.11 380–500 V, Enclosure Types A, B and C

	Recommended max. fuse			
Power [kW]	Bussmann JFHR2	Ferraz- Shawmut J	Ferraz- Shawmut JFHR2[1)]	Littelfuse JFHR2
0.5–1.5 [0.37–1.1]	FWH-6	HSJ-6	-	-
2–3 [1.5–2.2]	FWH-10	HSJ-10	-	-
4 [3]	FWH-15	HSJ-15	-	-
5 [4]	FWH-20	HSJ-20	-	-
7.5 [5.5]	FWH-25	HSJ-25	-	-
10 [7.5]	FWH-30	HSJ-30	-	-
15 [11]	FWH-40	HSJ-40	-	-
20 [15]	FWH-50	HSJ-50	-	-
24 [18]	FWH-60	HSJ-60	-	-
30 [22]	FWH-80	HSJ-80	-	-
40 [30]	FWH-100	HSJ-100	-	-
50 [37]	FWH-125	HSJ-125	-	-
60 [45]	FWH-150	HSJ-150	-	-
75 [55]	FWH-200	HSJ-200	A50-P-225	L50-S-225
100 [75]	FWH-250	HSJ-250	A50-P-250	L50-S-250

Table 9.12 380–500 V, Enclosure Types A, B and C

[1)] *Ferraz-Shawmut A50QS fuses may substitute for A50P fuses.*

	Recommended max. fuse					
Power [kW]	Bussmann Type RK1	Bussmann Type J	Bussmann Type T	Bussmann Type CC	Bussmann Type CC	Bussmann Type CC
1–1.5 [0.75–1.1]	KTS-R-5	JKS-5	JJS-6	FNQ-R-5	KTK-R-5	LP-CC-5
2–3 [1.5–2.2]	KTS-R-10	JKS-10	JJS-10	FNQ-R-10	KTK-R-10	LP-CC-10
4 [3]	KTS-R15	JKS-15	JJS-15	FNQ-R-15	KTK-R-15	LP-CC-15
5 [4]	KTS-R20	JKS-20	JJS-20	FNQ-R-20	KTK-R-20	LP-CC-20
7.5 [5.5]	KTS-R-25	JKS-25	JJS-25	FNQ-R-25	KTK-R-25	LP-CC-25
10 [7.5]	KTS-R-30	JKS-30	JJS-30	FNQ-R-30	KTK-R-30	LP-CC-30
15 [11]	KTS-R-35	JKS-35	JJS-35	-	-	-
20 [15]	KTS-R-45	JKS-45	JJS-45	-	-	-
24 [18]	KTS-R-50	JKS-50	JJS-50	-	-	-
30 [22]	KTS-R-60	JKS-60	JJS-60	-	-	-
40 [30]	KTS-R-80	JKS-80	JJS-80	-	-	-
50 [37]	KTS-R-100	JKS-100	JJS-100	-	-	-
60 [45]	KTS-R-125	JKS-125	JJS-125	-	-	-
75 [55]	KTS-R-150	JKS-150	JJS-150	-	-	-
100 [75]	KTS-R-175	JKS-175	JJS-175	-	-	-

Table 9.13 525–600 V, Enclosure Types A, B and C

9

	Recommended max. fuse			
Power [kW]	SIBA Type RK1	Littelfuse Type RK1	Ferraz-Shawmut Type RK1	Ferraz-Shawmut J
1–1.5 [0.75–1.1]	5017906-005	KLS-R-005	A6K-5-R	HSJ-6
2–3 [1.5–2.2]	5017906-010	KLS-R-010	A6K-10-R	HSJ-10
4 [3]	5017906-016	KLS-R-015	A6K-15-R	HSJ-15
5 [4]	5017906-020	KLS-R-020	A6K-20-R	HSJ-20
7.5 [5.5]	5017906-025	KLS-R-025	A6K-25-R	HSJ-25
10 [7.5]	5017906-030	KLS-R-030	A6K-30-R	HSJ-30
15 [11]	5014006-040	KLS-R-035	A6K-35-R	HSJ-35
20 [15]	5014006-050	KLS-R-045	A6K-45-R	HSJ-45
24 [18]	5014006-050	KLS-R-050	A6K-50-R	HSJ-50
30 [22]	5014006-063	KLS-R-060	A6K-60-R	HSJ-60
40 [30]	5014006-080	KLS-R-075	A6K-80-R	HSJ-80
50 [37]	5014006-100	KLS-R-100	A6K-100-R	HSJ-100
60 [45]	2028220-125	KLS-R-125	A6K-125-R	HSJ-125
75 [55]	2028220-150	KLS-R-150	A6K-150-R	HSJ-150
100 [75]	2028220-200	KLS-R-175	A6K-175-R	HSJ-175

Table 9.14 525–600 V, Enclosure Types A, B and C

	Recommended max. fuse					
Power [kW]	Bussmann Type RK1	Bussmann Type J	Bussmann Type T	Bussmann Type CC	Bussmann Type CC	Bussmann Type CC
(hp [kW])						
1.5 [1.1]	KTS-R-5	JKS-5	JJS-6	FNQ-R-5	KTK-R-5	LP-CC-5
2–3 [1.5–2.2]	KTS-R-10	JKS-10	JJS-10	FNQ-R-10	KTK-R-10	LP-CC-10
4 [3]	KTS-R15	JKS-15	JJS-15	FNQ-R-15	KTK-R-15	LP-CC-15
5 [4]	KTS-R20	JKS-20	JJS-20	FNQ-R-20	KTK-R-20	LP-CC-20
7.5 [5.5]	KTS-R-25	JKS-25	JJS-25	FNQ-R-25	KTK-R-25	LP-CC-25
10 [7.5]	KTS-R-30	JKS-30	JJS-30	FNQ-R-30	KTK-R-30	LP-CC-30
15 [11]	KTS-R-35	JKS-35	JJS-35	-	-	-
20 [15]	KTS-R-45	JKS-45	JJS-45	-	-	-
24 [18]	KTS-R-50	JKS-50	JJS-50	-	-	-
30 [22]	KTS-R-60	JKS-60	JJS-60	-	-	-
40 [30]	KTS-R-80	JKS-80	JJS-80	-	-	-
50 [37]	KTS-R-100	JKS-100	JJS-100	-	-	-
60 [45]	KTS-R-125	JKS-125	JJS-125	-	-	-
75 [55]	KTS-R-150	JKS-150	JJS-150	-	-	-
100 [75]	KTS-R-175	JKS-175	JJS-175	-	-	-

Table 9.15 525–690 V, Enclosure Types A, B and C

	Recommended max. fuse							
Power [kW]	Max. prefuse	Bussmann E52273 RK1/JDDZ	Bussmann E4273 J/JDDZ	Bussmann E4273 T/JDDZ	SIBA E180276 RK1/JDDZ	Littelfuse E81895 RK1/JDDZ	Ferraz-Shawmut E163267/E2137 RK1/JDDZ	Ferraz-Shawmut E2137 J/HSJ
15 [11]	30 A	KTS-R-30	JKS-30	JKJS-30	5017906-030	KLS-R-030	A6K-30-R	HST-30
20–25 [15–18.5]	45 A	KTS-R-45	JKS-45	JJS-45	5014006-050	KLS-R-045	A6K-45-R	HST-45
30 [22]	60 A	KTS-R-60	JKS-60	JJS-60	5014006-063	KLS-R-060	A6K-60-R	HST-60
40 [30]	80 A	KTS-R-80	JKS-80	JJS-80	5014006-080	KLS-R-075	A6K-80-R	HST-80
50 [37]	90 A	KTS-R-90	JKS-90	JJS-90	5014006-100	KLS-R-090	A6K-90-R	HST-90
60 [45]	100 A	KTS-R-100	JKS-100	JJS-100	5014006-100	KLS-R-100	A6K-100-R	HST-100
75 [55]	125 A	KTS-R-125	JKS-125	JJS-125	2028220-125	KLS-150	A6K-125-R	HST-125
100 [75]	150 A	KTS-R-150	JKS-150	JJS-150	2028220-150	KLS-175	A6K-150-R	HST-150

Table 9.16 525–690 V, Enclosure Types B and C

9.4 Motor Connection

⚠WARNING

INDUCED VOLTAGE

Induced voltage from output motor cables that run together can charge equipment capacitors even with the equipment turned off and locked out. Failure to run output motor cables separately or use shielded cables or metal conduits could result in death or serious injury.

- **run output motor cables separately, or**
- **use shielded cables or metal conduits**

Motor Connection

NOTICE!

To comply with EMC emission specifications, shielded/armored cables are required. For more information, see *chapter 5.2.1 EMC Test Results* and *Figure 3.3*.

See *chapter 6.2 General Specifications* for correct dimensioning of motor cable cross-section and length.

Term. no.	96	97	98	99	
	U	V	W	PE[1)]	Motor voltage 0–100% of AC line 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 9.17 Terminal Descriptions

1) Protected Ground Connection

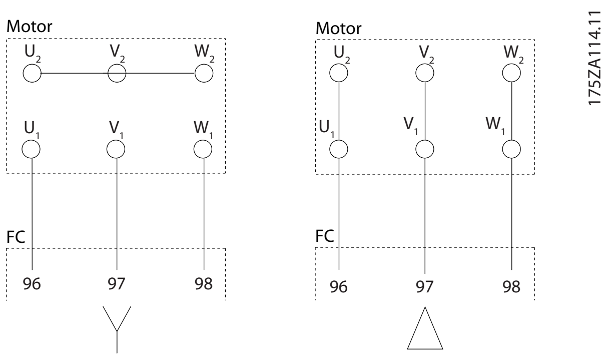


Figure 9.29 Star and Delta Connections

NOTICE!

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

Shielding of cables

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

NOTICE!

Strip a piece of the motor cable to expose the shield behind the cable clamp AND connect the ground connection to terminal 99.

Connect the motor cable shield to both the decoupling plate on the adjustable frequency drive and to the metal housing on the motor.
Make the shield connections with the largest possible surface area (cable clamp). This is done by using the supplied installation devices in the adjustable frequency drive.
If it is necessary to split the shield to install a motor isolator or motor relay, the shield must be continued with the lowest possible HF impedance.

Cable length and cross-section

The adjustable frequency drive 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, thereby requiring that the cable length is reduced accordingly. Keep the motor cable as short as possible to reduce the noise level and leakage currents.

Switching frequency

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

1. Fasten a decoupling plate to the bottom of the adjustable frequency drive with screws and washers from the accessory bag.
2. Attach motor cable to terminals 96 (U), 97 (V), 98 (W).
3. Connect to ground connection (terminal 99) on decoupling plate with screws from the accessory bag.

4. Insert plug connectors 96 (U), 97 (V), 98 (W) (up to 10 hp [7.5 kW]) and motor cable to terminals labeled MOTOR.
5. Fasten shielded cable to the decoupling plate with screws and washers from the accessory bag.

All types of three-phase asynchronous standard motors can be connected to the adjustable frequency drive. Normally, small motors are star-connected (230/400 V, Y). Large motors are normally delta-connected (400/690 V, Δ). Refer to the motor nameplate for correct connection mode and voltage.

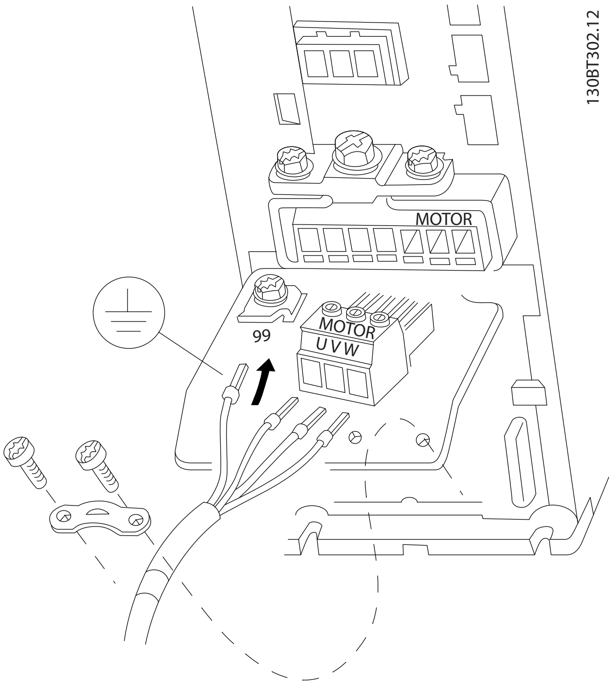


Figure 9.30 Motor Connection for Enclosures A1, A2 and A3

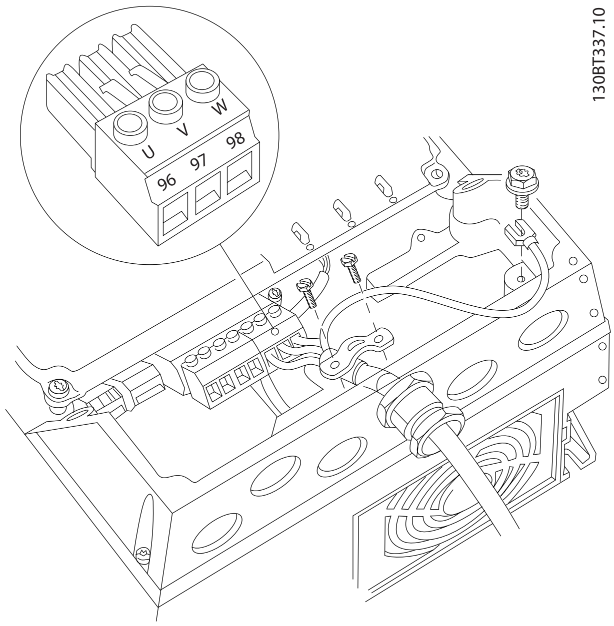


Figure 9.31 Motor Connection for Enclosures A4/A5

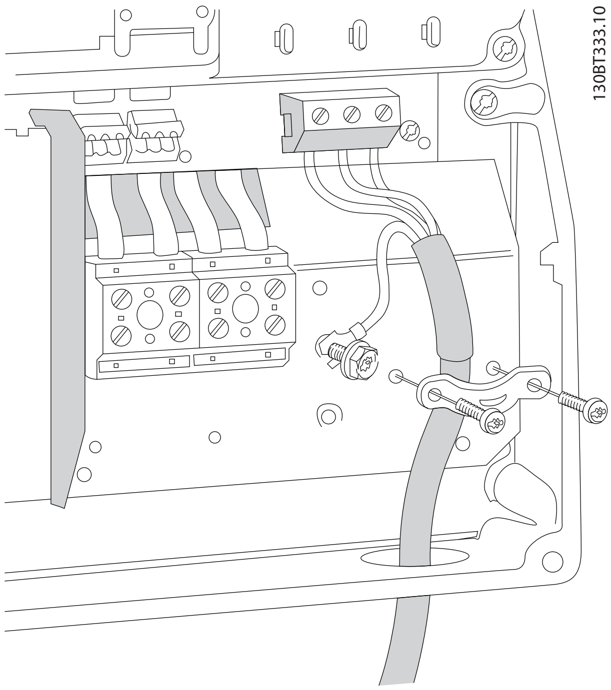


Figure 9.32 Motor Connection for Enclosures B1 and B2

9

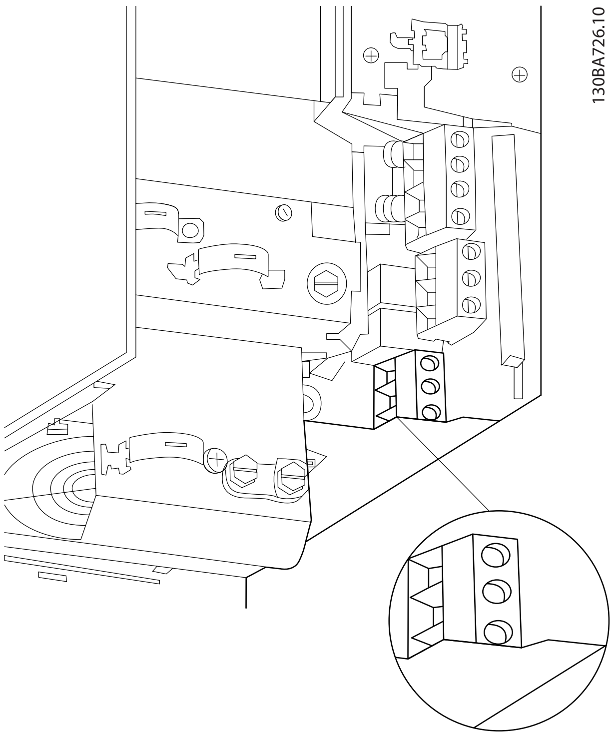


Figure 9.33 Motor Connection for Enclosure B3

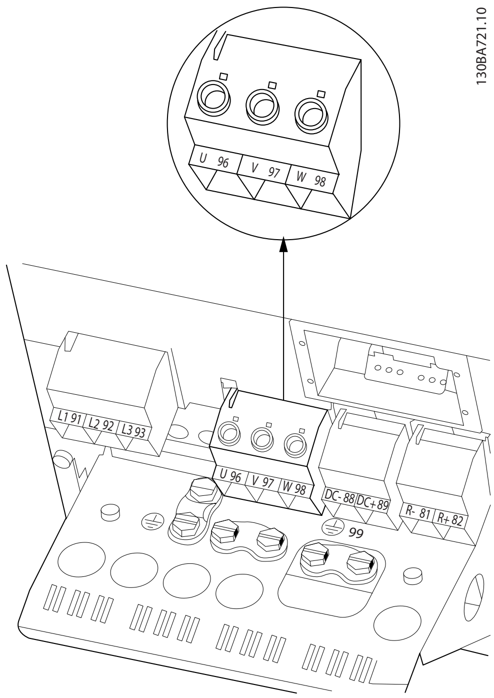


Figure 9.34 Motor Connection for Enclosure B4

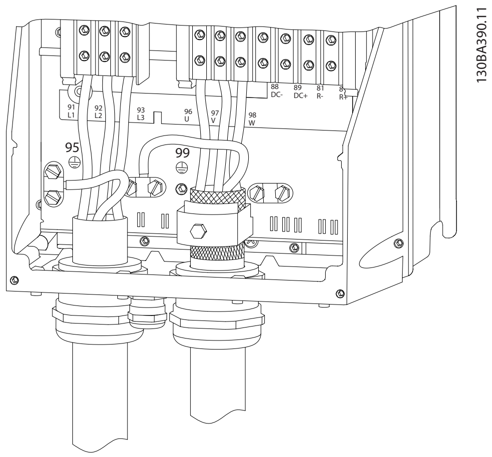


Figure 9.35 Motor Connection Enclosures C1 and C2 (IP21/ NEMA Type 1 and IP55/66/NEMA Type 12)

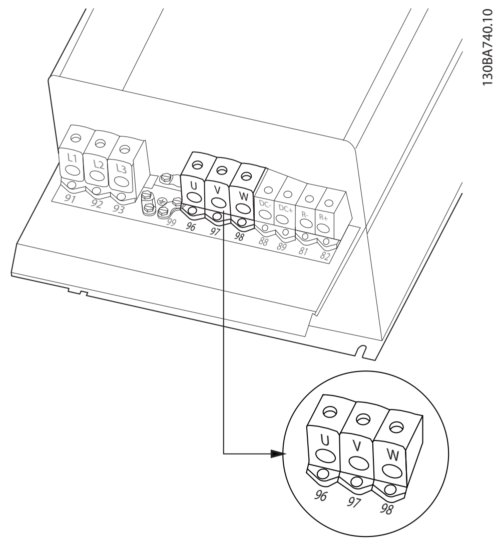


Figure 9.36 Motor Connection for Enclosures C3 and C4

9.5 Ground Leakage Current Protection

Follow national and local codes regarding protective grounding of equipment with a leakage current > 3.5 mA. The protective ground connection must have a cross section of minimum 10 mm^2 or consist of two separate wires each with the same cross-section as the phase wires. Adjustable frequency drive technology implies high frequency switching at high power. This generates a leakage current in the ground connection.
The ground leakage current is made up of several contributions and depends on various system configurations including RFI filtering, motor cable length, motor cable shielding, and adjustable frequency drive power.

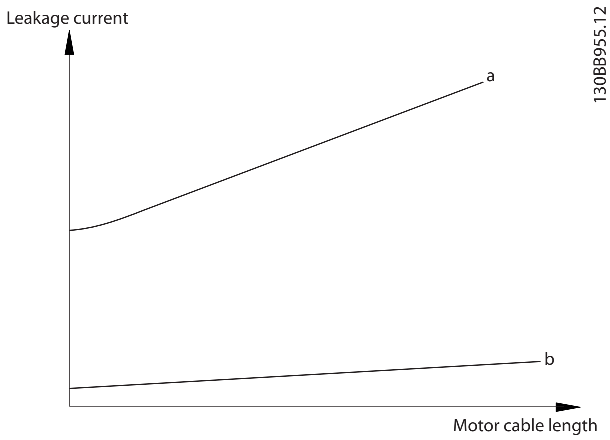


Figure 9.37 Motor Cable Length and Power Size Influence on Leakage Current. Powersize a > Powersize b

The leakage current also depends on the line distortion.

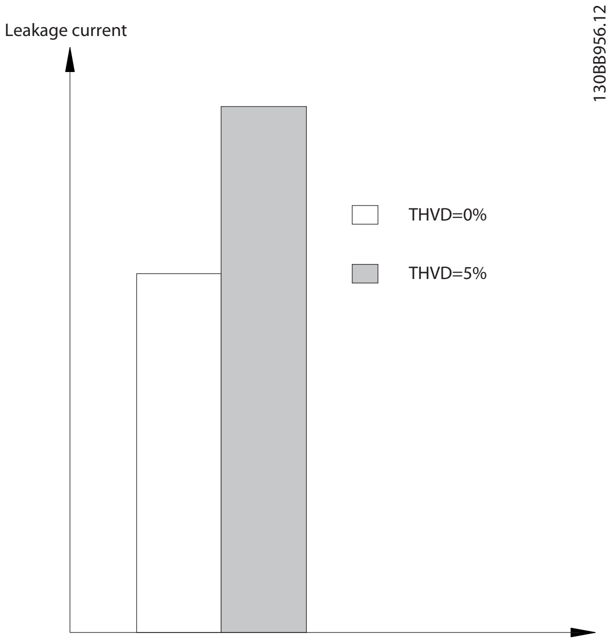


Figure 9.38 Line Distortion Influences Leakage Current

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

- Ground wire (terminal 95) of at least 0.016 in^2 [10 mm^2]
- Two separate ground wires both complying with the dimensioning rules

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

Using RCDs

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

- Use RCDs of type B only as they are capable of detecting AC and DC currents
- Use RCDs with a delay to prevent faults due to transient ground currents
- Dimension RCDs according to the system configuration and environmental considerations

The leakage current includes several frequencies originating from both the line power frequency and the switching frequency. Whether the switching frequency is detected depends on the type of RCD used.

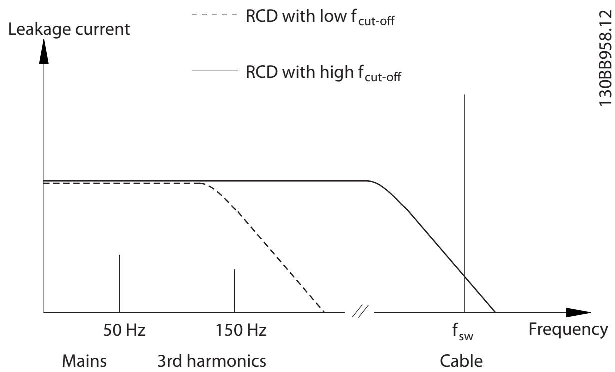


Figure 9.39 Main Contributions to Leakage Current

The amount of leakage current detected by the RCD depends on the cut-off frequency of the RCD.

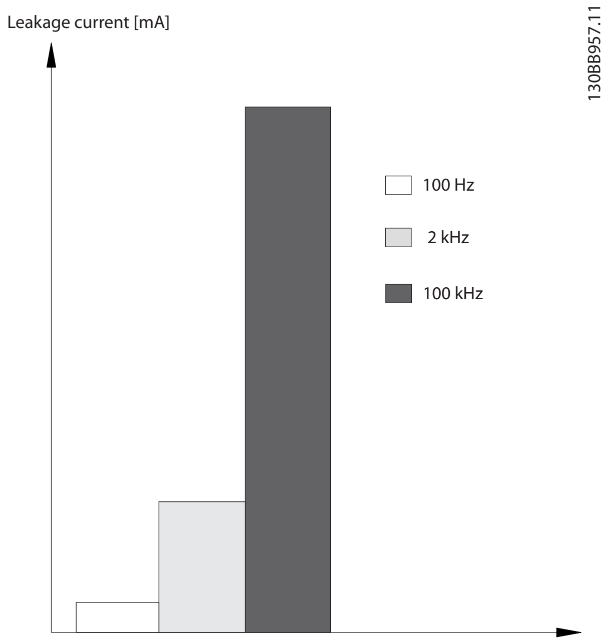


Figure 9.40 The Influence of the Cut-off Frequency of the RCD on What Is Responded to/Measured

9.6 Additional Connections

9.6.1 Relay

Relay 1

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

Relay 2 (Not FC 301)

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

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

Additional relay outputs by using Relay Option Module MCB 105.

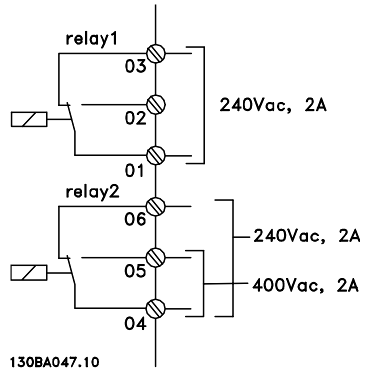


Figure 9.41 Relay Outputs 1 and 2

To set the relay output, see parameter group *5-4* Relays*.

No.	01-02	make (normally open)
	01-03	break (normally closed)
	04-05	make (normally open)
	04-06	break (normally closed)

Table 9.18 Description of Relays

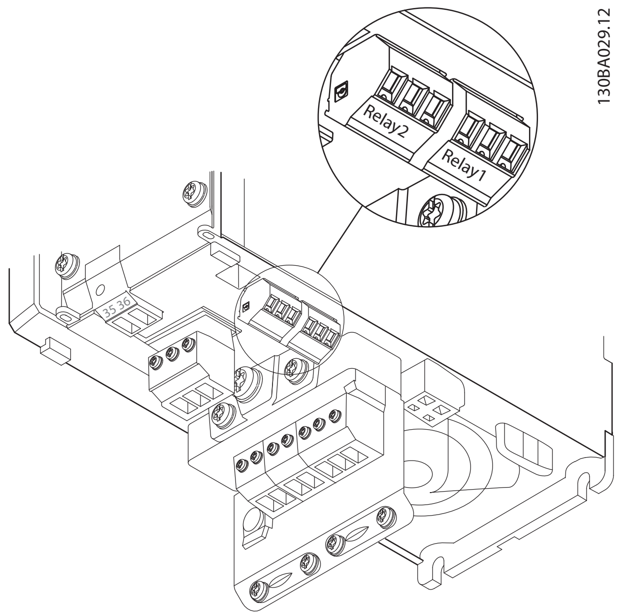


Figure 9.42 Terminals for Relay Connection (Enclosure Types A1, A2 and A3).

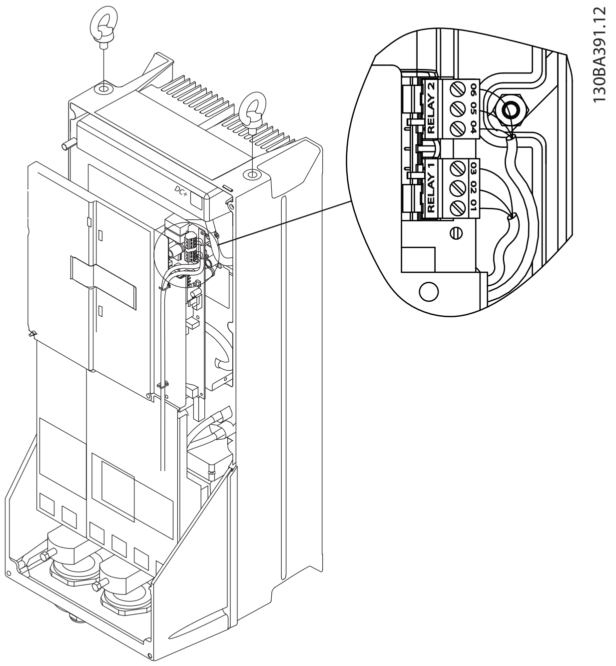


Figure 9.43 Terminals for Relay Connection (Enclosure Types C1 and C2).

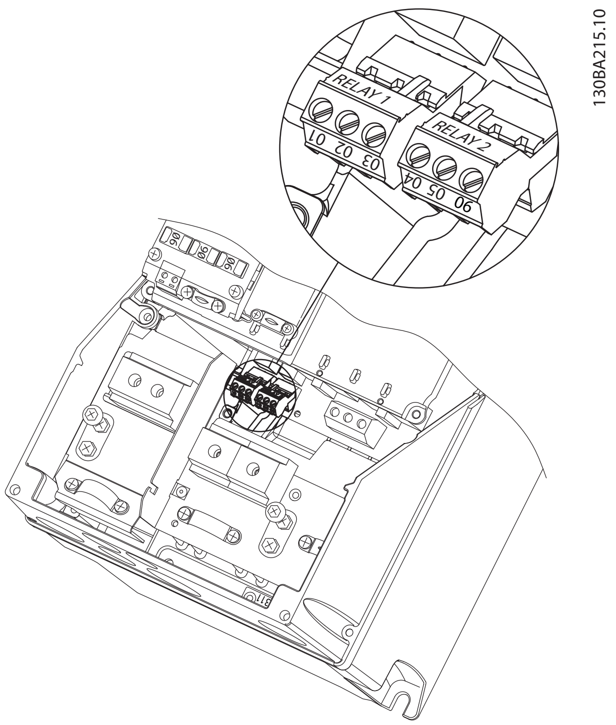


Figure 9.44 Terminals for Relay Connection (Enclosure Types A5, B1 and B2).

9.6.2 Disconnectors and Contactors

Assembling of IP55/NEMA Type 12 (enclosure type A5) with line power disconnector.

Line power switch is placed on left side on enclosure types B1, B2, C1 and C2. Line power switch on A5 enclosures is placed on right side.

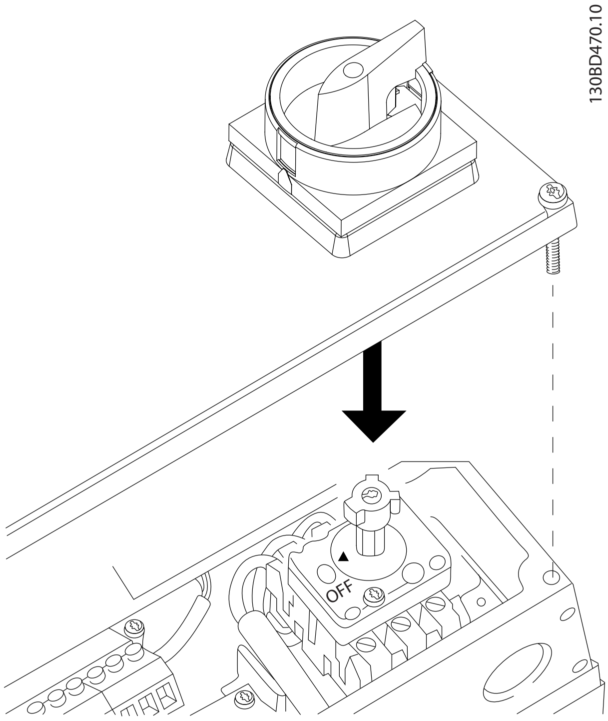
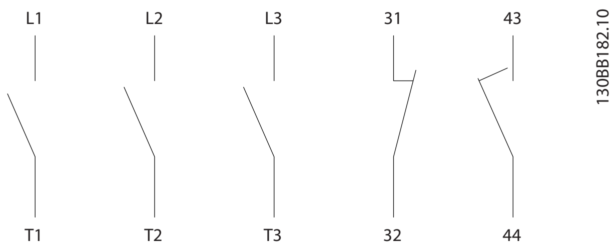


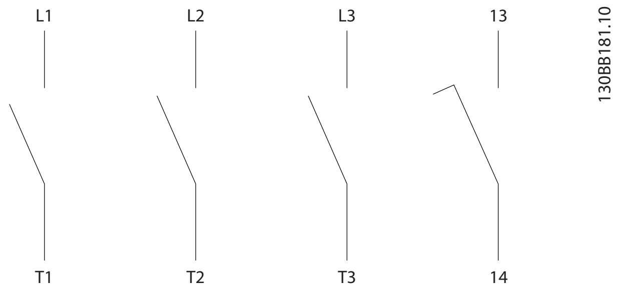
Figure 9.45 Location of Line Power Switch



Enclosure type	Type
A4/A5	Kraus&Naimer KG20A T303
B1	Kraus&Naimer KG64 T303
B2	Kraus&Naimer KG64 T303

Figure 9.46 Terminal Connections for A4, A5, B1, B2

9



Enclosure type	Type
C1	Kraus&Naimer KG100 T303
C1	Kraus&Naimer KG105 T303
C2	Kraus&Naimer KG160 T303

Figure 9.47 Terminal Connections for C1, C2

9.6.3 Load Sharing

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

The connection cable must be shielded and the max. length from the adjustable frequency drive to the DC bar is limited to 82 ft [25 m].
Load sharing enables the linking of the DC intermediate circuits of several adjustable frequency drives.

CAUTION

Note that voltages up to 1099 V DC may occur on the terminals.
Load sharing calls for extra equipment and safety considerations.

CAUTION

Note that line power disconnect may not isolate the adjustable frequency drive due to DC link connection.

9.6.4 Brake Resistor

The connection cable to the brake resistor must be shielded and the max. length from adjustable frequency drive to the DC bar is limited to 82 feet [25 m].

1. Connect the shield by means of cable clamps to the conductive backplate on the adjustable frequency drive and to the metal cabinet of the brake resistor.
2. Size the brake cable cross-section to match the brake torque.

Terminals 81 and 82 are brake resistor terminals.

NOTICE!

If a short circuit in the brake IGBT occurs, prevent power dissipation in the brake resistor by using a line switch or contactor to disconnect the line power from the adjustable frequency drive. Only the adjustable frequency drive should control the contactor.

CAUTION

Note that voltages up to 1,099 V DC, depending on the supply voltage, may occur on the terminals.

9.6.5 PC Software

The PC is connected via a standard (host/device) USB cable, or via the RS-485 interface.

USB is a serial bus utilizing four shielded wires with Ground pin 4 connected to the shield in the PC USB port. When connecting the PC to an adjustable frequency drive through the USB cable, there is a potential risk of damaging the PC USB host controller. All standard PCs are manufactured without galvanic isolation in the USB port. Any ground potential difference caused by not following the recommendations described in *AC Line Input Connection* in the *Instruction Manual* can damage the USB host controller through the shield of the USB cable.
It is recommended to use a USB isolator with galvanic isolation to protect the PC USB host controller from ground potential differences when connecting the PC to an adjustable frequency drive 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 adjustable frequency drive through a USB cable. It reduces the ground potential difference, but does not eliminate all potential differences due to the ground and shield connected in the PC USB port.

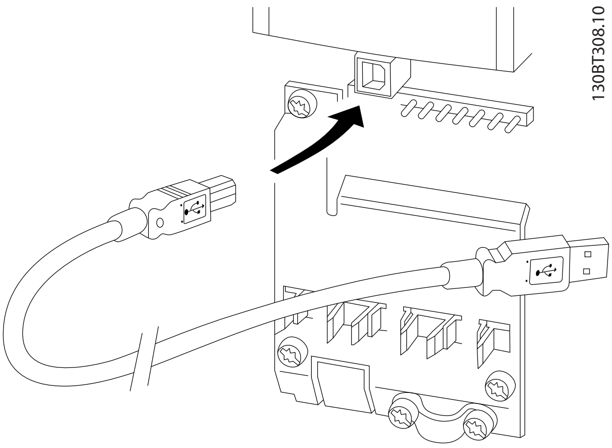


Figure 9.48 USB Connection

9.6.5.1 MCT 10

To control the adjustable frequency drive from a PC, install the MCT 10 Set-up Software.

Data storage in PC via MCT 10 Set-up Software

1. Connect a PC to the unit via the USB COM port.
2. Open MCT 10 Set-up Software.
3. Select the USB port in the *network* section.
4. Select *copy*.
5. Select the *project* section.
6. Select *paste*.
7. Select *Save as*.

All parameters are now stored.

Data transfer from PC to adjustable frequency drive via MCT 10 Set-up Software

1. Connect a PC to the unit via the USB COM port.
2. Open MCT 10 Set-up Software.
3. Select *Open* – stored files are shown.
4. Open the appropriate file.
5. Select *Write to drive*.

All parameters are now transferred to the adjustable frequency drive.

A separate manual for MCT 10 Set-up Software is available. Download it from *www.danfoss.com/BusinessAreas/DrivesSolutions/Softwaredownload/*.

9.6.5.2 MCT 31

The MCT 31 harmonic calculation PC tool enables easy estimation of the harmonic distortion in a given application. Both the harmonic distortion of Danfoss adjustable frequency drives as well as non-Danfoss adjustable frequency drives with additional harmonic reduction devices, such as Danfoss AHF filters and 12–18-pulse rectifiers, can be calculated.

MCT 31 can also be downloaded from *www.danfoss.com/BusinessAreas/DrivesSolutions/Softwaredownload/*.

9.6.5.3 Harmonic Calculation Software (HCS)

HCS is an advanced version of the harmonic calculation tool. The calculated results are compared to relevant norms and can be printed afterwards.

See *www.danfoss-hcs.com/Default.asp?LEVEL=START*

9

9.7 Additional Motor Information

9.7.1 Motor Cable

All types of three-phase asynchronous standard motors can be used with an adjustable frequency drive unit. The factory setting is for clockwise rotation with the adjustable frequency drive output connected as follows:

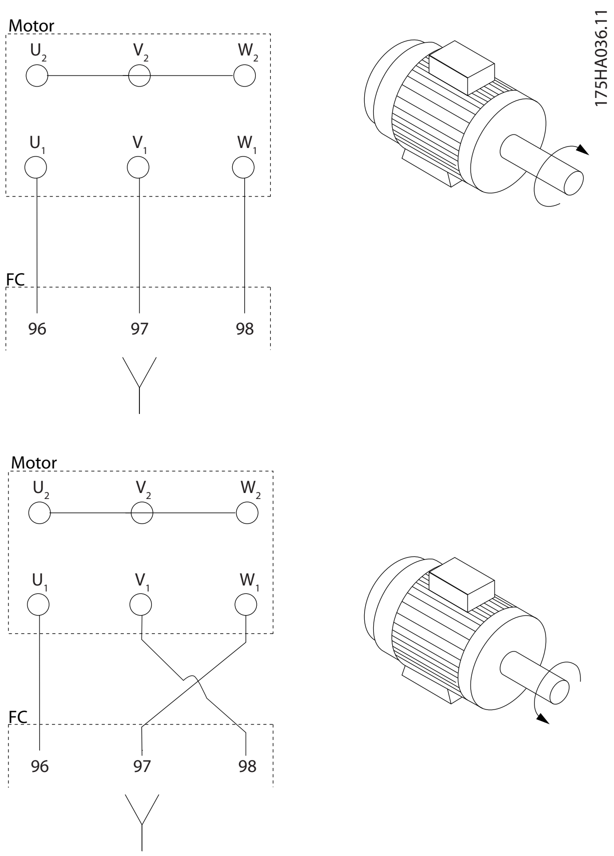


Figure 9.49 Terminal Connection for Clockwise and Counter-clockwise Rotation

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.

9.7.2 Connection of Multiple Motors

NOTICE!

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

The adjustable frequency drive can control several motors connected in parallel. When using parallel motor connection observe the following:

- VCC+ mode may be used in some applications.
- The total current consumption of the motors must not exceed the rated output current I_{INV} for the adjustable frequency drive.
- Do not use common joint connection for long cable lengths, see *Figure 9.51*.
- The total motor cable length specified in *Table 5.2*, is valid as long as the parallel cables are kept short (less than 10 m each), see *Figure 9.53* and *Figure 9.54*.
- Consider voltage drop across the motor cable, see *Figure 9.54*.
- For long parallel cables, use LC filter, see *Figure 9.54*.
- For long cables without parallel connection, see *Figure 9.55*.

NOTICE!

When motors are connected in parallel, *1-02 Flux Motor Feedback Source* cannot be used, and *1-01 Motor Control Principle* must be set to *[0] U/f*.

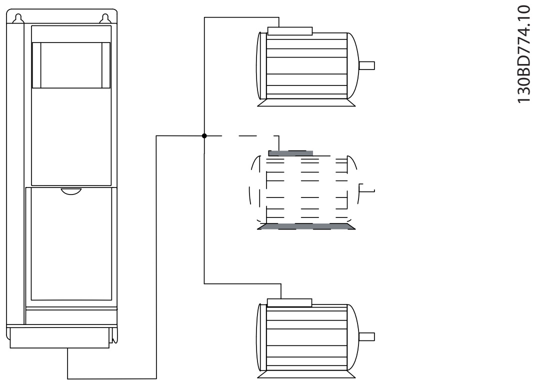


Figure 9.50 Common Joint Connection for Short Cable Lengths

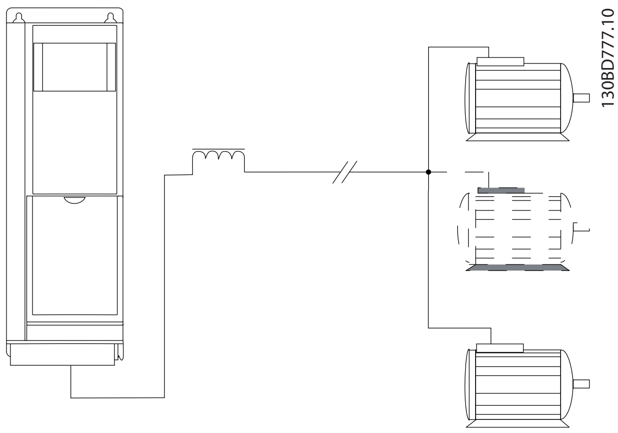


Figure 9.53 Parallel Cables with Load

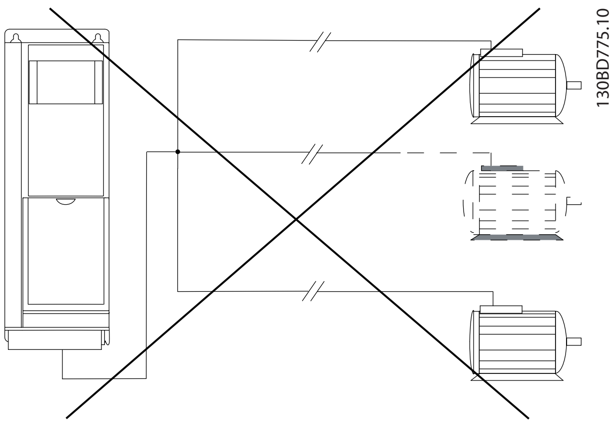


Figure 9.51 Common Joint Connection for Long Cable Lengths

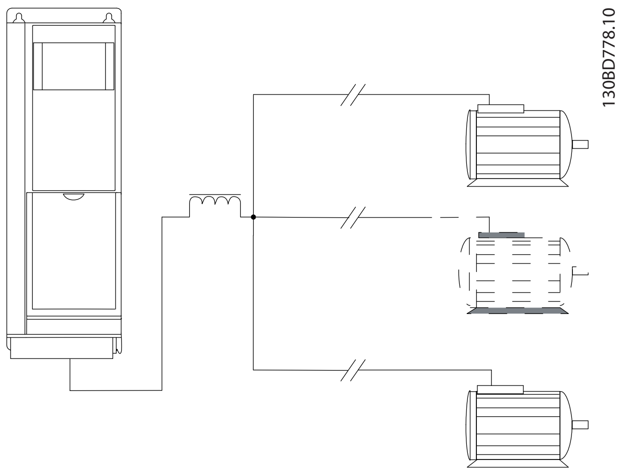


Figure 9.54 LC Filter for Long Parallel Cables

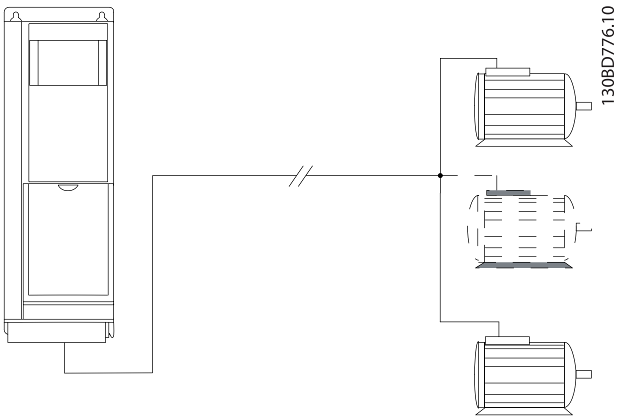


Figure 9.52 Parallel Cables without Load

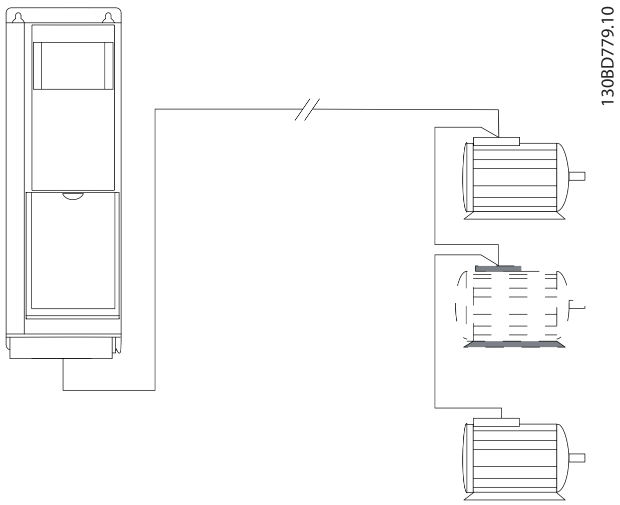


Figure 9.55 Long Cables in Series Connection

Enclosure types	Power Size (hp [kW])	Voltage [V]	1 cable (ft [m])	2 cables (ft [m])	3 cables (ft [m])	4 cables (ft [m])
A1, A2, A4, A5	0.5–1 [0.37–0.75]	400	500 [150]	145 [45]	26 [8]	20 [6]
		500	500 [150]	23 [7]	13 [4]	10 [3]
A2, A4, A5	1.5–2 [1.1–1.5]	400	500 [150]	145 [45]	66 [20]	26 [8]
		500	500 [150]	145 [45]	16 [5]	13 [4]
A2, A4, A5	3–5 [2.2–4]	400	500 [150]	145 [45]	66 [20]	36 [11]
		500	500 [150]	145 [45]	66 [20]	20 [6]
A3, A4, A5	7.5–10 [5.5–7.5]	400	500 [150]	145 [45]	66 [20]	36 [11]
		500	500 [150]	145 [45]	66 [20]	36 [11]
B1, B2, B3, B4, C1, C2, C3, C4	15–100 [11–75]	400	500 [150]	250 [75]	165 [50]	120 [37]
		500	500 [150]	250 [75]	165 [50]	120 [37]
A3	1.5–10 [1.1–7.5]	525–690	330 [100]	165 [50]	110 [33]	82 [25]
B4	11–30	525–690	500 [150]	250 [75]	165 [50]	120 [37]
C3	50–60 [37–45]	525–690	500 [150]	250 [75]	165 [50]	120 [37]

Table 9.19 Max. Cable Length for Each Parallel Cable

9.8 Safety

9.8.1 High Voltage Test

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

⚠WARNING

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

9.8.2 EMC Grounding

Proper EMC grounding practice

- Respect safety grounding.
- Keeping the ground connection as short as possible results in the best EMC performance.
- Wires with greater square have a lower impedance and better EMC grounding.
- In cases where multiple devices with metal cabinets are used, mount them on common metal mounting plate to improve EMC performance.

NOTICE!

If necessary, use washers for fastening bolts, e.g., in case of painted parts.

⚠CAUTION

POTENTIAL HAZARD IN THE EVENT OF INTERNAL FAILURE
Risk of personal injury when the adjustable frequency drive is not properly closed.

- **Before applying power, ensure all safety covers are in place and securely fastened.**

9

10 Application Examples

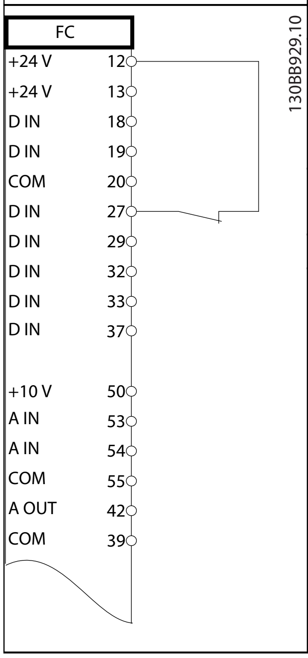
10.1 Commonly Used Applications

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

- Parameter settings are the regional default values unless otherwise indicated (selected in *0-03 Regional Settings*).
- Parameters associated with the terminals and their settings are shown next to the drawings.
- Where switch settings for analog terminals A53 or A54 are required, these are also shown.

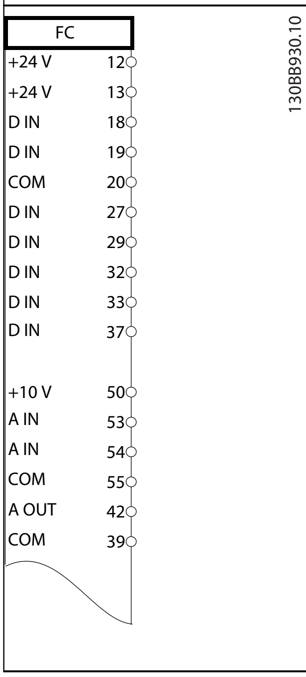
CAUTION

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



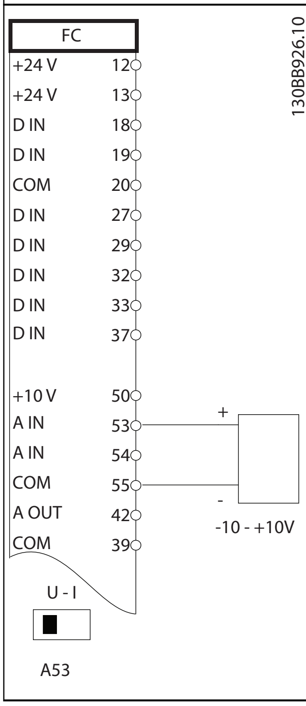
Parameters	
Function	Setting
1-29 Automatic Motor Adaptation (AMA)	[1] Enable complete AMA
5-12 Terminal 27 Digital Input	[2]* Coast inverse
*=Default Value	
Notes/comments: Parameter group *1–2* Motor Data* must be set according to motor	

Table 10.1 AMA with T27 Connected



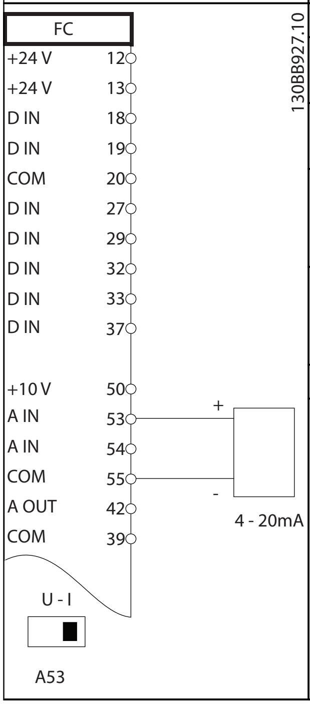
Parameters	
Function	Setting
1-29 Automatic Motor Adaptation (AMA)	[1] Enable complete AMA
5-12 Terminal 27 Digital Input	[0] No operation
*=Default Value	
Notes/comments: Parameter group *1–2* Motor Data* must be set according to motor	

Table 10.2 AMA without T27 Connected



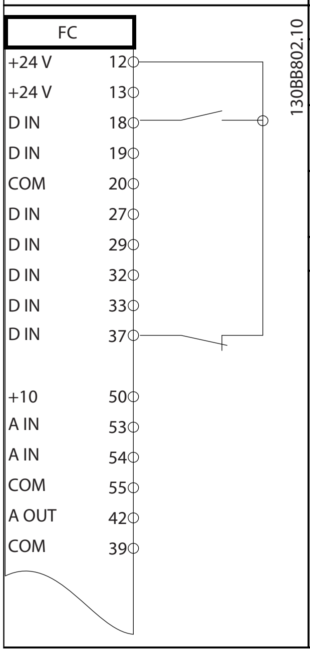
Parameters	
Function	Setting
6-10 Terminal 53 Low Voltage	0.07 V*
6-11 Terminal 53 High Voltage	10 V*
6-14 Terminal 53 Low Ref./Feedb. Value	0 RPM
6-15 Terminal 53 High Ref./Feedb. Value	1,500 RPM
*=Default Value	
Notes/comments:	

Table 10.3 Analog Speed Reference (Voltage)



Parameters	
Function	**Setting**
6-12 Terminal 53 Low Current	4 mA*
6-13 Terminal 53 High Current	20 mA*
6-14 Terminal 53 Low Ref./Feedb. Value	0 RPM
6-15 Terminal 53 High Ref./Feedb. Value	1,500 RPM
*=Default Value	
Notes/comments:	

Table 10.4 Analog Speed Reference (Current)



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

Table 10.5 Start/Stop Command with Safe Torque Off

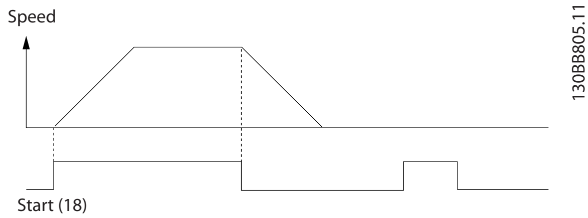
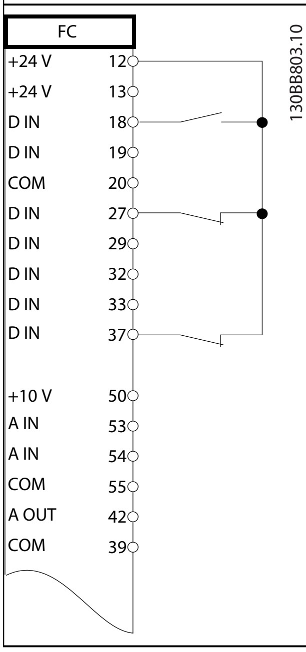


Figure 10.1 Start/Stop with Safe Torque Off



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

Table 10.6 Pulse Start/Stop

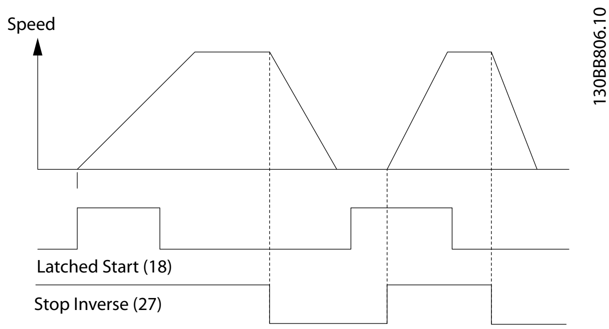
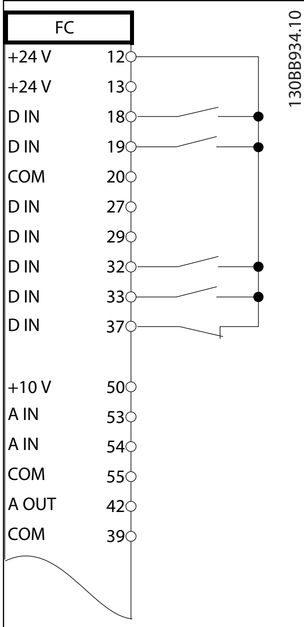


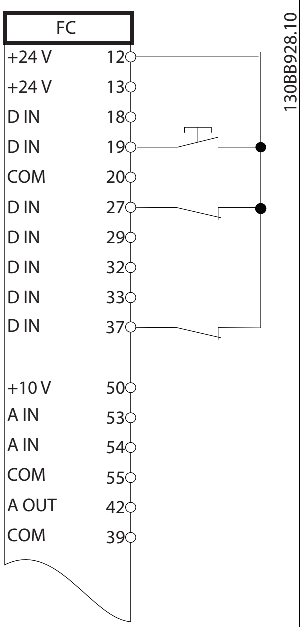
Figure 10.2 Latched Start/Stop Inverse

10



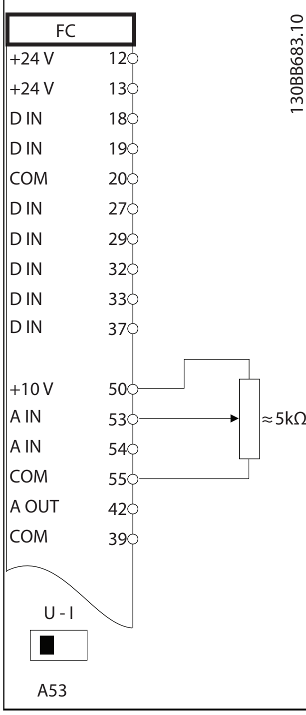
Parameters	
Function	**Setting**
5-10 Terminal 18 Digital Input	[8] Start
5-11 Terminal 19 Digital Input	[10] Reversing*
5-12 Terminal 27 Digital Input	[0] No operation
5-14 Terminal 32 Digital Input	[16] Preset ref bit 0
5-15 Terminal 33 Digital Input	[17] Preset ref bit 1
3-10 Preset Reference	
Preset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

Table 10.7 Start/Stop with Reversing and Four Preset Speeds



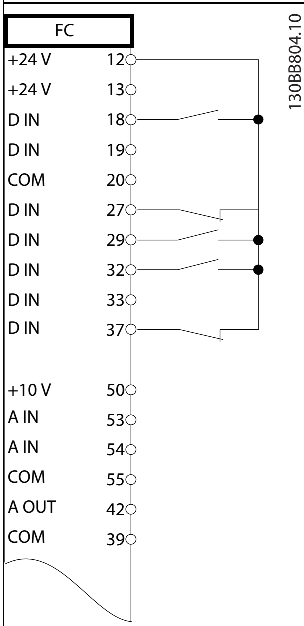
Parameters	
Function	**Setting**
5-11 Terminal 19 Digital Input	[1] Reset
*=Default Value	
Notes/comments:	

Table 10.8 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	1,500 RPM
*=Default Value	
Notes/comments:	

Table 10.9 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] Slow
*=Default Value	
Notes/comments:	

Table 10.10 Speed Up/Down

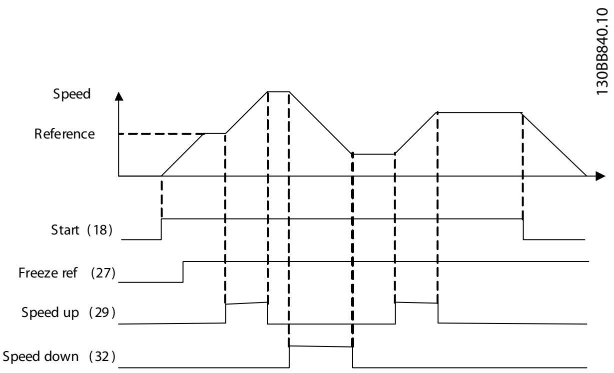


Figure 10.3 Speed Up/Down

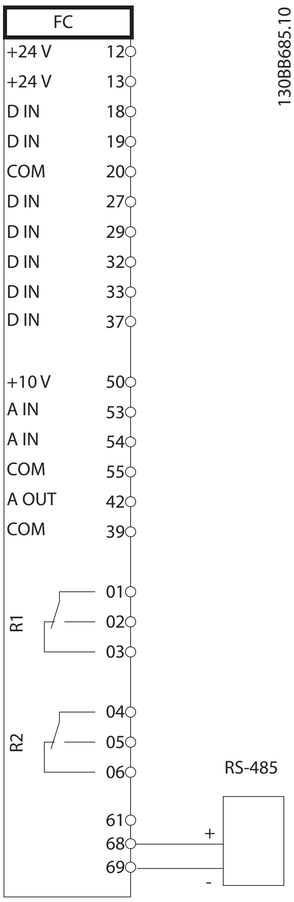
	Parameters	
	**Function**	**Setting**
	8-30 Protocol	FC*
	8-31 Address	1*
	8-32 Baud Rate	9,600*
	*=Default Value	
	Notes/comments: Select protocol, address, and Baud rate in the parameters mentioned above.	

Table 10.11 RS-485 Network Connection

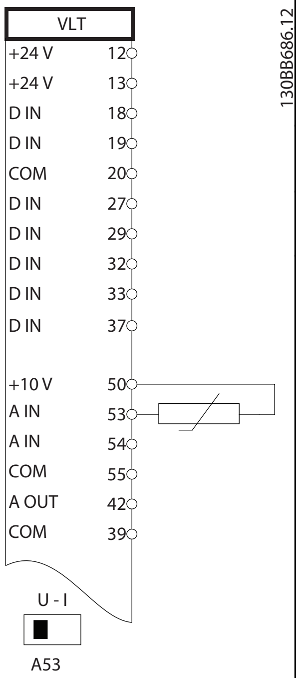
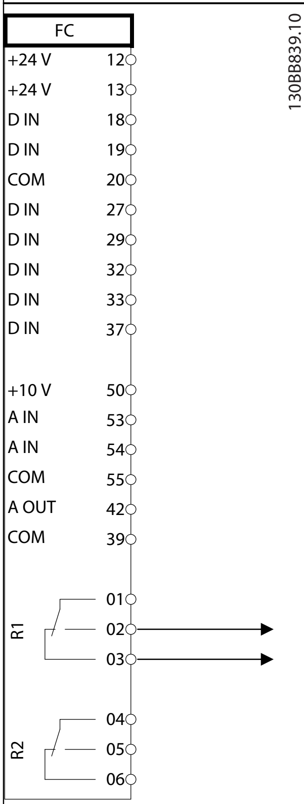
	Parameters	
	**Function**	**Setting**
	1-90 Motor Thermal Protection	[2] Thermistor trip
	1-93 Thermistor Source	[1] Analog input 53
	*=Default Value	
	Notes/comments: If only a warning is desired, set *1-90 Motor Thermal Protection* to *[1] Thermistor warning.*	

Table 10.12 Motor Thermistor

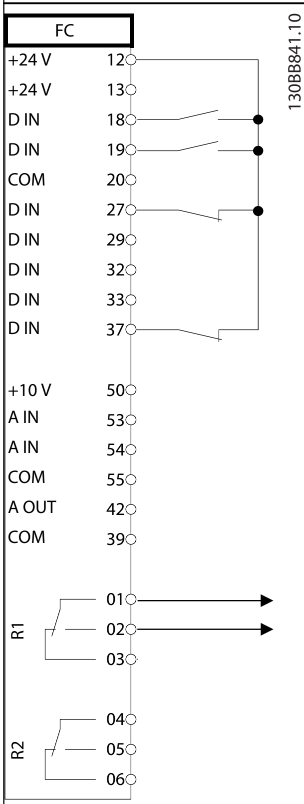
10



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

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

Table 10.13 Using SLC to Set a Relay



Parameters	
Function	**Setting**
1-00 Configuration Mode	[0] Speed open-loop
1-01 Motor Control Principle	[1] VVC^{plus}
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 10.14 Mechanical Brake Control (Open-loop)

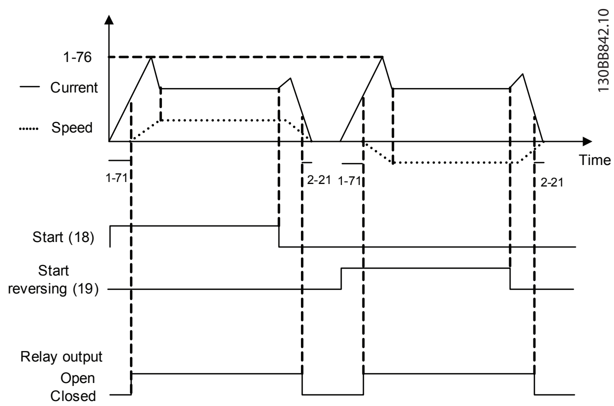


Figure 10.4 Mechanical Brake Control (Open-loop)

10.1.1 Closed-loop Drive System

An adjustable frequency drive system consist usually of more elements such as

- Motor
- Gearbox
- Mechanical Brake
- Adjustable frequency drive
- Encoder as feedback system
- Brake resistor for dynamic braking
- Transmission
- Load

Applications demanding mechanical brake control usually need a brake resistor.

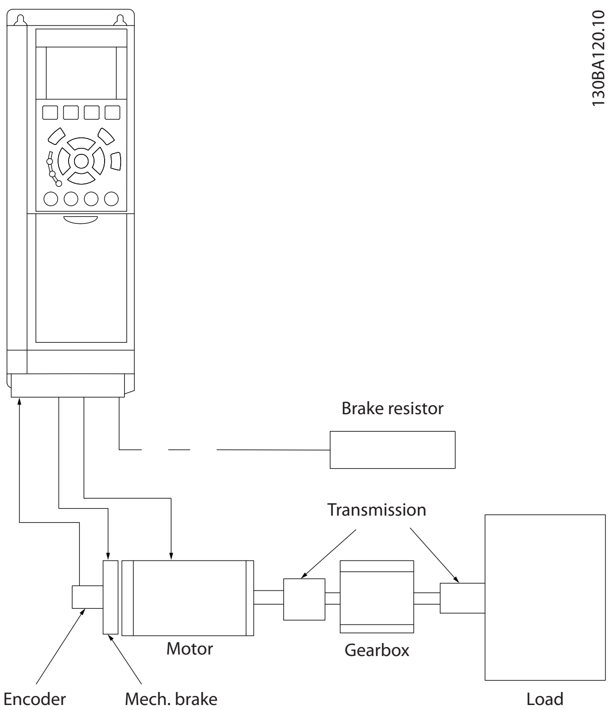


Figure 10.5 Example of FC 302 Closed-loop Speed Control

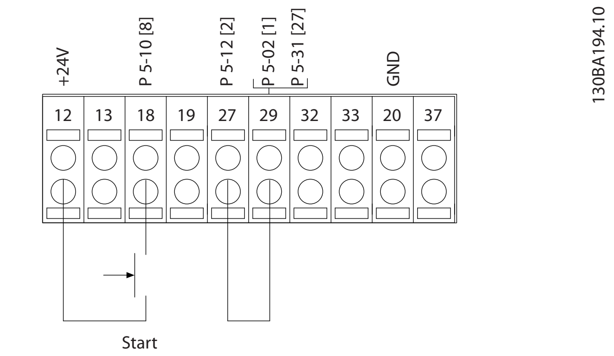
10.1.2 Programming of Torque Limit and Stop

In applications with an external electro-mechanical brake, such as hoisting applications, it is possible to stop the adjustable frequency drive via a 'standard' stop command and simultaneously activate the external electro-mechanical brake.
The example given below illustrates the programming of adjustable frequency drive 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 adjustable frequency drive is not at the torque limit, the motor ramps down to 0 Hz.
If the adjustable frequency drive is at the torque limit and a stop command is activated, terminal 29 Output (programmed to *[27] Torque limit and stop*) is activated. The signal to terminal 27 changes from 'logic 1' to 'logic 0', and the motor starts to coast, thereby ensuring that the hoist stops even if the adjustable frequency drive itself cannot handle the required torque (i.e., due to excessive overload).

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

10



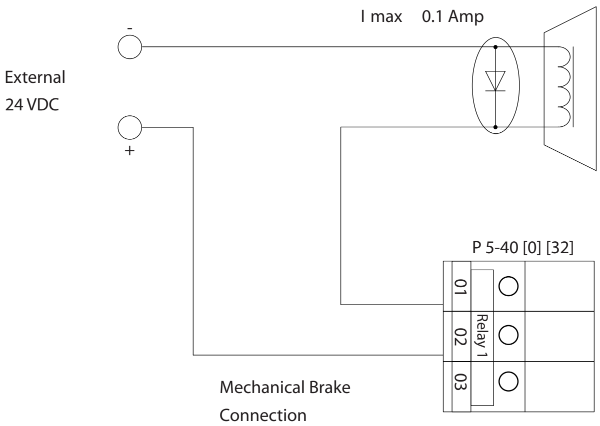


Figure 10.6 External Electro-mechanical Brake

10.1.3 Programming of Speed Control

The required motor speed is set via a potentiometer connected to terminal 53. The speed range is 0 to 1,500 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.

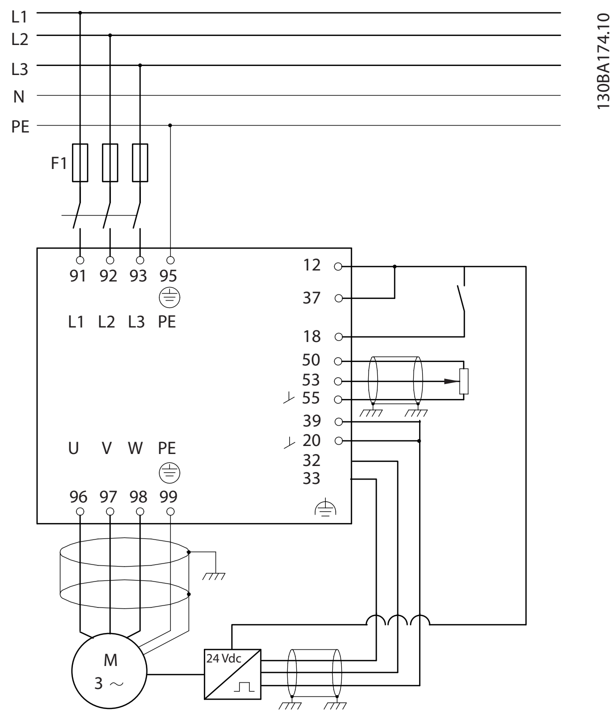
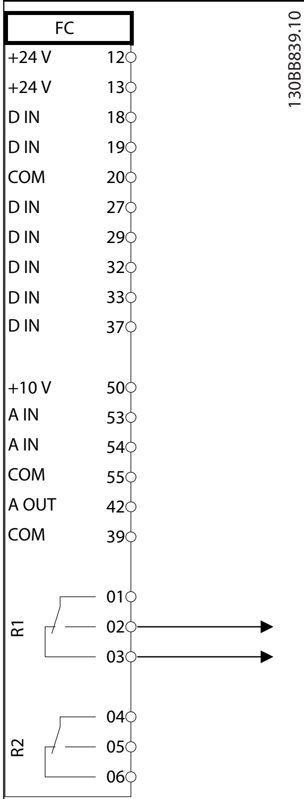


Figure 10.7 Example - Speed Control Connections

10

Application Example



Parameters	
Function	**Setting**
7-00 Speed PID Feedback Source	[2] MCB 102
17-11 Resolution (PPR)	1024*
13-00 SL Controller Mode	[1] On
13-01 Start Event	[19] Warning
13-02 Stop Event	[44] Reset key
13-10 Comparator Operand	[21] Warning no.
13-11 Comparator Operator	[1] ≈*
13-12 Comparator Value	90
13-51 SL Controller Event	[22] Comparator 0
13-52 SL Controller Action	[32] Set digital out A low
5-40 Function Relay	[80] SL digital output A
* = Default Value	
Notes/comments: Warning 90 will be issued when the feedback signal from the encoder does not correspond to the reference. The SLC monitors Warning 90 and if Warning 90 becomes TRUE, then Relay 1 is triggered. External equipment may then indicate that service may be required.	

Table 10.15 Using SLC to Set a Relay

11 Options and Accessories

11.1 Communication Options

- VLT® PROFIBUS DP V1 MCA 101
- VLT® DeviceNet MCA 104
- VLT® CAN Open MCA 105
- VLT® EtherCAT MCA 124
- VLT® PROFIBUS Drive MCA 114
- VLT® PROFINET MCA 120
- VLT® EtherNet/IP MCA 121
- VLT® Modbus TCP MCA 122
- VLT® POWERLINK MCA 122
- VLT® DeviceNet Converter MCA 194

11.2 I/O, Feedback and Safety Options

11.2.1 VLT® General Purpose I/O Module MCB 101

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

11

Fit MCB 101 into slot B in the VLT® AutomationDrive.

Contents:

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

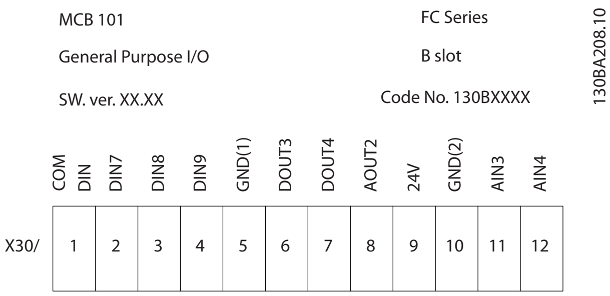


Figure 11.1 MCB 101 Option

11.2.1.1 Galvanic Isolation in MCB 101

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

If the digital inputs 7, 8 or 9 are to be switched by use of the internal 24 V power supply (terminal 9), establish connection between terminals 1 and 5, see *Figure 11.2*.

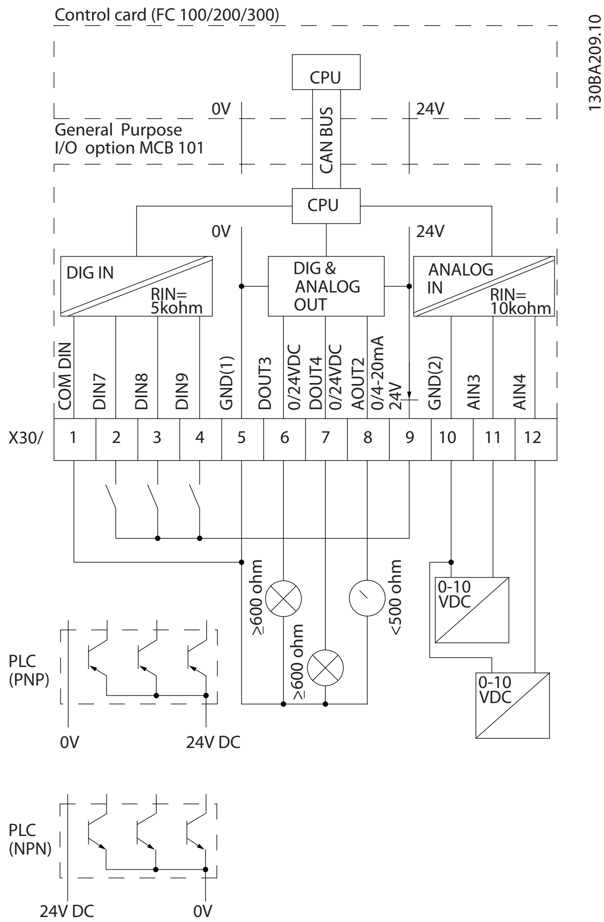


Figure 11.2 Principle Diagram

Digital input - terminal X30/1-4	
Number of digital inputs	3
Terminal number	X30.2, X30.3, X30.4
Logic	PNP or NPN
Voltage level	0–24 V DC
Voltage level, logic'0' PNP (GND = 0 V)	< 5 V DC
Voltage level, logic'1' PNP (GND = 0 V)	> 10 V DC
Voltage level, logic '0' NPN (GND = 24 V)	< 14 V DC
Voltage level, logic '1' NPN (GND = 24 V)	> 19 V DC
Maximum voltage on input	28 V continuous
Pulse frequency ranges	0–110 kHz
Duty cycle, min. pulse width	4.5 ms
Input impedance	> 2 kΩ

Analog input - terminal X30/11, 12	
Number of analog inputs	2
Terminal number	X30.11, X30.12
Modes	Voltage
Voltage level	0–10 V
Input impedance	> 10 kΩ
Max. voltage	20 V
Resolution for analog inputs	10 bit (+ sign)
Accuracy of analog inputs	Max. error 0.5% of full scale
Bandwidth	FC 301: 20 Hz/ FC 302: 100 Hz

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

Analog output - terminal X30/8	
Number of analog outputs	1
Terminal number	X30.8
Current range at analog output	0–20 mA
Max. load GND - analog output	500 Ω
Accuracy on analog output	Max. error: 0.5% of full scale
Resolution on analog output	12 bit

11.2.2 VLT® Encoder Option MCB 102

The encoder module can be used as feedback source for closed-loop flux control (*1-02 Flux Motor Feedback Source*) as well as closed-loop speed control (*7-00 Speed PID Feedback Source*). Configure encoder option in parameter group *17-** Feedback Option*.

Used for

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

Supported encoder types:
Incremental encoder: 5 V TTL type, RS-422, max. frequency: 410 kHz
Incremental encoder: 1 Vpp, sine-cosine
Hiperface® Encoder: Absolute and Sine-Cosine (Stegmann/SICK)
EnDat encoder: Absolute and Sine-Cosine (Heidenhain) Supports version 2.1
SSI encoder: Absolute

NOTICE!

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

NOTICE!

It is strongly recommended to always supply the encoder through the MCB 102. It shall be avoided to use external power supply for the encoder.

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

NOTICE!

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

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

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

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

Connector Designation X31	Incremental Encoder (refer to *Figure 11.3*)	SinCos Encoder Hiperface® (refer to *Figure 11.4*)	EnDat Encoder	SSI Encoder	Description
1	NC			24 V*	24 V output (21–25 V, I_{max}:125 mA)
2	NC	8 VCC			8 V Output (7–12 V, I_{max}: 200 mA)
3	5 VCC		5 VCC	5 V*	5 V output (5 V ± 5%, I_{max}: 200 mA)
4	GND		GND	GND	GND
5	A input	+COS	+COS		A input
6	A inv input	REFCOS	REFCOS		A inv input
7	B input	+SIN	+SIN		B input
8	B inv input	REFSIN	REFSIN		B inv input
9	Z input	+Data RS-485	Clock out	Clock out	Z input OR +Data RS-485
10	Z inv input	-Data RS-485	Clock out inv.	Clock out inv.	Z input OR -Data RS-485
11	NC	NC	Data in	Data in	Future use
12	NC	NC	Data in inv.	Data in inv.	Future use
Max. 5 V on X31.5-12					

Table 11.1 Encoder Connections

** Supply for encoder: see data on encoder*

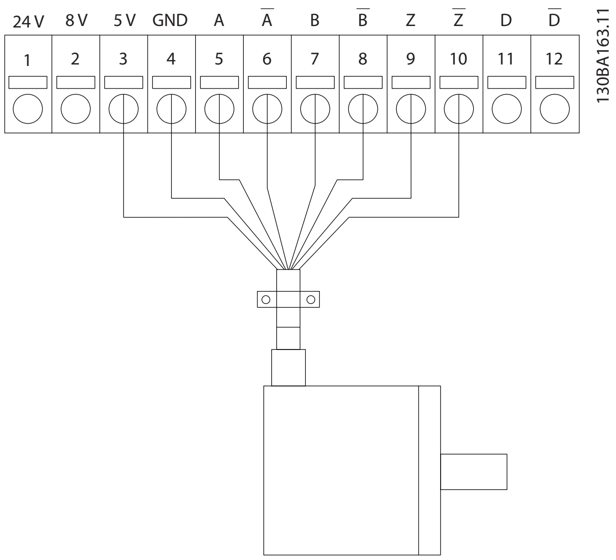


Figure 11.3 Incremental Encoder

NOTICE!

Max. cable length 492 ft [150 m].

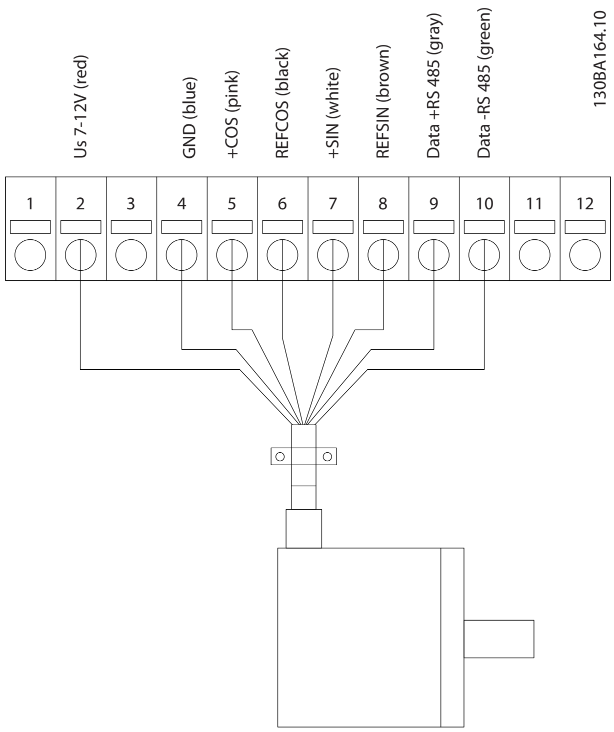


Figure 11.4 SinCos Encoder Hiperface

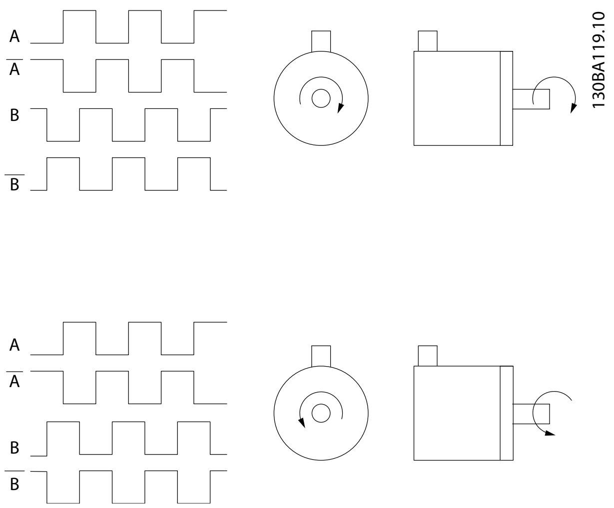


Figure 11.5 Rotation Direction

11.2.3 VLT® Resolver Option MCB 103

Resolver Option MCB 103 is used for interfacing resolver motor feedback to VLT® AutomationDrive. Resolvers are used basically as motor feedback device for permanent magnet brushless synchronous motors.

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

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

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

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

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

Table 11.2 Resolver Specifications

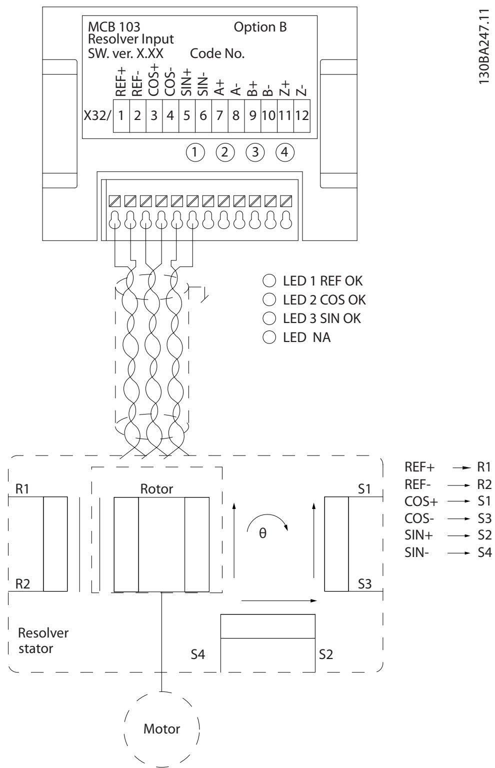


Figure 11.6 MCB 103 Resolver Input

LED indicators

LED 1 is on when the reference signal is OK to resolver.
LED 2 is on when cosine signal is OK from resolver
LED 3 is on when Sinus signal is OK from resolver.

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

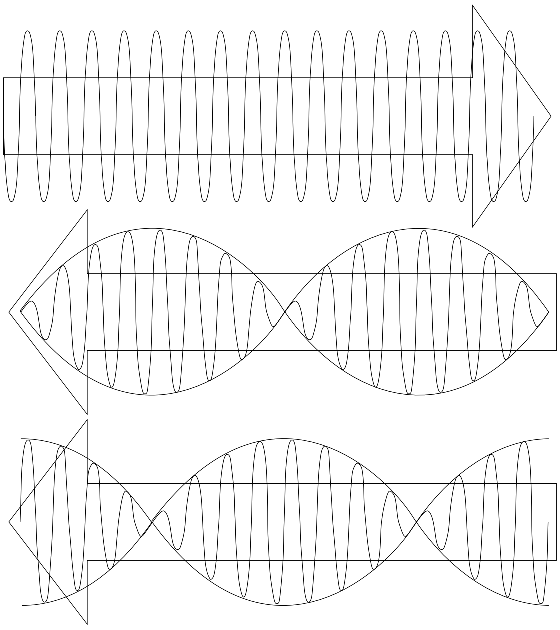


Figure 11.7 Permanent Magnet (PM) Motor with Resolver as Speed Feedback

Set-up example
In this example, a permanent magnet (PM) motor is used with resolver as speed feedback. A PM motor must usually operate in flux mode.

Wiring
The max cable length is 500 ft [150 m] when a twisted-pair cable is used.

NOTICE!

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

NOTICE!

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

NOTICE!

Always use shielded motor cables and brake chopper cables.

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

Table 11.3 Parameters to Adjust

11.2.4 VLT® Relay Card MCB 105

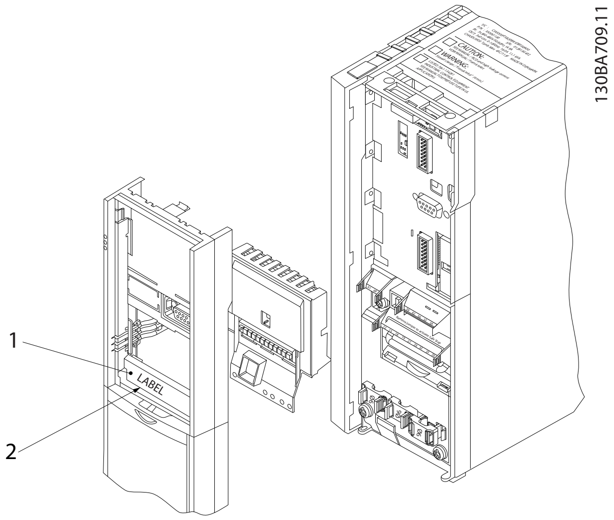
The Relay Option MCB 105 includes three pieces of SPDT contacts and must be fitted into option slot B.

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

1) IEC 947 part 4 and 5

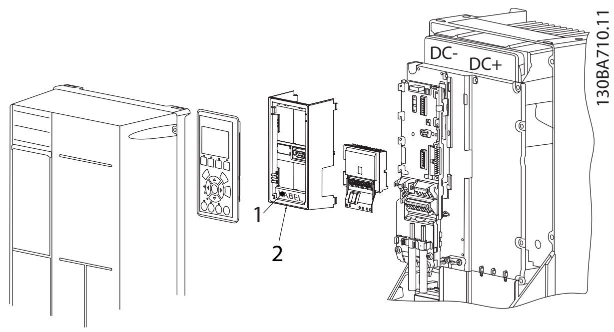
When the relay option kit is ordered separately the kit includes

- Relay Module MCB 105
- Enlarged LCP fixture and enlarged terminal cover
- Label for covering access to switches S201, S202 and S801
- Cable strips for fastening cables to relay module



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

Figure 11.8 Enclosure Types A2-A3-B3



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

Figure 11.9 Enclosure Types A5-B1-B2-B4-C1-C2-C3-C4

⚠WARNING

Warning Dual supply

How to add the Relay Card MCB 105 Option:

1. Disconnect power to the adjustable frequency drive.
2. Disconnect power to the live part connections on relay terminals.
3. Remove the LCP, the terminal cover and the LCP fixture from the adjustable frequency drive.
4. Fit the MCB 105 option in slot B.
5. Connect the control cables and fasten the cables with the enclosed cable strips.
6. Make sure the length of the stripped wire is correct (see *Figure 11.11*).
7. Do not mix live parts (high voltage) with control signals (PELV).
8. Fit the enlarged LCP fixture and enlarged terminal cover.
9. Replace the LCP.
10. Connect power to the adjustable frequency drive.
11. Select the relay functions in *5-40 Function Relay* [6-8], *5-41 On Delay, Relay* [6-8] and *5-42 Off Delay, Relay* [6-8].

NOTICE!

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

NOTICE!

To access RS-485 termination switch S801 or current/ voltage switches S201/S202, dismount the relay card (see *Figure 11.8* and *Figure 11.9*, position 2).

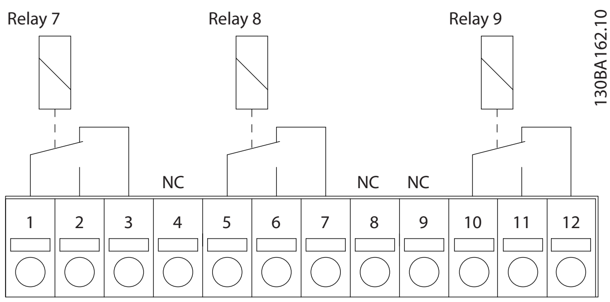


Figure 11.10 Relays

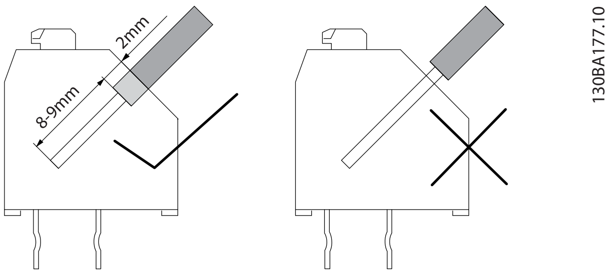
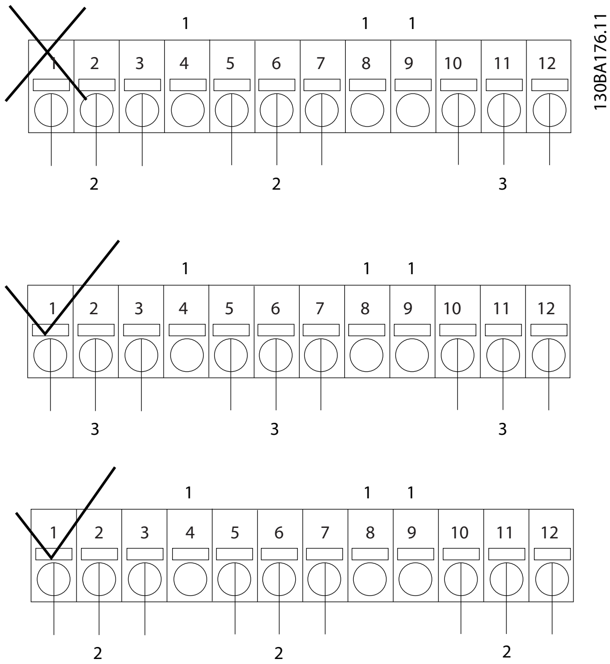


Figure 11.11 Correct Wire Inserting



1	NC
2	Live part
3	PELV

Figure 11.12 Correct Relay Wiring

NOTICE!

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

11.2.5 VLT® Safe PLC Interface Option MCB 108

The Safe PLC Interface Option MCB 108 is designed to be built-in between the Safe dual pole (plus/minus) on the Safe PLC and the Safe Stop input on FC 302. The Safe PLC interface allows the safe output on the Safe PLC to maintain the test pulses on the plus and minus output without impacting the sensor signal to safe stop T37.
It can be used in combination with safety devices to satisfy the requirement of IEC61800-5-2 SIL 2, ISO13849-1 cat. 3 for Safe Torque Off (STO).

The option module MCB 108 is galvanically isolated via an internal DC/DC drive and it can be fitted into option slot B.

Input voltage (DC)	18–28 V DC
Typical current input (DC)	60 mA
Max. current input (DC)	110 mA DC
Max. current inrush (DC)	500 mA DC
Output voltage (DC)	20 V DC@Vin = 24 V
Turn on delay	1 ms
Turn off delay	3 ms

Observe the following precautions

- The FC 302 with MCB 108 (including the connections between X31/9 and Terminal 37) must be placed inside an IP54 enclosure.
- Safe Stop activation (i.e., removal of 24 V DC voltage supply to terminal 37 by removing voltage to dual pole input of MCB 108) does not provide electrical safety.
- The safety device connected to the dual pole input of the MCB 108 must fulfill the requirements of cat. 3 / PL d according to ISO 13849-1 for interrupting the voltage/current to the MCB 108. This also applies for the connections between the MCB 108 and the safety device.
- Read and follow the instructions for the safety device to connect it properly to MCB 108.

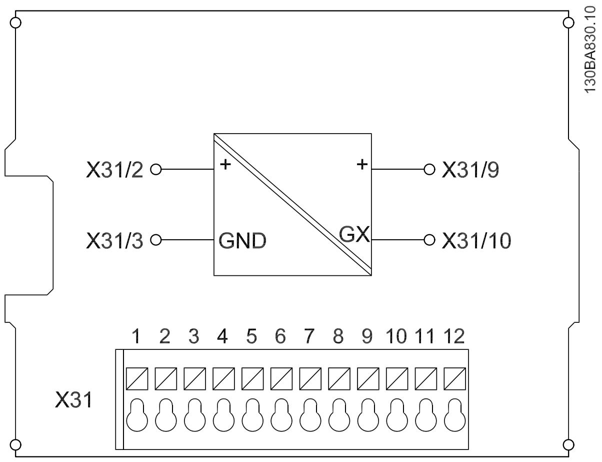


Figure 11.13 Option Module Safe PLC Interface MCB 108

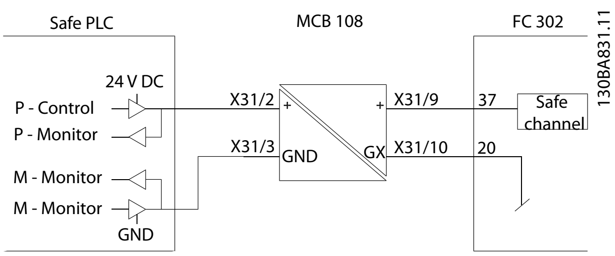


Figure 11.14 Safe PLC Interface MCB 108 Connection

11.2.6 VLT® PTC Thermistor Card MCB 112

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

For different application possibilities, see *chapter 10 Application Examples*.

X44/1 and X44/2 are the thermistor inputs. X44/12 enables Safe Torque Off of the adjustable frequency drive (T-37), if the thermistor values make it necessary, and X44/10 informs the adjustable frequency drive that a request for safe torque off came from the MCB 112 to ensure a suitable alarm handling. One of the digital inputs parameters (or a digital input of a mounted option) must be set to *[80] PTC Card 1* to use the information from X44/10. Configure *5-19 Terminal 37 Safe Stop* to the desired Safe Torque Off functionality (default is Safe Stop Alarm).

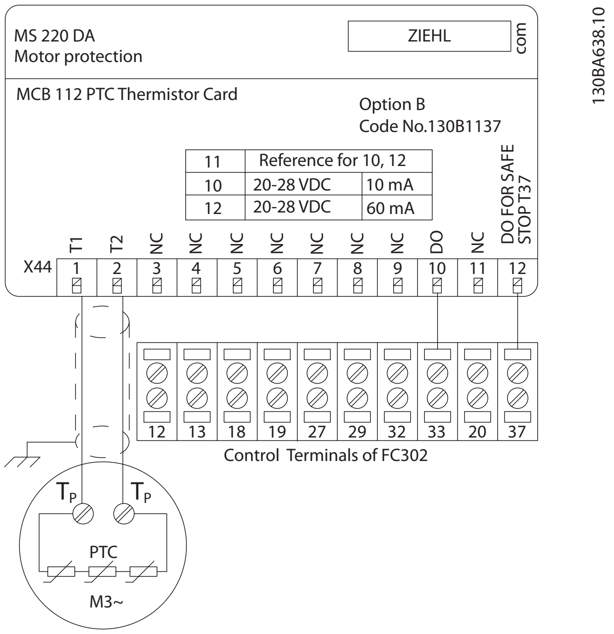


Figure 11.15 Installation of MCB 112

ATEX Certification with FC 102, FC 202 and FC 302

The MCB 112 has been certified for ATEX, which means that the adjustable frequency drive with the MCB 112 can be used with motors in potentially explosive atmospheres. See the *VLT® PTC Thermistor Card MCB 112 Instruction Manual* for more information.

Figure 11.16 ATmosphère EXplosive (ATEX)

Electrical Data

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

Testing conditions	
EN 60 947-8	
Measurement voltage surge resistance	6000 V
Overvoltage category	III
Pollution degree	2
Measurement isolation voltage Vbis	690 V
Reliable galvanic isolation until Vi	500 V
Perm. ambient temperature	-4°F–+140°F [-20°C–+60°C]
	EN 60068-2-1 Dry heat
Moisture	5–95%, no condensation permissible
Vibration resistance	10 to 1000 Hz 1.14 g
Shock resistance	50 g

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

11.2.7 VLT® Extended Relay Card MCB 113

The MCB 113 adds seven digital inputs, two analog outputs and 4 SPDT relays to the standard I/O of the adjustable frequency drive for increased flexibility and to comply with the German NAMUR NE37 recommendations.
The MCB 113 is a standard C1 option for the VLT® AutomationDrive and is automatically detected after mounting.

11

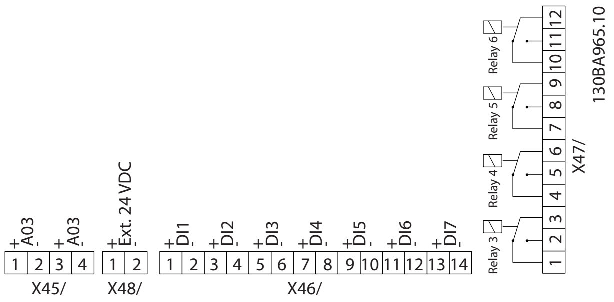


Figure 11.17 Electrical Connections of MCB 113

MCB 113 can be connected to an external 24 V on X58/ to ensure galvanical isolation between the VLT® AutomationDrive and the option card. If galvanical isolation is not needed, the option card can be supplied through internal 24 V from the adjustable frequency drive.

NOTICE!

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

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

NOTICE!

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

11

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
Overvoltage category (contact - ground)	III
Overvoltage 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 line power systems	

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

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

11.2.8 VLT® Sensor Input Option MCB 114

The sensor input option card MCB 114 can be used in the following cases:

- Sensor input for temperature transmitters PT100 and PT1000 for monitoring bearing temperatures
- As general extension of analog inputs with one additional input for multi-zone control or differential pressure measurements
- Support extended PID controllers with I/Os for setpoint, transmitter/sensor inputs

Typical motors, designed with temperature sensors to protect bearings from being overloaded, are fitted with 3 PT100/1000 temperature sensors; one in front, one in the backend bearing, and one in the motor windings. The Danfoss Option MCB 114 supports 2- or 3-wire sensors with individual temperature limits for under/over temperature. An auto detection of sensor type PT100 or PT1000 takes place at power-up.

The option can generate an alarm if the measured temperature is either below the low limit or above the high limit specified by the user. The individual measured temperature on each sensor input can be read out in the display or by readout parameters. If an alarm occurs, the relays or digital outputs can be programmed to be active high by selecting *[21] Thermal Warning* in parameter group *5-** Digital In/Out*.

A fault condition has a common warning/alarm number associated with it, which is Alarm/Warning 20, Temp. input error. Any present output can be programmed to be active in case the warning or alarm appears.

11.2.8.1 Electrical and Mechanical Specifications

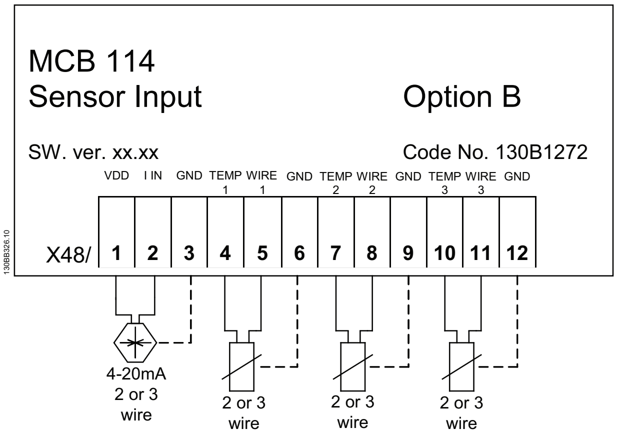
Analog Input	
Number of analog inputs	1
Format	0–20 mA or 4–20 mA
Wires	2
Input impedance	<200 Ω
Sample rate	1 kHz
Third order filter	100 Hz at 3 dB
The option is able to supply the analog sensor with 24 V DC (terminal 1).	

Temperature Sensor Input	
Number of analog inputs supporting PT100/1000	3
Signal type	PT100/1000
Connection	PT 100 2 or 3 wire/PT1000 2 or 3 wire
Frequency PT100 and PT1000 input	1 Hz for each channel
Resolution	10 bit
Temperature range	-50–204 °C -58–399 °F

Galvanic Isolation	
The sensors to be connected are expected to be galvanically isolated from the AC line voltage level.	IEC 61800-5-1 and UL508C

Cabling	
Maximum signal cable length	1,640 ft [500 m]

11.2.8.2 Electrical Wiring



Terminal	Name	Function
1	VDD	24 V DC to supply 4–20 mA sensor
2	I in	4–20 mA input
3	GND	Analog input GND
4, 7, 10	Temp 1, 2, 3	Temperature input
5, 8, 11	Wire 1, 2, 3	Third wire input if three wire sensors are used
6, 9, 12	GND	Temp. input GND

Figure 11.18 MCB 114

11.2.9 VLT® Safe Option MCB 15x

NOTICE!

For more information on MCB 15x, see the *MCB 15x Safe Option Instruction Manual*.

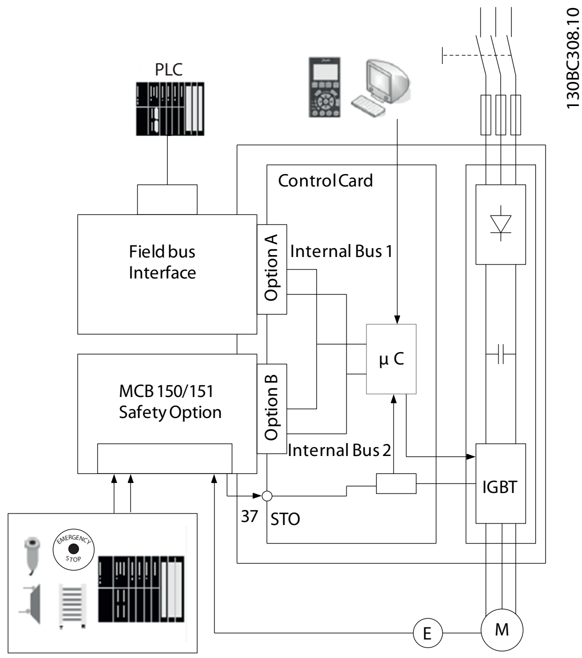


Figure 11.19 Safe Drive System

The MCB 15x performs safety functions in accordance with EN IEC 61800-5-2. It monitors safe motion sequences on adjustable frequency drives, 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

- Adjustable frequency drive, VLT® AutomationDrive FC 302
- MCB 15x built into the adjustable frequency drive

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 serial communication bus
- activates the selected failure reaction Safe Torque Off or Safe Stop 1 in the event of an error

There are two 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 adjustable frequency drive

- 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

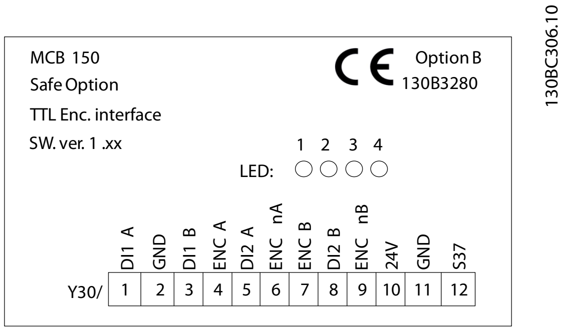


Figure 11.20 MCB 150

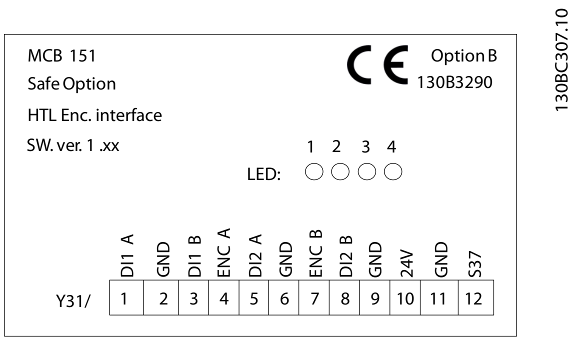


Figure 11.21 MCB 151

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	< 110 ft [30 m] (shielded or non-shielded cable) > 110 ft [30 m] (shielded 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	< 110 ft [30 m] (shielded 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	< 500 ft [150 m] (Tested with shielded cable - Heidenhain AWM Style 20963 176°F [80°C] 30 V E63216, 330 ft [100 m] shielded motor cable, no load on motor)

HTL encoder input (MCB 151)

Number of encoder inputs	2 (2 x single ended inputs A; B)
Encoder types	HTL incremental encoders; HTL Proximity sensor
Logic input	PNP
Input voltage range	0 to 24 V DC
Input voltage, logic '0'	< 5 V DC
Input voltage, logic '1'	> 12 V DC
Input voltage (max)	28 V DC
Input resistance	approx. 4 Ω
Maximum frequency	110 kHz
Short circuit-proof	Yes
Cable length	< 330 ft [100 m] (Tested with shielded cable - Heidenhain AWM Style 20963 176°F [80°C] 30 V E63216, 330 ft [100 m] shielded 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	< 110 ft [30 m] (shielded or non-shielded cable) > 110 ft [30 m] (shielded cable)

Ground I/O section

Cable length	< 110 ft [30 m] (shielded or non-shielded cable) > 110 ft [30 m] (shielded cable)

Cable cross-sections

Digital inputs/output supply voltage	0.75 mm^2/AWG 18, AEH without plastic collar in accordance with DIN 46228/1

Reset characteristics

Manual reset time	≤ 5 ms (MCB 15x) ≤ 5 ms (adjustable frequency drive) ≤ 10 ms (serial communication bus)
Manual reset pulse time	10 µs (MCB 15x and adjustable frequency drive)
Automatic reset time	≤ 4 ms
Start-up reset time	≤ 5 s (*42-90 Restart Safe Option*)

Response time

Input to output response time	≤ 2 ms
Emergency stop until beginning of SS1/SLS	≤ 7 ms
Cross fault detection time	≤ 3 ms (@activated output)

11

11.2.10 VLT® C Option Adapter MCF 106

The C Option Adapter MCF 106 makes it possible to add an additional B option to the adjustable frequency drive. One A and one B option can be installed in the standard A and B slots of the control card and up to two B options can be installed in the C Option Adapter.

For further information, see the *VLT® AutomationDrive FC 300, C Option Adapter MCF 106 Installation Instructions*.

11.3 Motion Control Options

Ordering

Motion Control Options (MCO) are supplied either as option cards for field installation or as built-in options. For retrofit, purchase a mounting kit. Each enclosure has its own mounting kit. MCO 3xx is to be used in slot C0, but can be combined with another option in slot C1.

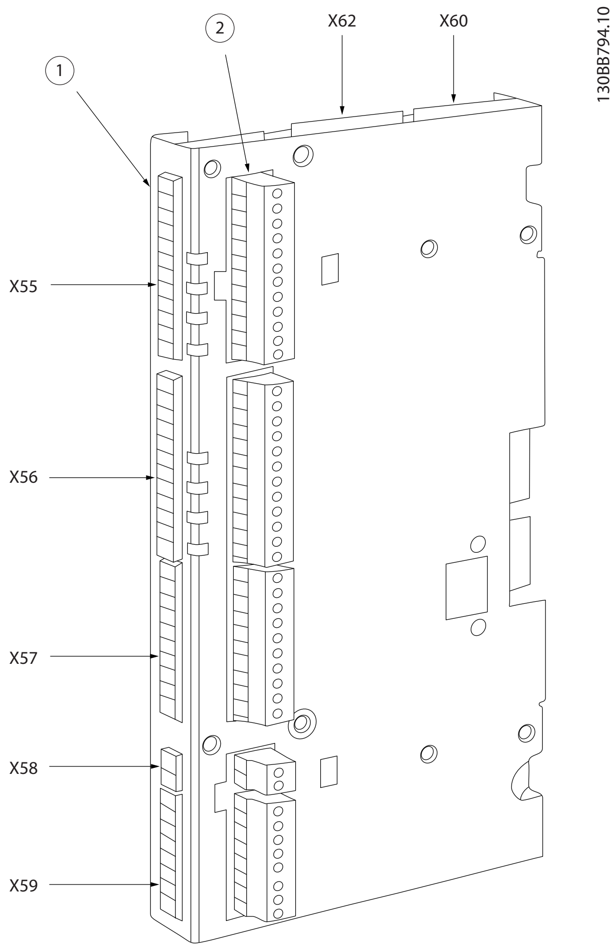
Mounting kit depending on enclosure type	Order no.
Bookstyle	
A2 and A3 (1.58 in [40 mm] for one C option)	130B7530
A2 and A3 (2.36 in [60 mm] for C0 + C1 option)	130B7531
B3 (1.58 [40 mm] for one C option)	130B1413
B3 (2.36 in [60 mm] for C0 + C1 option)	130B1414
Compact	
A5	130B7532
B, C, D, E and F (except B3)	130B7533

Table 11.4 Mounting Kit Ordering Numbers

Technical specifications

For enclosures A5, B1 and B2 all MCO 3xx terminals are located next to the control card. Remove the front cover to get access.

MCO control terminals are plug connectors with screw terminals. Terminals X55, X56, X57, X58 and X59 are duplicated to be used for both bookstyle and compact enclosures.



1	Terminal block for bookstyle
2	Terminal block for compact
X55	Encoder 2
X56	Encoder 1
X57	Digital inputs
X58	24 V DC supply
X59	Digital outputs
X62	MCO CAN Bus
X60	Debug connections (RS-485)

Figure 11.22 Location of Terminal Blocks

11

Terminal Overview

Terminal number	Descriptive Name Encoder 2 (Feedback)
1	+24 V Supply
2	+8 V Supply
3	+5 V Supply
4	GND
5	A
6	A not
7	B
8	B not
9	Z/Clock
10	Z not/Clock not
11	DATA
12	DATA not

Table 11.5 Terminal Block X55

Terminal number	Descriptive Name Encoder 1 (Master)
1	+24 V Supply
2	N/A
3	+5 V Supply
4	GND
5	A
6	A not
7	B
8	B not
9	Z/Clock
10	Z not/Clock not
11	DATA
12	DATA not

Table 11.6 Terminal Block X56

Terminal number	Descriptive Name Digital inputs
1	Digital Input
2	Digital Input
3	Digital Input
4	Digital Input
5	Digital Input
6	Digital Input
7	Digital Input
8	Digital Input
9	Digital Input
10	Digital Input

Table 11.7 Terminal Block X57

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

Table 11.8 Terminal Block X58

Terminal number	Descriptive Name Digital outputs
1	Digital Output/Input
2	Digital Output/Input
3	Digital Output
4	Digital Output
5	Digital Output
6	Digital Output
7	Digital Output
8	Digital Output

Table 11.9 Terminal Block X59

Terminal number	MCO Debug (RS-485)
[1]CS	Control Select
62	RxD/TxD - P
63	RxD/TxD - N
66	0 V
67	+5 V

Table 11.10 Terminal Block X60

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

Table 11.11 Terminal Block X62

11.3.1 VLT® Motion Control Option MCO 305

The MCO 305 is an integrated free programmable motion controller for FC 301 and FC 302, for more information, see *chapter 11.3.1 Motion Control Options*.

11.3.2 VLT® Synchronizing Controller MCO 350

NOTICE!

Terminal block X59 has fixed functionality for MCO 350.

NOTICE!

Terminal block X62 is not supported for MCO 350.

NOTICE!

Terminal block X60 is not used for MCO 350.

For more information, see *chapter 11.3.1 Motion Control Options*.

11.3.3 VLT® Positioning Controller MCO 351

NOTICE!

Terminal block X59 has fixed functionality for MCO 351.

NOTICE!

Terminal block X62 is not supported for MCO 351.

NOTICE!

Terminal block X60 is not used for MCO 351.

For more information, see *chapter 11.3.1 Motion Control Options*.

11.4 Accessories

11.4.1 Brake Resistors

In applications where the motor is used as a brake, energy is generated in the motor and sent back into the adjustable frequency drive. If the energy cannot be transported back to the motor, it increases the voltage in the adjustable frequency drive DC line. In applications with frequent braking and/or high inertia loads, this increase may lead to an overvoltage trip in the adjustable frequency drive and finally a shutdown. 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 adjustable frequency drives. See *chapter 5.5.3 Control with Brake Function* for dimensioning of brake resistors. Code numbers can be found in *chapter 7 How to Order*.

11.4.2 Sine-wave Filters

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

For the FC 300, Danfoss supplies a sine-wave filter to dampen the acoustic motor noise.

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

The ripple current in the sine-wave filter coils also causes some noise. Solve the problem by integrating the filter in a cabinet or similar.

11.4.3 dU/dt Filters

dU/dt filters are differential-mode low-pass filters which reduce motor terminal phase-to-phase peak voltages and reduce the rise time to a level that lowers the stress on the insulation at the motor windings. This is especially an issue at short motor cables.

Compared to sine-wave filters (see *chapter 11.4.2 Sine-wave Filters*), the dU/dt filters have a cut-off frequency above the switching frequency.

11.4.4 Common Mode Filters

High frequency common mode cores reduce electromagnetic interference and eliminate bearing damage by electrical discharge. They are special nanocrystalline magnetic cores which have superior filtering performance compared to regular ferrite cores. They act like a common-mode inductor (between phases and ground).

Installed around the three motor phases (U, V, W), the common mode filters reduce high-frequency common mode currents. As a result, high frequency electromagnetic interference from the motor cable is reduced.

11.4.5 Harmonic Filters

The Danfoss AHF 005 and AHF 010 are advanced harmonic filters not to be compared with traditional harmonic trap filters. The Danfoss harmonic filters have been specially designed to match the Danfoss adjustable frequency drives.

By connecting the Danfoss harmonic filters AHF 005 or AHF 010 in front of a Danfoss adjustable frequency drive, the total harmonic current distortion generated back to line power is reduced to 5% and 10% respectively.

11.4.6 IP21/Type 1 Enclosure Kit

IP20/IP4X top/TYPE 1 is an optional enclosure element available for IP20 compact units.
If the enclosure kit is used, an IP20 unit is upgraded to comply with enclosure IP21/4X top/TYPE 1.

The IP4X top can be applied to all standard IP20 FC 300 variants.

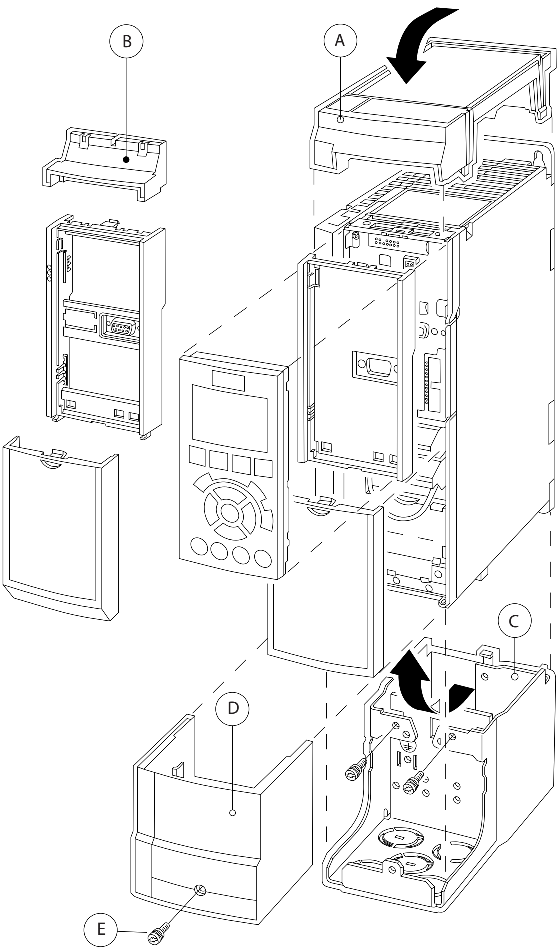


Figure 11.23 Enclosure Type A2

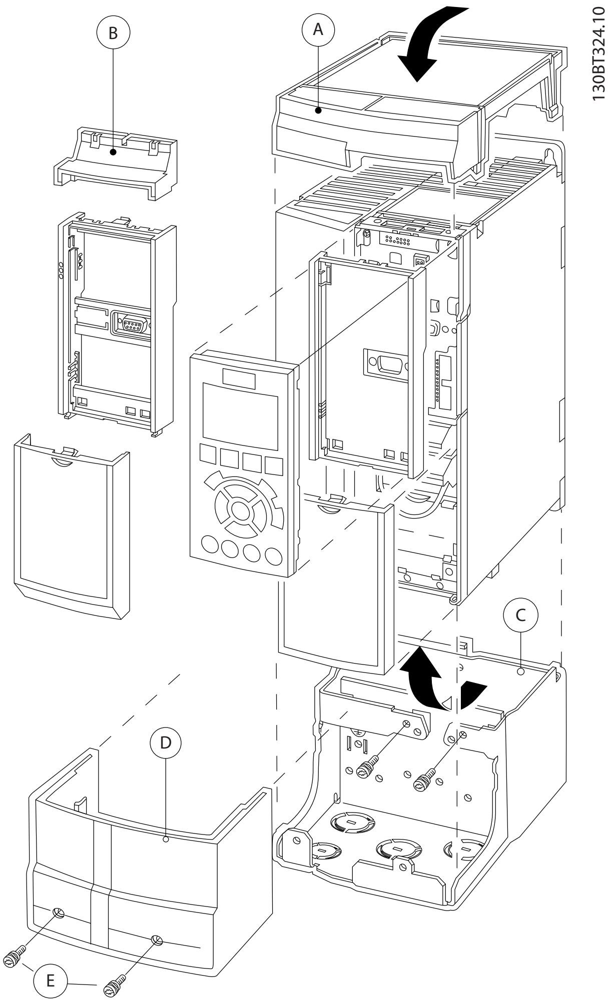


Figure 11.24 Enclosure Type A3

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

Table 11.12 Legend to *Figure 11.23* and *Figure 11.24*

Place the top cover as shown. If an A or B option is used, the brim must be fitted to cover the top inlet. Place the base part C at the bottom of the adjustable frequency drive and use the clamps from the accessory bag to correctly fasten the cables.

Holes for cable connectors:

- Size A2: 2x M25 and 3xM32
- Size A3: 3xM25 and 3xM32

11

Enclosure type	Height A (in [mm])	Width B (in [mm])	Depth C* (in [mm])
A2	14.65 [372]	3.54 [90]	8.07 [205]
A3	14.65 [372]	5.12 [130]	8.07 [205]
B3	18.70 [475]	6.50 [165]	9.8 [249]
B4	26.38 [670]	10.04 [255]	9.69 [246]
C3	29.72 [755]	12.95 [329]	13.27 [337]
C4	37.40 [950]	15.39 [391]	13.27 [337]

Table 11.13 Dimensions

** If option A/B is used, the depth increases (see chapter 8.2.1 Mechanical Dimensions for details)*

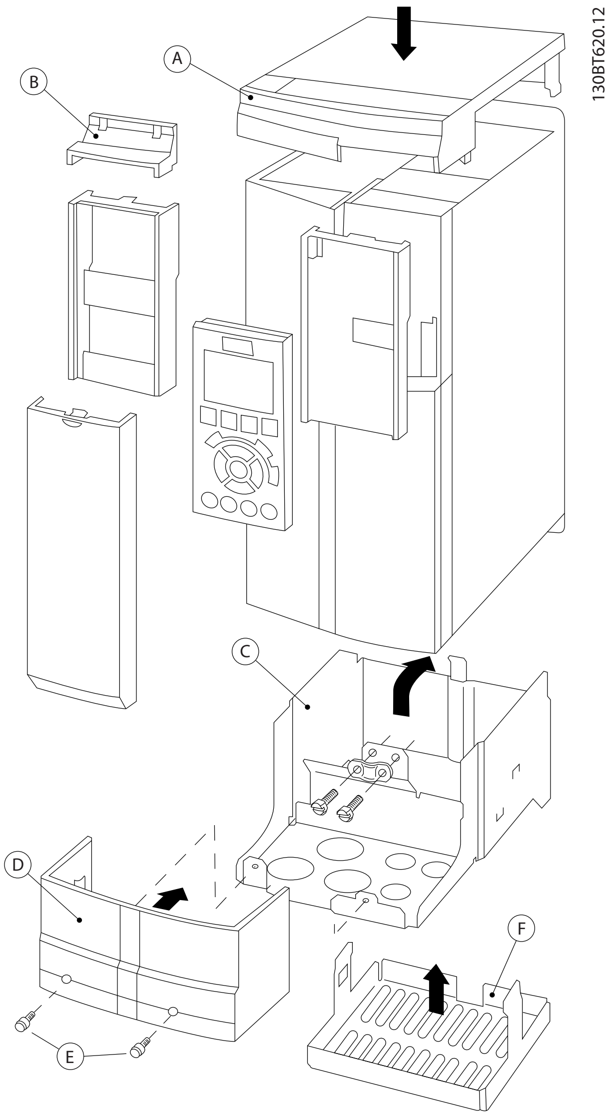


Figure 11.25 Enclosure Type B3

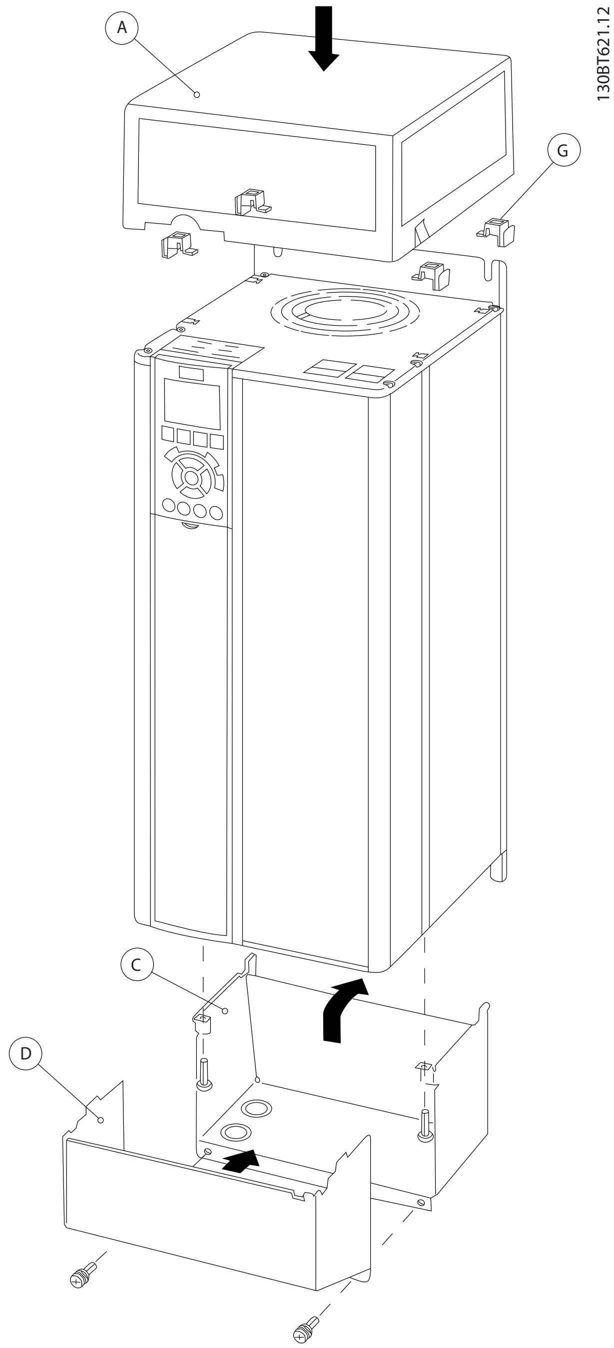


Figure 11.26 Enclosure Types B4 - C3 - C4

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

Table 11.14 Legend to *Figure 11.25* and *Figure 11.25*

NOTICE!

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

11.4.7 Remote Mounting Kit for LCP

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

The LCP enclosure is rated IP66

Enclosure	IP66 front
Max. cable length between and unit	10 ft [3 m]
Communication std	RS-485

Table 11.15 Technical Data

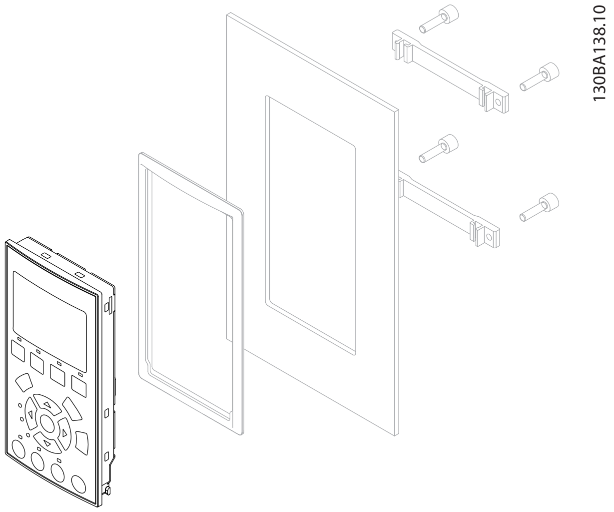


Figure 11.27 LCP Kit with Graphical LCP, Fasteners, 10 ft [3 m] Cable and Gasket
Ordering No. 130B1113

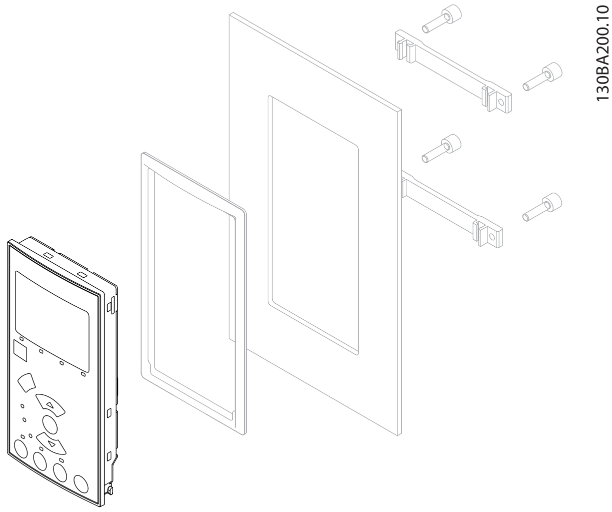


Figure 11.28 LCP Kit with Numerical LCP, Fasteners and Gasket
Ordering no. 130B1114

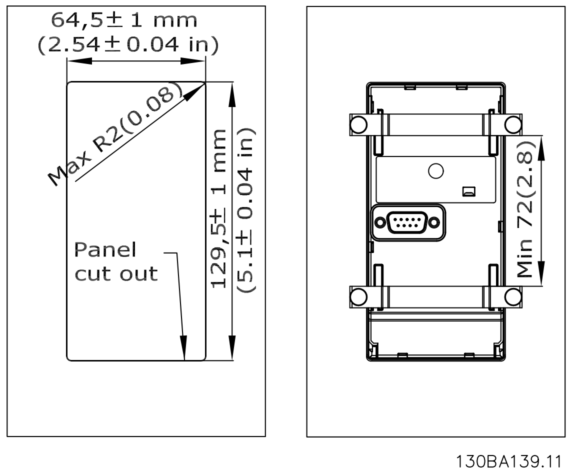


Figure 11.29 Dimensions

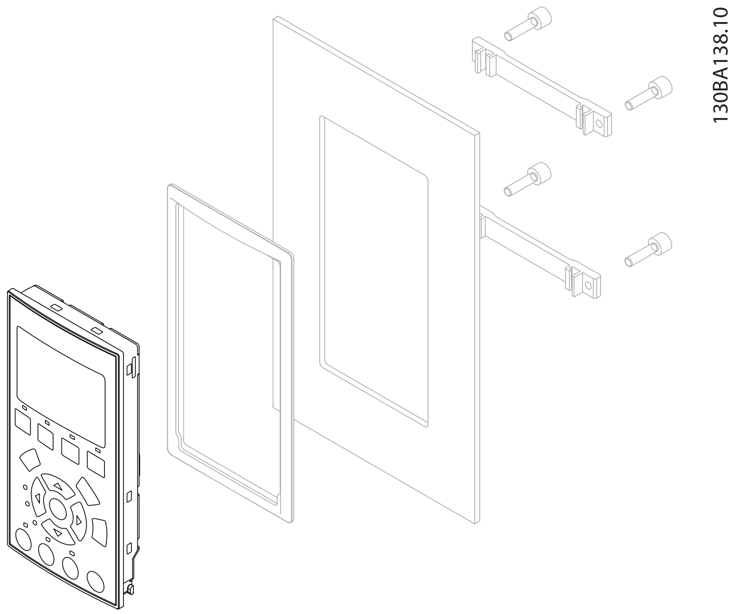


Figure 11.30 LCP Kit with Graphical LCP, Fasteners, 10 ft [3 m] Cable and Gasket, for US only

11.4.8 Mounting Bracket for Enclosure Types A5, B1, B2, C1 and C2

Step 1

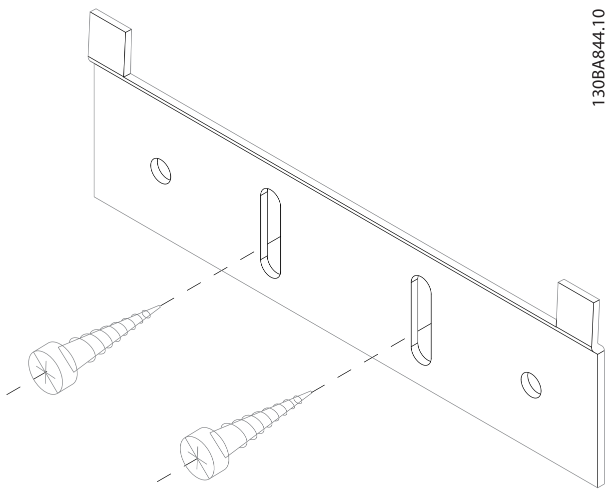


Figure 11.31 Lower Bracket

Position the lower bracket and mount it with screws. Do not tighten the screws completely, as this will make it difficult to mount the adjustable frequency drive.

Step 2

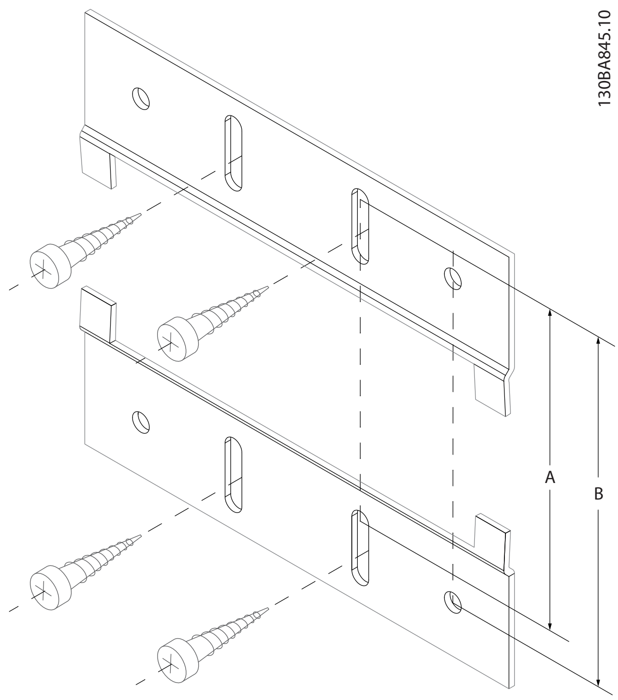


Figure 11.32 Upper Bracket

Measure distance A or B, and position the upper bracket, but do not tighten it. See dimensions in *Table 11.16*.

Enclosure	IP	A (ins [mm])	B (ins [mm])	Ordering number
A5	55/66	18.90 [480]	19.49 [495]	130B1080
B1	21/55/66	21.06 [535]	21.65 [550]	130B1081
B2	21/55/66	27.76 [705]	28.35 [720]	130B1082
B3	21/55/66	28.74 [730]	29.33 [745]	130B1083
B4	21/55/66	32.28 [820]	32.87 [835]	130B1084

Table 11.16 Details

11

Step 3

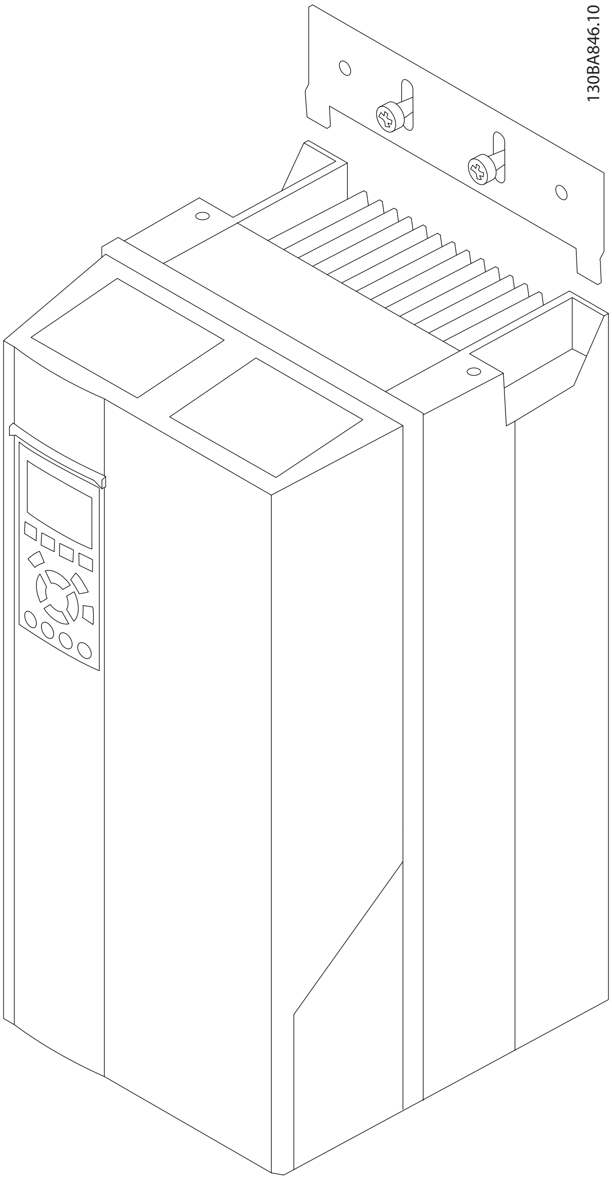


Figure 11.33 Positioning

Place the adjustable frequency drive in the lower bracket, and lift the upper one. When the adjustable frequency drive is in place, lower the upper bracket.

Step 4

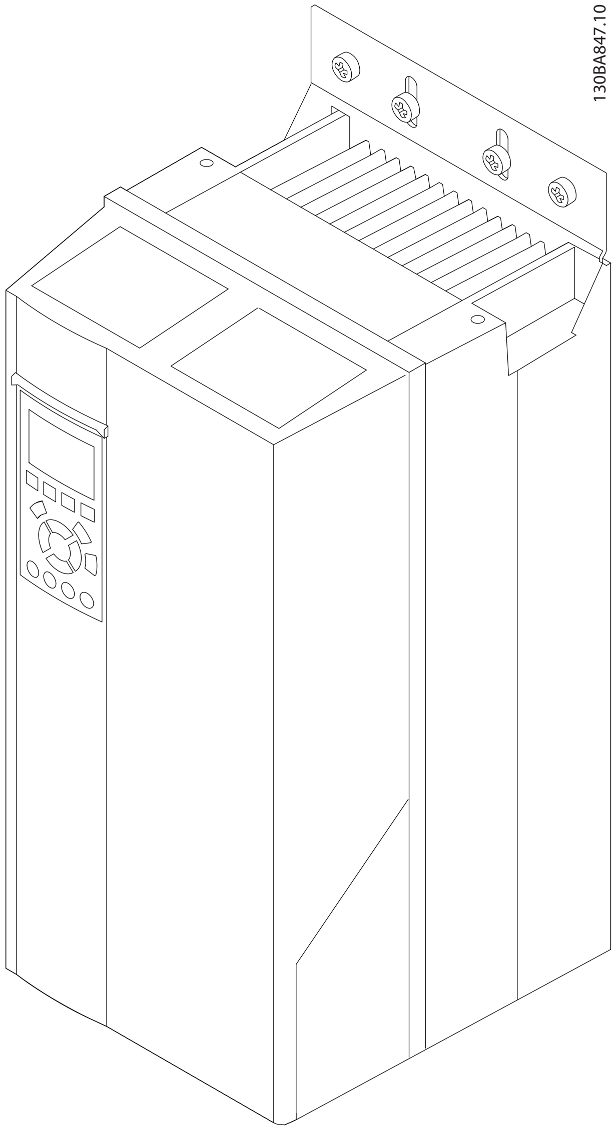


Figure 11.34 Tightening of Screws

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

12 RS-485 Installation and Set-up

12.1 Installation and Set-up

12.1.1 Overview

RS-485 is a 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, see *Figure 12.1*.

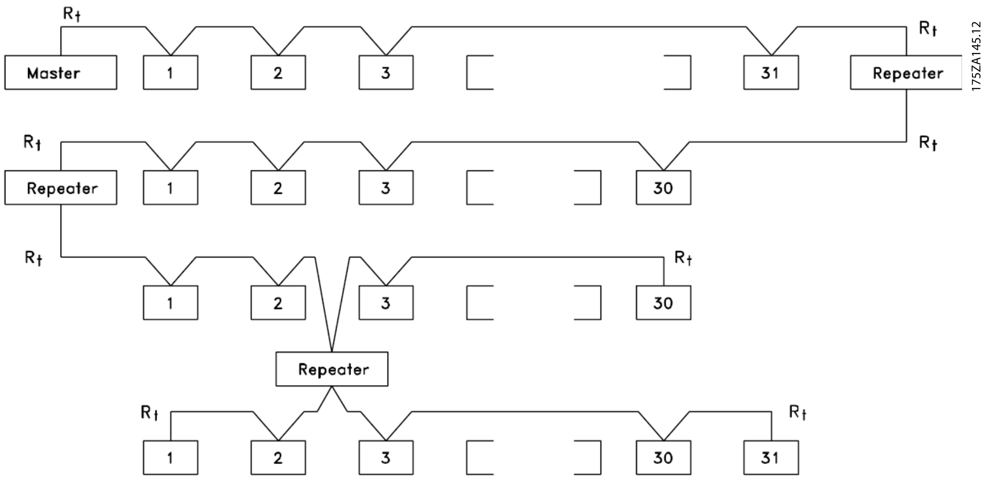


Figure 12.1 RS-485 Bus Interface

12

NOTICE!

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

Terminate each segment at both ends using either the termination switch (S801) of the adjustable frequency drives or a biased termination resistor network. Always use shielded twisted pair (STP) cable for bus cabling and follow good common installation practice.
Low-impedance ground connection of the shield at every node is important, including at high frequencies. Thus, connect a large surface of the shield to ground, for example with a cable clamp or a conductive cable connector. It may be necessary to apply potential-equalizing cables to maintain the same ground potential throughout the network - particularly in installations with long cables.
To prevent impedance mismatch, always use the same type of cable throughout the entire network. When connecting a motor to the adjustable frequency drive, always use shielded motor cable.

Cable	Shielded twisted pair (STP)
Impedance [Ω]	120
Cable length [m]	Max. 4,000 ft [1,200 m] (including drop lines) Max. 1,650 ft [500 m] station-to-station

Table 12.1 Cable Specifications

12.2 Network Connection

One or more adjustable frequency drives 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 *chapter 3.5 Wiring Schematic*.

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

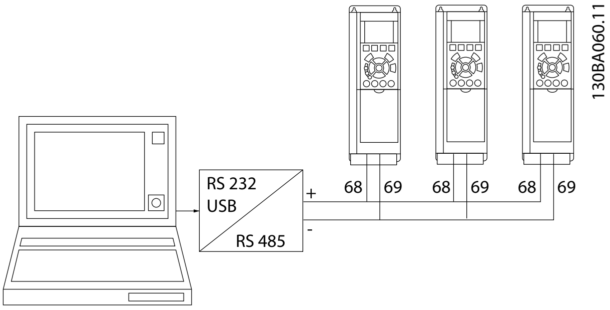


Figure 12.2 Parallel Connections

To avoid potential equalizing currents in the shield, ground the cable shield via terminal 61, which is connected to the frame via an RC link.

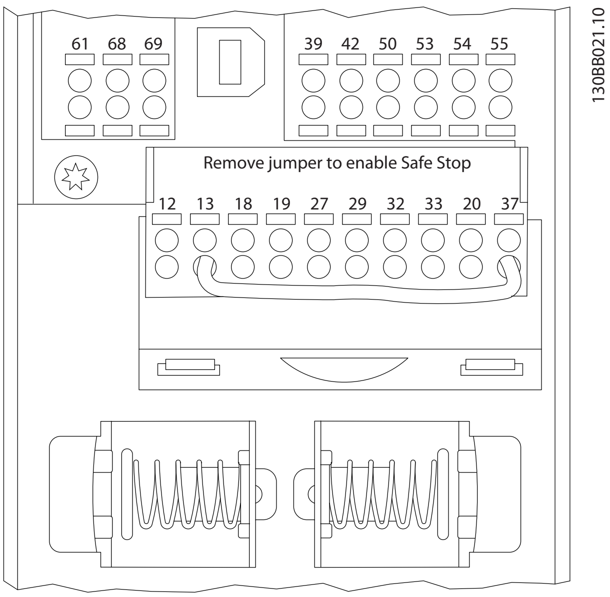


Figure 12.3 Control Card Terminals

12.3 Bus Termination

The RS-485 bus must be terminated by a resistor network at both ends. For this purpose, set switch S801 on the control card to "ON".

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

12.4 RS-485 Installation and Set-up

12.4.1 EMC Precautions

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

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

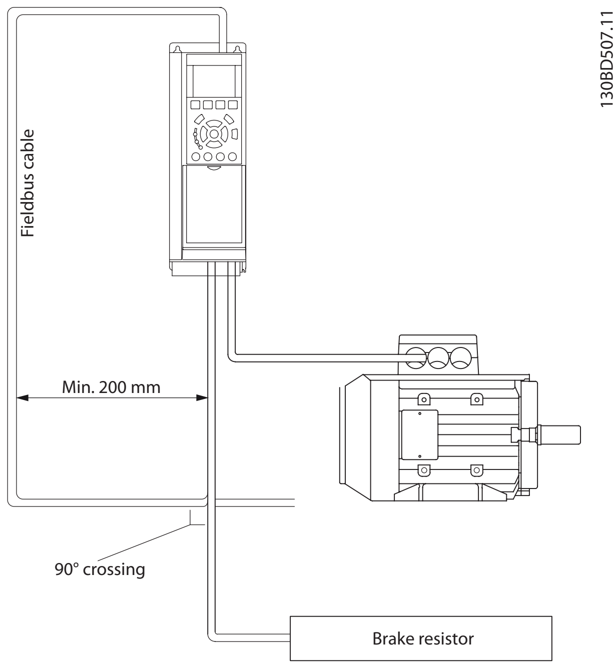


Figure 12.4 Cable Routing

12

12.5 FC Protocol Overview

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

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

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

12.6 Network Configuration

12.6.1 Adjustable Frequency Drive Set-up

Set the following parameters to enable the FC protocol for the adjustable frequency drive.

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

Table 12.2 FC Protocol Parameters

12.7 FC Protocol Message Framing Structure

12.7.1 Content of a Character (byte)

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.

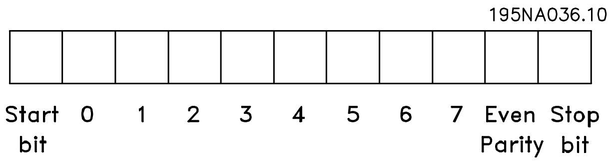


Figure 12.5 Content of a Character

12.7.2 Message Structure

Each message has the following structure:

1. Start character (STX)=02 hex
2. A byte denoting the message length (LGE)
3. A byte denoting the adjustable frequency drive address (ADR)

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

A data control byte (BCC) completes the message.

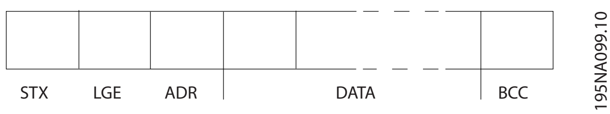


Figure 12.6 Message Structure

12.7.3 Message Length (LGE)

The message 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
Messagescontaining texts	10[1)]+n bytes

Table 12.3 Length of Messages

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

12.7.4 Adjustable Frequency Drive Address (ADR)

Two different address formats are used.
The address range of the adjustable frequency drive 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 = adjustable frequency drive address 1-31

2. Address format 1-126:

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

    Bit 0-6 = adjustable frequency drive address 1-126

    Bit 0-6 = 0 Broadcast

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

12.7.5 Data Control Byte (BCC)

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

12.7.6 The Data Field

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

The three types of message are:

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

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

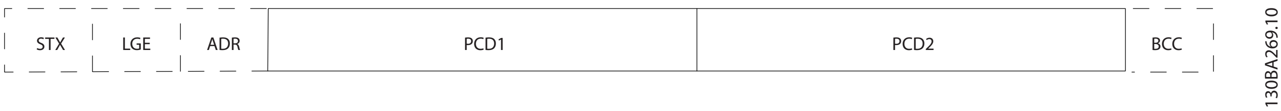


Figure 12.7 Process Block

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

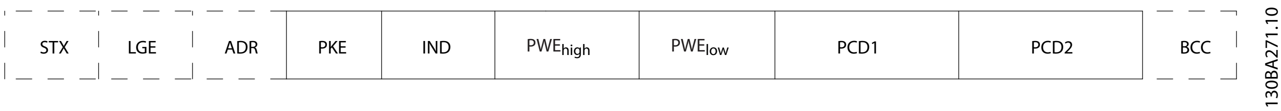


Figure 12.8 Parameter Block

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

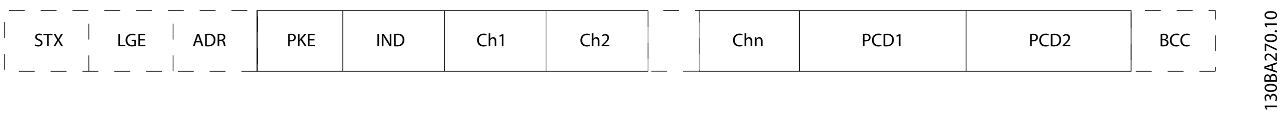


Figure 12.9 Text Block

12.7.7 The PKE Field

The PKE field contains two subfields: Parameter command and response AK, and parameter number PNU:

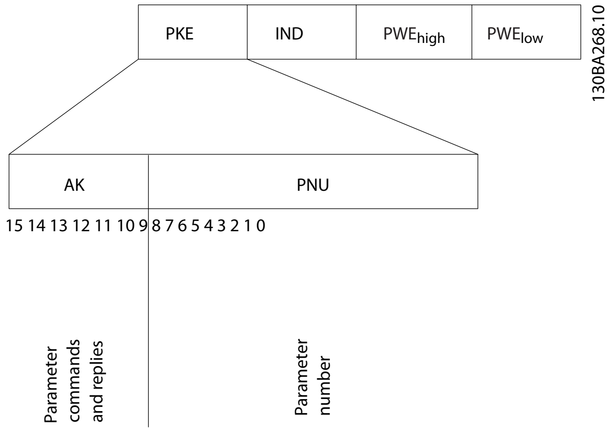


Figure 12.10 PKE Field

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

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

Table 12.4 Parameter Commands Master ⇒ Follower

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

Table 12.5 Response Follower⇒ Master

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

PWE low (Hex)	Fault Report
0	The parameter number used does not exist
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 exist
4	The parameter is not the array type.
5	The data type does not match the defined parameter
11	Data change in the defined parameter is not possible in the adjustable frequency drive's present mode. Certain parameters can only be changed when the motor is turned off
82	There is no bus access to the defined parameter
83	Data change is not possible because factory set-up is selected

Table 12.6 Parameter Value Fault Report

12.7.8 Parameter Number (PNU)

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

12.7.9 Index (IND)

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

Only the low byte is used as an index.

12

12.7.10 Parameter Value (PWE)

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

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

15-40 FC Type to *15-53 Power Card Serial Number* contain data type 9.
For example, read the unit size and AC line voltage range in *15-40 FC Type*. When a text string is transferred (read), the length of the message is variable, and the texts are of different lengths. The message length is defined in the second byte of the message, 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".

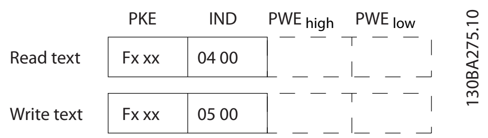


Figure 12.11 Text via PWE Block

12.7.11 Supported Data Types

Unsigned means that there is no operational sign in the message.

Data types	Description
3	Integer 16
4	Integer 32
5	Unsigned 8
6	Unsigned 16
7	Unsigned 32
9	Text string
10	Byte string
13	Time difference
33	Reserved
35	Bit sequence

Table 12.7 Supported Data Types

12.7.12 Conversion

The various attributes of each parameter are displayed in factory setting. Parameter values are transferred as whole numbers only. Conversion factors are therefore used to transfer decimals.

4-12 Motor Speed Low Limit [Hz] has a conversion factor of 0.1. To preset the minimum frequency to 10 Hz, transfer the value 100. A conversion factor of 0.1 means that the value transferred is multiplied by 0.1. The value 100 is therefore read as 10.0.

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

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

Table 12.8 Conversion Table

12.7.13 Process Words (PCD)

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

PCD 1	PCD 2
Control message (master⇒follower control word)	Reference value
Control message (follower⇒master) status word	Present output frequency

Table 12.9 Process Words (PCD)

12.8 Examples

12.8.1 Writing a Parameter Value

Change *4-14 Motor Speed High Limit [Hz]* to 100 Hz.
Write the data in EEPROM.

PKE = E19E Hex - Write single word in *4-14 Motor Speed High Limit [Hz]*
IND = 0000 Hex
PWEHIGH = 0000 Hex
PWELOW = 03E8 Hex - Data value 1000, corresponding to 100 Hz, see *chapter 12.7.12 Conversion*.

The message looks like this:

E19E H	0000 H	0000 H	03E8 H
PKE	IND	PWE_{high}	PWE_{low}

130BA092.10

Figure 12.12 Write Data in EEPROM

NOTICE!

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

The response from the follower to the master is:

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

130BA093.10

Figure 12.13 Response from Follower

12.8.2 Reading a Parameter Value

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

PKE = 1155 Hex - Read parameter value in *3-41 Ramp 1 Ramp-up Time*
IND = 0000 Hex
PWEHIGH = 0000 Hex
PWELOW = 0000 Hex

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

130BA094.10

Figure 12.14 Parameter Value

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

130BA267.10

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

Figure 12.15 Response from Follower

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

12

12.9 Modbus RTU Overview

12.9.1 Assumptions

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

12.9.2 What the User Should Already Know

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

12.9.3 Modbus RTU Overview

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

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

If a reply is required, the controller constructs the reply message and sends it.
Controllers communicate using a master-follower technique in which only the master can initiate transactions (called queries). Followers respond by supplying the requested data to the master, or by taking the action requested in the query.

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

12.9.4 Adjustable Frequency Drive with Modbus RTU

The adjustable frequency drive 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 adjustable frequency drive.

The control word allows the Modbus master to control several important functions of the adjustable frequency drive:

- Start
- Stop of the adjustable frequency drive 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 adjustable frequency drive'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 adjustable frequency drive when its internal PI controller is used.

12.10 Network Configuration

To enable Modbus RTU on the adjustable frequency drive, set the following parameters

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

Table 12.10 Modbus RTU Parameters

12.11 Modbus RTU Message Framing Structure

12.11.1 Adjustable Frequency Drive 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 two 4-bit hexadecimal characters. The format for each byte is shown in *Table 12.11*.

Start bit	Data byte								Stop/ parity	Stop

Table 12.11 Format for Each Byte

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

12.11.2 Modbus RTU Message Structure

The transmitting device places a Modbus RTU message into a frame with a known beginning and ending point. This allows receiving devices to begin at the start of the message, read the address portion, determine which device is addressed (or all devices, if the message is broadcast), and to recognize when the message is completed. Partial messages are detected, and errors are set as a result. Characters for transmission must be in hexadecimal 00 to FF format in each field. The adjustable frequency drive continuously monitors the network bus, also during 'silent' intervals. When the first field (the address field) is received, each adjustable frequency drive or device decodes it to determine which device is being addressed. Modbus RTU messages addressed to zero are broadcast messages. No response is permitted for broadcast messages. A typical message frame is shown in *Table 12.12*.

Start	Address	Function	Data	CRC check	End
T1-T2-T3-T4	8 bits	8 bits	N x 8 bits	16 bits	T1-T2-T3-T4

Table 12.12 Typical Modbus RTU Message Structure

12.11.3 Start/Stop Field

Messages start with a silent period of at least 3.5 character intervals. This is implemented as a multiple of character intervals at the selected network baud rate (shown as Start T1-T2-T3-T4). The first field to be transmitted is the device address. Following the last transmitted character, a similar period of at least 3.5 character intervals marks the end of the message. A new message can begin after this period. The entire message frame must be transmitted as a continuous stream. If a silent period of more than 1.5 character intervals occurs before completion of the frame, the receiving device flushes the incomplete message and assumes that the next byte is the address field of a new message. Similarly, if a new message begins before 3.5 character intervals after a previous message, the receiving device considers it a continuation of the previous message. This causes a timeout (no response from the follower), since the value in the final CRC field is not valid for the combined messages.

12.11.4 Address Field

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

12.11.5 Function Field

The function field of a message frame contains 8 bits. Valid codes are in the range of 1-FF. Function fields are used to send messages between master and follower. When a message is sent from a master to a follower device, the function code field tells the follower what kind of action to perform. When the follower responds to the master, it uses the function code field to indicate either a normal (error-free) response, or that some kind of error occurred (called an exception response). For a normal response, the follower simply echoes the original function code. For an exception response, the follower returns a code that is equivalent to the original function code with its most significant bit set to logic 1. In addition, the follower places a unique code into the data field of the response message. This tells the master what kind of error occurred, or the reason for the exception. Also refer to *chapter 12.11.10 Function Codes Supported by Modbus RTU* and *chapter 12.11.11 Modbus Exception Codes*.

12.11.6 Data Field

The data field is constructed using sets of 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 follower device contains additional information which the follower must use to take the action defined by the function code. This can include items such as coil or register addresses, the quantity of items to be handled and the count of actual data bytes in the field.

12.11.7 CRC Check Field

Messages include an error-checking field, operating based on a Cyclical Redundancy Check (CRC) method. The CRC field checks the contents of the entire message. It is applied regardless of any parity check method used for the individual characters of the message. The CRC value is calculated by the transmitting device, which appends the CRC as the last field in the message. The receiving device recalculates a CRC during receipt of the message and compares the calculated value to the actual value received in the CRC field. If the two values are unequal, a bus timeout 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.

12.11.8 Coil Register Addressing

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

Coil number	Description		Signal direction
1-16	Adjustable frequency drive control word		Master to follower
17-32	Adjustable frequency driver speed or setpoint reference Range 0x0–0xFFFF (-200% ... ~200%)		Master to follower
33-48	Adjustable frequency drive status word (see *Table 12.15*)		Follower to master
49-64	Open-loop mode: Adjustable frequency drive output frequency closed-loop mode: Adjustable frequency drive feedback signal		Follower to master
65	Parameter write control (master to follower)		Master to follower
	0 =	Parameter changes are written to the RAM of the adjustable frequency drive.	
	1 =	Parameter changes are written to the RAM and EEPROM of the adjustable frequency drive.	
66-65536	Reserved		

Table 12.13 Coil Descriptions

Coil	0	1
01	Preset reference LSB	
02	Preset reference MSB	
03	DC brake	No DC brake
04	Coast stop	No coast stop
05	Quick stop	No quick stop
06	Freeze freq.	No freeze freq.
07	Ramp stop	Start
08	No reset	Reset
09	No jog	Jog
10	Ramp 1	Ramp 2
11	Data not valid	Data valid
12	Relay 1 off	Relay 1 on
13	Relay 2 off	Relay 2 on
14	Set up LSB	
15	Set up MSB	
16	No reversing	Reversing

Table 12.14 Adjustable Frequency Drive Control Word (FC Profile)

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

Table 12.15 Adjustable Frequency Drive 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: Adjustable frequency drive control word register (CTW).
50010	Input data: Bus reference register (REF).
...	...
50200	Output data: Adjustable frequency drive status word register (STW).
50210	Output data: Adjustable frequency drive main actual value register (MAV).

Table 12.16 Holding Registers

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

12

12.11.9 How to Control the Adjustable Frequency Drive

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

12.11.10 Function Codes Supported by Modbus RTU

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

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

Table 12.17 Function Codes

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

Table 12.18 Function Codes

12.11.11 Modbus Exception Codes

For a full explanation of the structure of an exception code response, refer to *chapter 12.11.5 Function Field*.

Code	Name	Meaning
1	Illegal function	The function code received in the query is not an allowable action for the server (or follower). This may be because the function code is only applicable to newer devices and was not implemented in the unit selected. It could also indicate that the server (or follower) is in the wrong state to process a request of this type, for example, because it is not configured and is being asked to return register values.

Code	Name	Meaning
2	Illegal data address	The data address received in the query is not an allowable address for the server (or follower). More specifically, the combination of reference number and transfer length is invalid. For a controller with 100 registers, a request with offset 96 and length 4 would succeed, a request with offset 96 and length 5 generates exception 02.
3	Illegal data value	A value contained in the query data field is not an allowable value for server (or follower). This indicates a fault in the structure of the remainder of a complex request, such as that the implied length is incorrect. It specifically does NOT mean that a data item submitted for storage in a register has a value outside the expectation of the application program, since the Modbus protocol is unaware of the significance of any particular value of any particular register.
4	Follower device failure	An unrecoverable error occurred while the server (or follower) was attempting to perform the requested action.

Table 12.19 Modbus Exception Codes

12.12 How to Access Parameters

12.12.1 Parameter Handling

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

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

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

12.12.2 Storage of Data

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

12.12.3 IND (Index)

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

12.12.4 Text Blocks

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

12.12.5 Conversion Factor

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

12.12.6 Parameter Values

Standard data types
Standard data types are int 16, int 32, uint 8, uint 16 and uint 32. They are stored as 4x registers (40001–4FFFF). The parameters are read using function 03hex "Read Holding Registers." Parameters are written using the function 6hex "Preset Single Register" for 1 register (16 bits), and the function 10 hex "Preset Multiple Registers" for two registers (32 bits). Readable sizes range from one register (16 bits) up to ten 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 one register (two characters) up to ten registers (20 characters).

12.13 Danfoss FC Control Profile

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

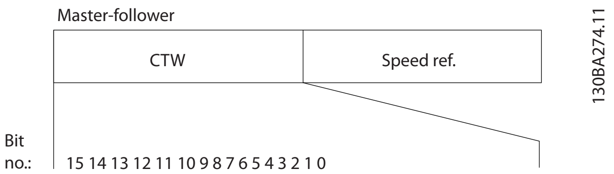


Figure 12.16 Control Word

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

Table 12.20 Control Word Bits

Explanation of the Control Bits

Bits 00/01
Bits 00 and 01 are used to select between the four reference values, which are pre-programmed in *3-10 Preset Reference* according to *Table 12.21*.

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

Table 12.21 Reference Values

NOTICE!

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

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

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

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

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

Bit 05, Hold output frequency
Bit 05 = ’0’: The present output frequency (in Hz) freezes. Change the frozen output frequency only with the digital inputs (*5-10 Terminal 18 Digital Input* to *5-15 Terminal 33 Digital Input*) programmed to *Speed up* and *Slow-down*.

NOTICE!

If Freeze output is active, the adjustable frequency drive 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 adjustable frequency drive to start the motor if the other starting conditions are met.

Make a selection in *8-53 Start Select* to define how Bit 06 Ramp stop/start gates with the corresponding function on a digital input.

Bit 07, Reset
Bit 07 = ’0’: No reset. Bit 07 = ’1’: Resets a trip. Reset is activated on the leading edge of the signal, i.e. when changing from logic ’0’ to logic ’1’.

Bit 08, Jog
Bit 08 = ’1’: The output frequency is determined by *3-19 Jog Speed [RPM]*.

Bit 09, Selection of ramp 1/2
Bit 09 = "0": Ramp 1 is active (*3-41 Ramp 1 Ramp-up Time* to *3-42 Ramp 1 Ramp-down Time*). Bit 09 = "1": Ramp 2 (*3-51 Ramp 2 Ramp-up Time* to *3-52 Ramp 2 Ramp-down Time*) is active.

Bit 10, Data not valid/Data valid
Tell the adjustable frequency drive 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 message always contains the control word, regardless of the message type. Turn off the control word if it should not be used when updating or reading parameters.

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

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

Bit 13/14, Selection of set-up
Use bits 13 and 14 to select from the four menu set-ups according to *Table 12.22*.

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

Table 12.22 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 Reverse Select*. Bit 15 causes reversing only when ser. communication, logic or OR logic and is selected.

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

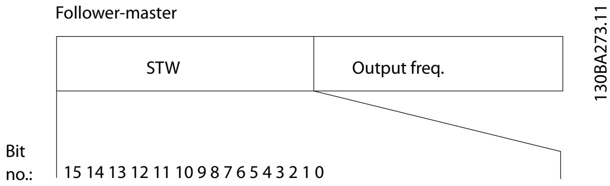


Figure 12.17 Status Word

Bit	Bit = 0	Bit = 1
00	Control not ready	Control ready
01	Drive not ready	Drive ready
02	Coasting	Enable
03	No error	Trip
04	No error	Error (no trip)
05	Reserved	-
06	No error	Trip lock
07	No warning	Warning
08	Speed ≠ reference	Speed = reference
09	Local operation	Bus control
10	Out of frequency limit	Frequency limit OK
11	No operation	In operation
12	Drive OK	Stopped, auto-start
13	Voltage OK	Voltage exceeded
14	Torque OK	Torque exceeded
15	Timer OK	Timer exceeded

Table 12.23 Status Word Bits

12

Explanation of the Status Bits

Bit 00, Control not ready/ready
Bit 00 = ’0’: The adjustable frequency drive trips.
Bit 00 = ’1’: The adjustable frequency drive controls are ready, but the power component does not necessarily receive any power supply (in case of external 24 V supply to controls).

Bit 01, Drive ready
Bit 01 = ’1’: The adjustable frequency drive 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 adjustable frequency drive releases the motor.
Bit 02 = ’1’: The adjustable frequency drive starts the motor with a start command.

Bit 03, No error/trip
Bit 03 ='0': The adjustable frequency drive is not in fault mode. Bit 03 = '1': The adjustable frequency drive trips. To re-establish operation, enter [Reset].

Bit 04, No error/error (no trip)
Bit 04 = '0': The adjustable frequency drive is not in fault mode. Bit 04 = "1": The adjustable frequency drive 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 adjustable frequency drive is not in fault mode. Bit 06 = "1": The adjustable frequency drive 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. For example, this might be the case when the speed ramps up/down during start/stop.
Bit 08 = '1': The motor speed matches the preset speed reference.

Bit 09, Local operation/bus control
Bit 09 = '0': [STOP/RESET] is activated on the control unit or *Local control* in *3-13 Reference Site* is selected. Control via serial communication is not possible.
Bit 09 = '1' It is possible to control the adjustable frequency drive via the serial communication / bus communication.

12

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 adjustable frequency drive has a start signal, or the output frequency is greater than 0 Hz.

Bit 12, Drive OK/stopped, autostart
Bit 12 = '0': There is no temporary overtemperature on the inverter.
Bit 12 = '1': The inverter stops because of overtemperature, but the unit does not trip and resumes operation once the overtemperature stops.

Bit 13, Voltage OK/limit exceeded
Bit 13 = '0': There are no voltage warnings.
Bit 13 = '1': The DC voltage in the adjustable frequency drive'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 adjustable frequency drive is lost, or if an internal communication problem has occurred.

12.13.3 Bus Speed Reference Value

Speed reference value is transmitted to the adjustable frequency drive in a relative value expressed as %. 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.

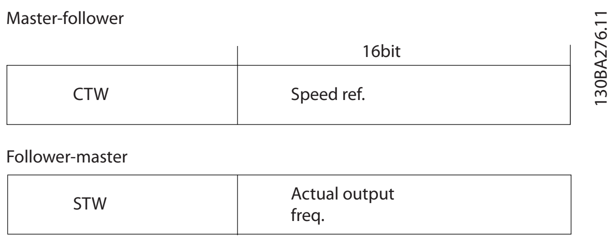


Figure 12.18 Actual Output Frequency (MAV)

The reference and MAV are scaled as follows:

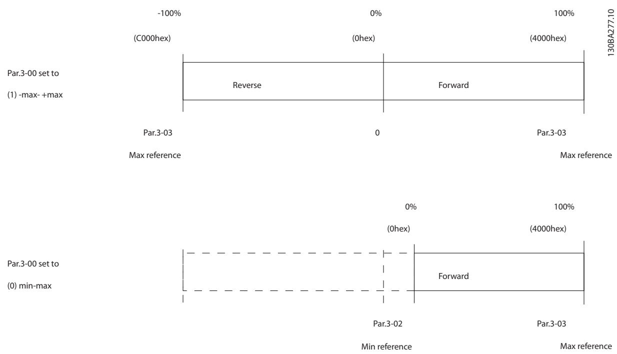


Figure 12.19 Reference and MAV

12.13.4 Control Word according to PROFIdrive Profile (CTW)

The control word is used to send commands from a master (for example, a PC) to a follower.

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

Table 12.24 Control Word Bits

Explanation of the control bits

Bit 00, OFF 1/ON 1
Normal ramp stops using the ramp times of the actual selected ramp.
Bit 00="0" leads to the stop and activation of the output relay 1 or 2 if the output frequency is 0 Hz and if [Relay 123] has been selected in *5-40 Function Relay*.
When bit 0="1", the adjustable frequency drive 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 adjustable frequency drive is in State 1: "Switching on inhibited".

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

NOTICE!

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

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

NOTICE!

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

Bit 05, Hold frequency output/Use ramp
When bit 05="0", the current output frequency is being maintained even if the reference value is modified.
When bit 05="1", the adjustable frequency drive 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 adjustable frequency drive can start if the other start conditions are satisfied.

NOTICE!

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

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

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

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

12

Bit 10, Data invalid/valid
Is used to tell the adjustable frequency drive 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 message regardless of which type of message is used, that is, it is possible to turn off the control word if it should not be used for updating or reading parameters.

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

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

Bits 13/14, Set-up selection
Bits 13 and 14 are used to select between the four parameter set-ups according to *Table 12.25*:

The function is only possible if *[9] Multi Set-up* has been selected in *0-10 Active Set-up*. The selection in *8-55 Set-up Select* determines how bits 13 and 14 are linked with the corresponding function of the digital inputs. Changing set-up while running is only possible if the set-ups have been linked in *0-12 This Set-up Linked to*.

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

Table 12.25 Set-up Selection

Bit 15, No function/Reverse
Bit 15="0" causes no reversing.
Bit 15="1" causes reversing.
Note: In the factory setting, reversing is set to *digital* in *8-54 Reverse Select*.

NOTICE!

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

12

12.13.5 Status Word according to PROFIdrive Profile (STW)

The status word is used to notify a master (for example, a PC) about the status of a follower.

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

Table 12.26 Status Word Bits

Explanation of the status bits

Bit 00, Control not ready/ready
When bit 00="0", bit 00, 01 or 02 of the Control word is "0" (OFF 1, OFF 2 or OFF 3) - or the adjustable frequency drive is switched off (trip).
When bit 00="1", the adjustable frequency drive 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 from the power unit. The adjustable frequency drive 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 adjustable frequency drive is switched off (trip).
When bit 02="1", bit 00, 01 or 02 of the control word is "1"; the adjustable frequency drive has not tripped.

Bit 03, No error/Trip
When bit 03="0", no error condition of the adjustable frequency drive exists.
When bit 03="1", the adjustable frequency drive has tripped and requires a reset signal before it can start.

Bit 04, ON 2/OFF 2
When bit 01 of the control word is "0", then bit 04="0".
When bit 01 of the control word is "1", then bit 04="1".

Bit 05, ON 3/OFF 3
When bit 02 of the control word is "0", then bit 05="0".
When bit 02 of the control word is "1", then bit 05="1".

Bit 06, Start possible/Start not possible
If PROFIdrive has been selected in *8-10 Control Word Profile*, bit 06 is "1" after a switch-off acknowledgment, after activation of OFF2 or OFF3, and after switching on the AC line 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 adjustable frequency drive has been stopped with [Stop] on the LCP, or that [Linked to hand] or [Local] has been selected in *3-13 Reference Site*.
When bit 09="1", the adjustable frequency drive 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 adjustable frequency drive 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 adjustable frequency drive has not switched off (trip) and starts again after the overloading has ended.

Bit 13, Voltage OK/Voltage exceeded
When bit 13 = "0", the voltage limits of the adjustable frequency drive are not exceeded.
When bit 13 = "1", the direct voltage in the intermediate circuit of the adjustable frequency drive 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 adjustable frequency drive protection have not exceeded 100%.
When bit 15="1", one of the timers has exceeded 100%.

Index

www.danfoss.com/drives

Danfoss A/S
Ulsnaes 1
DK-6300 Graasten
www.danfoss.com/drives

130R0301 MG33BF22 Rev. 2014-04-04