MAKING MODERN LIVING POSSIBLE

Design Guide

VLT® AutomationDrive

THE REAL DRIVE

Contents

1 How to Read this Design Guide

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

Available literature for FC 300

- The VLT AutomationDrive Instruction Manual MG.33.AX.YY provides the necessary information for getting the drive up and running.
- The VLT AutomationDrive High Power Instruction Manual MG.33.UX.YY
- The VLT AutomationDrive Design Guide MG.33.BX.YY contains all technical information about the drive and customer design and applications.
- The VLT AutomationDrive Programming Guide MG.33.MX.YY provides information on how to program and includes complete parameter descriptions.
- The VLT AutomationDrive Profibus Instruction Manual MG.33.CX.YY provides the information required for controlling, monitoring and programming the drive via a Profibus serial communication bus.
- The VLT AutomationDrive DeviceNet Instruction Manual MG.33.DX.YY provides the information required for controlling, monitoring and programming the drive via a DeviceNet serial communication bus.

X = Revision number
YY = Language code

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

1.1.1 Symbols

Symbols used in this guide.

NOTE!
Indicates something to be noted by the reader.

CAUTION
Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury or equipment damage.

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

*	Indicates default setting

Table 1.1

1.1.2 Abbreviations

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

Table 1.2

1.1.3 Definitions

Adjustable frequency drive:

Coast

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

I_{MAX}

The maximum output current.

I_N

The rated output current supplied by the adjustable frequency drive.

U_{MAX}

The maximum output voltage.

Input:

Control command

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

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

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

Table 1.3

Motor:

f_{JOG}

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

f_M

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

f_{MAX}

The maximum output frequency the adjustable frequency drive applies on its output. The maximum output frequency is set in limit par. 4-12, 4-13 and 4-19.

f_{MIN}

The minimum motor frequency from adjustable frequency drive. Default 0 Hz.

$f_{M,N}$

The rated motor frequency (nameplate data).

I_M

The motor current.

$I_{M,N}$

The rated motor current (nameplate data).

$n_{M,N}$

The rated motor speed (nameplate data).

n_s
Synchronous motor speed

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

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

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

U_M
The instantaneous motor voltage.

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

Break-away torque

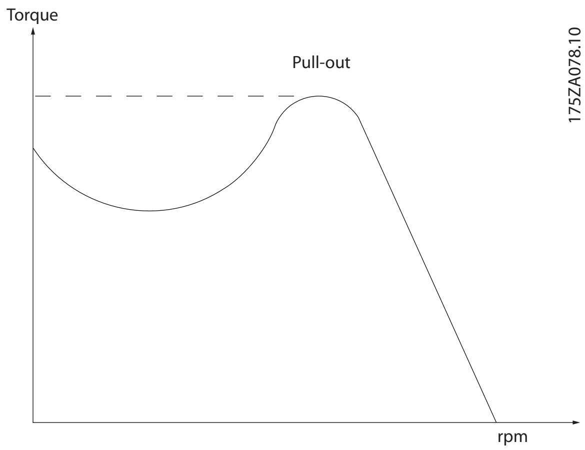


Figure 1.1

η
The efficiency of the adjustable frequency drive is defined as the ratio between the power output and the power input.

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

Stop command
See Control commands.

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

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

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

Pulse Reference
A pulse reference applied to term 29 or 33, selected by par. 5-13 or 5-15 [32]. Scaling in par. group 5-5*.

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

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

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

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

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

Brake Resistor
The brake resistor is a module capable of absorbing the 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.

Digital Inputs
The digital inputs can be used for controlling various adjustable frequency drive functions.

Digital Outputs
The adjustable frequency drive features two solid state outputs that can supply a 24V DC (max. 40mA) signal.

DSP
Digital Signal Processor.

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

Hiperface®
Hiperface® is a registered trademark by Stegmann.

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.

LCP
The Local Control Panel makes up a complete interface for control and programming of the adjustable frequency drive. The control panel is detachable and can be installed up to 10ft/3m from the adjustable frequency drive, i.e., in a front panel by means of the installation kit option.

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

lsb
Least significant bit.

msb
Most significant bit.

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

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

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

PCD
Process Data

Pulse Input/Incremental Encoder
An external digital sensor used for feedback information of motor speed and direction. Encoders are used for high speed accuracy feedback and in high dynamic applications. The encoder connection is either via term 32 and 32 or encoder option MCB 102.

RCD
Residual Current Device.

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

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

Slip Compensation
The 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. (Par. group 13-** *Smart Logic Control (SLC)*.

STW
Status Word

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

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

THD
Total Harmonic Distortion state the total contribution of harmonic.

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

Trip Locked
A state entered in fault situations when the 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 cancelled by activating reset or, in some cases, by being programmed to reset automatically. Trip may not be used for personal safety.

VT Characteristics
Variable torque characteristics used for pumps and fans.

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

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

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

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

The power factor for 3-phase control:

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

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.

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

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

2 Safety and Conformity

2.1 Safety Precautions

WARNING

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

Safety Regulations

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

Warning against unintended start

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

NOTE!

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

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

⚠WARNING

High Voltage

Touching the electrical parts may be fatal - even after the equipment has been disconnected from line power.
Also make sure that other voltage inputs have been disconnected, such as external 24V DC, load sharing (linkage of DC intermediate circuit), as well as the motor connection for kinetic backup.
Systems where adjustable frequency drives are installed must, if necessary, be equipped with additional monitoring and protective devices according to the valid safety regulations, e.g., law on mechanical tools, regulations for the prevention of accidents, etc. Modifications on the adjustable frequency drives by means of the operating software are allowed.

NOTE!

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

NOTE!

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

Protection Mode

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

NOTE!

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

The DC link capacitors remain charged after power has been disconnected. Be aware that there may be high voltage on the DC link even when the control card LEDs are turned off. A red LED is mounted on a circuit board inside the drive to indicate the DC bus voltage. The red LED will stay lit until the DC link is 50 VDC or lower. To avoid electrical shock hazard, disconnect the adjustable frequency drive from line power before carrying out maintenance. When using a PM motor, make sure it is disconnected. Before servicing the adjustable frequency drive, wait the minimum amount of time indicated below:

Voltage	Power	Waiting Time
380–500 V	0.34–10 hp [0.25–7.5 kW]	4 minutes
	15–100 hp [11–75 kW]	15 minutes
	125–300 hp [90–200 kW]	20 minutes
	350–1075 hp [250–800 kW]	40 minutes
525–690 V	15–100 hp [11–75 kW] (frame size B and C)	15 minutes
	50–450 hp [37–315 kW] (frame size D)	20 minutes
	500–1350 hp [355–1000 kW]	30 minutes

Table 2.1

2.2.1 Disposal Instructions

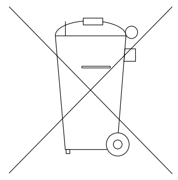
	Equipment containing electrical components may not be disposed of together with domestic waste. It must be separately collected with electrical and electronic waste according to local and currently valid legislation.

Table 2.2

FC 300 Design Guide Software version: 6.4x
This Design Guide can be used for all FC 300 adjustable frequency drives with software version 6.4x. The software version number can be seen from *15-43 Software Version*.

Table 2.3

2.3.1 CE Conformity and Labeling

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

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

2.3.2 What Is Covered

The EU "*Guidelines on the Application of Council Directive 2004/108/EC*" outline three typical situations of using a Adjustable frequency drive. See below for EMC coverage and CE labeling.

1. The Adjustable frequency drive is sold directly to the end-consumer. The Adjustable frequency drive is for example sold to a DIY market. The end-consumer is a layman. He installs the Adjustable frequency drive himself for use with a hobby machine, a kitchen appliance, etc. For such applications, the Adjustable frequency drive must be CE labeled in accordance with the EMC directive.
2. The Adjustable frequency drive is sold for installation in a plant. The plant is built up by professionals of the trade. It could be a production plant or a heating/ventilation plant designed and installed by professionals of the trade. Neither the Adjustable frequency drive nor the finished plant has to be CE labeled under the EMC directive. However, the unit must comply with the basic EMC requirements of the directive. This is ensured by using components, appliances and systems that are CE-labeled under the EMC directive.
3. The Adjustable frequency drive is sold as part of a complete system. The system is being marketed as complete and could, for example, be an air-conditioning system. The complete system must be CE-labeled in accordance with the EMC directive. The manufacturer can ensure CE labeling under the EMC directive either by using CE labeled components or by testing the EMC of the system. If he chooses to use only CE labeled components, he does not have to test the entire system.

2.3.3 Danfoss Adjustable Frequency Drive and CE Labeling

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

However, CE labeling may cover many different specifications. Thus, you have to check what a given CE label specifically covers.

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

Danfoss CE labels the adjustable frequency drives in accordance with the low-voltage directive. This means that if the Adjustable frequency drive is installed correctly, we guarantee compliance with the low-voltage directive. Danfoss issues a declaration of conformity that confirms our CE labeling in accordance with the low-voltage directive.

The CE label also applies to the EMC directive provided that the instructions for EMC-correct installation and filtering are followed. On this basis, a declaration of conformity in accordance with the EMC directive is issued.

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

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

2.3.4 Compliance with EMC Directive 2004/108/EC

As mentioned, the Adjustable frequency drive is mostly used by professionals of the trade as a complex component forming part of a larger appliance, system, or installation. It must be noted that the responsibility for the final EMC properties of the appliance, system or installation rests with the installer. As an aid to the installer, Danfoss has prepared EMC installation guidelines for the Power Drive system. The standards and test levels stated for power drive systems are complied with, provided that the EMC-compatible instructions for installation are followed; see the section *EMC Immunity*.

The Adjustable frequency drive has been designed to meet the IEC/EN 60068-2-3 standard, EN 50178 pkt. 9.4.2.2 at 122ºF [50°C].

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

⚠CAUTION

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

Degree of protection as per IEC 60529

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

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

Airborne particles such as dust may cause mechanical, electrical, or thermal failure in the Adjustable frequency drive. A typical indicator of excessive levels of airborne particles is dust particles around the Adjustable frequency drive fan. In very dusty environments, use equipment with enclosure rating IP 54/55 or a cabinet for IP 00/IP 20/TYPE 1 equipment.

In environments with high temperatures and humidity, corrosive gases such as sulfur, nitrogen and chlorine compounds will cause chemical processes on the Adjustable frequency drive components.

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

NOTE!

Mounting adjustable frequency drives in aggressive environments increases the risk of stoppages and considerably reduces the life of the drive.

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

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

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

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

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

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

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

3 Introduction to FC 300

3.1 Product Overview

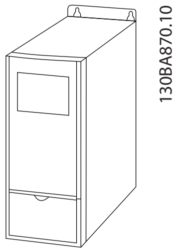
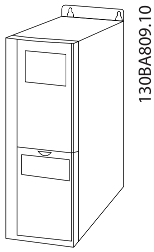
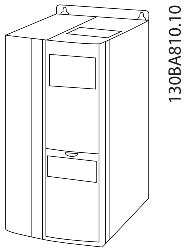
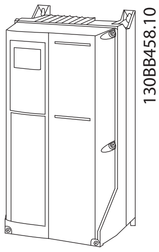
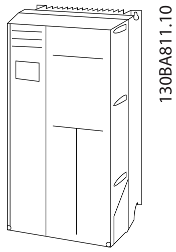
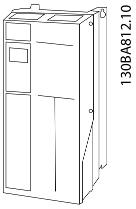
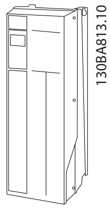
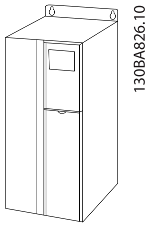
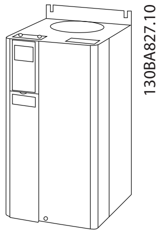
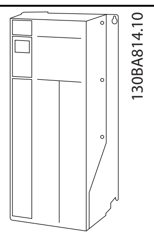
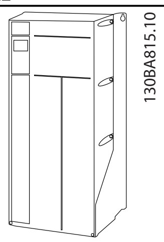
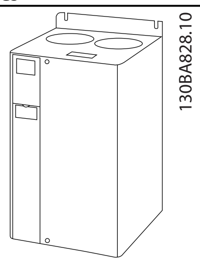
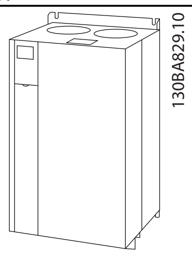
Frame size depends on enclosure type, power range and AC line voltage						
Frame size		**A1***	**A2***	**A3***	**A4**	**A5**
						
Enclosure protection	IP	20/21	20/21	20/21	55/66	55/66
	NEMA	Chassis/Type 1	Chassis/ Type 1	Chassis/ Type 1	Type 12	Type 12
High overload rated power - 160% overload torque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

Table 3.1

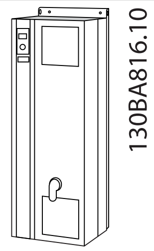
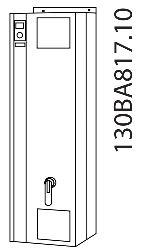
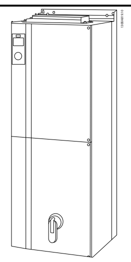
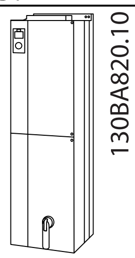
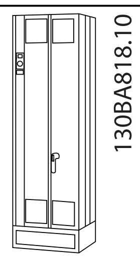
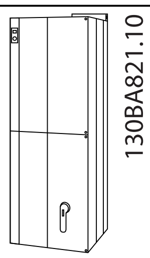
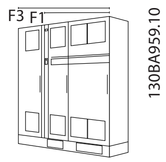
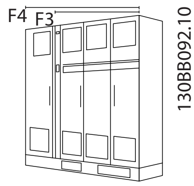
Frame size		D1	D2	D3	D4
					
Enclosure protection	IP	21/54	21/54	00	00
	NEMA	Type 1/ Type 12	Type 1/ Type 12	Chassis	Chassis
High overload rated power - 160% overload torque		90–110kW at 400V (380–/ 500V) 37–132kW at 690V (525–690V)	132–200kW at 400V (380–/ 500V) 160–315kW at 690V (525–690V)	90–110kW at 400V (380–/500V) 37–132kW at 690V (525–690V)	132–200kW at 400V (380–-/ 500V) 160–315kW at 690V (525–690V)
Frame size		**E1**	**E2**	**F1/F3**	**F2/ F4**
					
Enclosure protection	IP	21/54	00	21/54	21/54
	NEMA	Type 1/ Type 12	Chassis	Type 1/ Type 12	Type 1/ Type 12
High overload rated power - 160% overload torque		250–400kW at 400V (380–/500V) 355–560kW at 690V (525–690V)	250–400kW at 400V (380–/500V) 355–560kW at 690V (525–690V)	450–630kW at 400V (380–/500V) 630–800kW at 690V (525–690V)	710–800kW at 400V (380–/ 500V) 900–1000kW at 690V (525–690V)

Table 3.2

NOTE!

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

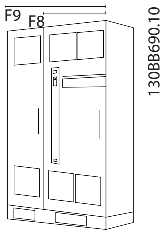
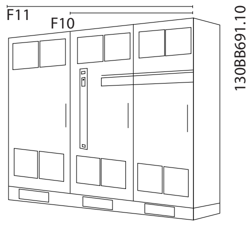
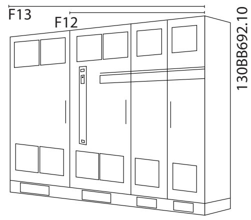
12-Pulse Units						
Frame size	**F8**	**F9**	**F10**	**F11**	**F12**	**F13**
IP NEMA	21, 54 Type 1/Type 12	21, 54 Type 1/Type 12	21, 54 Type 1/Type 12	21, 54 Type 1/Type 12	21, 54 Type 1/Type 12	21, 54 Type 1/Type 12
						
High overload rated power - 160% overload torque	**250–400kW (380–500V) 355–560kW (525–690V)**	**250–400kW (380–500V) 355–56kW (525–690V)**	**450–630kW (380–500V) 630–800kW (525–690V)**	**450–630kW (380–500V) 630–800kW (525–690V)**	**710–800kW (380–500V) 900–1200kW (525–690V)**	**710–800kW (380–500V) 900–1200kW (525–690V)**

Table 3.3

NOTE!

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

3.2.1 Control Principle

An adjustable frequency drive rectifies AC voltage from line 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 infinitely variable speed control of three-phased, standard AC motors and permanent magnet synchronous motors.

3.2.2 FC 300 Controls

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 requires a speed feedback to an input. Properly optimized speed closed-loop control will have higher accuracy than speed open-loop control.

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

Torque control (FC 302 only):
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 par. 1-00, either in VVC+ open-loop [4] or flux control closed-loop with motor speed feedback [2]. Torque setting is done by setting an analog, digital or bus controlled reference. The max speed limit factor is set in par. 4-21. 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+ 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. See Application Example Torque Open-loop

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 later in this section.

3.2.3 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 asynchronous motors only.
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 3 lower IGBTs and the brake.

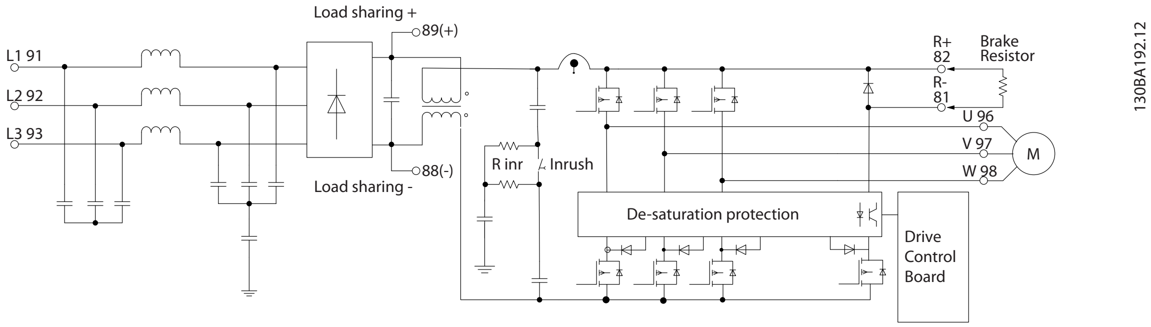


Figure 3.1 FC 301

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 3 current transducers in the motor phases and the desaturation protection with feedback from the brake.

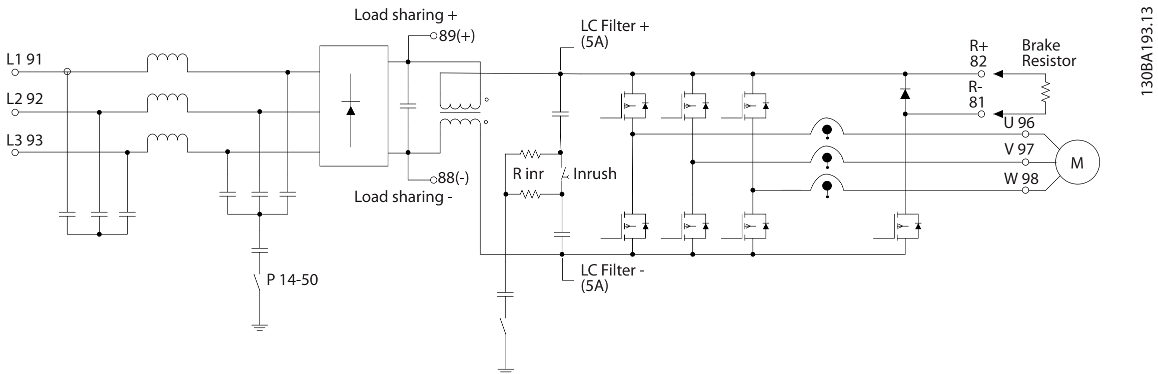


Figure 3.2 FC 302

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

Control structure in VVC^{plus} open-loop and closed-loop configurations:

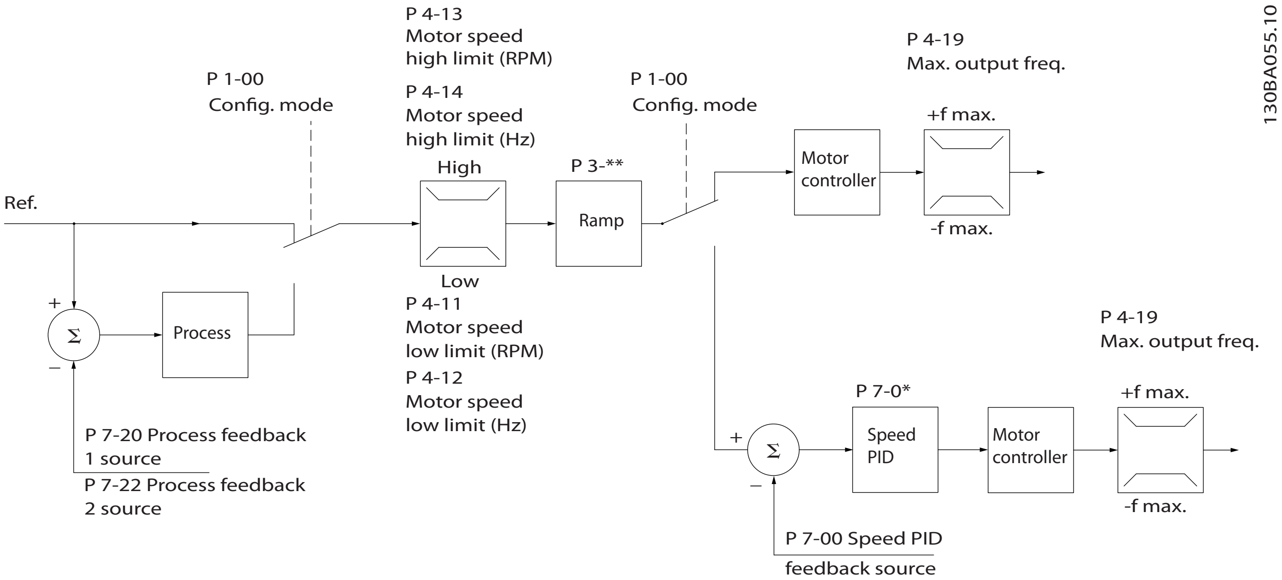


Figure 3.3

In the configuration shown in *Figure 3.3*, *1-01 Motor Control Principle* is set to “VVC^{plus} [1]” and *1-00 Configuration Mode* is set to “Speed open-loop [0]”. 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 “Speed closed-loop [1]” the resulting reference will be passed from the ramp limitation and speed limitation into a speed PID control. The Speed PID control parameters are located in the parameter group 7-0*. The resulting reference from the speed PID control is sent to the motor control limited by the frequency limit.

Select “Process [3]” 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* and 7-3*.

3

3.2.5 Control Structure in Flux Sensorless (FC 302 only)

Control structure in flux sensorless open-loop and closed-loop configurations.

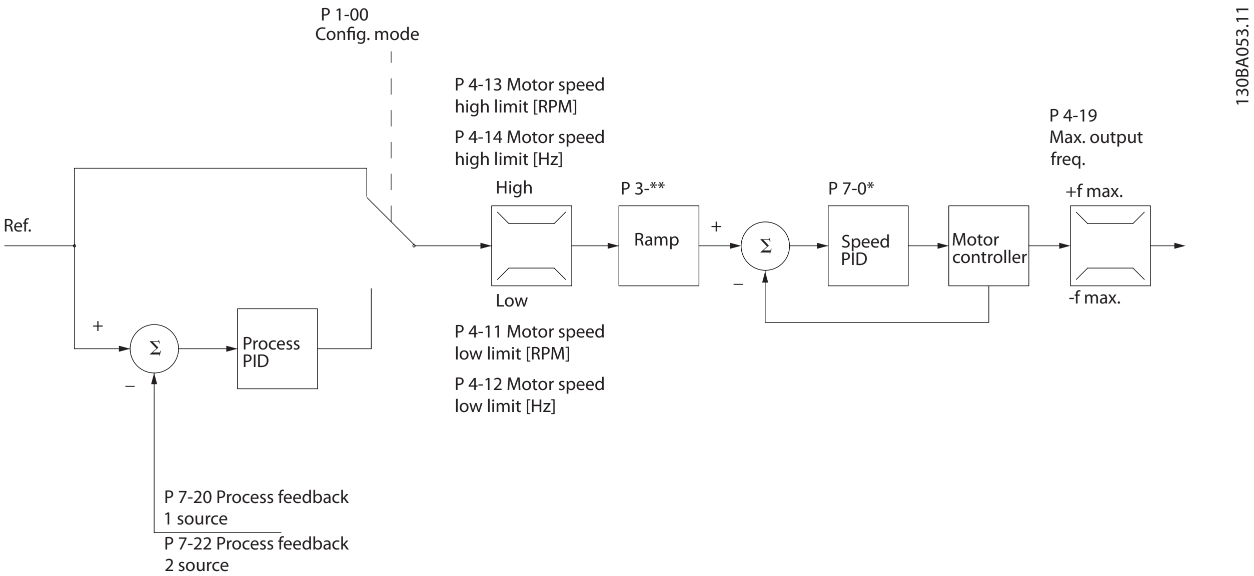


Figure 3.4

In the shown configuration, *1-01 Motor Control Principle* is set to “Flux sensorless [2]” and *1-00 Configuration Mode* is set to “Speed open-loop [0]”. 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*).

Select “Process [3]” 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* and 7-3*.

3.2.6 Control Structure in Flux with Motor Feedback

Control structure in Flux with motor feedback configuration (only available in FC 302):

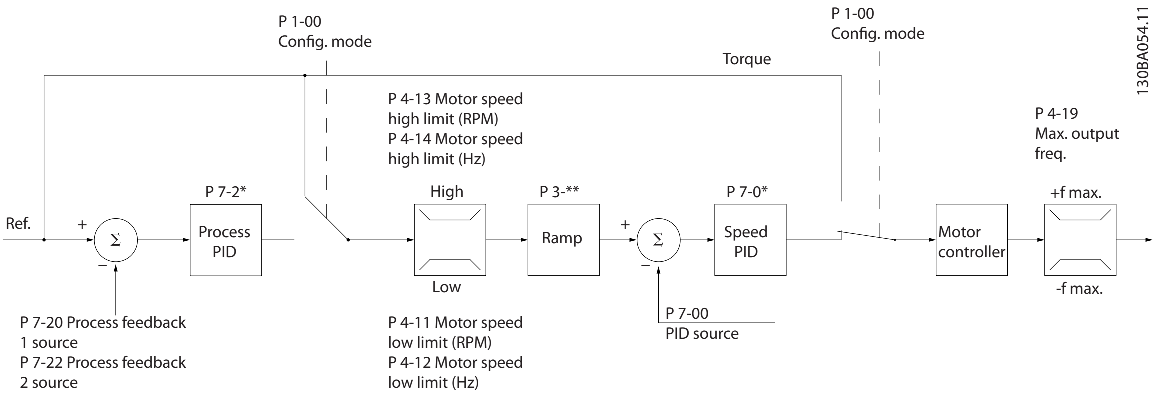


Figure 3.5

In the shown configuration, *1-01 Motor Control Principle* is set to "Flux w motor feedb [3]" and *1-00 Configuration Mode* is set to "Speed closed-loop [1]".

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

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

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

Select "Process [3]" 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

3.2.7 Internal Current Control in VVC^{plus} Mode

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

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

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

After pressing the [Auto On] key, the adjustable frequency drive goes into 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).

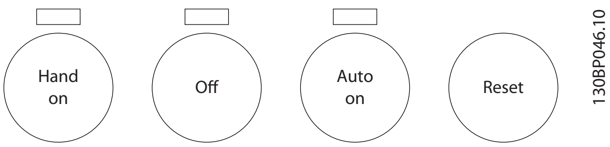


Figure 3.6

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 *Local* [2].
To permanently select the remote reference select *Remote* [1]. By selecting *Linked to Hand/Auto* [0] (default) the reference site will depend on which mode is active. (Hand Mode or Auto Mode).

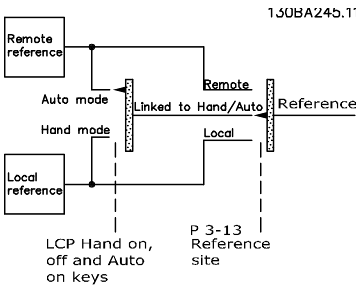


Figure 3.7

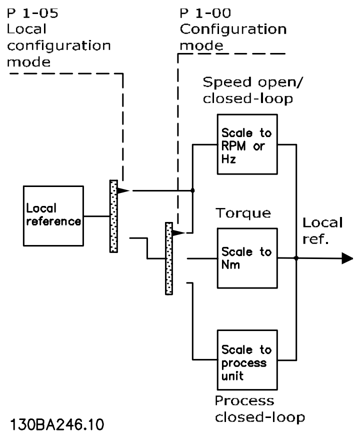


Figure 3.8

Hand OnAutoLCP 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 3.4 Conditions for Local/Remote Reference Activation.

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

3.3 Reference Handling

Local Reference

The local reference is active when the adjustable frequency drive is operated with ‘Hand On’ button active. Adjust the reference by up/down and left/right arrows respectively.

Remote Reference

The reference handling system for calculating the remote reference is shown in *Figure 3.9*.

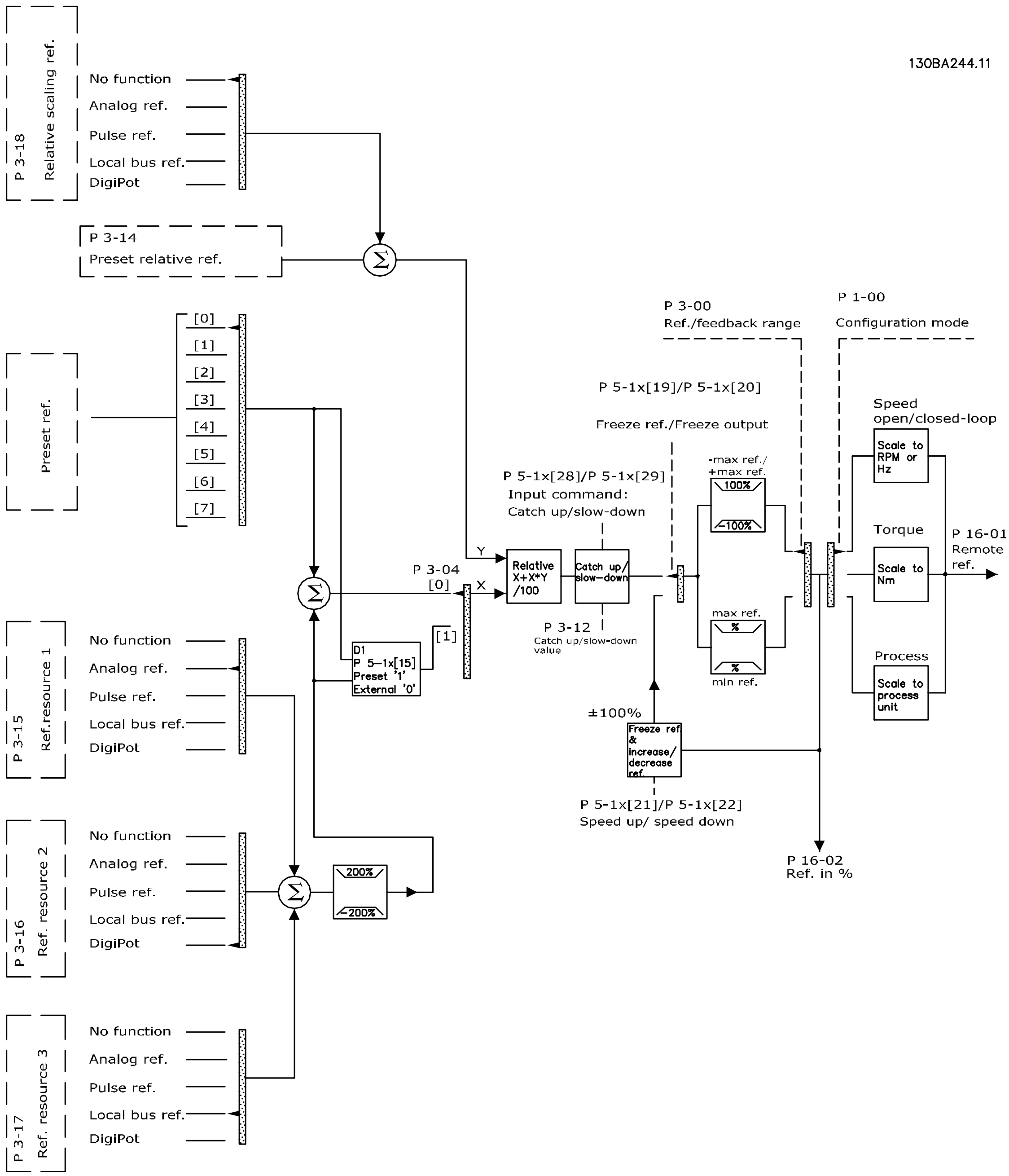


Figure 3.9 Remote reference

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

1. X (the external reference): A sum (see *3-04 Reference Function*) of up to four externally selected references, comprising any combination (determined by the setting of *3-15 Reference Resource 1*, *3-16 Reference Resource 2* and *3-17 Reference Resource 3*) of a fixed preset reference (*3-10 Preset Reference*), variable 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, par. 3-18 must be set to *No function* and par. 3-14 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, MG33MXYY.
The scaling of analog references are described in parameter groups 6-1* and 6-2*, and the scaling of digital pulse references are described in parameter group 5-5*.
Reference limits and ranges are set in parameter group 3-0*.

3.3.1 Reference Limits

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

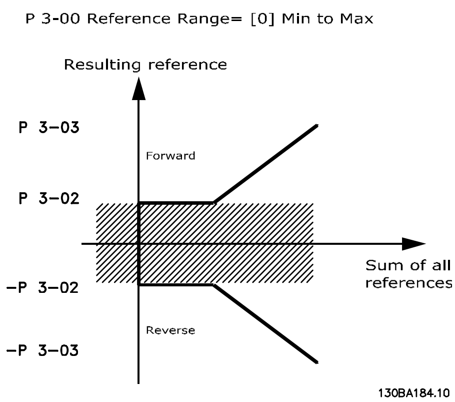


Figure 3.10

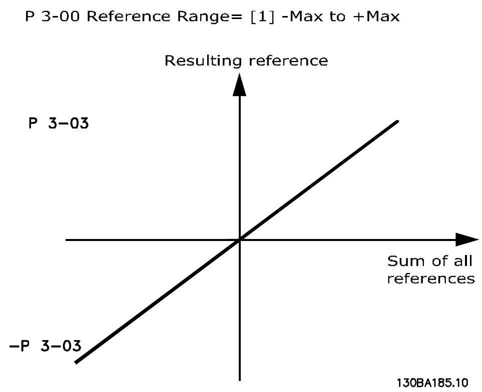


Figure 3.11

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 as shown in *Figure 3.12*.

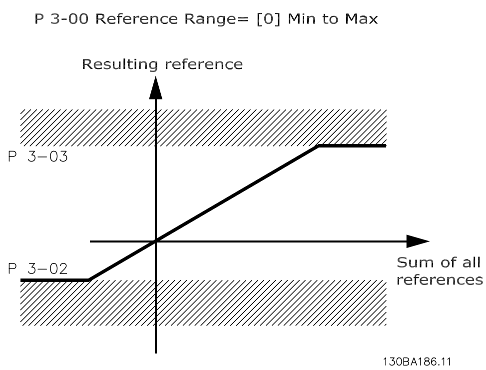


Figure 3.12 Sum of all References

3.3.2 Scaling of Preset References and Bus References

Preset references are scaled according to the following rules:

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

Bus references are scaled according to the following rules:

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

3.3.3 Scaling of Analog and Pulse References and Feedback

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

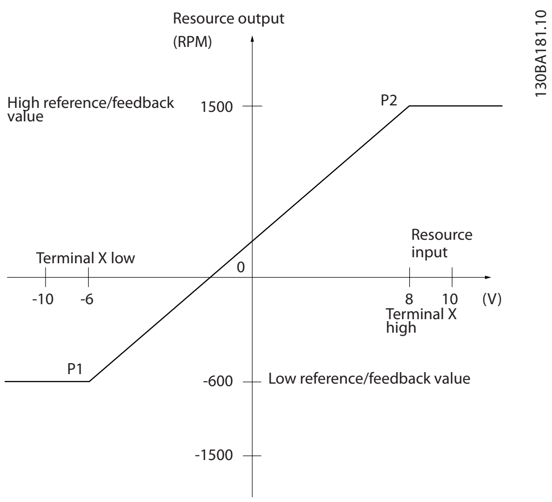


Figure 3.13 Scaling of Analog and Pulse References and Feedback

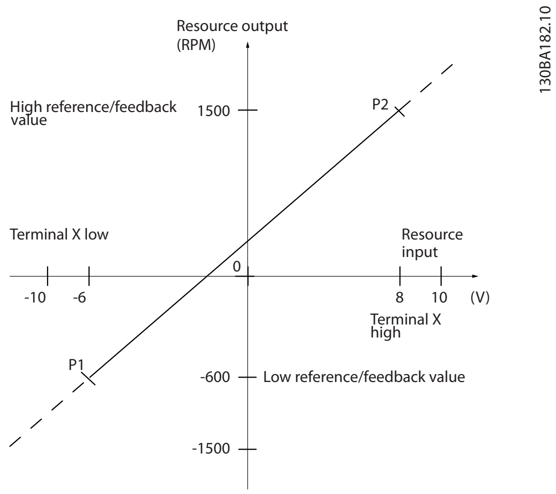


Figure 3.14

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

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

Table 3.5

3.3.4 Dead Band Around Zero

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

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

- Either Minimum Reference Value (see table above for relevant parameter) or Maximum Reference Value must be zero. In other words, either P1 or P2 must be on the X-axis in the graph below.
- 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 3.15*.

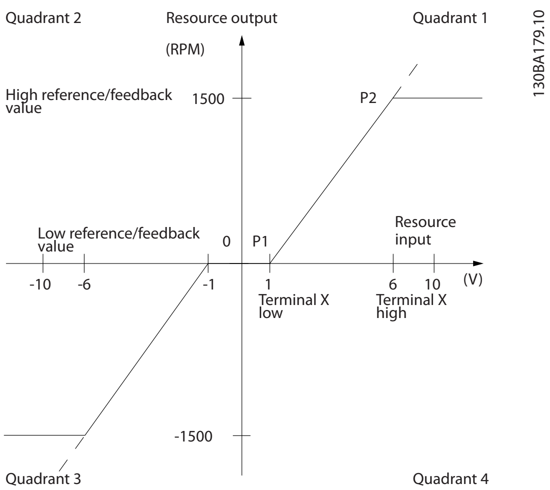


Figure 3.15

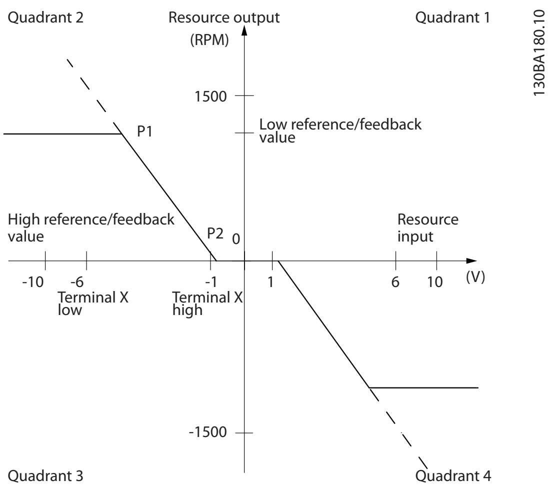


Figure 3.16

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

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

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

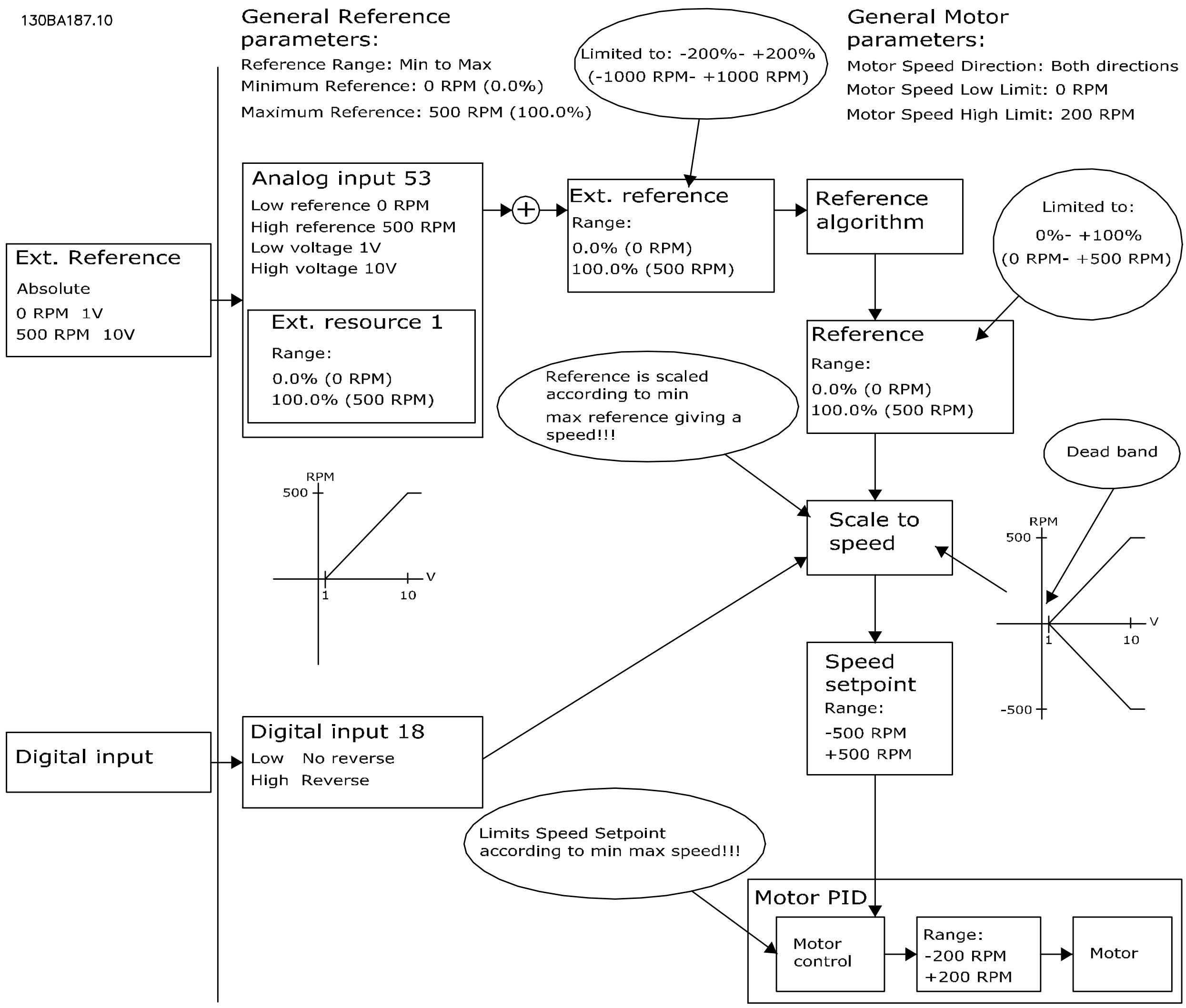


Figure 3.17

3

Case 2: Positive reference with dead band, digital input to trigger reverse. Clamping rules.
This case shows how a reference input with limits outside -Max – +Max limits clamps to the input's low and high limits before addition to external reference, And how the External reference is clamped to -Max – +Max by the Reference algorithm.

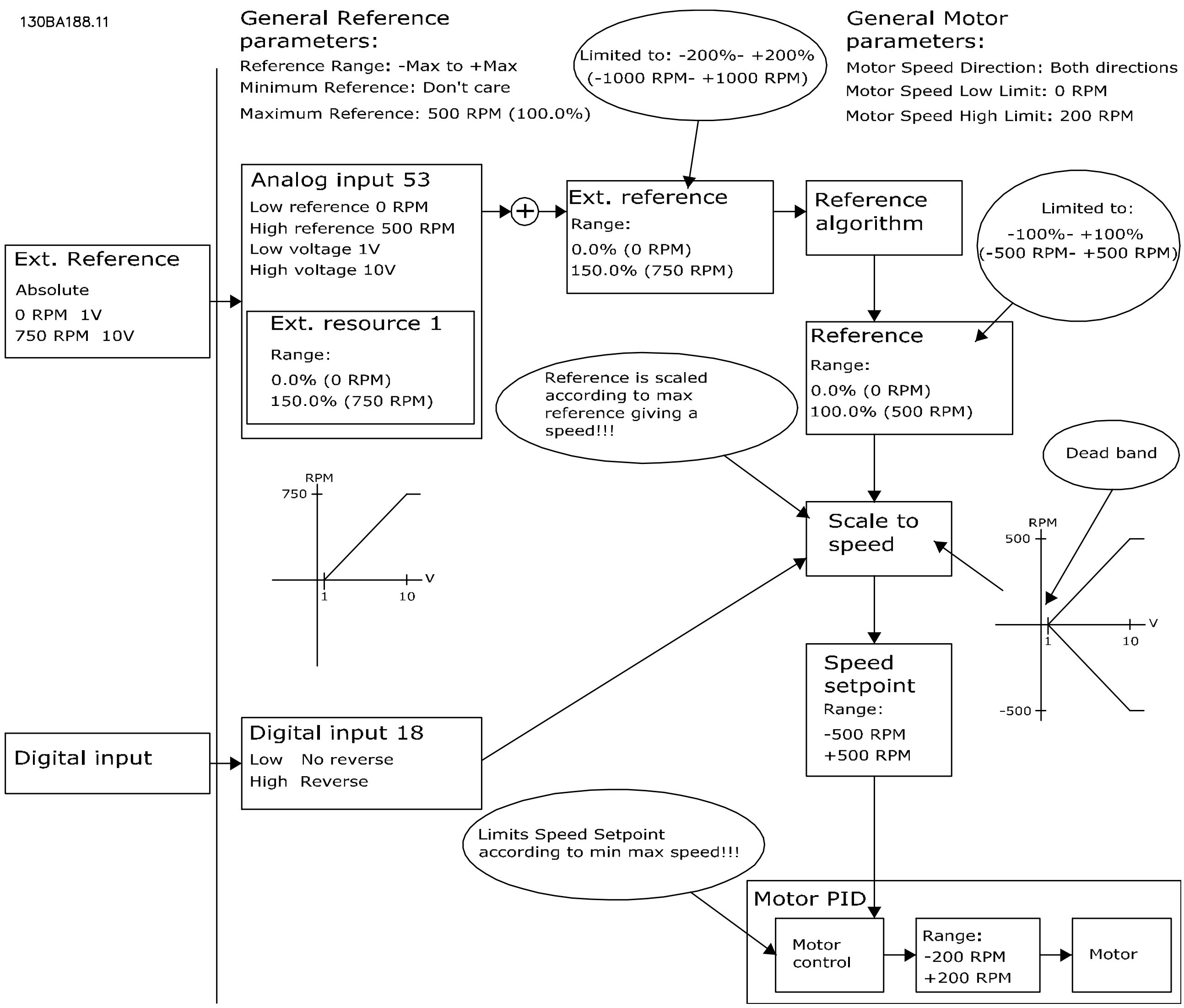


Figure 3.18

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

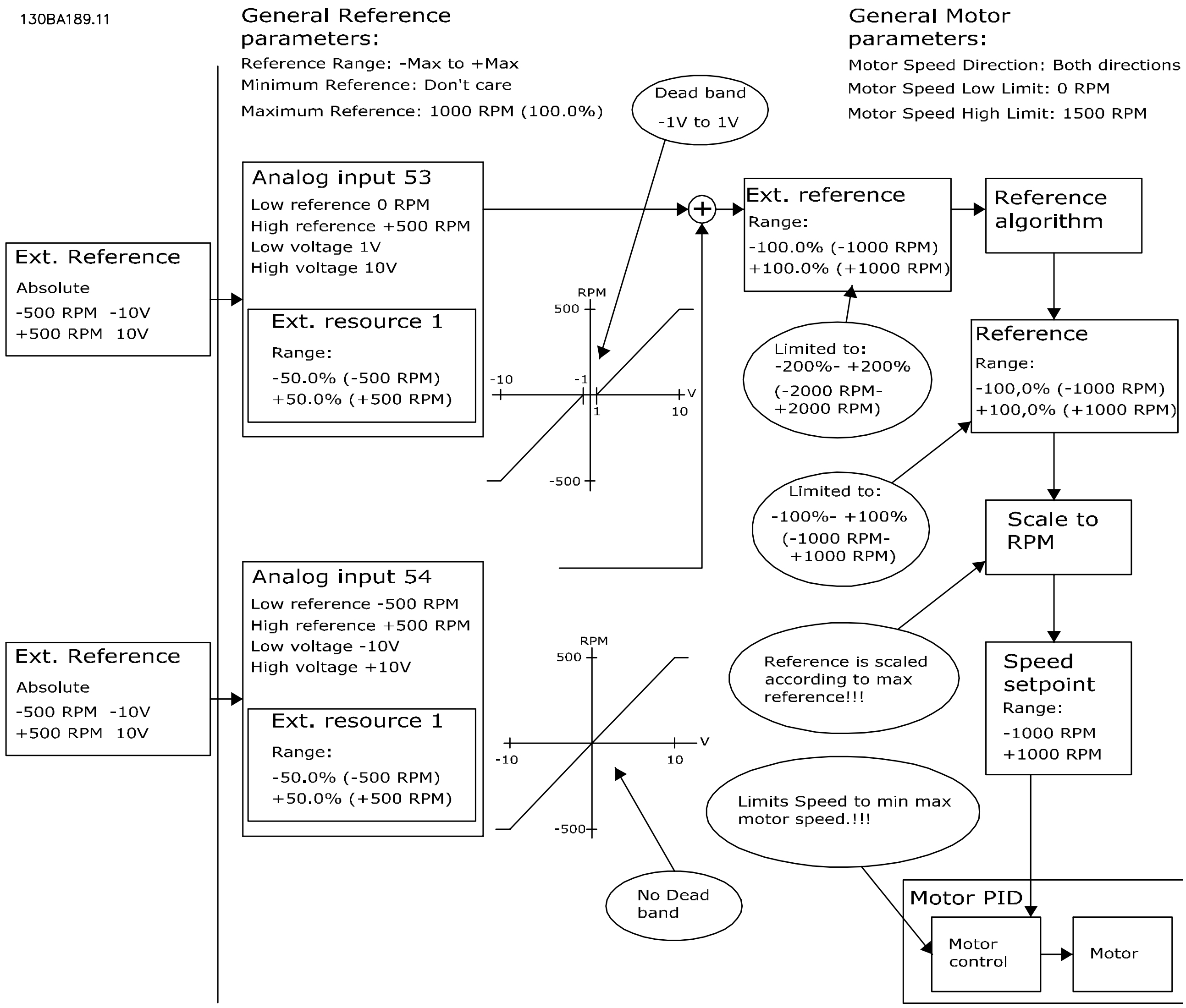


Figure 3.19

3.4 PID Control

3.4.1 Speed PID Control

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

Table 3.6 Control configurations where the Speed Control is active

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

NOTE!

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

The following parameters are relevant for the Speed Control:

Parameter	Description of function
7-00 Speed PID Feedback Source	Select from which input the speed PID should get its feedback.
30-83 Speed PID Proportional Gain	The higher the value, the quicker the control. However, too high value may lead to oscillations.
7-03 Speed PID Integral Time	Eliminates steady state speed error. Lower value means quick reaction. However, too high value may lead to oscillations.
7-04 Speed PID Differentiation Time	Provides a gain proportional to the rate of change of the feedback. A setting of zero disables the differentiator.
7-05 Speed PID Diff. Gain Limit	If there are quick changes in reference or feedback in a given application - which means that the error changes swiftly - the differentiator may soon become too dominant. This is because it reacts to changes in the error. The quicker the error changes, the stronger the differentiator gain is. The differentiator gain can thus be limited to allow setting of the reasonable differentiation time for slow changes and a suitably quick gain for quick changes.
7-06 Speed PID Lowpass Filter Time	A low-pass filter that dampens oscillations on the feedback signal and improves steady state performance. However, a filter time that is too long will deteriorate the dynamic performance of the speed PID control. Practical settings of parameter 7-06 taken from the number of pulses per revolution on from encoder (PPR):

Encoder PPR	*7-06 Speed PID Lowpass Filter Time*
512	10 ms
1024	5 ms
2048	2 ms
4096	1 ms

Table 3.7

Example of How to Program the Speed Control

In this case, speed PID control is used to maintain a constant motor speed regardless of the changing load on the motor. The required motor speed is set via a potentiometer connected to terminal 53. The speed range is 0–1500 RPM, which corresponds to 0–10 V over the potentiometer. Starting and stopping is controlled by a switch connected to terminal 18. The Speed PID monitors the actual RPM of the motor by using a 24V (HTL) incremental encoder as feedback. The feedback sensor is an encoder (1024 pulses per revolution) connected to terminals 32 and 33.

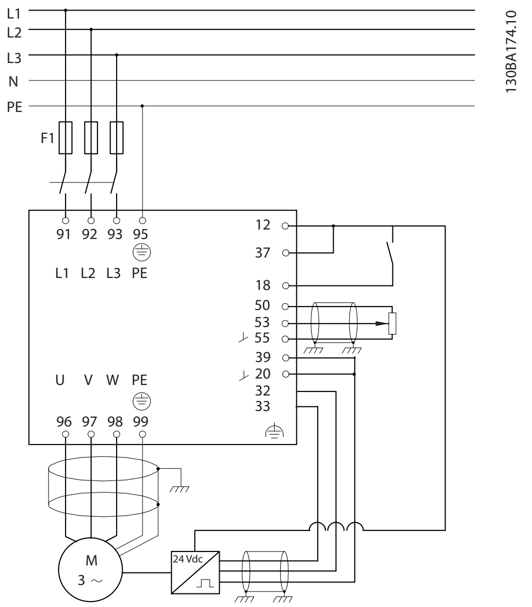

L1
L2
L3
N
PE
F1
91 92 93 95
L1 L2 L3 PE
U V W PE
96 97 98 99
12
37
18
50
53
55
39
20
32
33
M
3 ~
24 Vdc
130BA174.10

Figure 3.20

3

The following must be programmed in order shown (see explanation of settings in the Programming Guide)
In the list, it is assumed that all other parameters and switches remain at their default setting.

Function	parameter no.	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
Have the adjustable frequency drive makes an Automatic Motor Adaptation	*1-29 Automatic Motor Adaptation (AMA)*	[1] Enable complete AMA
2) Check the motor is running and the encoder is attached properly. Do the following:		
Press the “Hand On” LCP key. Make sure the motor is running and note in which direction it is turning (henceforth referred to as the “positive direction”).		Set a **positive** reference.
Go to *16-20 Motor Angle*. Turn the motor slowly in the positive direction. It must be turned so slowly (only a few RPM) that it can be determined if the value in *16-20 Motor Angle* is increasing or decreasing.	*16-20 Motor Angle*	N.A. (read-only parameter) Note: An increasing value overflows at 65,535 and starts again at 0.
If *16-20 Motor Angle* is decreasing, then change the encoder direction in *5-71 Term 32/33 Encoder Direction*.	*5-71 Term 32/33 Encoder Direction*	[1] Counter clockwise (if *16-20 Motor Angle* is decreasing)
3) Make sure the drive limits are set to safe values		
Set acceptable limits for the references.	*3-02 Minimum Reference* *3-03 Maximum Reference*	0 RPM (default) 1500 RPM (default)
Check that the ramp settings are within drive capabilities and allowed application operating specifications.	*3-41 Ramp 1 Ramp-up Time* *3-42 Ramp 1 Ramp-down Time*	default setting default setting
Set acceptable limits for the motor speed and frequency.	*4-11 Motor Speed Low Limit [RPM]* *4-13 Motor Speed High Limit [RPM]* *4-19 Max Output Frequency*	0 RPM (default) 1500 RPM (default) 60 Hz (default 132 Hz)
4) Configure the Speed Control and select the Motor Control principle		
Activation of Speed Control	*1-00 Configuration Mode*	[1] Speed closed-loop
Selection of Motor Control Principle	*1-01 Motor Control Principle*	[3] Flux w motor feedb
5) Configure and scale the reference to the Speed Control		
Set up Analog Input 53 as a reference source	*3-15 Reference Resource 1*	Not necessary (default)
Scale Analog Input 53 0 RPM (0V) to 1500 RPM (10V)	6-1*	Not necessary (default)
6) Configure the 24V HTL encoder signal as feedback for the Motor Control and the Speed Control		
Set up digital input 32 and 33 as encoder inputs	*5-14 Terminal 32 Digital Input* *5-15 Terminal 33 Digital Input*	[0] No operation (default)
Choose terminal 32/33 as motor feedback	*1-02 Flux Motor Feedback Source*	Not necessary (default)
Choose terminal 32/33 as Speed PID feedback	*7-00 Speed PID Feedback Source*	Not necessary (default)
7) Tune the Speed Control PID parameters		
Use the tuning guidelines when relevant or tune manually	7-0*	See the guidelines below
8) Finished!		
Save the parameter setting to the LCP for safe keeping	*0-50 LCP Copy*	[1] All to LCP

Table 3.8

3.4.2 Tuning PID speed control

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

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

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

NOTE!

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

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

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

A good start value for *7-06 Speed PID Lowpass Filter Time* is 5 ms (lower encoder resolution calls for a higher filter value). Typically, a max torque ripple of 3% is acceptable. For incremental encoders, the encoder resolution is found in either *5-70 Term 32/33 Pulses per Revolution* (24V HTL on standard drive) or *17-11 Resolution (PPR)* (5 V TTL on MCB102 Option).

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

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

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

3.4.3 Process PID Control

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

The table shows the control configurations where the process control is possible. When a flux vector motor control principle is used, take care also to tune the speed control PID parameters. Refer to the section about the Control Structure to see where the Speed Control is active.

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

Table 3.9

NOTE!

Process control PID will work 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 (prior to tuning the process control PID) to yield their full potential.

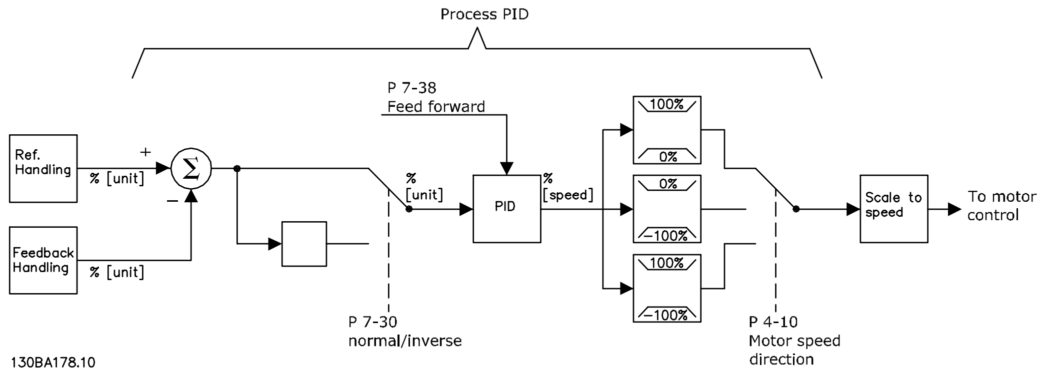


Figure 3.21 Process PID Control diagram

The following parameters are relevant for 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 will be added together before being used in process PID control.
7-30 Process PID Normal/Inverse Control	Under [0] Normal operation, the process control will respond with an increase of the motor speed if the feedback is getting lower than the reference. In the same situation, but under [1] Inverse operation, the process control will respond with a decreasing motor speed instead.
7-31 Process PID Anti Windup	The anti-windup function ensures that when either a frequency limit or a torque limit is reached, the integrator will be set to a gain that corresponds to the actual frequency. This avoids integrating on an error that cannot in any case be compensated for by means of a speed change. This function can be disabled by selecting [0] "Off".
7-32 Process PID 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.
5-54 Pulse Filter Time Constant #29 (Pulse term. 29), *5-59 Pulse Filter Time Constant #33* (Pulse term. 33), *6-16 Terminal 53 Filter Time Constant* (Analog term 53), *6-26 Terminal 54 Filter Time Constant* (Analog term. 54)	If there are oscillations of the current/voltage feedback signal, these can be dampened by means of a low-pass filter. This time constant represents the speed limit of the ripples occurring on the feedback signal. Example: If the low-pass filter has been set to 0.1s, the limit speed will be 10 RAD/sec. (the reciprocal of 0.1 s), corresponding to (10/(2 x π)) = 1.6 Hz. This means that all currents/voltages that vary by more than 1.6 oscillations per second will be damped by the filter. The control will only be carried out on a feedback signal that varies by a frequency (speed) of less than 1.6 Hz. The low-pass filter improves steady state performance, but selecting filter time that is too long will deteriorate the dynamic performance of the process PID control.

Table 3.10

3.4.4 Example of Process PID Control

The following is an example of process PID control used in a ventilation system:

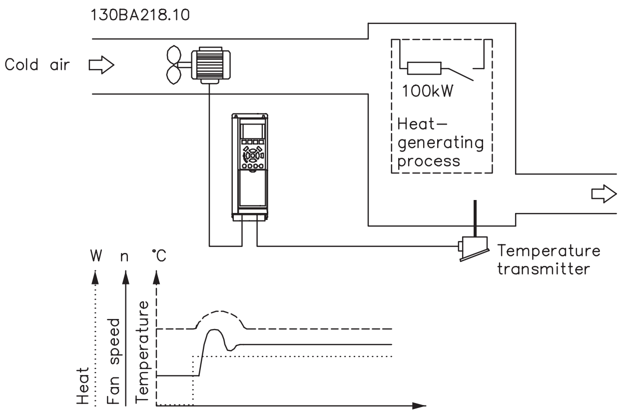


Figure 3.22

In a ventilation system, the temperature is to be able to be set from 23°–95°F [-5°–35°C] with a potentiometer of 0–10 V. The set temperature must be kept constant, for which purpose the Process Control is to be used.

The control is of the inverse type, which means that when the temperature increases, the ventilation speed is increased as well, so as to generate more air. When the temperature drops, the speed is reduced. The transmitter used is a temperature sensor with a working range of 14°–104°F [-10°–+40°C], 4-20 mA. / Max. speed 300 /1,500 RPM.

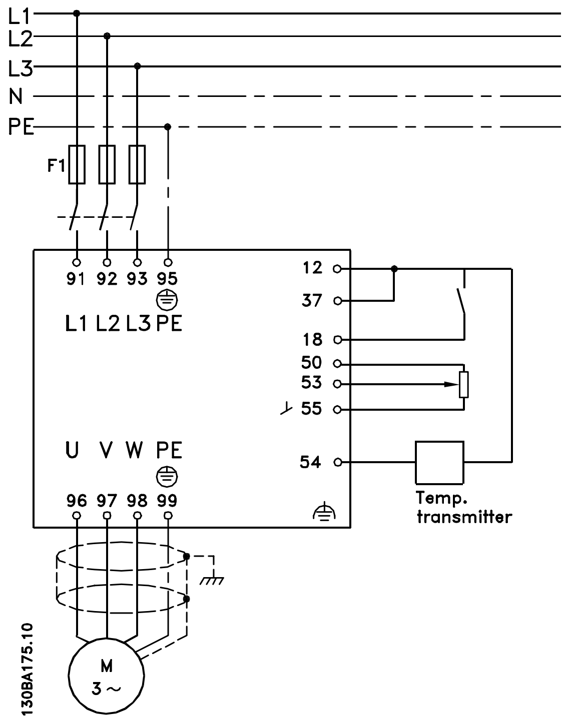


Figure 3.23 Two-wire transmitter

1. Start/Stop via switch connected to terminal 18.
2. Temperature reference via potentiometer (23°–95°F [-5°–+35°C], 0–10 VDC) connected to terminal 53.
3. Temperature feedback via transmitter (14°–104°F [-10°–+40°C], 4–20 mA) connected to terminal 54. Switch S202 set to ON (current input).

3

Function	Par. no.	Setting
Initialize the adjustable frequency drive	14-22	[2] Initialization - make a power cycling - press reset
1) Set motor parameters:		
Set the motor parameters according to nameplate data	1-2*	As stated on motor nameplate
Perform a full Automation Motor Adaptation	1-29	[1] Enable complete AMA
2) Check that motor is running in the right direction. When motor is connected to an adjustable frequency drive with straight forward phase order as U - U; V- V; W - W motor shaft usually turns clockwise seen into shaft end.		
Press "Hand On" LCP key. Check shaft direction by applying a manual reference.		
If motor turns opposite of required direction: 1. Change motor direction in *4-10 Motor Speed Direction* 2. Turn off line power - wait for DC link to discharge - switch two of the motor phases	4-10	Select correct motor shaft direction.
Set configuration mode.	1-00	[3] Process
Set Local Mode Configuration	1-05	[0] Speed Open-loop
3) Set reference configuration, i.e., the range for reference handling. Set scaling of analog input in par. 6-xx		
Set reference/feedback units Set min. reference (50°F [10°C]) Set max. reference (176°F [80°C]) If set value is determined from a preset value (array parameter), set other reference sources to No Function.	3-01 3-02 3-03 3-10	[140]ºF [[60] °C] Unit shown on display 23ºF [-5°C] 95ºF [35°C] [0] 35% $Ref = \frac{Par.\ 3-10_{(0)}}{100} \times ((Par.\ 3-03) - (par.\ 3-02)) = 24,5°\ C$ *3-14 Preset Relative Reference* to *3-18 Relative Scaling Reference Resource* [0] = No Function
4) Adjust limits for the adjustable frequency drive:		
Set ramp times to an appropriate value as 20 sec.	3-41 3-42	20 sec. 20 sec.
Set min. speed limits Set motor speed max. limit Set max. output frequency	4-11 4-13 4-19	300 RPM 1500 RPM 60 Hz
Set S201 or S202 to desired analog input function (Voltage (V) or milli-Amps (I)) NOTE! Switches are sensitive - Make a power cycling keeping default setting of V		
5) Scale analog inputs used for reference and feedback		
Set terminal 53 low voltage Set terminal 53 high voltage Set terminal 54 low feedback value Set terminal 54 high feedback value Set feedback source	6-10 6-11 6-24 6-25 7-20	0V 10V 23ºF [-5°C] 95ºF [35°C] [2] Analog input 54
6) Basic PID settings		
Process PID Normal/Inverse	7-30	[0] Normal
Process PID Anti Wind-up	7-31	[1] On
Process PID start speed	7-32	300 rpm
Save parameters to LCP	0-50	[1] All to LCP

Table 3.11 Example of Process PID Control set-up

Optimization of the process regulator

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

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

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

3.4.5 Ziegler Nichols Tuning Method

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

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

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

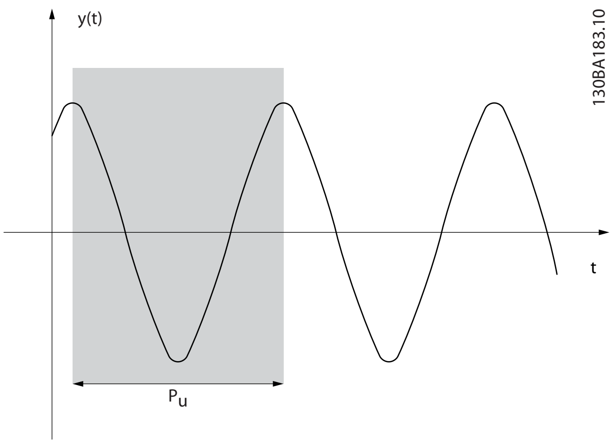


Figure 3.24 Marginally Stable System

P_u should be measured when the amplitude of oscillation is quite small. Then we "back off" from this gain again, as shown in Table 1.

K_u is the gain at which the oscillation is obtained.

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

Table 3.12 Ziegler Nichols tuning for regulator, based on a stability boundary.

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

Step-by-step Description:

Step 1: Select only proportional control, meaning that the integral time is selected to the maximum value, while the differentiation time is selected to zero.

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

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

Step 4: Use the table above to calculate the necessary PID control parameters.

3

3.5 General Aspects of EMC

3.5.1 General Aspects of EMC Emissions

Electrical interference is usually conducted at frequencies in the range 150kHz to 30MHz. Airborne interference from the Adjustable frequency drive system in the range 30MHz to 1GHz is generated from the inverter, motor cable, and the motor. As shown in the figure below, capacitive currents 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 below), because shielded cables have higher capacitance to ground than non-shielded cables. If the leakage current is not filtered, it will cause greater interference on the line power in the radio frequency range below approximately 5MHz. Since the leakage current (I_1) is carried back to the unit through the shield (I_3), there will in principle only be a small electro-magnetic field (I_4) from the shielded motor cable according to the below figure.

The shield reduces the radiated interference, but increases the low-frequency interference in the line power supply. The motor cable shield must be connected 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). These 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 serial communication bus, relay, control cable, signal interface and brake, the shield must be mounted on the enclosure at both ends. In some situations, however, it will be necessary to break the shield to avoid current loops.

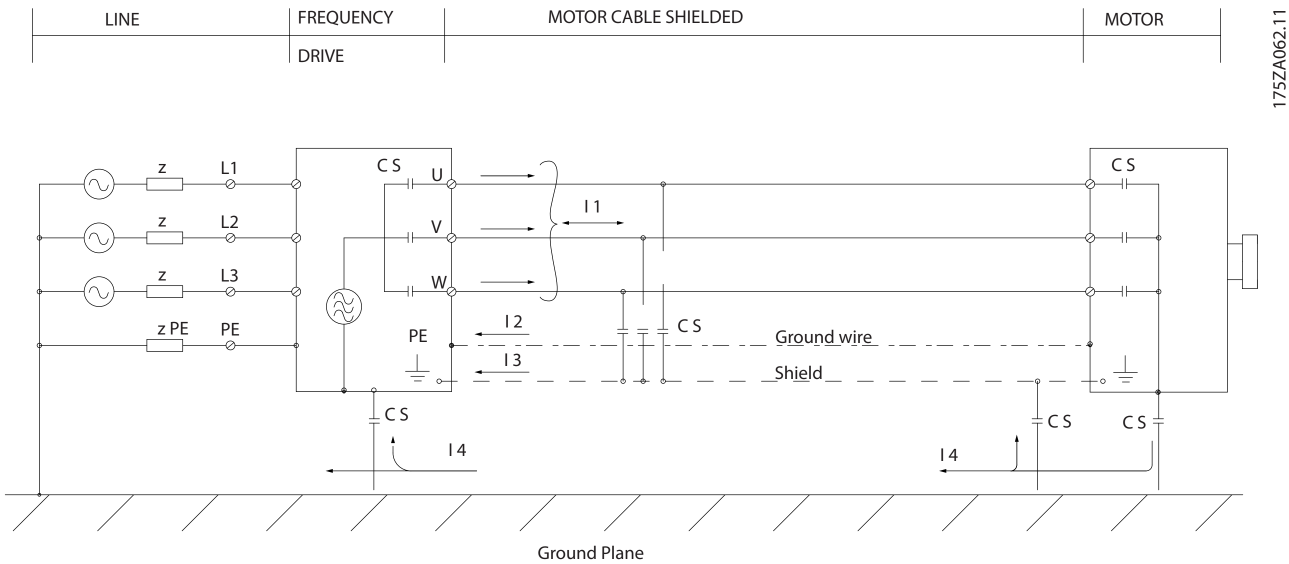


Figure 3.25

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

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

In order to reduce the interference level from the entire system (unit + 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 50MHz (airborne) is especially generated by the control electronics. Please see for more information on EMC.

3.5.2 EMC Test Results

The following test results were obtained using a system with an adjustable frequency drive (with options, if relevant), a shielded control cable, a control box with potentiometer, as well as a motor and motor-shielded cable.

RFI filter type		Conducted emission			Radiated emission	
Standards and requirements	EN 55011	Class B Housing, trades and light industries	Class A Group 1 Industrial environment	Class A Group 2 Industrial environment	Class B Housing, trades and light industries	Class A Group 1 Industrial environment
	EN/IEC 61800-3	Category C1 First environment home and office	Category C2 First environment home and office	Category C3 Second environment Industrial	Category C1 First environment home and office	Category C2 First environment home and office
H1						
FC 301:	0–50 hp [0–37 kW] 200–240 V	33 ft [10 m]	164 ft [50 m]	246 ft [75m]	No	Yes
	0–100 hp [0–75kW] 380–480 V	33 ft [10 m]	164 ft [50 m]	246 ft [75m]	No	Yes
FC 302:	0–50 hp [0–37 kW] 200–240 V	164 ft [50 m]	492 ft [150 m]	492 ft [150 m]	No	Yes
	0–100 hp [0–75kW] 380–480 V	164 ft [50 m]	492 ft [150 m]	492 ft [150 m]	No	Yes
H2						
FC 301/	0–5.0 hp [0–3.7 kW] 200–240 V	No	No	16 ft [5 m]	No	No
FC 302:	7.5–50 hp [5.5–37 kW], 200–240V	No	No	82 ft [25 m]	No	No
	0–10 hp [0–7.5 kW] 380–480 V	No	No	16 ft [5 m]	No	No
	15–100 hp [11–75 kW] 380–480 V	No	No	82 ft [25 m]	No	No
	125–1075 hp [90–800 kW] 380–500 V	No	No	492 ft [150 m]	No	No
	15–30 hp [11–22 kW] 525–690V 1)	No	No	82 ft [25 m]	No	No
	40–100 hp [30–75 kW] 525–690V 2)	No	No	82 ft [25 m]	No	No
	50–1600 hp [37–1200 kW] 525–690V 3)	No	No	492 ft [150 m]	No	No
H3						
FC 301:	0–200 hp [0–1.5 kW] 200–240 V	8.2 ft [2.5 m]	82 ft [25 m]	164 ft [50 m]	No	Yes
	0–2 hp [0–1.5kW] 380–480V	8.2 ft [2.5 m]	82 ft [25 m]	164 ft [50 m]	No	Yes
H4						
FC 302	125–1075 hp [90–800 kW] 380–500 V	No	492 ft [150 m]	492 ft [150 m]	No	Yes
	15–30 hp [11–22 kW] 525–690V 1)	No	328 ft [100 m]	328 ft [100 m]	No	Yes
	40–100 hp [30–75 kW] 525–690V 2)	No	492 ft [150 m]	492 ft [150 m]	No	Yes
	50–425 hp [37–315 kW] 525–690V 3)	No	98 ft [30 m]	492 ft [150 m]	No	No
Hx						
FC 302	0.1–100 hp [0.75–75 kW] 525–600V	-	-	-	-	-

Table 3.13 EMC Test Results (Emission, Immunity)

1) Frame size B

2) Frame size C

3) Frame size D, E and F

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

HX - No EMC filters built-in the adjustable frequency drive (600V 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 - Integrated EMC filter. Fulfill EN 55011 class A1/B and EN/IEC 61800-3 Category 1/2 (Frame size A1 only)

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

3.5.3 Emission Requirements

According to the EMC product standard for adjustable frequency drives EN/IEC 61800-3:2004 the EMC requirements depend on the intended use of the Adjustable frequency drive. Four categories are defined in the EMC product standard. The definitions of the four categories together with the requirements for line power supply voltage conducted emissions are given in *Table 3.14*.

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

Table 3.14 Emission Requirements

When the generic emission standards are used the adjustable frequency drives are required to comply with the following limits:

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

Table 3.15

3.5.4 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.

In order to document immunity against electrical interference from electrical phenomena, the following immunity tests have been made on a system consisting of a Adjustable frequency drive (with options if relevant), a shielded control cable and a control box with potentiometer, motor cable and motor.
The tests were performed in accordance with the following basic standards:

- **EN 61000-4-2 (IEC 61000-4-2):** Electrostatic discharges (ESD): Simulation of electrostatic discharges from human beings.
- **EN 61000-4-3 (IEC 61000-4-3):** Incoming electromagnetic field radiation, amplitude modulated simulation of the effects of radar and radio communication equipment as well as mobile communications equipment.
- **EN 61000-4-4 (IEC 61000-4-4):** 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 3.16*.

Voltage range: 200–240V, 380–480V					
Basic standard	Burst IEC 61000-4-4	Surge IEC 61000-4-5	ESD IEC 61000-4-2	Radiated electromagnetic field IEC 61000-4-3	RF common mode voltage IEC 61000-4-6
Acceptance criterion	B	B	B	A	A
Line	4kV CM	2kV/2 Ω DM 4kV/12 Ω CM	—	—	$10V_{RMS}$
Motor	4kV CM	4kV/2 Ω 1)	—	—	$10V_{RMS}$
Brake	4kV CM	4kV/2 Ω 1)	—	—	$10V_{RMS}$
Load sharing	4kV CM	4kV/2 Ω 1)	—	—	$10V_{RMS}$
Control wires	2kV CM	2kV/2 Ω 1)	—	—	$10V_{RMS}$
Standard bus	2kV CM	2kV/2 Ω 1)	—	—	$10V_{RMS}$
Relay wires	2kV CM	2kV/2 Ω 1)	—	—	$10V_{RMS}$
Application and serial communication bus options	2kV CM	2kV/2 Ω 1)	—	—	$10V_{RMS}$
LCP cable	2kV CM	2kV/2 Ω 1)	—	—	$10V_{RMS}$
External 24V DC	2V CM	0.5kV/2 Ω DM 1 kV/12 Ω CM	—	—	$10V_{RMS}$
Enclosure	—	—	8kV AD 6 kV CD	10V/m	—

Table 3.16 EMC Immunity Form

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

3.6.1 PELV - Protective Extra Low Voltage

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

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

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

The components that make up the electrical isolation, as described 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 3.26*):

In order to maintain PELV, all connections made to the control terminals must be PELV. For example, the thermistor must be reinforced/double insulated.

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

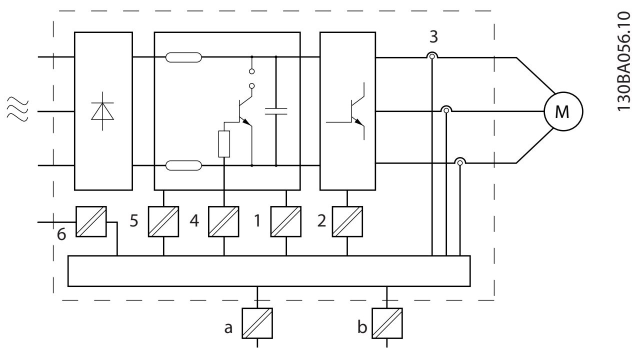


Figure 3.26 Galvanic Isolation

The functional galvanic isolation (a and b on drawing) is for the 24V backup option and for the RS485 standard bus interface.

WARNING

Installation at high altitude:
380–500V, enclosure A, B and C: At altitudes above 6561 ft [2 km], please contact Danfoss regarding PELV.
380–500V, enclosure D, E and F: At altitudes above 9842 ft [3 km], please contact Danfoss regarding PELV.
525–690V: At altitudes above 6561 ft [2 km], please 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 the *Safety Precautions* section. Shorter time is allowed only if indicated on the nameplate for the specific unit.

3.7.1 Ground Leakage Current

Follow national and local codes regarding protective grounding of equipment with a leakage current > 3.5 mA.
Adjustable frequency drive technology implies high frequency switching at high power. This will generate a leakage current in the ground connection. A fault current in the adjustable frequency drive at the output power terminals might contain a DC component which can charge the filter capacitors and cause a transient ground current.
The ground leakage current is made up of several contributions and depends on various system configurations including RFI filtering, shielded motor cables and adjustable frequency drive power.

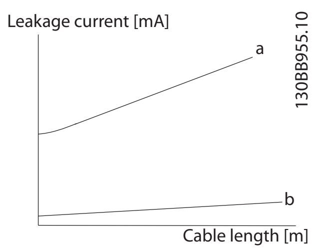


Figure 3.27 How the leakage current is influenced by the cable length and power size. Pa > Pb.

The leakage current also depends on the line distortion.

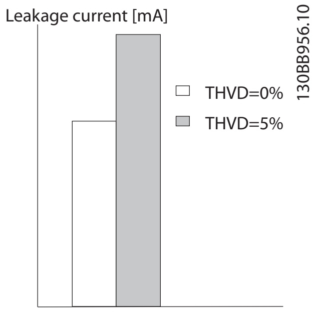


Figure 3.28 How the leakage current is influenced by line distortion.

NOTE!

When a filter is used, turn off *14-50 RFI 1* when charging the filter to avoid that a high leakage current makes the RCD switch.

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

- Earth ground wire (terminal 95) of at least $10mm^2$
- 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 (ELCBs), are used, comply with the following:

Use RCDs of type B only which are capable of detecting AC and DC currents

Use RCDs with an inrush delay to prevent faults due to transient ground currents

Dimension RCDs according to the system configuration and environmental considerations

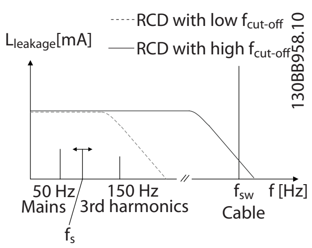


Figure 3.29 Main Contributions to Leakage Current.

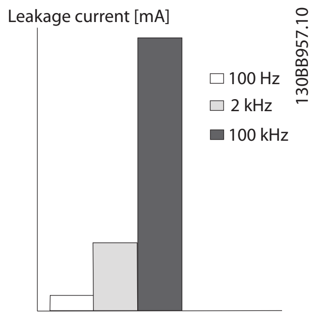


Figure 3.30 The influence of the cut-off frequency of the RCD on what is responded to/measured.

See also RCD Application Note, MN.90.GX.02.

3.8 Brake Functions in FC 300

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

3.8.1 Mechanical Holding Brake

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

When the holding brake is included in a safety chain: An adjustable frequency drive cannot safely control a mechanical brake. A redundancy circuit for the brake control must be a part of the total installation.

3.8.2 Dynamic Braking

Dynamic Brake established by:

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

3.8.3 Selection of Brake Resistor

To handle higher demands by generatoric braking, a brake resistor is necessary. Using a brake resistor ensures that the energy is absorbed in the brake resistor and not in the adjustable frequency drive. For more information, see the Brake Resistor Design Guide, MG.90.OX.YY.

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. The below figure shows a typical braking cycle.

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

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

Duty cycle = t_b/T

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

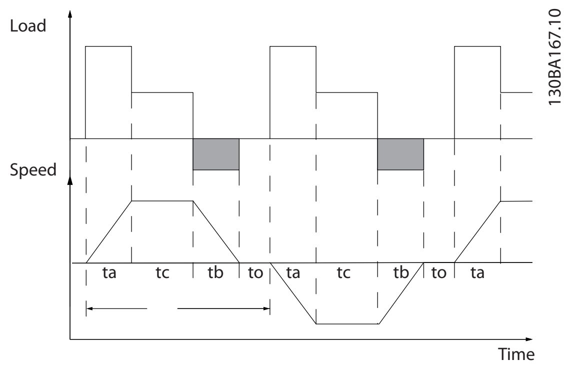


Figure 3.31

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

Table 3.17 Braking at High overload torque level

1) 750 hp [500 kW] at 86% braking torque
750 hp [560 kW] at 76% braking torque
2) 750 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 will be used on dissipating excess heat.

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

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

The brake resistance is calculated as shown:

$R_{br}[\Omega] = \frac{U_{dc}^2}{P_{peak}}$
where
$P_{peak} = P_{motor} \times M_{br}[\%] \times \eta_{motor} \times \eta_{VLT}[W]$

Table 3.18

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

Size	Brake active	Warning before cut out	Cut out (trip)
FC301/302 3 x 200–240 V	390V (UDC)	405V	410V
FC301 3 x 380–480 V	778V	810V	820V
FC302 3 x 380–500 V*	810V/ 795V	840V/ 828V	850V/ 855V
FC302 3 x 525–600 V	943V	965V	975V
FC302 3 x 525–690 V	1084V	1109V	1130V
* Power size dependent			

Table 3.19

Check that the brake resistor can cope with a voltage of 410V, 820V, 850V, 975V or 1130V - 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:

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

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

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

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

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

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

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

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

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

1) For adjustable frequency drives ≤ 10 hp [7.5 kW] shaft output
2) For adjustable frequency drives 15–100 hp [11–75 kW] shaft output

NOTE!

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

NOTE!

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

NOTE!

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

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

3.8.4 Control with Brake Function

The brake is protected against short-circuiting of the brake resistor, and the brake transistor is monitored to ensure that short-circuiting of the transistor is detected. A relay/ digital output can be used for protecting the brake resistor

against overloading in connection with a fault in the Adjustable frequency drive.
In addition, the brake makes it possible to read out the momentary power and the mean power for the latest 120 seconds. The brake can also monitor the power energizing and make sure it does not exceed a limit selected in *2-12 Brake Power Limit (kW)*. In *2-13 Brake Power Monitoring*, select the function to carry out when the power transmitted to the brake resistor exceeds the limit set in *2-12 Brake Power Limit (kW)*.

NOTE!

Monitoring the 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 very 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.

3.9.1 Mechanical Brake Control

For hoisting applications, it is necessary to be able to control an electro-magnetic brake. For controlling the brake, a relay output (relay1 or relay2) or a programmed digital output (terminal 27 or 29) is required. Normally, this output must be closed for as long as the adjustable frequency drive is unable to 'hold' the motor, due to a load that is too large, for example. In *5-40 Function Relay* (Array parameter), *5-30 Terminal 27 Digital Output*, or *5-31 Terminal 29 digital Output*, select *mechanical brake control* [32] for applications with an electro-magnetic brake.

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

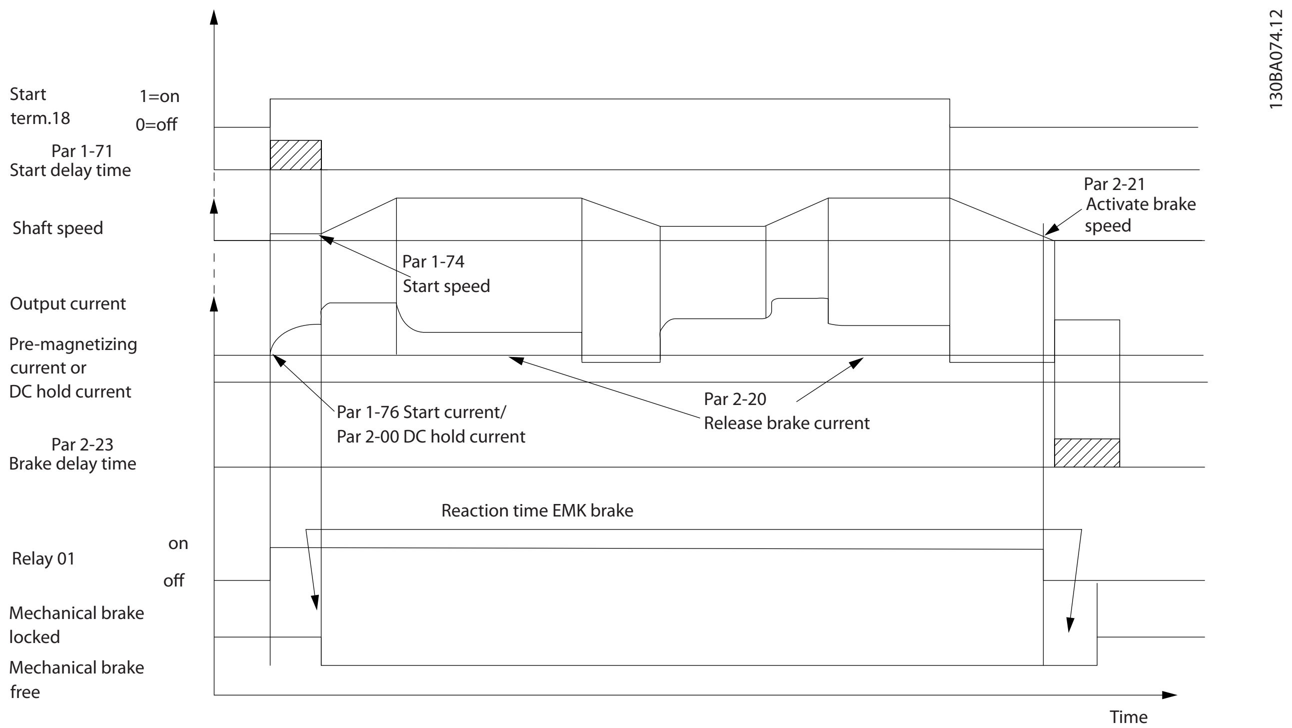


Figure 3.32

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

Step-by-step Description

- To control the mechanical brake, any relay output or digital output (terminal 27 or 29) can be used. If necessary, use a suitable contactor.
- Ensure that the output is switched off as long as the adjustable frequency drive is unable to drive the motor, such as when the load is too heavy or the motor has not been mounted, for example.
- Select *Mechanical brake control* [32] in parameter group5-4* (or in group 5-3*) before connecting the mechanical brake.
- The brake is released when the motor current exceeds the preset value in *2-20 Release Brake Current*.
- The brake is engaged when the output frequency is less than the frequency set in *2-21 Activate Brake Speed [RPM]* or *2-22 Activate Brake Speed [Hz]* and only if the adjustable frequency drive carries out a stop command.

NOTE!

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

NOTE!

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

3.9.2 Hoist Mechanical Brake

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

3-step sequence

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

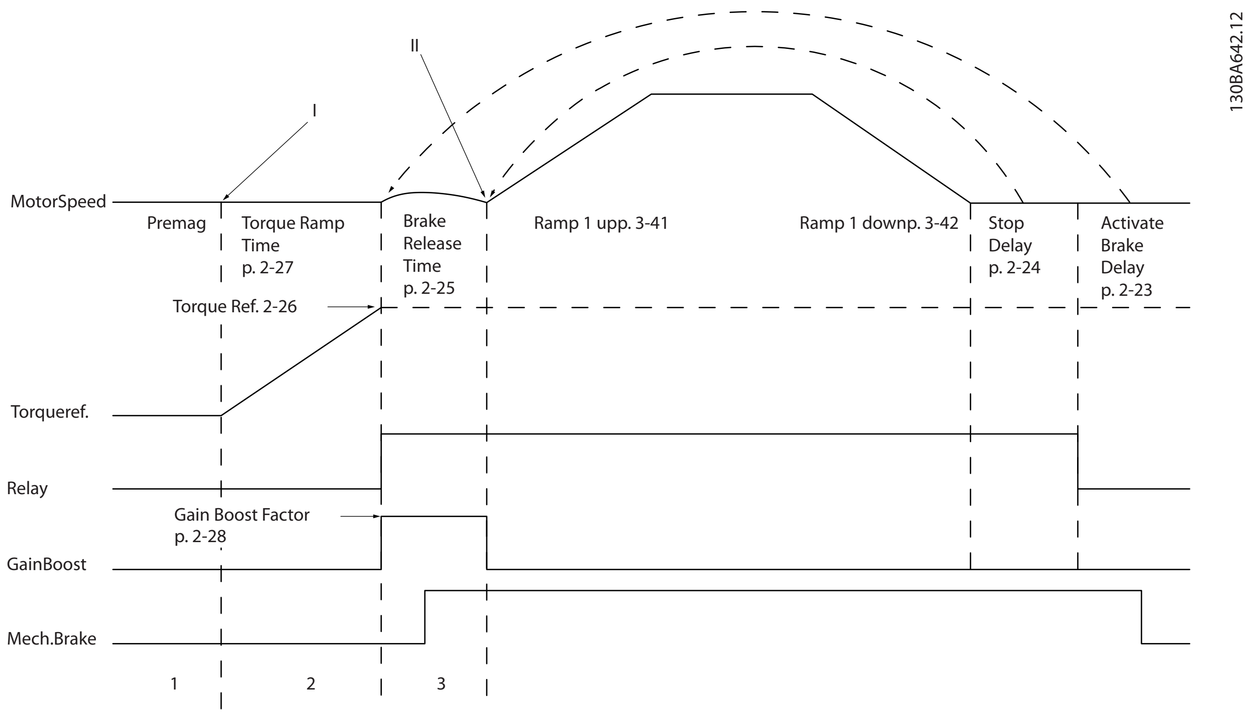


Figure 3.33 Brake release sequence for hoist mechanical brake control

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

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

NOTE!

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

3.9.3 Brake Resistor Cabling

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

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

3.10 Smart Logic Controller

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

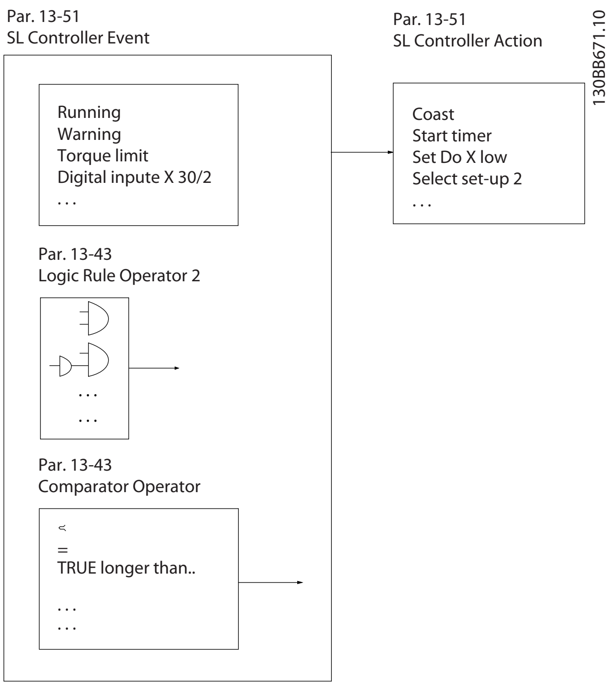


Figure 3.34

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

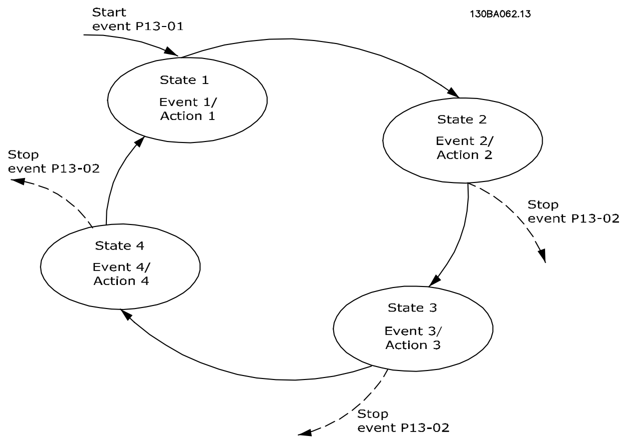


Figure 3.35

Comparators

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

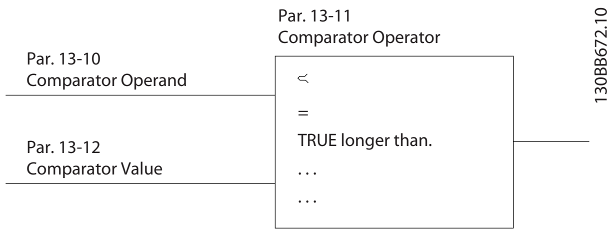


Figure 3.36

Logic Rules

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

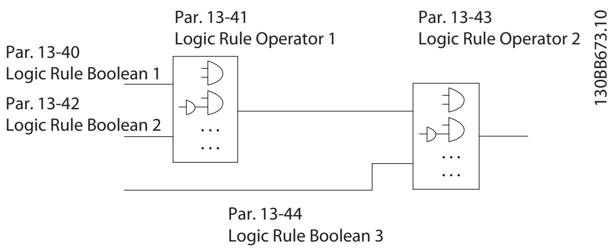
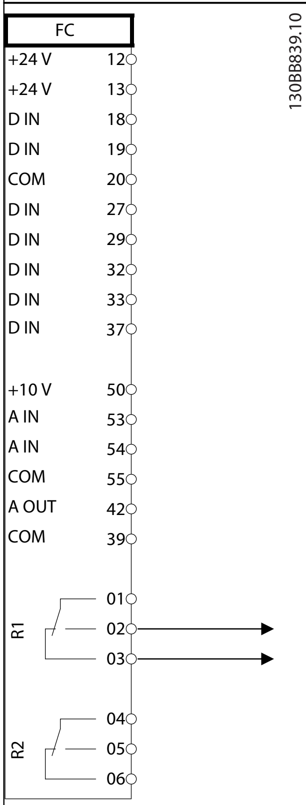


Figure 3.37

3

Application Example



Parameters	
Function	Setting
4-30 Motor Feedback Loss Function	[1] Warning
4-31 Motor Feedback Speed Error	100 RPM
4-32 Motor Feedback Loss Timeout	5 sec
7-00 Speed PID Feedback Source	[2] MCB 102
17-11 Resolution (PPR)	1024*
13-00 SL Controller Mode	[1] On
13-01 Start Event	[19] Warning
13-02 Stop Event	[44] Reset key
13-10 Comparator Operand	[21] Warning no.
13-11 Comparator Operator	[1] ≈*
13-12 Comparator Value	90
13-51 SL Controller Event	[22] Comparator 0
13-52 SL Controller Action	[32] Set digital out A low
5-40 Function Relay	[80] SL digital output A
* = Default Value	
Notes/comments: If the limit in the feedback monitor is exceeded, Warning 90 will be issued. The SLC monitors Warning 90 and if Warning 90 becomes TRUE, then Relay 1 is triggered. External equipment may then indicate that service may be required. If the feedback error goes below the limit again within 5 sec., then the drive continues and the warning disappears. But Relay 1 will still be triggered until [Reset] on the LCP.	

Table 3.20 Using SLC to Set a Relay

3.11 Extreme Running Conditions

Short Circuit (Motor Phase – Phase)

The Adjustable frequency drive is protected against short circuits by means of current measurement in each of the three motor phases or in the DC link. A short circuit between two output phases will cause an overcurrent in the inverter. The inverter will be turned off individually when the short circuit current exceeds the permitted value (Alarm 16 Trip Lock).
To protect the Adjustable frequency drive against a short circuit at the load sharing and brake outputs, please see the design guidelines.
See certificate in *3.9 Certificates*.

Switching on the Output

Switching on the output between the motor and the Adjustable frequency drive is fully permitted. You cannot damage the Adjustable frequency drive in any way by switching on the output. However, fault messages may appear.

Motor-generated Overvoltage

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

1. The load drives the motor (at constant output frequency from the Adjustable frequency drive), i.e., the load generates energy.
2. During deceleration ("ramp-down") if the moment of inertia is high, the friction is low and the ramp-down time is too short for the energy to be dissipated as a loss in the Adjustable frequency drive, the motor and the installation.
3. Incorrect slip compensation setting may cause higher DC link voltage.
4. Back-EMF from PM motor operation. If coasted at high rpm, the PM motor back-EMF may potentially exceed the maximum voltage tolerance of the 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*. If it is possible that the motor may overspeed (e.g., due to excessive windmilling effects) then it is recommended to equip a brake resistor. Note: the drive must be equipped with a brake chopper.

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

NOTE!

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

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 determine how long it takes for the inverter to coast.

Static Overload in VVC^plus Mode

When the Adjustable frequency drive is overloaded (the torque limit in *4-16 Torque Limit Motor Mode*/*4-17 Torque Limit Generator Mode* is reached), the controls reduce the output frequency to reduce the load.
If the overload is excessive, a current may occur that makes the Adjustable frequency drive cut out after approx. 5–10 sec.

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

3.11.1 Motor Thermal Protection

To protect the application from serious damage, VLT AutomationDrive offers several dedicated features
Torque Limit: The Torque limit feature, the motor is protected for being overloaded independent of the speed. Torque limit is controlled in *4-16 Torque Limit Motor Mode* and or *4-17 Torque Limit Generator Mode* and the time before the torque limit warning shall trip is controlled in *14-25 Trip Delay at Torque Limit*.
Current Limit: The current limit is controlled in *4-18 Current Limit* and the time before the current limit warning shall trip is controlled in *14-24 Trip Delay at Current Limit*.
Min Speed Limit: (*4-11 Motor Speed Low Limit [RPM]* or *4-12 Motor Speed Low Limit [Hz]*) limit the operating speed range to for instance between 30 and 50/60Hz. Max Speed Limit: (*4-13 Motor Speed High Limit [RPM]* or *4-19 Max Output Frequency*) limit the max output speed the drive can provide
ETR (Electronic Thermal relay): The adjustable frequency drive ETR function measures actual current, speed and time to calculate motor temperature and protect the motor from being overheated (warning or trip). An external thermistor input is also available. ETR is an electronic feature that simulates a bimetal relay based on internal measurements. The characteristic is shown in the following figure:

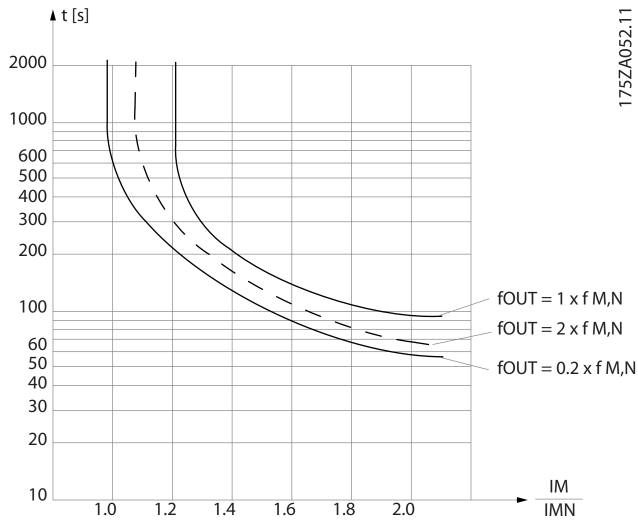


Figure 3.38 Figure ETR: The X-axis shows the ratio between I_{motor} and I_{motor} nominal. The Y-axis shows the time in seconds before the ETR cuts off and trips the drive. The curves show the characteristic nominal speed, at twice the nominal speed and at 0.2 x the nominal speed.
At lower speed the ETR cuts off at lower heat due to less cooling of the motor. In that way, the motors are protected from being overheated even at low speeds. The ETR feature calculates the motor temperature based on actual current and speed. The calculated temperature is visible as a read out parameter in *16-18 Motor Thermal* in the FC 300.

3.12 Safe Stop of FC 300

The FC 302, and also the FC 301 in A1 enclosure, can perform the safety function *Safe Torque Off* (STO, as defined by EN IEC 61800-5-2[1]) and *Stop Category 0* (as defined in EN 60204-1[2]).
Danfoss has named this functionality *Safe Stop*. Prior to integration and use of safe stop in an installation, a thorough risk analysis must be carried out on the installation in order to determine whether the safe stop functionality and safety levels are appropriate and sufficient. It is designed and approved as suitable for the requirements of:

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

1) Refer to EN IEC 61800-5-2 for details of Safe torque off (STO) function.
2) Refer to EN IEC 60204-1 for details of stop category 0 and 1.

Activation and Termination of Safe Stop
The Safe Stop (STO) function is activated by removing the voltage at Terminal 37 of the Safe Inverter. By connecting the Safe Inverter to external safety devices providing a safe delay, an installation for a safe Stop Category 1 can be obtained. The Safe Stop function of FC 302 can be used for asynchronous, synchronous motors and permanent magnet motors. See examples in *3.12.1 Terminal 37 Safe Stop Function*.

NOTE!

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

⚠WARNING

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

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

Reaction time for T37

- Typical reaction time: 10ms

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

Data for EN ISO 13849-1

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

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

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

Data for EN IEC 61508 low demand

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

SISTEMA Data
Danfoss provides functional safety data via a data library for use with the SISTEMA calculation tool from IFA (Institute for Occupational Safety and Health of the German Social Accident Insurance), as well as data for manual calculation. The library is completed and continually extended.

Abbreviations related to Functional Safety

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

Table 3.21

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

3.12.1 Terminal 37 Safe Stop Function

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

Liability Conditions

It is the responsibility of the user to ensure that the personnel properly installs and operates the Safe Stop function:

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

User is defined as: integrator, operator, servicing, maintenance staff.

Standards

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

EN 954-1: 1996 Category 3

IEC 60204-1: 2005 category 0 – uncontrolled stop

IEC 61508: 1998 SIL2

IEC 61800-5-2: 2007 – safe torque off (STO) function

IEC 62061: 2005 SIL CL2

ISO 13849-1: 2006 Category 3 PL d

ISO 14118: 2000 (EN 1037) – prevention of unexpected start-up

The information and instructions of the instruction manual are not sufficient for a proper and safe use of the safe stop functionality. The related information and instructions of the relevant *Design Guide* must be followed.

Protective Measures

- Safety engineering systems may only be installed and commissioned by qualified and skilled personnel
- The unit must be installed in an IP54 cabinet or in an equivalent environment. In special applications, a higher IP degree may be necessary

- The cable between terminal 37 and the external safety device must be short circuit protected according to ISO 13849-2 table D.4
- If any external forces influence the motor axis (e.g., suspended loads), additional measures (e.g., a safety holding brake) are required in order to eliminate hazards.

Safe Stop Installation and Set-up

WARNING

SAFE STOP FUNCTION!

The safe stop function does NOT isolate AC line voltage to the Adjustable frequency drive or auxiliary circuits. Perform work on electrical parts of the Adjustable frequency drive or the motor only after isolating the AC line voltage supply and waiting the length of time specified under Safety in this manual. Failure to isolate the AC line voltage supply from the unit and waiting the time specified could result in death or serious injury.

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

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

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

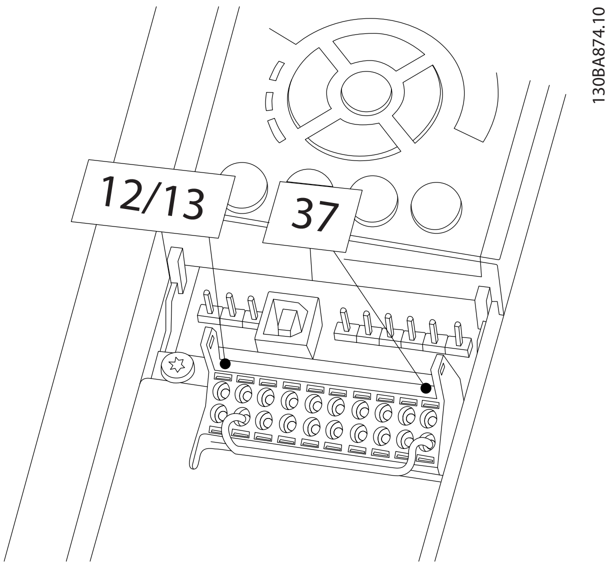


Figure 3.39 Jumper between Terminal 12/13 (24V) and 37

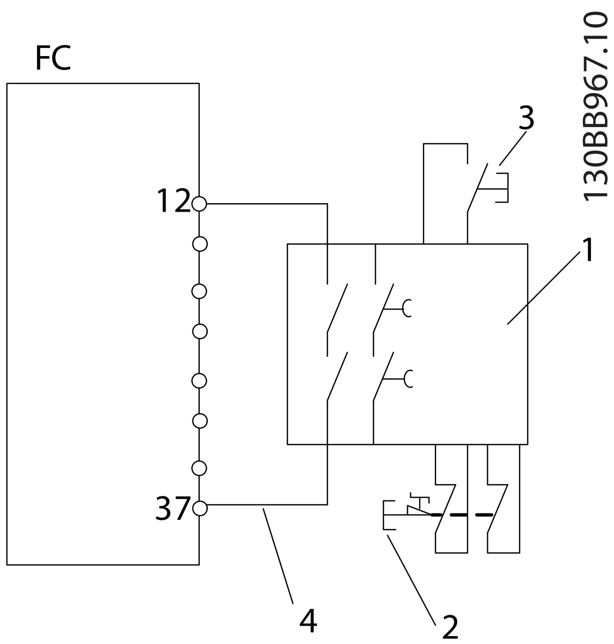


Figure 3.40 Installation to Achieve a Stopping Category 0 (EN 60204-1) with Safety Cat. 3 (EN 954-1) / PL “d” (ISO 13849-1) or SIL 2 (EN 62061).

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

Table 3.22

Safe Stop Commissioning Test

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

Example with STO

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

NOTE!

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

Example with SS1

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

NOTE!

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

Example with Category 4/PL e application

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

Paralleling of Safe Stop input the one Safety Relay

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

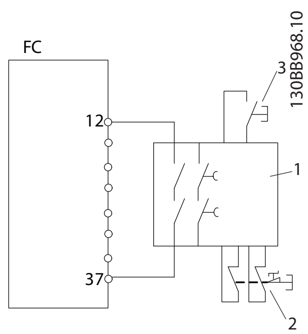


Figure 3.41 STO example

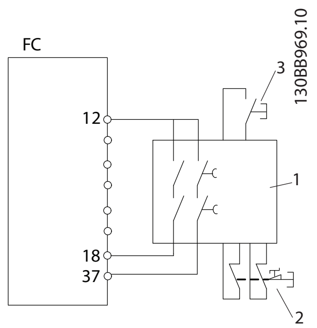


Figure 3.42 SS1 example

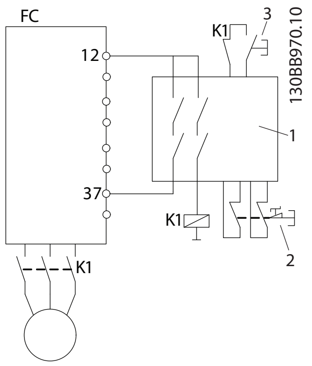


Figure 3.43 STO category 4 example

1	Safety relay
2	Emergency stop button
3	Reset button

Table 3.23

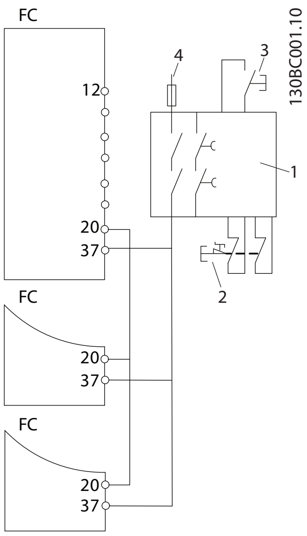


Figure 3.44 Paralleling of multiple drives example

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

Table 3.24

WARNING

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

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

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

NOTE!

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

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

By default, the safe stop function is set to unintended restart prevention behavior. This means, in order to terminate Safe Stop and resume normal operation, first the 24V DC must be reapplied to Terminal 37. Subsequently, a reset signal must be given (via Bus, Digital I/O or [Reset] key).

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

WARNING

Automatic restart behavior is only allowed in one of the two following situations:

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

3.12.2 Installation of External Safety Device in Combination with MCB 112

If the Ex-certified thermistor module MCB 112, which uses Terminal 37 as its safety-related switch-off channel, is connected, then the output X44/12 of MCB 112 must be AND-ed with the safety-related sensor (such as emergency stop button, safety-guard switch, etc.) that activates Safe Stop. This means that the output to Safe Stop terminal 37 is HIGH (24V) only if both the signal from MCB 112 output X44/12 and the signal from the safety-related sensor are HIGH. If at least one of the two signals is LOW, then the output to Terminal 37 must be LOW, too. The safety device with this AND logic itself must conform to IEC 61508, SIL 2. The connection from the output of the safety device with safe AND logic to Safe Stop terminal 37 must be short-circuit protected. See *Figure 3.45*.

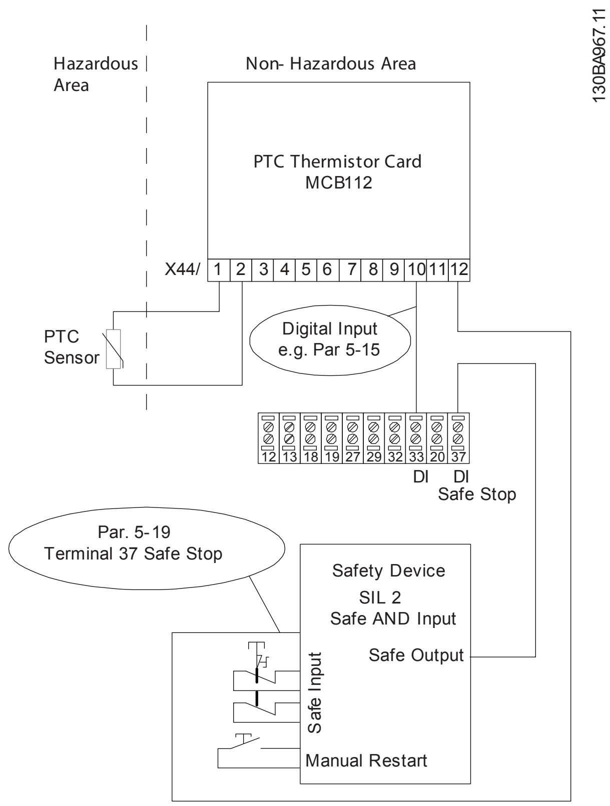


Figure 3.45 Figure of the essential aspects for installing a combination of a Safe Stop application and a MCB 112 application. The diagram shows a Restart input for the external Safety Device. This means that in this installation, *5-19 Terminal 37 Safe Stop* might be set to value [7] or [8]. Refer to MCB 112 Instruction Manual, MG.33.VX.YY for further details.

Parameter settings for external safety device in combination with MCB112
If MCB 112 is connected, then additional selections ([4] – [9]) become possible for par. 5-19 (Terminal 37 Safe Stop). Selection [1]* and [3] are still available but are not to be used as those are for installations without MCB 112 or any external safety devices. If [1]* or [3] should be chosen by mistake and MCB 112 is triggered, then the adjustable frequency drive will react with an alarm "Dangerous Failure [A72]" and coast the drive safely, without automatic restart. Selections [4] and [5] are not to be selected when an external safety device is used. Those selections are for when only the MCB 112 uses the safe stop. If selections [4] or [5] are chosen by mistake and the external safety device triggers safe stop, the adjustable frequency drive will react with an alarm "Dangerous Failure [A72]" and coast the drive safely, without automatic restart.
Selections [6] – [9] must be chosen for the combination of external safety device and MCB 112.

NOTE!

Note that selection [7] and [8] opens up for an automatic restart when the external safety device is de-activated again.

This is only allowed in the following cases:

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

See *10.6 MCB 112 PTC Thermistor Card* and the Instruction Manual for the MCB 112 for further information.

3.12.3 Safe Stop Commissioning Test

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

NOTE!

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

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

Case 1: restart prevention for Safe Stop is required (i.e., Safe Stop only where *5-19 Terminal 37 Safe Stop* is set to default value [1], or combined Safe Stop and MCB112 where *5-19 Terminal 37 Safe Stop* is set to [6] or [9]):

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

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

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

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

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

Case 2: Automatic Restart of Safe Stop is wanted and allowed (i.e., Safe Stop only where *5-19 Terminal 37 Safe Stop* is set to [3], or combined Safe Stop and MCB112 where *5-19 Terminal 37 Safe Stop* is set to [7] or [8]):

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

2.2 Reapply 24V DC to terminal 37.

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

NOTE!

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

NOTE!

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

3.13 Certificates

TÜV NORD

Certificate

TÜV NORD SysTec GmbH & Co. KG hereby certifies

Danfoss Drives A/S
Ulsnæs 1
DK-6300 Graasten
Denmark

for the realisation of the function "Safe Stop - STO"
in the Danfoss drives types

VLT® Automation Drive FC 302, VLT® Automation Drive FC 301 in the A1 housing
VLT® AQUA Drive FC 202, VLT® HVAC Drive FC 102

the compliance with the requirements listed in the following standards

- IEC 61800-5-2:2007; Designated Safety Function "Safe Torque Off - STO; SIL2 capability
- IEC 61508; Part 1:1998 + Corrigendum 1999
- EN 61508; Part 2:2000; SIL 2 capability for STO function
- EN ISO 13849-1:2006; PL d, EN 954-1:1996; Category 3
- IEC 62061:2005; SILCL 2

based on report No. SAS-163/2006C in the valid version.
This certificate entitles the holder to use the mark:

Expiry date: 2013-01-16
Certification No.: SAS1724/07, Vers. 1.0
Reference No.: M.IB5.03.122.01.SLA
86150 Augsburg
Augsburg, 2008-01-16

TÜV NORD SysTec GmbH & Co. KG
Branch South
Halderstraße 27
86150 Augsburg
Germany

Dr. Immanuel Höfer

130BB178.10

Figure 3.46

Danfoss Drives A/S

Ulsnæs 1
DK-6300 Graasten Denmark
Reg.No.: 233981

Telephone: +45 7488 2222
Telefax: +45 7465 2580

E-mail: led@Danfoss.com
Homepage: www.danfoss.com

130BB837.10

Your ref.	Our ref.	Date	Direct dialling
	501G1225en01	2009-05-26	+45 7488 4615

MANUFACTURE'S DECLARATION

Danfoss Drives A/S
DK-6300 Graasten Denmark

declares on our responsibility that below products including all available power and control options:

VLT® HVAC Drive series FC-102 (FC-102P1K1T2 - FC-102P45KT2)
VLT® HVAC Drive series FC-102 (FC-102P1K1T4 - FC-102P450T4)
VLT® HVAC Drive series FC-102 (FC-102P1K1T6 - FC-102P90KT6)
VLT® HVAC Drive series FC-102 (FC-102P75KT6 - FC-102P500T6)
VLT® AQUA Drive series FC-202 (FC-202PK25T2 - FC-202P45KT2)
VLT® AQUA Drive series FC-202 (FC-202PK37T4 - FC-202P1M0T4)
VLT® AQUA Drive series FC-202 (FC-202PK75T6 - FC-202P90KT6)
VLT® AQUA Drive series FC-202 (FC-202P45KT7 - FC-202P1M2T7)
VLT® AutomationDrive series FC-301 (FC-301PK25T2 - FC-301P37KT2)
VLT® AutomationDrive series FC-301 (FC-301PK37T4 - FC-301P75KT4)
VLT® AutomationDrive series FC-302 (FC-302PK25T2 - FC-302P37KT2)
VLT® AutomationDrive series FC-302 (FC-302PK37T5 - FC-302P800T5)
VLT® AutomationDrive series FC-302 (FC-302PK75T6 - FC-302P75KT6)
VLT® AutomationDrive series FC-302 (FC-302P37KT7 - FC-302P1M0T7)

covered by this certificate are short circuit protected and meets the requirements in IEC61800-5-1 2nd edition clause 5.2.3.6.3, if the product is used and installedaccording to our instructions. The short circuit protection will operate within 20µS in case of a full short circuit from motor output terminal to protective earth.

Issued by:

Lars Erik Donau
Quality Systems Manager

Figure 3.47

4 FC 300 Selection

4.1 Electrical Data - 200–240V

Line Power Supply 3 x 200–240V AC										
FC 301/FC 302		PK25	PK37	PK55	PK75	P1K1	P1K5	P2K2	P3K0	P3K7
	Typical Shaft Output [kW]	0.25	0.37	0.55	0.75	1.1	1.5	2.2	3	3.7
	Enclosure IP20/IP21	A2	A2	A2	A2	A2	A2	A2	A3	A3
	Enclosure IP 20 (FC 301 only)	A1	A1	A1	A1	A1	A1	-	-	-
	Enclosure IP 55, 66	A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A4/A5	A5	A5
Output current										
	Continuous (3 x 200–240V) [A]	1.8	2.4	3.5	4.6	6.6	7.5	10.6	12.5	16.7
	Intermittent (3 x 200–240V) [A]	2.9	3.8	5.6	7.4	10.6	12.0	17.0	20.0	26.7
	Continuous kVA (208V AC) [kVA]	0.65	0.86	1.26	1.66	2.38	2.70	3.82	4.50	6.00
Max. input current										
	Continuous (3 x 200–240V) [A]	1.6	2.2	3.2	4.1	5.9	6.8	9.5	11.3	15.0
	Intermittent (3 x 200–240V) [A]	2.6	3.5	5.1	6.6	9.4	10.9	15.2	18.1	24.0
Additional specifications										
	IP20, 21 max. cable cross-section5) (line power, motor, brake and load sharing) [mm^2 (AWG)]2)	4,4,4 (12,12,12) (min. 0.2(24))								
	IP55, 66 max. cable cross-section5) (line power, motor, brake and load sharing) [mm^2 (AWG)]	4,4,4 (12,12,12)								
	Max. cable cross-section5) with disconnect	6,4,4 (10,12,12)								
	Estimated power loss at rated max. load [W] 4)	21	29	42	54	63	82	116	155	185
	Weight, enclosure IP20 (lbs [kg])	10.36 [4.7]	10.36 [4.7]	10.58 [4.8]	10.58 [4.8]	10.8 [4.9]	10.8 [4.9]	10.8 [4.9]	14.55 [6.6]	14.55 [6.6]
	A1 (IP20)	2.7	2.7	2.7	2.7	2.7	2.7	-	-	-
	A5 (IP 55, 66)	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5
	Efficiency 4)	0.94	0.94	0.95	0.95	0.96	0.96	0.96	0.96	0.96
0.25–3.7 kW only available as 160% high overload.										

Table 4.1

Line Power Supply 3 x 200–240V AC							
FC 301/FC 302		P5K5		P7K5		P11K	
High/ Normal Load[1)]		HO	NO	HO	NO	HO	NO
	Typical Shaft Output [kW]	5.5	7.5	7.5	11	11	15
	Enclosure IP20	B3		B3		B4	
	Enclosure IP21	B1		B1		B2	
	Enclosure IP55, 66	B1		B1		B2	
Output current							
	Continuous (3 x 200–240V) [A]	24.2	30.8	30.8	46.2	46.2	59.4
	Intermittent (60 sec overload) (3 x 200–240V) [A]	38.7	33.9	49.3	50.8	73.9	65.3
	Continuous kVA (208V AC) [kVA]	8.7	11.1	11.1	16.6	16.6	21.4
Max. input current							
	Continuous (3 x 200–240V) [A]	22	28	28	42	42	54
	Intermittent (60 sec overload) (3 x 200–240V) [A]	35.2	30.8	44.8	46.2	67.2	59.4
Additional specifications							
	IP21 max. cable cross-section[5)] (line power, brake, load sharing) [mm² (AWG)] [2)]	16,10, 16 (6,8,6)		16,10, 16 (6,8,6)		35,-,- (2,-,-)	
	IP21 max. cable cross-section[5)] (motor) [mm² (AWG)] [2)]	10,10,- (8,8,-)		10,10,- (8,8,-)		35,25,25 (2,4,4)	
	IP20 max. cable cross-section[5)] (line power, brake, motor and load sharing)	10,10,- (8,8,-)		10,10,- (8,8,-)		35,-,- (2,-,-)	
	Max. cable cross-section with disconnect [mm² (AWG)] [2)]	16,10,10 (6,8,8)					
	Estimated power loss at rated max. load [W] [4)]	239	310	371	514	463	602
	Weight, enclosure IP21, IP55, 66 (lbs [kg])	50.71 [23]		50.71 [23]		59.52 [27]	
	Efficiency[4)]	0.964		0.959		0.964	

Table 4.2

Line Power Supply 3 x 200–240V AC											
FC 301/FC 302		P15K		P18K		P22K		P30K		P37K	
High/ Normal Load[1)]		HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
	Typical Shaft Output [kW]	15	18.5	18.5	22	22	30	30	37	37	45
	Enclosure IP20	B4		C3		C3		C4		C4	
	Enclosure IP21	C1		C1		C1		C1		C1	
	Enclosure IP55, 66	C1		C1		C1		C2		C2	
Output current											
	Continuous (3 x 200–240V) [A]	59.4	74.8	74.8	88	88	115	115	143	143	170
	Intermittent (60 sec overload) (3 x 200–240V) [A]	89.1	82.3	112	96.8	132	127	173	157	215	187
	Continuous kVA (208V AC) [kVA]	21.4	26.9	26.9	31.7	31.7	41.4	41.4	51.5	51.5	61.2
Max. input current											
	Continuous (3 x 200–240V) [A]	54	68	68	80	80	104	104	130	130	154
	Intermittent (60 sec overload) (3 x 200–240V) [A]	81	74.8	102	88	120	114	156	143	195	169
Additional specifications											
	IP20 max. cable cross-section[5)] (line power, brake, motor and load sharing)	35 (2)		50 (1)		50 (1)		150 (300MCM)		150 (300MCM)	
	IP21, 55, 66 max. cable cross-section[5)] (line power, motor) [mm^2 (AWG)] [2)]	50 (1)		50 (1)		50 (1)		150 (300MCM)		150 (300MCM)	
	IP21, 55, 66 max. cable cross-section[5)] (brake, load sharing) [mm^2 (AWG)] [2)]	50 (1)		50 (1)		50 (1)		95 (3/0)		95 (3/0)	
	Max. cable size with line power disconnect [mm^2 (AWG)] [2)]	50, 35, 35 (1, 2, 2)						95, 70, 70 (3/0, 2/0, 2/0)		185, 150, 120 (350MCM, 300MCM, 4/0)	
	Estimated power loss at rated max. load [W] [4)]	624	737	740	845	874	1140	1143	1353	1400	1636
	Weight, enclosure IP21, 55/66 (lbs [kg])	99.21 [45]		99.21 [45]		99.21 [45]		143.3 [65]		143.3 [65]	
	Efficiency[4)]	0.96		0.97		0.97		0.97		0.97	

Table 4.3

For fuse ratings, see 8.3.1 Fuses

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

2) American Wire Gauge.

3) Measured using 16.4 ft [5 m] shielded motor cables at rated load and rated frequency.

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

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

4.2 Electrical Data - 380–500V

Line Power Supply 3 x 380–500V AC (FC 302), 3 x 380–480V AC (FC 301)											
		PK 37	PK 55	PK75	P1K1	P1K5	P2K2	P3K0	P4K0	P5K5	P7K5
FC 301/FC 302 Typical Shaft Output [kW]		0.37	0.55	0.75	1.1	1.5	2.2	3	4	5.5	7.5
Enclosure IP20/IP21		A2	A2	A2	A2	A2	A2	A2	A2	A3	A3
Enclosure IP20 (FC 301 only)		A1	A1	A1	A1	A1					
Enclosure IP 55, 66		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 (3 x 380–440V) [A]	1.3	1.8	2.4	3	4.1	5.6	7.2	10	13	16
	Intermittent (3 x 380–440V) [A]	2.1	2.9	3.8	4.8	6.6	9.0	11.5	16	20.8	25.6
	Continuous (3 x 441–500V) [A]	1.2	1.6	2.1	2.7	3.4	4.8	6.3	8.2	11	14.5
	Intermittent (3 x 441–500V) [A]	1.9	2.6	3.4	4.3	5.4	7.7	10.1	13.1	17.6	23.2
	Continuous kVA (400V AC) [kVA]	0.9	1.3	1.7	2.1	2.8	3.9	5.0	6.9	9.0	11.0
	Continuous kVA (460V AC) [kVA]	0.9	1.3	1.7	2.4	2.7	3.8	5.0	6.5	8.8	11.6
Max. input current											
	Continuous (3 x 380–440V) [A]	1.2	1.6	2.2	2.7	3.7	5.0	6.5	9.0	11.7	14.4
	Intermittent (3 x 380–440V) [A]	1.9	2.6	3.5	4.3	5.9	8.0	10.4	14.4	18.7	23.0
	Continuous (3 x 441–500V) [A]	1.0	1.4	1.9	2.7	3.1	4.3	5.7	7.4	9.9	13.0
	Intermittent (3 x 441–500V) [A]	1.6	2.2	3.0	4.3	5.0	6.9	9.1	11.8	15.8	20.8
Additional specifications											
	IP20, 21 max. cable cross-section[5] (line power, motor, brake and load sharing) [mm^2 (AWG)][2]	4,4,4 (12,12,12) (min. 0.2(24))									
	IP55, 66 max. cable cross-section[5] (line power, motor, brake and load sharing) [mm^2 (AWG)]	4,4,4 (12,12,12)									
	Max. cable cross-section[5] with disconnect	6,4,4 (10,12,12)									
	Estimated power loss at rated max. load [W] [4]	35	42	46	58	62	88	116	124	187	255
	Weight, enclosure IP20	10.36 [4.7]	10.36 [4.7]	10.58 [4.8]	10.58 [4.8]	10.8 [4.9]	10.8 [4.9]	10.8 [4.9]	10.8 [4.9]	14.55 [6.6]	14.55 [6.6]
	Enclosure IP 55, 66	29.76 [13.5]	29.76 [13.5]	29.76 [13.5]	29.76 [13.5]	29.76 [13.5]	29.76 [13.5]	29.76 [13.5]	29.76 [13.5]	31.3 [14.2]	31.3 [14.2]
	Efficiency [4]	0.93	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.97
0.33–10 hp [0.37–7.5 kW] only available as 160% high overload.											

Table 4.4

Line Power Supply 3 x 380–500V AC (FC 302), 3 x 380–480V AC (FC 301)									
FC 301/FC 302		P11K		P15K		P18K		P22K	
High/ Normal Load 1)		HO	NO	HO	NO	HO	NO	HO	NO
	Typical Shaft output [kW]	11	15	15	18.5	18.5	22.0	22.0	30.0
	Enclosure IP20	B3		B3		B4		B4	
	Enclosure IP21	B1		B1		B2		B2	
	Enclosure IP55, 66	B1		B1		B2		B2	
Output current									
	Continuous (3 x 380–440V) [A]	24	32	32	37.5	37.5	44	44	61
	Intermittent (60 sec overload) (3 x 380–440V) [A]	38.4	35.2	51.2	41.3	60	48.4	70.4	67.1
	Continuous (3 x 441–500V) [A]	21	27	27	34	34	40	40	52
	Intermittent (60 sec overload) (3 x 441–500V) [A]	33.6	29.7	43.2	37.4	54.4	44	64	57.2
	Continuous kVA (400V AC) [kVA]	16.6	22.2	22.2	26	26	30.5	30.5	42.3
	Continuous kVA (460V AC) [kVA]		21.5		27.1		31.9		41.4
Max. input current									
	Continuous (3 x 380–440V) [A]	22	29	29	34	34	40	40	55
	Intermittent (60 sec overload) (3 x 380–440V) [A]	35.2	31.9	46.4	37.4	54.4	44	64	60.5
	Continuous (3 x 441–500V) [A]	19	25	25	31	31	36	36	47
	Intermittent (60 sec overload) (3 x 441–500V) [A]	30.4	27.5	40	34.1	49.6	39.6	57.6	51.7
Additional specifications									
	IP21, 55, 66 max. cable cross-section 5) (line power, brake, load sharing) [mm² (AWG)] 2)	16, 10, 16 (6, 8, 6)		16, 10, 16 (6, 8, 6)		35,-,-(2,-,-)		35,-,-(2,-,-)	
	IP21, 55, 66 max. cable cross-section 5) (motor) [mm² (AWG)] 2)	10, 10,- (8, 8,-)		10, 10,- (8, 8,-)		35, 25, 25 (2, 4, 4)		35, 25, 25 (2, 4, 4)	
	IP20 max. cable cross-section 5) (line power, brake, motor and load sharing)	10, 10,- (8, 8,-)		10, 10,- (8, 8,-)		35,-,-(2,-,-)		35,-,-(2,-,-)	
	Max. cable cross-section with disconnect [mm² (AWG)] 2)	16, 10, 10 (6, 8, 8)							
	Estimated power loss at rated max. load [W] 4)	291	392	379	465	444	525	547	739
	Weight, enclosure IP20 (lbs [kg])	26.46 [12]		26.46 [12]		51.8 [23.5]		51.8 [23.5]	
	Weight, enclosure IP21, IP55, 66 (lbs [kg])	50.71 [23]		50.71 [23]		59.52 [27]		59.52 [27]	
	Efficiency 4)	0.98		0.98		0.98		0.98	

Table 4.5

Line Power Supply 3 x 380–500V AC (FC 302), 3 x 380–480V AC (FC 301)										
FC 301/FC 302	P30K		P37K		P45K		P55K		P75K	
High/ Normal Load[1]	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft output [kW]	30	37	37	45	45	55	55	75	75	90
Enclosure IP20	B4		C3		C3		C4		C4	
Enclosure IP21	C1		C1		C1		C2		C2	
Enclosure IP55, 66	C1		C1		C1		C2		C2	
Output current										
Continuous (3 x 380–440V) [A]	61	73	73	90	90	106	106	147	147	177
Intermittent (60 sec. overload) (3 x 380–440V) [A]	91.5	80.3	110	99	135	117	159	162	221	195
Continuous (3 x 441–500V) [A]	52	65	65	80	80	105	105	130	130	160
Intermittent (60 sec overload) (3 x 441–500V) [A]	78	71.5	97.5	88	120	116	158	143	195	176
Continuous kVA (400V AC) [kVA]	42.3	50.6	50.6	62.4	62.4	73.4	73.4	102	102	123
Continuous kVA (460V AC) [kVA]		51.8		63.7		83.7		104		128
Max. input current										
Continuous (3 x 380–440V) [A]	55	66	66	82	82	96	96	133	133	161
Intermittent (60 sec overload) (3 x 380–440V) [A]	82.5	72.6	99	90.2	123	106	144	146	200	177
Continuous (3 x 441–500V) [A]	47	59	59	73	73	95	95	118	118	145
Intermittent (60 sec overload) (3 x 441–500V) [A]	70.5	64.9	88.5	80.3	110	105	143	130	177	160
Additional specifications										
IP20 max. cable cross-section[5] (line power and motor)	35 (2)		50 (1)		50 (1)		150 (300 mcm)		150 (300 mcm)	
IP20 max. cable cross-section[5] (brake and load sharing)	35 (2)		50 (1)		50 (1)		95 (4/0)		95 (4/0)	
IP21, 55, 66 max. cable cross-section[5] (line power, motor) [mm^2 (AWG)] [2]	50 (1)		50 (1)		50 (1)		150 (300MCM)		150 (300MCM)	
IP21, 55, 66 max. cable cross-section[5] (brake, load sharing) [mm^2 (AWG)] [2]	50 (1)		50 (1)		50 (1)		95 (3/0)		95 (3/0)	
Max. cable size with line power disconnect [mm^2 (AWG)] [2]	50, 35, 35 (1, 2, 2)						95, 70, 70 (3/0, 2/0, 2/0)		185, 150, 120 (350MCM, 300MCM, 4/0)	
Estimated power loss at rated max. load [W] [4]	570	698	697	843	891	1083	1022	1384	1232	1474
Weight, enclosure IP21, IP55, 66 (lbs [kg])	99.21 [45]		99.21 [45]		99.21 [45]		143.3 [65]		143.3 [65]	
Efficiency[4]	0.98		0.98		0.98		0.98		0.99	

Table 4.6

For fuse ratings, see 8.3.1 Fuses

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

2) American Wire Gauge.

3) Measured using 16.4 ft [5 m] shielded motor cables at rated load and rated frequency.

4) The typical power loss is at nominal load conditions and expected to be within +/-15% (tolerance relates to variety in voltage and cable conditions).
Values are based on a typical motor efficiency (eff2/eff3 border line) value. Motors with lower efficiency will also add to the power loss in the adjustable frequency drive and vice-versa.

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

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

Line Power Supply 3 x 380–500 VAC											
FC 302		P90K		P110		P132		P160		P200	
High/ Normal Load*		HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
	Typical Shaft output at 400V [kW]	90	110	110	132	132	160	160	200	200	250
	Typical Shaft output at 460V [HP]	125	150	150	200	200	250	250	300	300	350
	Typical Shaft output at 500V [kW]	110	132	132	160	160	200	200	250	250	315
	EnclosureIP21	D1		D1		D2		D2		D2	
	EnclosureIP54	D1		D1		D2		D2		D2	
	Enclosure IP00	D3		D3		D4		D4		D4	
Output current											
	Continuous (at 400V) [A]	177	212	212	260	260	315	315	395	395	480
	Intermittent (60 sec overload) (at 400V) [A]	266	233	318	286	390	347	473	435	593	528
	Continuous (at 460/ 500V) [A]	160	190	190	240	240	302	302	361	361	443
	Intermittent (60 sec overload) (at 460/ 500V) [A]	240	209	285	264	360	332	453	397	542	487
	Continuous kVA (at 400V) [kVA]	123	147	147	180	180	218	218	274	274	333
	Continuous kVA (at 460V) [kVA]	127	151	151	191	191	241	241	288	288	353
	Continuous kVA (at 500V) [kVA]	139	165	165	208	208	262	262	313	313	384
Max. input current											
	Continuous (at 400V) [A]	171	204	204	251	251	304	304	381	381	463
	Continuous (at 460/ 500V) [A]	154	183	183	231	231	291	291	348	348	427
	Max. cable size, line power motor, brake and load share [mm^2 (AWG[2]))]	2 x 70 (2 x 2/0)		2 x 70 (2 x 2/0)		2 x 150 (2 x 300 mcm)		2 x 150 (2 x 300 mcm)		2 x 150 (2 x 300 mcm)	
	Max. external electrical fuses [A] 1	300		350		400		500		630	
	Estimated power loss at 400V [W] [4)]	2369	2907	2634	3357	3117	3914	3640	4812	4288	5517
	Estimated power loss at 460V [W]	2162	2599	2350	3078	2886	3781	3629	4535	3624	5025
	Weight, enclosure IP21, IP 54 (lbs [kg])	211.64 [96]		229.28 [104]		275.58 [125]		299.83 [136]		332.9 [151]	
	Weight, enclosure IP00 (lbs [kg])	180.78 [82]		200.6 [91]		246.92 [112]		271.17 [123]		304.24 [138]	
	Efficiency[4)]	0.98									
	Output frequency	0–800 Hz									
	Heatsink overtemp. trip	194°F [90°C]		230°F [110°C]		230°F [110°C]		230°F [110°C]		230°F [110°C]	
	Power card ambient trip	167°F [75°C]									
* High overload = 160% torque during 60 sec., Normal overload = 110% torque during 60 sec.											

Table 4.7

Line Power Supply 3 x 380–500VAC									
FC 302		P250		P315		P355		P400	
High/ Normal Load*		HO	NO	HO	NO	HO	NO	HO	NO
	Typical Shaft output at 400V [kW]	250	315	315	355	355	400	400	450
	Typical Shaft output at 460V [HP]	350	450	450	500	500	600	550	600
	Typical Shaft output at 500V [kW]	315	355	355	400	400	500	500	530
	Enclosure IP21	E1		E1		E1		E1	
	Enclosure IP54	E1		E1		E1		E1	
	Enclosure IP00	E2		E2		E2		E2	
Output current									
	Continuous (at 400V) [A]	480	600	600	658	658	745	695	800
	Intermittent (60 sec overload) (at 400V) [A]	720	660	900	724	987	820	1043	880
	Continuous (at 460/ 500V) [A]	443	540	540	590	590	678	678	730
	Intermittent (60 sec overload) (at 460/ 500V) [A]	665	594	810	649	885	746	1017	803
	Continuous kVA (at 400V) [kVA]	333	416	416	456	456	516	482	554
	Continuous kVA (at 460V) [kVA]	353	430	430	470	470	540	540	582
	Continuous kVA (at 500V) [kVA]	384	468	468	511	511	587	587	632
Max. input current									
	Continuous (at 400V) [A]	472	590	590	647	647	733	684	787
	Continuous (at 460/ 500V) [A]	436	531	531	580	580	667	667	718
	Max. cable size, line power, motor and load share [mm^2 (AWG[2)])]	4x240 (4x500 mcm)		4x240 (4x500 mcm)		4x240 (4x500 mcm)		4x240 (4x500 mcm)	
	Max. cable size, brake [mm^2 (AWG[2)])	2 x 185 (2 x 350 mcm)		2 x 185 (2 x 350 mcm)		2 x 185 (2 x 350 mcm)		2 x 185 (2 x 350 mcm)	
	Max. external electrical fuses [A] 1	700		900		900		900	
	Estimated power loss at 400V [W] [4)]	5059	6705	6794	7532	7498	8677	7976	9473
	Estimated power loss at 460V [W]	4822	6082	6345	6953	6944	8089	8085	7814
	Weight, enclosure IP21, IP 54 (lbs [kg])	579.82 [263]		595.25 [270]		599.66 [272]		690.05 [313]	
	Weight, enclosure IP00 (lbs [kg])	487.22 [221]		515.88 [234]		520.29 [236]		610.68 [277]	
	Efficiency[4)]	0.98							
	Output frequency	0–600 Hz							
	Heatsink overtemp. trip	230°F [110°C]							
	Power card ambient trip	167°F [75°C]							
* High overload = 160% torque during 60 sec., Normal overload = 110% torque during 60 sec.									

Table 4.8

Line Power Supply 3 x 380–500VAC													
FC 302		P450		P500		P560		P630		P710		P800	
High/ Normal Load*		HO	NO	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
	Typical Shaft output at 400V [kW]	450	500	500	560	560	630	630	710	710	800	800	1000
	Typical Shaft output at 460V [HP]	600	650	650	750	750	900	900	1000	1000	1200	1200	1350
	Typical Shaft output at 500V [kW]	530	560	560	630	630	710	710	800	800	1000	1000	1100
	EnclosureIP21, 54 without/ with options cabinet	F1/ F3		F1/ F3		F1/ F3		F1/ F3		F2/ F4		F2/ F4	
Output current													
	Continuous (at 400V) [A]	800	880	880	990	990	1120	1120	1260	1260	1460	1460	1720
	Intermittent (60 sec overload) (at 400V) [A]	1200	968	1320	1089	1485	1232	1680	1386	1890	1606	2190	1892
	Continuous (at 460/ 500V) [A]	730	780	780	890	890	1050	1050	1160	1160	1380	1380	1530
	Intermittent (60 sec overload) (at 460/ 500V) [A]	1095	858	1170	979	1335	1155	1575	1276	1740	1518	2070	1683
	Continuous kVA (at 400V) [kVA]	554	610	610	686	686	776	776	873	873	1012	1012	1192
	Continuous kVA (at 460V) [kVA]	582	621	621	709	709	837	837	924	924	1100	1100	1219
	Continuous kVA (at 500V) [kVA]	632	675	675	771	771	909	909	1005	1005	1195	1195	1325
Max. input current													
	Continuous (at 400V) [A]	779	857	857	964	964	1090	1090	1227	1227	1422	1422	1675
	Continuous (at 460/ 500V) [A]	711	759	759	867	867	1022	1022	1129	1129	1344	1344	1490
	Max. cable size, motor [mm^2 (AWG$^{2)}$)]	8x150 (8x300 mcm)								12x150 (12x300 mcm)			
	Max. cable size, line power F1/F2 [mm^2 (AWG$^{2)}$)]	8x240 (8x500 mcm)											
	Max. cable size, line power F3/F4 [mm^2 (AWG$^{2)}$)]	8x456 (8x900 mcm)											
	Max. cable size, load-sharing [mm^2 (AWG$^{2)}$)]	4x120 (4x250 mcm)											
	Max. cable size, brake [mm^2 (AWG$^{2)}$)	4x185 (4x350 mcm)								6x185 (6x350 mcm)			
	Max. external electrical fuses [A] 1	1600				2000				2500			
	Estimated power loss at 400V [W] [4)]	9031	10162	10146	11822	10649	12512	12490	14674	14244	17293	15466	19278
	Estimated power loss at 460V [W]	8212	8876	8860	10424	9414	11595	11581	13213	13005	16229	14556	16624
	F3/F4 max. added losses A1 RFI, CB or Disconnect, & contactor F3/F4	893	963	951	1054	978	1093	1092	1230	2067	2280	2236	2541
	Max. panel options losses	400											
	Weight, enclosure IP21, IP 54 (lbs [kg])	2213 [1004]/ 2863 [1299]		2213 [1004]/ 2863 [1299]		2213 [1004]/ 2863 [1299]		2213 [1004]/ 2863 [1299]		2747 [1246]/ 3397 [1541]		2747 [1246]/ 3397 [1541]	
	Weight, Rectifier Module (lbs [kg])	224.87 [102]		224.87 [102]		224.87 [102]		224.87 [102]		299.83 [136]		299.83 [136]	
	Weight, Inverter Module (lbs [kg])	224.87 [102]		224.87 [102]		224.87 [102]		299.83 [136]		224.87 [102]		224.87 [102]	
	Efficiency[4)]	0.98											
	Output frequency	0–600 Hz											
	Heatsink overtemp. trip	203°F [95°C]											
	Power card ambient trip	167°F [75°C]											
* High overload = 160% torque during 60 sec., Normal overload = 110% torque during 60 sec.													

Table 4.9

Line Power Supply 6 x 380–500V AC, 12-Pulse								
FC 302	P250		P315		P355		P400	
High/ Normal Load*	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft output at 400V [kW]	250	315	315	355	355	400	400	450
Typical Shaft output at 460V [HP]	350	450	450	500	500	600	550	600
Typical Shaft output at 500V [kW]	315	355	355	400	400	500	500	530
Enclosure IP21	F8/F9		F8/F9		F8/F9		F8/F9	
Enclosure IP54	F8/F9		F8/F9		F8/F9		F8/F9	
Output current								
Continuous (at 400V) [A]	480	600	600	658	658	745	695	800
Intermittent (60 sec overload) (at 400V) [A]	720	660	900	724	987	820	1043	880
Continuous (at 460/ 500V) [A]	443	540	540	590	590	678	678	730
Intermittent (60 sec overload) (at 460/ 500V) [A]	665	594	810	649	885	746	1017	803
Continuous KVA (at 400V) [KVA]	333	416	416	456	456	516	482	554
Continuous KVA (at 460V) [KVA]	353	430	430	470	470	540	540	582
Continuous KVA (at 500V) [KVA]	384	468	468	511	511	587	587	632
Max. input current								
Continuous (at 400V) [A]	472	590	590	647	647	733	684	787
Continuous (at 460/ 500V) [A]	436	531	531	580	580	667	667	718
Max. cable size, line power [mm^2 (AWG$^{2)}$)]	4x90 (3/0)		4x90 (3/0)		4x240 (500 mcm)		4x240 (500 mcm)	
Max. cable size, motor [mm^2 (AWG$^{2)}$)]	4x240 (4x500 mcm)		4x240 (4x500 mcm)		4x240 (4x500 mcm)		4x240 (4x500 mcm)	
Max. cable size, brake [mm^2 (AWG$^{2)}$)	2 x 185 (2 x 350 mcm)		2 x 185 (2 x 350 mcm)		2 x 185 (2 x 350 mcm)		2 x 185 (2 x 350 mcm)	
Max. external electrical fuses [A] 1	700							
Estimated power loss at 400V [W] 4)	5164	6790	6960	7701	7691	8879	8178	9670
Estimated power loss at 460V [W]	4822	6082	6345	6953	6944	8089	8085	8803
Weight,enclosure IP21, IP 54 (lbs [kg])	970 [440]/1446.23 [656]							
Efficiency4)	0.98							
Output frequency	0–600Hz							
Heatsink overtemp. trip	203°F [95°C]							
Power card ambient trip	167°F [75°C]							
* High overload = 160% torque during 60 sec., Normal overload = 110% torque during 60 sec.								

Table 4.10

Line Power Supply 6 x 380–500V AC, 12-Pulse												
FC 302	P450		P500		P560		P630		P710		P800	
High/ Normal Load *	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft output at 400V [kW]	450	500	500	560	560	630	630	710	710	800	800	1000
Typical Shaft output at 460V [HP]	600	650	650	750	750	900	900	1000	1000	1200	1200	1350
Typical Shaft output at 500V [kW]	530	560	560	630	630	710	710	800	800	1000	1000	1100
EnclosureIP21, 54 without/ with options cabinet	F10/F11		F10/F11		F10/F11		F10/F11		F12/F13		F12/F13	
Output current												
Continuous (at 400V) [A]	800	880	880	990	990	1120	1120	1260	1260	1460	1460	1720
Intermittent (60 sec overload) (at 400V) [A]	1200	968	1320	1089	1485	1232	1680	1386	1890	1606	2190	1892
Continuous (at 460/ 500V) [A]	730	780	780	890	890	1050	1050	1160	1160	1380	1380	1530
Intermittent (60 sec overload) (at 460/ 500V) [A]	1095	858	1170	979	1335	1155	1575	1276	1740	1518	2070	1683
Continuous KVA (at 400V) [KVA]	554	610	610	686	686	776	776	873	873	1012	1012	1192
Continuous KVA (at 460V) [KVA]	582	621	621	709	709	837	837	924	924	1100	1100	1219
Continuous KVA (at 500V) [KVA]	632	675	675	771	771	909	909	1005	1005	1195	1195	1325
Max. input current												
Continuous (at 400V) [A]	779	857	857	964	964	1090	1090	1227	1227	1422	1422	1675
Continuous (at 460/ 500V) [A]	711	759	759	867	867	1022	1022	1129	1129	1344	1344	1490
Max. cable size, motor [mm^2 (AWG$^{2)}$)]	8x150 (8x300 mcm)								12x150 (12x300 mcm)			
Max. cable size, line power [mm^2 (AWG$^{2)}$)]	6x120 (6x250 mcm)											
Max. cable size, brake [mm^2 (AWG$^{2)}$)	4x185 (4x350 mcm)								6x185 (6x350 mcm)			
Max. external electrical fuses [A] 1	900						1500					
Estimated power loss at 400V [W] $^{4)}$	9492	10647	10631	12338	11263	13201	13172	15436	14967	18084	16392	20358
Estimated power loss at 460V [W]	8730	9414	9398	11006	10063	12353	12332	14041	13819	17137	15577	17752
F9/F11/F13 max. added losses A1 RFI, CB or Disconnect, & contactor F9/F11/F13	893	963	951	1054	978	1093	1092	1230	2067	2280	2236	2541
Max. panel options losses	400											
Weight, enclosure IP21, IP 54 (lbs [kg])	2213 [1004]/ 2863 [1299]		2213 [1004]/ 2863 [1299]		2213 [1004]/ 2863 [1299]		2213 [1004]/ 2863 [1299]		2747 [1246]/3397 [1541]		2747 [1246]/3397 [1541]	
Weight, Rectifier Module (lbs [kg])	224.87 [102]		224.87 [102]		224.87 [102]		224.87 [102]		299.83 [136]		299.83 [136]	
Weight, Inverter Module (lbs [kg])	224.87 [102]		224.87 [102]		224.87 [102]		299.83 [136]		224.87 [102]		224.87 [102]	
Efficiency$^{4)}$	0.98											
Output frequency	0–600Hz											
Heatsink overtemp. trip	203°F [95°C]											
Power card ambient trip	167°F [75°C]											
* High overload = 160% torque during 60 sec., Normal overload = 110% torque during 60 sec.												

Table 4.11

4.3 Electrical Data - 525–600V

Line Power Supply 3 x 525–600V AC (FC 302 only)									
FC 302		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, 21	A3	A3	A3	A3	A3	A3	A3	A3
	Enclosure IP55	A5	A5	A5	A5	A5	A5	A5	A5
Output current									
	Continuous (3 x 525–550V) [A]	1.8	2.6	2.9	4.1	5.2	6.4	9.5	11.5
	Intermittent (3 x 525–550V) [A]	2.9	4.2	4.6	6.6	8.3	10.2	15.2	18.4
	Continuous (3 x 551–600V) [A]	1.7	2.4	2.7	3.9	4.9	6.1	9.0	11.0
	Intermittent (3 x 551–600V) [A]	2.7	3.8	4.3	6.2	7.8	9.8	14.4	17.6
	Continuous kVA (525V AC) [kVA]	1.7	2.5	2.8	3.9	5.0	6.1	9.0	11.0
	Continuous kVA (575V AC) [kVA]	1.7	2.4	2.7	3.9	4.9	6.1	9.0	11.0
Max. input current									
	Continuous (3 x 525–600V) [A]	1.7	2.4	2.7	4.1	5.2	5.8	8.6	10.4
	Intermittent (3 x 525–600V) [A]	2.7	3.8	4.3	6.6	8.3	9.3	13.8	16.6
Additional specifications									
	IP20, 21 max. cable cross-section5) (line power, motor, brake and load sharing) [mm² (AWG)]2)	4,4,4 (12,12,12) (min. 0.2(24))							
	IP55, 66 max. cable cross-section5) (line power, motor, brake and load sharing) [mm² (AWG)]	4,4,4 (12,12,12)							
	Max. cable cross-section5) with disconnect	6,4,4 (10,12,12)							
	Estimated power loss at rated max. load [W] 4)	35	50	65	92	122	145	195	261
	Weight, Enclosure IP20 (lbs [kg])	14.33 [6.5]	14.33 [6.5]	14.33 [6.5]	14.33 [6.5]	14.33 [6.5]	14.33 [6.5]	14.55 [6.6]	14.55 [6.6]
	Weight, enclosure IP55 (lbs [kg])	29.76 [13.5]	29.76 [13.5]	29.76 [13.5]	29.76 [13.5]	29.76 [13.5]	29.76 [13.5]	31.3 [14.2]	31.3 [14.2]
	Efficiency 4)	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97

Table 4.12

Line Power Supply 3 x 525–600V AC											
FC 302		P11K		P15K		P18K		P22K		P30K	
High/ Normal Load[1)]		HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft Output [kW]		11	15	15	18.5	18.5	22	22	30	30	37
	Enclosure IP21, 55, 66	B1		B1		B2		B2		C1	
	Enclosure IP20	B3		B3		B4		B4		B4	
Output current											
	Continuous (3 x 525–550V) [A]	19	23	23	28	28	36	36	43	43	54
	Intermittent (3 x 525–550V) [A]	30	25	37	31	45	40	58	47	65	59
	Continuous (3 x 525–600V) [A]	18	22	22	27	27	34	34	41	41	52
	Intermittent (3 x 525–600V) [A]	29	24	35	30	43	37	54	45	62	57
	Continuous kVA (550V AC) [kVA]	18.1	21.9	21.9	26.7	26.7	34.3	34.3	41.0	41.0	51.4
	Continuous kVA (575V AC) [kVA]	17.9	21.9	21.9	26.9	26.9	33.9	33.9	40.8	40.8	51.8
Max. input current											
	Continuous at 550V [A]	17.2	20.9	20.9	25.4	25.4	32.7	32.7	39	39	49
	Intermittent at 550V [A]	28	23	33	28	41	36	52	43	59	54
	Continuous at 575V [A]	16	20	20	24	24	31	31	37	37	47
	Intermittent at 575V [A]	26	22	32	27	39	34	50	41	56	52
Additional specifications											
	IP21, 55, 66 max. cable cross-section[5)] (line power, brake, load sharing) [mm^2 (AWG)] [2)]	16, 10, 10 (6, 8, 8)		16, 10, 10 (6, 8, 8)		35,-,-(2,-,-)		35,-,-(2,-,-)		50,-,- (1,-,-)	
	IP21, 55, 66 max. cable cross-section[5)] (motor) [mm^2 (AWG)] [2)]	10, 10,- (8, 8,-)		10, 10,- (8, 8,-)		35, 25, 25 (2, 4, 4)		35, 25, 25 (2, 4, 4)		50,-,- (1,-,-)	
	IP20 max. cable cross-section[5)] (line power, brake, motor and load sharing)	10, 10,- (8, 8,-)		10, 10,- (8, 8,-)		35,-,-(2,-,-)		35,-,-(2,-,-)		35,-,-(2,-,-)	
	Max. cable cross-section with disconnect [mm^2 (AWG)] [2)]	16, 10, 10 (6, 8, 8)								50, 35, 35 (1,2, 2)	
	Estimated power loss at rated max. load [W] [4)]		225		285		329		700		700
	Weight, enclosure IP21, (lbs [kg])	50.71 [23]		50.71 [23]		59.52 [27]		59.52 [27]		59.52 [27]	
	Weight, enclosure IP20 (lbs [kg])	26.46 [12]		26.46 [12]		51.8 [23.5]		51.8 [23.5]		51.8 [23.5]	
	Efficiency [4)]	0.98		0.98		0.98		0.98		0.98	

Table 4.13

Line Power Supply 3 x 525–600V AC									
FC 302		P37K		P45K		P55K		P75K	
High/ Normal Load*		HO	NO	HO	NO	HO	NO	HO	NO
	Typical Shaft Output [kW]	37	45	45	55	55	75	75	90
	Enclosure IP21, 55, 66	C1	C1	C1		C2		C2	
	Enclosure IP20	C3	C3	C3		C4		C4	
Output current									
	Continuous (3 x 525–550V) [A]	54	65	65	87	87	105	105	137
	Intermittent (3 x 525–550V) [A]	81	72	98	96	131	116	158	151
	Continuous (3 x 525–600V) [A]	52	62	62	83	83	100	100	131
	Intermittent (3 x 525–600V) [A]	78	68	93	91	125	110	150	144
	Continuous kVA (550V AC) [kVA]	51.4	61.9	61.9	82.9	82.9	100.0	100.0	130.5
	Continuous kVA (575V AC) [kVA]	51.8	61.7	61.7	82.7	82.7	99.6	99.6	130.5
Max. input current									
	Continuous at 550V [A]	49	59	59	78.9	78.9	95.3	95.3	124.3
	Intermittent at 550V [A]	74	65	89	87	118	105	143	137
	Continuous at 575V [A]	47	56	56	75	75	91	91	119
	Intermittent at 575V [A]	70	62	85	83	113	100	137	131
Additional specifications									
	IP20 max. cable cross-section[5)] (line power and motor)	50 (1)				150 (300MCM)			
	IP20 max. cable cross-section[5)] (brake and load sharing)	50 (1)				95 (4/0)			
	IP21, 55, 66 max. cable cross-section[5)] (line power, motor) [mm^2 (AWG)] [2)]	50 (1)				150 (300MCM)			
	IP21, 55, 66 max. cable cross-section[5)] (brake, load sharing) [mm^2 (AWG)] [2)]	50 (1)				95 (4/0)			
	Max. cable size with line power disconnect [mm^2 (AWG)] [2)]	50, 35, 35 (1, 2, 2)				95, 70, 70 (3/0, 2/0, 2/0)		185, 150, 120 (350MCM, 300MCM, 4/0)	
	Estimated power loss at rated max. load [W] [4)]		850		1100		1400		1500
	Weight, enclosure IP20 (lbs [kg])	77.2 [35]		77.2 [35]		110.23 [50]		110.23 [50]	
	Weight, enclosure IP21, 55 (lbs [kg])	99.21 [45]		99.21 [45]		143.3 [65]		143.3 [65]	
	Efficiency [4)]	0.98		0.98		0.98		0.98	

Table 4.14

4.4 Electrical Data - 525–690V

Line Power Supply 3 x 525–690V AC									
FC 302		P11K		P15K		P18K		P22K	
High/ Normal Load[1)]		HO	NO	HO	NO	HO	NO	HO	NO
	Typical Shaft output at 550V [kW]	7.5	11	11	15	15	18.5	18.5	22
	Typical Shaft output at 575V [HP]	11	15	15	20	20	25	25	30
	Typical Shaft output at 690V [kW]	11	15	15	18.5	18.5	22	22	30
	Enclosure IP21, 55	B2		B2		B2		B2	
Output current									
	Continuous (3 x 525–550V) [A]	14	19	19	23	23	28	28	36
	Intermittent (60 sec overload) (3 x 525–550V) [A]	22.4	20.9	30.4	25.3	36.8	30.8	44.8	39.6
	Continuous (3 x 551–690V) [A]	13	18	18	22	22	27	27	34
	Intermittent (60 sec overload) (3 x 551–690V) [A]	20.8	19.8	28.8	24.2	35.2	29.7	43.2	37.4
	Continuous KVA (at 550V) [KVA]	13.3	18.1	18.1	21.9	21.9	26.7	26.7	34.3
	Continuous KVA (at 575V) [KVA]	12.9	17.9	17.9	21.9	21.9	26.9	26.9	33.9
	Continuous KVA (at 690V) [KVA]	15.5	21.5	21.5	26.3	26.3	32.3	32.3	40.6
Max. input current									
	Continuous (3 x 525–690V) [A]	15	19.5	19.5	24	24	29	29	36
	Intermittent (60 sec overload) (3 x 525–690V) [A]	23.2	21.5	31.2	26.4	38.4	31.9	46.4	39.6
Additional specifications									
	Max. cable cross-section (line power, load share and brake) [mm^2 (AWG)]	35,-,- (2,-,-)							
	Max. cable cross-section (motor) [mm^2 (AWG)]	35, 25, 25 (2, 4, 4)							
	Max. cable size with line power disconnect [mm^2 (AWG)] [2)]	16,10,10 (6,8, 8)							
	Estimated power loss at rated max. load [W] [4)]	228		285		335		375	
	Weight, enclosure IP21, IP55 (lbs [kg])	59.52 [27]							
	Efficiency[4)]	0.98		0.98		0.98		0.98	

Table 4.15

Line Power Supply 3 x 525–690V AC											
FC 302		P30K		P37K		P45K		P55K		P75K	
High/ Normal Load*		HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
	Typical Shaft output at 550V [kW]	22	30	30	37	37	45	45	55	55	75
	Typical Shaft output at 575V [HP]	30	40	40	50	50	60	60	75	75	100
	Typical Shaft output at 690V [kW]	30	37	37	45	45	55	55	75	75	90
	Enclosure IP21, 55	C2		C2		C2		C2		C2	
Output current											
	Continuous (3 x 525–550V) [A]	36	43	43	54	54	65	65	87	87	105
	Intermittent (60 sec overload) (3 x 525–550V) [A]	54	47.3	64.5	59.4	81	71.5	97.5	95.7	130.5	115.5
	Continuous (3 x 551–690V) [A]	34	41	41	52	52	62	62	83	83	100
	Intermittent (60 sec overload) (3 x 551–690V) [A]	51	45.1	61.5	57.2	78	68.2	93	91.3	124.5	110
	Continuous KVA (at 550V) [KVA]	34.3	41.0	41.0	51.4	51.4	61.9	61.9	82.9	82.9	100.0
	Continuous KVA (at 575V) [KVA]	33.9	40.8	40.8	51.8	51.8	61.7	61.7	82.7	82.7	99.6
	Continuous KVA (at 690V) [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 550V) [A]	36	49	49	59	59	71	71	87	87	99
	Continuous (at 575V) [A]	54	53.9	72	64.9	87	78.1	105	95.7	129	108.9
Additional specifications											
	Max. cable cross-section (line power and motor) [mm² (AWG)]	150 (300MCM)									
	Max. cable cross-section (load share and brake) [mm² (AWG)]	95 (3/0)									
	Max. cable size with line power disconnect [mm² (AWG)] 2)	95, 70, 70 (3/0, 2/0, 2/0)						185, 150, 120 (350MCM, 300MCM, 4/0)		-	
	Estimated power loss at rated max. load [W] 4)	480		592		720		880		1200	
	Weight, enclosure IP21, IP55 (lbs [kg])	143.3 [65]									
	Efficiency4)	0.98		0.98		0.98		0.98		0.98	

Table 4.16

For fuse ratings, see 8.3.1 Fuses

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

2) American Wire Gauge.

3) Measured using 16.4 ft [5 m] shielded motor cables at rated load and rated frequency.

4) The typical power loss is at nominal load conditions and expected to be within +/-15% (tolerance relates to variety in voltage and cable conditions).
Values are based on a typical motor efficiency (eff2/eff3 border line) value. Motors with lower efficiency will also add to the power loss in the adjustable frequency drive and vice-versa.
If the switching frequency is increased compared to the default setting, the power losses may rise significantly,
LCP and typical control card power consumptions are included. Further options and customer load may add up to 30W to the losses. (Though typical, only 4 W extra for a fully loaded control card, or options for slot A or slot B, each.)

Although measurements are made with state of the art equipment, some measurement inaccuracy must be allowed for (+/-5%).

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

Line Power Supply 3 x 525–690V AC											
FC 302		P37K		P45K		P55K		P75K		P90K	
High/ Normal Load*		HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
	Typical Shaft output at 550V [kW]	30	37	37	45	45	55	55	75	75	90
	Typical Shaft output at 575V [HP]	40	50	50	60	60	75	75	100	100	125
	Typical Shaft output at 690V [kW]	37	45	45	55	55	75	75	90	90	110
	Enclosure IP21	D1		D1		D1		D1		D1	
	Enclosure IP54	D1		D1		D1		D1		D1	
	Enclosure IP00	D3		D3		D3		D3		D3	
Output current											
	Continuous (at 550V) [A]	48	56	56	76	76	90	90	113	113	137
	Intermittent (60 sec overload) (at 550V) [A]	77	62	90	84	122	99	135	124	170	151
	Continuous (at 575/690V) [A]	46	54	54	73	73	86	86	108	108	131
	Intermittent (60 sec overload) (at 575/690V) [A]	74	59	86	80	117	95	129	119	162	144
	Continuous KVA (at 550V) [KVA]	46	53	53	72	72	86	86	108	108	131
	Continuous KVA (at 575V) [KVA]	46	54	54	73	73	86	86	108	108	130
	Continuous KVA (at 690V) [KVA]	55	65	65	87	87	103	103	129	129	157
Max. input current											
	Continuous (at 550V) [A]	53	60	60	77	77	89	89	110	110	130
	Continuous (at 575V) [A]	51	58	58	74	74	85	85	106	106	124
	Continuous (at 690V) [A]	50	58	58	77	77	87	87	109	109	128
	Max. cable size, line power, motor, load share and brake [mm^2 (AWG)]	2x70 (2x2/0)									
	Max. external electrical fuses [A] 1	125		160		200		200		250	
	Estimated power loss at 600V [W] 4)	1299	1398	1459	1645	1643	1827	1350	1599	1597	1891
	Estimated power loss at 690V [W] 4)	1002	1071	1071	1251	1251	1392	1392	1648	1650	1951
	Weight, enclosure IP21, IP54 (lbs [kg])	211.64 [96]									
	Weight, enclosure IP00 (lbs [kg])	180.78 [82]									
	Efficiency 4)	0.97		0.97		0.98		0.98		0.98	
	Output frequency	0–600Hz									
	Heatsink overtemp. trip	194°F [90°C]									
	Power card ambient trip	167°F [75°C]									
* High overload = 160% torque during 60 sec., Normal overload = 110% torque during 60 sec.											

Table 4.17

Line Power Supply 3 x 525–690V AC									
FC 302		P110		P132		P160		P200	
High/ Normal Load*		HO	NO	HO	NO	HO	NO	HO	NO
	Typical Shaft output at 550V [kW]	90	110	110	132	132	160	160	200
	Typical Shaft output at 575V [HP]	125	150	150	200	200	250	250	300
	Typical Shaft output at 690V [kW]	110	132	132	160	160	200	200	250
	Enclosure IP21	D1		D1		D2		D2	
	Enclosure IP54	D1		D1		D2		D2	
	Enclosure IP00	D3		D3		D4		D4	
Output current									
	Continuous (at 550V) [A]	137	162	162	201	201	253	253	303
	Intermittent (60 sec overload) (at 550V) [A]	206	178	243	221	302	278	380	333
	Continuous (at 575/690V) [A]	131	155	155	192	192	242	242	290
	Intermittent (60 sec overload) (at 575/690V) [A]	197	171	233	211	288	266	363	319
	Continuous KVA (at 550V) [KVA]	131	154	154	191	191	241	241	289
	Continuous KVA (at 575V) [KVA]	130	154	154	191	191	241	241	289
	Continuous KVA (at 690V) [KVA]	157	185	185	229	229	289	289	347
Max. input current									
	Continuous (at 550V) [A]	130	158	158	198	198	245	245	299
	Continuous (at 575V) [A]	124	151	151	189	189	234	234	286
	Continuous (at 690V) [A]	128	155	155	197	197	240	240	296
	Max. cable size, line power motor, load share and brake [mm^2 (AWG)]	2 x 70 (2 x 2/0)		2 x 70 (2 x 2/0)		2 x 150 (2 x 300 mcm)		2 x 150 (2 x 300 mcm)	
	Max. external electrical fuses [A] 1	315		350		350		400	
	Estimated power loss at 600V [W] [4)]	1890	2230	2101	2617	2491	3197	3063	3757
	Estimated power loss at 690V [W] [4)]	1953	2303	2185	2707	2606	3320	3192	3899
	Weight, Enclosure IP21, IP54 (lbs [kg])	211.64 [96]		229.28 [104]		275.58 [125]		299.83 [136]	
	Weight, Enclosure IP00 (lbs [kg])	180.78 [82]		200.6 [91]		246.92 [112]		271.17 [123]	
	Efficiency[4)]	0.98							
	Output frequency	0–600 Hz							
	Heatsink overtemp. trip	195.8°F [90°C]		230°F [110°C]		230°F [110°C]		230°F [110°C]	
	Power card ambient trip	167°F [75°C]							
* High overload = 160% torque during 60 sec., Normal overload = 110% torque during 60 sec.									

Table 4.18

Line Power Supply 3 x 525–690 VAC							
FC 302		P250		P315		P355	
High/ Normal Load*		HO	NO	HO	NO	HO	NO
	Typical Shaft output at 550V [kW]	200	250	250	315	315	355
	Typical Shaft output at 575V [HP]	300	350	350	400	400	450
	Typical Shaft output at 690V [kW]	250	315	315	400	355	450
	Enclosure IP21	D2		D2		E1	
	Enclosure IP54	D2		D2		E1	
	Enclosure IP00	D4		D4		E2	
Output current							
	Continuous (at 550V) [A]	303	360	360	418	395	470
	Intermittent (60 sec overload) (at 550V) [A]	455	396	540	460	593	517
	Continuous (at 575/690V) [A]	290	344	344	400	380	450
	Intermittent (60 sec overload) (at 575/ 690V) [A]	435	378	516	440	570	495
	Continuous KVA (at 550V) [KVA]	289	343	343	398	376	448
	Continuous KVA (at 575V) [KVA]	289	343	343	398	378	448
	Continuous KVA (at 690V) [KVA]	347	411	411	478	454	538
Max. input current							
	Continuous (at 550V) [A]	299	355	355	408	381	453
	Continuous (at 575V) [A]	286	339	339	390	366	434
	Continuous (at 690V) [A]	296	352	352	400	366	434
	Max. cable size, line power, motor and load share [mm^2 (AWG)]	2 x 150 (2 x 300 mcm)		2 x 150 (2 x 300 mcm)		4 x 240 (4 x 500 mcm)	
	Max. cable size, brake [mm^2 (AWG)]	2 x 150 (2 x 300 mcm)		2 x 150 (2 x 300 mcm)		2 x 185 (2 x 350 mcm)	
	Max. external electrical fuses [A] 1	500		550		700	
	Estimated power loss at 600V [W] [4)]	3552	4307	3971	4756	4130	4974
	Estimated power loss at 690V [W] [4)]	3704	4485	4103	4924	4240	5128
	Weight, enclosure IP21, IP54 (lbs [kg])	332.9 [151]		363.76 [165]		579.82 [263]	
	Weight, enclosure IP00 (lbs [kg])	304.24 [138]		332.9 [151]		487.22 [221]	
	Efficiency[4)]	0.98					
	Output frequency	0–600Hz		0–500Hz		0–500Hz	
	Heatsink overtemp. trip	[212°F [110°C]		212°F [110°C]		212°F [110°C]	
	Power card ambient trip	167°F [75°C]		167°F [75°C]		167°F [75°C]	
* High overload = 160% torque during 60 sec., Normal overload = 110% torque during 60 sec.							

Table 4.19

Line Power Supply 3 x 525–690V AC							
FC 302		P400		P500		P560	
High/ Normal Load*		HO	NO	HO	NO	HO	NO
	Typical Shaft output at 550V [kW]	315	400	400	450	450	500
	Typical Shaft output at 575V [HP]	400	500	500	600	600	650
	Typical Shaft output at 690V [kW]	400	500	500	560	560	630
	Enclosure IP21	E1		E1		E1	
	Enclosure IP54	E1		E1		E1	
	Enclosure IP00	E2		E2		E2	
Output current							
	Continuous (at 550V) [A]	429	523	523	596	596	630
	Intermittent (60 sec overload) (at 550V) [A]	644	575	785	656	894	693
	Continuous (at 575/ 690V) [A]	410	500	500	570	570	630
	Intermittent (60 sec overload) (at 575/690V) [A]	615	550	750	627	855	693
	Continuous KVA (at 550V) [KVA]	409	498	498	568	568	600
	Continuous KVA (at 575V) [KVA]	408	498	498	568	568	627
	Continuous KVA (at 690V) [KVA]	490	598	598	681	681	753
Max. input current							
	Continuous (at 550V) [A]	413	504	504	574	574	607
	Continuous (at 575V) [A]	395	482	482	549	549	607
	Continuous (at 690V) [A]	395	482	482	549	549	607
	Max. cable size, line power, motor and load share [mm^2 (AWG)]	4x240 (4x500 mcm)		4x240 (4x500 mcm)		4x240 (4x500 mcm)	
	Max. cable size, brake [mm^2 (AWG)]	2 x 185 (2 x 350 mcm)		2 x 185 (2 x 350 mcm)		2 x 185 (2 x 350 mcm)	
	Max. external electrical fuses [A] 1	700		900		900	
	Estimated power loss at 600V [W] [4)]	4478	5623	6153	7018	7007	7793
	Estimated power loss at 690V [W] [4)]	4605	5794	6328	7221	7201	8017
	Weight, enclosure IP21, IP54 (lbs [kg])	579.82 [263]		599.66 [272]		690.05 [313]	
	Weight, enclosure IP00 (lbs [kg])	487.22 [221]		520.29 [236]		610.68 [277]	
	Efficiency[4)]	0.98					
	Output frequency	0–500Hz					
	Heatsink overtemp. trip	212°F [110°C]					
	Power card ambient trip	167°F [75°C]					
* High overload = 160% torque during 60 sec., Normal overload = 110% torque during 60 sec.							

Table 4.20

4

Line Power Supply 3 x 525–690V AC							
FC 302		P630		P710		P800	
High/ Normal Load*		HO	NO	HO	NO	HO	NO
	Typical Shaft output at 550V [kW]	500	560	560	670	670	750
	Typical Shaft output at 575V [HP]	650	750	750	950	950	1050
	Typical Shaft output at 690V [kW]	630	710	710	800	800	900
	Enclosure IP21, 54 without/with options cabinet	F1/ F3		F1/ F3		F1/ F3	
Output current							
	Continuous (at 550V) [A]	659	763	763	889	889	988
	Intermittent (60 sec overload) (at 550V) [A]	989	839	1145	978	1334	1087
	Continuous (at 575/690V) [A]	630	730	730	850	850	945
	Intermittent (60 sec overload) (at 575/690V) [A]	945	803	1095	935	1275	1040
	Continuous KVA (at 550V) [KVA]	628	727	727	847	847	941
	Continuous KVA (at 575V) [KVA]	627	727	727	847	847	941
	Continuous KVA (at 690V) [KVA]	753	872	872	1016	1016	1129
Max. input current							
	Continuous (at 550V) [A]	642	743	743	866	866	962
	Continuous (at 575V) [A]	613	711	711	828	828	920
	Continuous (at 690V) [A]	613	711	711	828	828	920
	Max. cable size, motor [mm^2 (AWG$^{2)}$)]	8x150 (8x300 mcm)					
	Max. cable size, line power F1 [mm^2 (AWG$^{2)}$)]	8x240 (8x500 mcm)					
	Max. cable size, line power F3 [mm^2 (AWG$^{2)}$)]	8x456 (8x900 mcm)					
	Max. cable size, load-sharing [mm^2 (AWG$^{2)}$)]	4x120 (4x250 mcm)					
	Max. cable size, brake [mm^2 (AWG$^{2)}$)	4x185 (4x350 mcm)					
	Max. external electrical fuses [A] 1	1600					
	Estimated power loss at 600V [W] $^{4)}$	7586	8933	8683	10310	10298	11692
	Estimated power loss at 690V [W] $^{4)}$	7826	9212	8983	10659	10646	12080
	F3/F4 Max added losses CB or Disconnect & Contactor	342	427	419	532	519	615
	Max panel options losses	400					
	Weight, enclosure IP21, IP 54 (lbs [kg])	2213 [1004]/ 2864 [1299]		2213 [1004]/ 2864 [1299]		2213 [1004]/ 2864 [1299]	
	Weight, Rectifier Module (lbs [kg])	224.87 [102]		224.87 [102]		224.87 [102]	
	Weight, Inverter Module (lbs [kg])	224.87 [102]		224.87 [102]		299.83 [136]	
	Efficiency$^{4)}$	0.98					
	Output frequency	0-500 Hz					
	Heatsink overtemp. trip	203°F [95°C]		221°F [105°C]		203°F [95°C]	
	Power card ambient trip	167°F [75°C]					
* High overload = 160% torque during 60 sec., Normal overload = 110% torque during 60 sec.							

Table 4.21

Line Power Supply 3 x 525–690V AC							
FC 302		P900		P1M0		P1M2	
High/ Normal Load*		HO	NO	HO	NO	HO	NO
	Typical Shaft output at 550V [kW]	750	850	850	1000	1000	1100
	Typical Shaft output at 575V [HP]	1050	1150	1150	1350	1350	1550
	Typical Shaft output at 690V [kW]	900	1000	1000	1200	1200	1400
	Enclosure IP21, 54 without/ with options cabinet	F2/ F4		F2/ F4		F2/ F4	
Output current							
	Continuous (at 550V) [A]	988	1108	1108	1317	1317	1479
	Intermittent (60 sec overload) (at 550V) [A]	1482	1219	1662	1449	1976	1627
	Continuous (at 575/690V) [A]	945	1060	1060	1260	1260	1415
	Intermittent (60 sec overload) (at 575/690V) [A]	1418	1166	1590	1386	1890	1557
	Continuous KVA (at 550V) [KVA]	941	1056	1056	1255	1255	1409
	Continuous KVA (at 575V) [KVA]	941	1056	1056	1255	1255	1409
	Continuous KVA (at 690V) [KVA]	1129	1267	1267	1506	1506	1691
Max. input current							
	Continuous (at 550V) [A]	962	1079	1079	1282	1282	1440
	Continuous (at 575V) [A]	920	1032	1032	1227	1227	1378
	Continuous (at 690V) [A]	920	1032	1032	1227	1227	1378
	Max. cable size, motor [mm² (AWG2))]	12x150 (12x300 mcm)					
	Max. cable size, line power F2 [mm² (AWG2))]	8x240 (8x500 mcm)					
	Max. cable size, line power F4 [mm² (AWG2))]	8x456 (8x900 mcm)					
	Max. cable size, load-sharing [mm² (AWG2))]	4x120 (4x250 mcm)					
	Max. cable size, brake [mm² (AWG2))	6x185 (6x350 mcm)					
	Max. external electrical fuses [A] 1	1600		2000		2500	
	Estimated power loss at 600V [W] 4)	11329	12909	12570	15358	15258	17602
	Estimated power loss at 690V [W] 4)	11681	13305	12997	15865	15763	18173
	F3/F4 Max added losses CB or Disconnect & Contactor	556	665	634	863	861	1044
	Max panel options losses	400					
	Weight, enclosure IP21, IP54 (lbs [kg])	2747 [1246]/3397 [1541]		2747 [1246]/3397 [1541]		2822 [1280]/3472 [1575]	
	Weight, Rectifier Module (lbs [kg])	299.83 [136]		299.83 [136]		299.83 [136]	
	Weight, Inverter Module (lbs [kg])	224.87 [102]		224.87 [102]		299.83 [136]	
	Efficiency4)	0.98					
	Output frequency	0–500Hz					
	Heatsink overtemp. trip	221°F [105°C]		221°F [105°C]		203°F [95°C]	
	Power card ambient trip	167°F [75°C]					
* High overload = 160% torque during 60 sec., Normal overload = 110% torque during 60 sec.							

Table 4.22

1) For type of fuse, see section Fuses.

2) American Wire Gauge.

3) Measured using 16.4 ft. [5 m] shielded motor cables at rated load and rated frequency.

4) The typical power loss is at nominal load conditions and expected to be within +/-15% (tolerance relates to variety in voltage and cable conditions).
Values are based on a typical motor efficiency (eff2/eff3 border line) value. Motors with lower efficiency will also add to the power loss in the adjustable frequency drive and vice-versa.

If the switching frequency is increased compared to the default setting, the power losses may rise significantly, LCP and typical control card power consumptions are included. Further options and customer load may add up to 30W to the losses. (Though typical, only 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%).

Line Power Supply 6 x 525–690V AC, 12-Pulse								
FC 302	P355		P400		P500		P560	
High/ Normal Load	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft output at 550V [kW]	315	355	315	400	400	450	450	500
Typical Shaft output at 575V [HP]	400	450	400	500	500	600	600	650
Typical Shaft output at 690V [kW]	355	450	400	500	500	560	560	630
Enclosure IP21	F8/F9		F8/F9		F8/F9		F8/F9	
Enclosure IP54	F8/F9		F8/F9		F8/F9		F8/F9	
Output current								
Continuous (at 550V) [A]	395	470	429	523	523	596	596	630
Intermittent (60 sec overload) (at 550V) [A]	593	517	644	575	785	656	894	693
Continuous (at 575/ 690V) [A]	380	450	410	500	500	570	570	630
Intermittent (60 sec overload) (at 575/ 690V) [A]	570	495	615	550	750	627	855	693
Continuous KVA (at 550V) [KVA]	376	448	409	498	498	568	568	600
Continuous KVA (at 575V) [KVA]	378	448	408	498	498	568	568	627
Continuous KVA (at 690V) [KVA]	454	538	490	598	598	681	681	753
Max. input current								
Continuous (at 550V) [A]	381	453	413	504	504	574	574	607
Continuous (at 575V) [A]	366	434	395	482	482	549	549	607
Continuous (at 690V) [A]	366	434	395	482	482	549	549	607
Max. cable size, line power [mm^2 (AWG)]	4x85 (3/0)							
Max. cable size, motor [mm^2 (AWG)]	4 x 250 (500 mcm)							
Max. cable size, brake [mm^2 (AWG)]	2 x 185 (2 x 350 mcm)		2 x 185 (2 x 350 mcm)		2 x 185 (2 x 350 mcm)		2 x 185 (2 x 350 mcm)	
Max. external electrical fuses [A] 1	630							
Estimated power loss at 600V [W] 4)	5107	6132	5538	6903	7336	8343	8331	9244
Estimated power loss at 690V [W] 4)	5383	6449	5818	7249	7671	8727	8715	9673
Weight, enclosure IP21, IP 54 (lbs [kg])	970 [440]/1446.23 [656]							
Efficiency4)	0.98							
Output frequency	0–500Hz							
Heatsink overtemp. trip	185°F [85°C]							
Power card ambient trip	167°F [75°C]							
* High overload = 160% torque during 60 sec., Normal overload = 110% torque during 60 sec.								

Table 4.23

Line Power Supply 6 x 525–690V AC, 12-Pulse						
FC 302	P630		P710		P800	
High/ Normal Load	HO	NO	HO	NO	HO	NO
Typical Shaft output at 550V [kW]	500	560	560	670	670	750
Typical Shaft output at 575V [HP]	650	750	750	950	950	1050
Typical Shaft output at 690V [kW]	630	710	710	800	800	900
Enclosure IP21, 54 without/with options cabinet	F10/F11		F10/F11		F10/F11	
Output current						
Continuous (at 550V) [A]	659	763	763	889	889	988
Intermittent (60 sec overload) (at 550V) [A]	989	839	1145	978	1334	1087
Continuous (at 575/ 690V) [A]	630	730	730	850	850	945
Intermittent (60 sec overload) (at 575/ 690V) [A]	945	803	1095	935	1275	1040
Continuous KVA (at 550V) [KVA]	628	727	727	847	847	941
Continuous KVA (at 575V) [KVA]	627	727	727	847	847	941
Continuous KVA (at 690V) [KVA]	753	872	872	1016	1016	1129
Max. input current						
Continuous (at 550V) [A]	642	743	743	866	866	962
Continuous (at 575V) [A]	613	711	711	828	828	920
Continuous (at 690V) [A]	613	711	711	828	828	920
Max. cable size, motor [mm^2 (AWG[2)])]	8x150 (8x300 mcm)					
Max. cable size, line power [mm^2 (AWG[2)])]	6x120 (6x250 mcm)					
Max. cable size, brake [mm^2 (AWG[2)])	4x185 (4x350 mcm)					
Max. external electrical fuses [A] 1	900					
Estimated power loss at 600V [W] [4)]	9201	10771	10416	12272	12260	13835
Estimated power loss at 690V [W] [4)]	9674	11315	10965	12903	12890	14533
F3/F4 Max added losses CB or Disconnect & Contactor	342	427	419	532	519	615
Max panel options losses	400					
Weight, enclosure IP21, IP 54 (lbs [kg])	2213 [1004]/ 2864 [1299]		2213 [1004]/ 2864 [1299]		2213 [1004]/ 2864 [1299]	
Weight, Rectifier Module (lbs [kg])	224.87 [102]		224.87 [102]		224.87 [102]	
Weight, Inverter Module (lbs [kg])	224.87 [102]		224.87 [102]		299.83 [136]	
Efficiency[4)]	0.98					
Output frequency	0–500Hz					
Heatsink overtemp. trip	185°F [85°C]					
Power card ambient trip	167°F [75°C]					
* High overload = 160% torque during 60 s, Normal overload = 110% torque during 60 s						

Table 4.24

Line Power Supply 6 x 525–690VAC, 12-Pulse						
FC 302	P900		P1M0		P1M2	
High/ Normal Load*	HO	NO	HO	NO	HO	NO
Typical Shaft output at 550V [kW]	750	850	850	1000	1000	1100
Typical Shaft output at 575V [HP]	1050	1150	1150	1350	1350	1550
Typical Shaft output at 690V [kW]	900	1000	1000	1200	1200	1400
Enclosure IP21, 54 without/with options cabinet	F12/F13		F12/F13		F12/F13	
Output current						
Continuous (at 550V) [A]	988	1108	1108	1317	1317	1479
Intermittent (60 sec overload) (at 550V) [A]	1482	1219	1662	1449	1976	1627
Continuous (at 575/ 690V) [A]	945	1060	1060	1260	1260	1415
Intermittent (60 sec overload) (at 575/ 690V) [A]	1418	1166	1590	1386	1890	1557
Continuous KVA (at 550V) [KVA]	941	1056	1056	1255	1255	1409
Continuous KVA (at 575V) [KVA]	941	1056	1056	1255	1255	1409
Continuous KVA (at 690V) [KVA]	1129	1267	1267	1506	1506	1691
Max. input current						
Continuous (at 550V) [A]	962	1079	1079	1282	1282	1440
Continuous (at 575V) [A]	920	1032	1032	1227	1227	1378
Continuous (at 690V) [A]	920	1032	1032	1227	1227	1378
Max. cable size, motor [mm^2 (AWG[2]))]	12x150 (12x300 mcm)					
Max. cable size, line power F12 [mm^2 (AWG[2]))]	8x240 (8x500 mcm)					
Max. cable size, line power F13 [mm^2 (AWG[2]))]	8x400 (8x900 mcm)					
Max. cable size, brake [mm^2 (AWG[2]))]	6x185 (6x350 mcm)					
Max. external electrical fuses [A] 1	1600		2000		2500	
Estimated power loss at 600V [W] [4)]	13755	15592	15107	18281	18181	20825
Estimated power loss at 690V [W] [4)]	14457	16375	15899	19207	19105	21857
F3/F4 Max added losses CB or Disconnect & Contactor	556	665	634	863	861	1044
Max panel options losses	400					
Weight, enclosure IP21, IP 54 (lbs [kg])	2747 [1246]/3397 [1541]		2747 [1246]/3397 [1541]		2822 [1280]/3472 [1575]	
Weight, Rectifier Module (lbs [kg])	299.83 [136]		299.83 [136]		299.83 [136]	
Weight, Inverter Module (lbs [kg])	224.87 [102]		224.87 [102]		299.83 [136]	
Efficiency[4)]	0.98					
Output frequency	0–500 Hz					
Heatsink overtemp. trip	185°F [85°C]					
Power card ambient trip	167°F [75°C]					
* High overload = 160% torque during 60 sec., Normal overload = 110% torque during 60 sec.						

Table 4.25

1) For type of fuse, see section Fuses.

2) American Wire Gauge.

3) Measured using 16.4 ft. [5 m] shielded motor cables at rated load and rated frequency.

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

LCP and typical control card power consumptions are included. Further options and customer load may add up to 30W to the losses. (Though typical, only 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%).

4.5 General Specifications

Line power supply:

Supply Terminals (6-pulse)	L1, L2, L3
Supply Terminals (12-pulse)	L1-1, L2-1, L3-1, L1-2, L2-2, L3-2
Supply voltage	200–240V ±10%
Supply voltage	FC 301: 380–480V / FC 302: 380–500V ±10%
	FC 302: 525–600V ±10%
Supply voltage	FC 302: 525–690V ±10%

AC line voltage low / line drop-out:
During low AC line voltage or a line drop-out, the FC 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	50/60Hz ±5%
Max. imbalance temporary 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 [7.5kW]	maximum 2 times/min.
Switching on input supply L1, L2, L3 (power-ups) 15–100 hp [11–75 kW]	maximum 1 time/min.
Switching on input supply L1, L2, L3 (power-ups) ≥ 125 hp [90kW]	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, 240/500/600/690V maximum.

Motor output (U, V, W):

Output voltage	0–100% of supply voltage
Output frequency (0.33–10 hp [0.25–75 kW])	FC 301: 0.2–1000Hz / FC 302: 0 - 1000Hz
Output frequency (125–1350 hp [90–1000 kW])	0–800[1)]Hz
Output frequency in flux mode (FC 302 only)	0–300Hz
Switching on output	Unlimited
Ramp times	0.01–3600 sec.

[1)] *Voltage and power dependent*

Torque characteristics:

Starting torque (Constant torque)	maximum 160% for 60 sec.[1)]
Starting torque	maximum 180% up to 0.5 sec.[1)]
Overload torque (Constant torque)	maximum 160% for 60 sec.[1)]
Starting torque (Variable torque)	maximum 110% for 60 sec.[1)]
Overload torque (Variable torque)	maximum 110% for 60 sec.

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

Table 4.26 Overload capability

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

Table 4.27 Overload capability

Torque rise time in VVC+ (independent of fsw)	10 ms
Torque rise time in FLUX (for 5 kHz fsw)	1 ms

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

Cable lengths and cross-sections for control cables[1]:

Max. motor cable length, shielded	FC 301: 164 ft [50m]/FC 301 (A1): 82 ft [25m]/ FC 302: 492 ft [150 m]
Max. motor cable length, non-shielded	FC 301: 246 ft [75m]/FC 301 (A1): 164 ft [50 m]/ FC 302: 984 ft [300 m]
Maximum cross section to control terminals, flexible/rigid wire without cable end sleeves	1.5mm^2/16 AWG
Maximum cross-section to control terminals, flexible wire with cable end sleeves	1mm^2/18 AWG
Maximum cross-section to control terminals, flexible wire with cable end sleeves with collar	0.5mm^2/20 AWG
Minimum cross-section to control terminals	0.25mm^2/ 24AWG

[1]For power cables, see electrical data tables.

Protection and Features:

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

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	0–24V DC
Voltage level, logic'0' PNP	< 5V DC
Voltage level, logic'1' PNP	> 10V DC
Voltage level, logic '0' NPN[2]	> 19V DC
Voltage level, logic '1' NPN[2]	< 14V DC
Maximum voltage on input	28V DC
Pulse frequency range	0–110 kHz
(Duty cycle) Min. pulse width	4.5ms
Input resistance, R_i	approx. 4 kΩ

Safe stop Terminal 37[3, 4] (Terminal 37 is fixed PNP logic):

Voltage level	0–24V DC
Voltage level, logic'0' PNP	< 4V DC
Voltage level, logic'1' PNP	>20V DC
Maximum voltage on input	28V DC
Typical input current at 24V	50mA rms
Typical input current at 20V	60mA rms

Input capacitance	400nF

All digital inputs are galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.
1) Terminals 27 and 29 can also be programmed as output.

2) Except safe stop input Terminal 37.
3) See 3.8 Safe Stop of FC 300 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 50V 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	FC 301: 0–+10/ FC 302: -10 to +10 V (scaleable)
Input resistance, R_i	approx. 10 kΩ
Max. voltage	± 20V
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	FC 301: 20 Hz/ FC 302: 100 Hz

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

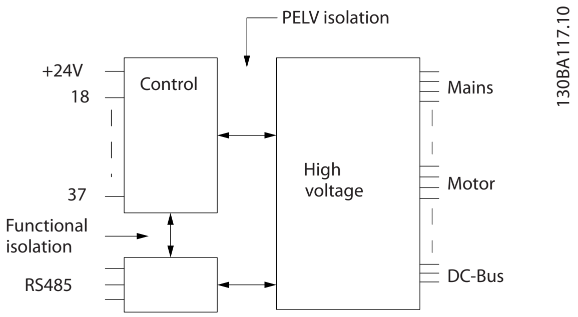


Figure 4.1

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	28V DC
Input resistance, R_i	approx. 4kΩ
Pulse input accuracy (0.1–1 kHz)	Max. error: 0.1% of full scale
Encoder input accuracy (1–11 kHz)	Max. error: 0.05% of full scale

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

[1] FC 302 only

[2] Pulse inputs are 29 and 33

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

Analog output:

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

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

Control card, RS-485 serial communication:

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

The RS-485 serial communication circuit is functionally separated from other central circuits and galvanically isolated from the supply voltage (PELV).

Digital output:

Programmable digital/pulse outputs	2
Terminal number	27, 29 [1]
Voltage level at digital/frequency output	0–24V
Max. output current (sink or source)	40mA
Max. load at frequency output	1kΩ
Max. capacitive load at frequency output	10nF
Minimum output frequency at frequency output	0Hz
Maximum output frequency at frequency output	32kHz
Accuracy of frequency output	Max. error: 0.1% of full scale
Resolution of frequency outputs	12 bit

[1] Terminal 27 and 29 can also be programmed as input.

The digital output is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

Control card, 24V DC output:

Terminal number	12, 13
Output voltage	24V +1, -3 V
Max. load	FC 301: 130mA/ FC 302: 200mA

The 24 V DC supply is galvanically isolated from the supply voltage (PELV), but has the same potential as the analog and digital inputs and outputs.

Relay outputs:

Programmable relay outputs	FC 301all 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)	240V AC, 2A
Max. terminal load (AC-15)[1] (Inductive load @ cosφ 0.4)	240V AC, 0.2A
Max. terminal load (DC-1)[1] on 1-2 (NO), 1-3 (NC) (Resistive load)	60V DC, 1A
Max. terminal load (DC-13)[1] (Inductive load)	24 V DC, 0.1A
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	400V AC, 2A
Max. terminal load (AC-15)[1] on 4-5 (NO) (Inductive load @ cosφ 0.4)	240V AC, 0.2A
Max. terminal load (DC-1)[1] on 4-5 (NO) (Resistive load)	80V DC, 2A
Max. terminal load (DC-13)[1] on 4-5 (NO) (Inductive load)	24 V DC, 0.1A
Max. terminal load (AC-1)[1] on 4-6 (NC) (Resistive load)	240V AC, 2A
Max. terminal load (AC-15)[1] on 4-6 (NC) (Inductive load @ cosφ 0.4)	240V AC, 0.2A
Max. terminal load (DC-1)[1] on 4-6 (NC) (Resistive load)	50V DC, 2A

Max. terminal load (DC-13)[1)] on 4-6 (NC) (Inductive load)	24 V DC, 0.1A
Min. terminal load on 1-3 (NC), 1-2 (NO), 4-6 (NC), 4-5 (NO)	24V DC 10mA, 24V AC 20mA
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 300V AC2A

Control card, 10V DC output:

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

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

Control characteristics:

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

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

Control card performance:

Scan interval	FC 301: 5 ms / FC 302: 1 ms

Surroundings:

Frame size A1A2, A3 and A5 (see *3.1 Product Overview* for power ratings)	IP 20, IP 55, IP 66
Frame size B1, B2, C1 and C2	IP 21, IP 55, IP 66
Frame size B3, B4, C3 and C4	IP 20
Frame size D1, D2, E1, F1, F2, F3 and F4	IP 21, IP 54
Frame size D3, D4 and E2	IP 00
Enclosure kit available ≤ 10 hp [7.5 kW]	IP21/TYPE 1/IP 4X top
Vibration test, frame size A, B and C	1.0 g RMS
Vibration test, frame size D, E and F	1 g
Max. relative humidity	5–95%(IEC 60 721-3-3; Class 3K3 (non-condensing) during operation
Aggressive environment (IEC 60068-2-43) H_2S test	class Kd
Test method according to IEC 60068-2-43 H2S (10 days)	
Ambient temperature, frame size A, B and C	Max. 122°F [50°C]
Ambient temperature, frame size D, E and F	Max. 113°F [45°C]

Derating for high ambient temperature, see section on special conditions

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	3280 ft [1000 m]

Derating for high altitude, see section on special conditions

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

See section on special conditions

Control card, USB serial communication:	
USB standard	1.1 (Full speed)
USB plug	USB type B "device" plug

Connection to PC is carried out via a standard host/device USB cable.
The USB connection is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.
The USB ground connection is not galvanically isolated from protection ground. Use only an isolated laptop as PC connection to the USB connector on the adjustable frequency drive.

4.6.1 Efficiency

Efficiency of the Adjustable frequency drive (η_{VLT})
The load on the Adjustable frequency drive has little effect on its efficiency. In general, the efficiency is the same at the rated motor frequency $f_{M,N}$, even if the motor supplies 100% of the rated shaft torque or only 75%, i.e., in case of part loads.

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

The efficiency declines a little when the switching frequency is set to a value greater than 5 kHz. The efficiency will also be slightly reduced if the AC line voltage is 480 V, or if the motor cable is longer than 98 ft [30 m].

Adjustable frequency drive efficiency calculation
Calculate the efficiency of the Adjustable frequency drive at different loads based on *Figure 4.2*. The factor in this graph must be multiplied with the specific efficiency factor listed in the specification tables:

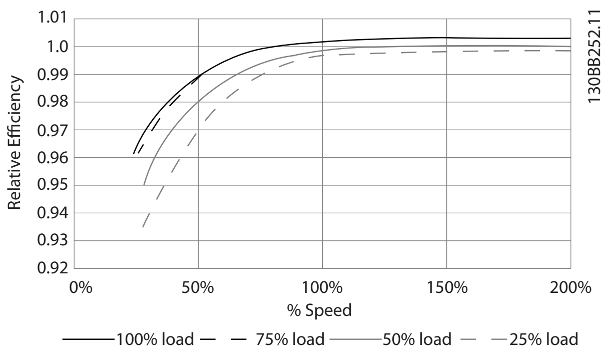


Figure 4.2 Typical Efficiency Curves

Example: Assume a 75 hp [55 kW], 380–480V AC Adjustable frequency drive at 25% load at 50% speed. The graph is showing 0.97 - rated efficiency for a 75 hp [55 kW] FC is 0.98. The actual efficiency is then: 0.97x0.98=0.95.

Efficiency of the motor (η_{MOTOR})
The efficiency of a motor connected to the adjustable frequency drive depends on magnetizing level. In general, the efficiency is just as good as with line power operation. The efficiency of the motor depends on the type of motor.

In the range of 75–100% of the rated torque, the efficiency of the motor is practically constant, both when it is controlled by the Adjustable frequency drive and when it runs directly on line power.

In small motors, the influence from the U/f characteristic on efficiency is marginal. However, in motors from 15 hp [11 kW] and up, the advantages are significant.

In general, 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.

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

4.7.1 Acoustic Noise

The acoustic noise from the adjustable frequency drive comes from three sources:

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

Typical values are measured at a distance of 3.28 ft. [1 m] from the unit:

Frame size	At reduced fan speed (50%) [dBA] ***	Full fan speed [dBA]
A1	51	60
A2	51	60
A3	51	60
A5	54	63
B1	61	67
B2	58	70
C1	52	62
C2	55	65
C4	56	71
D1+D3	74	76
D2+D4	73	74
E1/E2 *	73	74
E1/E2 **	82	83
F1/F2/F3/F4	78	80

* 250 kW, 380–500 VAC and 355–400 kW, 525–690 VAC only
** Remaining E1+E2 power sizes.
*** For D and E sizes, reduced fan speed is at 87%.

Table 4.28

4.8.1 du/dt Conditions

NOTE!

380–690 V
To avoid premature ageing of motors (without phase insulation paper or other insulation reinforcement) not designed for adjustable frequency drive operation, Danfoss strongly recommend to fit a du/dt filter or a sine-wave filter on the output of the adjustable frequency drive. For further information about du/dt and sine-wave filters, see the Output Filters Design Guide - MG.90.NY.XX.

When a transistor in the inverter bridge switches, the voltage across the motor increases by a du/dt ratio depending on:

- the motor cable (type, cross-section, length, shielded or unshielded)
- inductance

The natural induction causes an overshoot U_{PEAK} in the motor voltage before it stabilizes itself at a level depending on the voltage in the intermediate circuit. The rise time and the peak voltage U_{PEAK} affect the service life of the motor. If the peak voltage is too high, motors without phase coil insulation are especially affected. If the motor cable is short (by a few yards), the rise time and peak voltage are lower.
If the motor cable is long (328 ft. [100 m]), the rise time and peak voltage are higher.

Peak voltage on the motor terminals is caused by the switching of the IGBTs. The FC 300 complies with the demands of IEC 60034-25 regarding motors designed to be controlled by adjustable frequency drives. The FC 300 also complies with IEC 60034-17 regarding norm motors controlled by adjustable frequency drives.
Measured values from lab tests:

FC 300, P5K5T2				
Cable length [m]	AC line voltage [V]	Rise time [μsec]	Upeak [kV]	du/dt [kV/μsec]
5	240	0.13	0.510	3.090
50	240	0.23		2.034
100	240	0.54	0.580	0.865
150	240	0.66	0.560	0.674

Table 4.29

FC 300, P7K5T2				
Cable length [m]	AC line voltage [V]	Rise time [μsec]	Upeak [kV]	du/dt [kV/μsec]
36	240	0.264	0.624	1.890
136	240	0.536	0.596	0.889
150	240	0.568	0.568	0.800

Table 4.30

FC 300, P11KT2				
Cable length [m]	AC line voltage [V]	Rise time [μsec]	Upeak [kV]	du/dt [kV/μsec]
30	240	0.556	0.650	0.935
100	240	0.592	0.594	0.802
150	240	0.708	0.587	0.663

Table 4.31

FC 300, P15KT2				
Cable length [m]	AC line voltage [V]	Rise time [μsec]	Upeak [kV]	du/dt [kV/μsec]
36	240	0.244	0.608	1.993
136	240	0.568	0.580	0.816
150	240	0.720	0.574	0.637

Table 4.32

FC 300, P18KT2				
Cable length [m]	AC line voltage [V]	Rise time [μsec]	Upeak [kV]	du/dt [kV/μsec]
36	240	0.244	0.608	1.993
136	240	0.568	0.580	0.816
150	240	0.720	0.574	0.637

Table 4.33

FC 300, P22KT2				
Cable length [m]	AC line voltage [V]	Rise time [μsec]	Upeak [kV]	du/dt [kV/μsec]
15	240	0.194	0.626	2.581
50	240	0.252	0.574	1.822
150	240	0.488	0.538	0.882

Table 4.34

FC 300, P30KT2				
Cable length [m]	AC line voltage [V]	Rise time [μsec]	Upeak [kV]	du/dt [kV/μsec]
30	240	0.300	0.598	1.594
100	240	0.536	0.566	0.844
150	240	0.776	0.546	0.562

Table 4.35

FC 300, P37KT2				
Cable length [m]	AC line voltage [V]	Rise time [μsec]	Upeak [kV]	du/dt [kV/μsec]
30	240	0.300	0.598	1.594
100	240	0.536	0.566	0.844
150	240	0.776	0.546	0.562

Table 4.36

FC 300, P1K5T4				
Cable length [m]	AC line voltage [V]	Rise time [μsec]	Upeak [kV]	du/dt [kV/μsec]
5	480	0.640	0.690	0.862
50	480	0.470	0.985	0.985
150	480	0.760	1.045	0.947

Table 4.37

FC 300, P4K0T4				
Cable length [m]	AC line voltage [V]	Rise time [μsec]	Upeak [kV]	du/dt [kV/μsec]
5	480	0.172	0.890	4.156
50	480	0.310		2.564
150	480	0.370	1.190	1.770

Table 4.38

FC 300, P7K5T4				
Cable length [m]	AC line voltage [V]	Rise time [μsec]	Upeak [kV]	du/dt [kV/μsec]
5	480	0.04755	0.739	8.035
50	480	0.207		4.548
150	480	0.6742	1.030	2.828

Table 4.39

FC 300, P11KT4				
Cable length [m]	AC line voltage [V]	Rise time [μsec]	Upeak [kV]	du/dt [kV/μsec]
36	480	0.396	1.210	2.444
100	480	0.844	1.230	1.165
150	480	0.696	1.160	1.333

Table 4.40

FC 300, P15KT4				
Cable length [m]	AC line voltage [V]	Rise time [μsec]	Upeak [kV]	du/dt [kV/μsec]
36	480	0.396	1.210	2.444
100	480	0.844	1.230	1.165
150	480	0.696	1.160	1.333

Table 4.41

FC 300, P18KT4				
Cable length [m]	AC line voltage [V]	Rise time [μsec]	Upeak [kV]	du/dt [kV/μsec]
36	480	0.312		2.846
100	480	0.556	1.250	1.798
150	480	0.608	1.230	1.618

Table 4.42

FC 300, P22KT4				
Cable length [m]	AC line voltage [V]	Rise time [μsec]	Upeak [kV]	du/dt [kV/μsec]
15	480	0.288		3.083
100	480	0.492	1.230	2.000
150	480	0.468	1.190	2.034

Table 4.43

FC 300, P30KT4				
Cable length [m]	AC line voltage	Rise time [μsec]	Upeak [kV]	du/dt [kV/μsec]
5	480	0.368	1.270	2.853
50	480	0.536	1.260	1.978
100	480	0.680	1.240	1.426
150	480	0.712	1.200	1.334

Table 4.44

4

FC 300, P37KT4				
Cable length [m]	AC line voltage [V]	Rise time [μsec]	Upeak [kV]	du/dt [kV/μsec]
5	480	0.368	1.270	2.853
50	480	0.536	1.260	1.978
100	480	0.680	1.240	1.426
150	480	0.712	1.200	1.334

Table 4.45

FC 300, P45KT4				
Cable length [m]	AC line voltage [V]	Rise time [μsec]	Upeak [kV]	du/dt [kV/μsec]
15	480	0.256	1.230	3.847
50	480	0.328	1.200	2.957
100	480	0.456	1.200	2.127
150	480	0.960	1.150	1.052

Table 4.46

FC 300, P55KT5				
Cable length [m]	AC line voltage [V]	Rise time [μsec]	Upeak [kV]	du/dt [kV/μsec]
5	480	0.371	1.170	2.523

Table 4.47

FC 300, P75KT5				
Cable length [m]	AC line voltage [V]	Rise time [μsec]	Upeak [kV]	du/dt [kV/μsec]
5	480	0.371	1.170	2.523

Table 4.48

High Power range:

The power sizes below at the appropriate AC line voltages comply with the requirements of IEC 60034-17 regarding normal motors controlled by adjustable frequency drives, IEC 60034-25 regarding motors designed to be controlled by adjustable frequency drives, and NEMA MG 1-1998 Part 31.4.4.2 for inverter fed motors. The power sizes below do not comply with NEMA MG 1-1998 Part 30.2.2.8 for general purpose motors.

90–200 kW / 380–500V				
Cable length [m]	AC line voltage [V]	Rise time [μs]	Peak voltage [V]	du/dt [V/μs]
30 m	400	0.34	1040	2447

Table 4.49

250–800 kW / 380–500V				
Cable length [m]	AC line voltage [V]	Rise time [μs]	Peak voltage [V]	du/dt [V/μs]
30	500	0.71	1165	1389
30	500 1)	0.80	906	904
30	400	0.61	942	1233
30	400 1)	0.82	760	743
1) With Danfoss du/dt filter				

Table 4.50

90–315 kW/ 525–690V				
Cable length [m]	AC line voltage [V]	Rise time [μs]	Peak voltage [V]	du/dt [V/μs]
30	690	0.38	1573	3309
30	690 1)	1.72	1329	640
30	575	0.23	1314	2750
30	575 2)	0.72	1061	857
1) With Danfoss du/dt filter 2) With du/dt filter				

Table 4.51

355–1200 kW / 525–690V				
Cable length [m]	AC line voltage [V]	Rise time [μs]	Peak voltage [V]	du/dt [V/μs]
30	690	0.57	1611	2261
30	575	0.25		2510
30	690 1)	1.13	1629	1150
1) With Danfoss du/dt filter.				

Table 4.52

4.9 Special Conditions

Under some special conditions, where the operation of the drive is challenged, derating must be taken into account. In some conditions, derating must be done manually.
In other conditions, the drive automatically performs a degree of derating when necessary. This is done in order to ensure the performance at critical stages where the alternative could be a trip.

4.9.1 Manual Derating

Manual derating must be considered for:

- Air pressure – relevant for installation at altitudes above 0.6 miles [1 km]
- Motor speed – at continuous operation at low RPM in constant torque applications
- Ambient temperature – relevant for ambient temperatures above 122°F [50°C]

See application note MN.33.FX.YY for tables and elaboration. Only the case of running at low motor speeds is elaborated here.

4.9.1.1 Derating for Running at Low Speed

When a motor is connected to a 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).

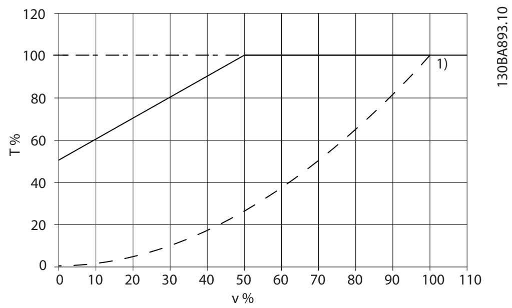
An alternative is to reduce the load level of the motor by choosing a larger motor. However, the design of the Adjustable frequency drive puts a limit to the motor size.

Variable (quadratic) torque applications (VT)

In VT applications such as centrifugal pumps and fans, where the torque is proportional to the square of the speed and the power is proportional to the cube of the speed, there is no need for additional cooling or de-rating of the motor.

In the graphs shown below, the typical VT curve is below the maximum torque with de-rating and maximum torque with forced cooling at all speeds.

Maximum load for a standard motor at 104°F [40°C] driven by a Adjustable frequency drive type VLT FCxxx



Legend: – – – –Typical torque at VT load –•–•– Max torque with forced cooling ——Max torque

Note 1) Oversynchronous speed operation will result in the available motor torque decreasing inversely proportional to the increase in speed. This must be considered during the design phase to avoid overloading the motor.

Table 4.53

4.9.2 Automatic Derating

The drive constantly checks for critical levels:

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

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

NOTE!

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

5 How to Order

5.1.1 Ordering from Type Code

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

130BB836.10

Table 5.1

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

Table 5.2

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

5.1.2 Drive Configurator

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

For the FC 300 series, you can order standard drives and drives with integral options by sending a type code string describing the product to the local Danfoss sales office, e.g.:

FC-302PK75T5E20H1BGCXXXSXXXXA0BXCXXXXD0

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

From the Internet-based drive configurator, you can configure the right drive for the right application and generate the type code string. The drive configurator will automatically generate an eight-digit sales number to be delivered to your local sales office.
Furthermore, you can establish a project list with several products and send it to a Danfoss sales representative.

The drive configurator can be found on the Danfoss homepage: www.danfoss.com/drives.

Drives will automatically be delivered with a language package relevant to the region from which it is ordered. Four regional language packages cover the following languages:
Language package 1
English, German, French, Danish, Dutch, Spanish, Swedish, Italian and Finnish.

5

Language package 2
English, German, Chinese, Korean, Japanese, Thai, Traditional Chinese and Bahasa Indonesian.
Language package 3
English, German, Slovenian, Bulgarian, Serbian, Romanian, Hungarian, Czech and Russian.
Language package 4
English, German, Spanish, English US, Greek, Brazilian Portuguese, Turkish and Polish.
To order drives with a different language package, please contact your local sales office.

Ordering type codemodel number frame sizes A, B and C		
Description	Pos	Possible choice
Product group	1-3	FC 30x
Drive series	4-6	301:FC 301 302: FC 302
Power rating	8-10	0.34–100 hp [0.25–75 kW]
Phases	11	Three phases (T)
AC line voltage	11-12	T 2: 200–240V AC T 4: 380–480V AC T 5: 380-500V AC T 6: 525–600V AC T 7: 525–690V AC
Enclosure	13-15	E20: IP20 E55: IP 55/NEMA Type 12 P20: IP20 (with backplate) P21: IP21/ NEMA Type 1 (with backplate) P55: IP55/ NEMA Type 12 (with backplate) Z20: IP 20[1)] E66: IP 66
RFI filter	16-17	H1: RFI filter class A1/B1 H2: No RFI filter, observes class A2 H3: RFI filter class A1/B1[1)] H6: RFI filter Maritime use[1)] HX: No filter (600V only)
Brake	18	B: Brake chopper included X: No brake chopper included T: Safe Stop No brake[1)] U: Safe stop brake chopper[1)]
Display	19	G: Graphical Local Control Panel (LCP) N: Numerical Local Control Panel (LCP) X: No Local Control Panel
Coating PCB	20	C: Coated PCB X. No coated PCB
Line power option	21	X: No AC line option 1: Line power disconnect 3: Line power disconnect and Fuse[2)] 5: Line power disconnect, fuse and load sharing[2, 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 (A5, B1, B2, C1, C2 only)
Adaptation	23	X: No adaptation
Software release	24-27	SXXX: Latest release - standard software
Software language	28	X: Not used
1): FC 301/ frame sizeA1 only 2) US Market only 3): A and B frames have load sharing built-in by default		

Table 5.3

Ordering type codemodel number frame sizes D and E		
Description	Pos	Possible choice
Product group	1-3	301: FC 302
Drive series	4-6	302: FC 302
Power rating	8-10	50–750 hp [37–560 kW]
Phases	11	Three phases (T)
AC line voltage	11-12	T 5: 380-500V AC T 7: 525–690V AC
Enclosure	13-15	E00: IP00/Chassis C00: IP00/Chassis w/ stainless steel back channel E0D: IP00/Chassis, D3 P37K-P75K, T7 C0D: IP00/Chassis w/ stainless steel back channel, D3 P37K-P75K, T7 E21: IP 21/ NEMA Type 1 E54: IP 54/ NEMA Type 12 E2D: IP 21/ NEMA Type 1, D1 P37K-P75K, T7 E5D: IP 54/ NEMA Type 12, D1 P37K-P75K, T7 E2M: IP 21/ NEMA Type 1 with line power shield E5M: IP 54/ NEMA Type 12 with line power shield
RFI filter	16-17	H2: RFI filter, class A2 (standard) H4: RFI filter class A1[1)] H6: RFI filter Maritime use[2)] L2: Low Harmonic Drive with RFI filter, class A2 L4: Low Harmonic Drive with RFI filter, class A1 B2: 12-pulse drive with RFI filter, class A2 B4: 12-pulse drive with RFI filter, class A1
Brake	18	B: Brake IGBT mounted X: No brake IGBT R: Regeneration terminals (E frames only)
Display	19	G: Graphical Local Control Panel LCP N: Numerical Local Control Panel (LCP) X: No Local Control Panel (D frames IP00 and IP 21 only)
Coating PCB	20	C: Coated PCB X. No coated PCB (D frames 380–480/500V only)
Line power option	21	X: No line power option 3: Line power disconnect and fuse 5: Line power disconnect, fuse and load sharing 7: Fuse A: Fuse and load sharing D: Load sharing
Adaptation	22	X: Standard cable entries
Adaptation	23	X: No adaptation
Software release	24-27	Current software
Software language	28	
1): Available for all D frames. E frames 380–480/500V only 2) Consult factory for applications requiring maritime certification		

Table 5.4

Ordering type codemodel number frame size F		
Description	Pos	Possible choice
Product group	1-3	FC 302
Drive series	4-6	FC 302
Power rating	8-10	600–1600 hp [450–1200 kW]
Phases	11	Three phases (T)
AC line voltage	11-12	T 5: 380-500V AC T 7: 525–690V AC
Enclosure	13-15	C21: IP21/NEMA Type 1 with stainless steel back channel C54: IP54/Type 12 Stainless steel back channel E21: IP 21/ NEMA Type 1 E54: IP 54/ NEMA Type 12 L2X: IP21/NEMA 1 with cabinet light & IEC 230V power outlet L5X: IP54/NEMA 12 with cabinet light & IEC 230V power outlet L2A: IP21/NEMA 1 with cabinet light & NAM 115V power outlet L5A: IP54/NEMA 12 with cabinet light & NAM 115V power outlet H21: IP21 with space heater and thermostat H54: IP54 with space heater and thermostat R2X: IP21/NEMA1 with space heater, thermostat, light & IEC 230V outlet R5X: IP54/NEMA12 with space heater, thermostat, light & IEC 230V outlet R2A: IP21/NEMA1 with space heater, thermostat, light, & NAM 115V outlet R5A: IP54/NEMA12 with space heater, thermostat, light, & NAM 115V outlet
RFI filter	16-17	H2: RFI filter, class A2 (standard) H4: RFI filter, class A1[2, 3] HE: RCD with Class A2 RFI filter[2] HF: RCD with class A1 RFI filter[2, 3] HG: IRM with Class A2 RFI filter[2] HH: IRM with class A1 RFI filter[2, 3] HJ: NAMUR terminals and class A2 RFI filter[1] HK: NAMUR terminals with class A1 RFI filter[1, 2, 3] HL: RCD with NAMUR terminals and class A2 RFI filter[1, 2] HM: RCD with NAMUR terminals and class A1 RFI filter[1, 2, 3] HN: IRM with NAMUR terminals and class A2 RFI filter[1, 2] HP: IRM with NAMUR terminals and class A1 RFI filter[1, 2, 3] N2: Low Harmonic Drive with RFI filter, class A2 N4: Low Harmonic Drive with RFI filter, class A1 B2: 12-pulse drive with RFI filter, class A2 B4: 12-pulse drive with RFI filter, class A1 BE: 12-pulse + RCD for TN/TT line power + Class A2 RFI BF: 12-pulse + RCD for TN/TT line power + Class A1 RFI BG: 12-pulse + IRM for IT line power + Class A2 RFI BH: 12-pulse + IRM for IT line power + Class A1 RFI BM: 12-pulse + RCD for TN/TT line power + NAMUR Terminals + Class A1 RFI*
Brake	18	B: Brake IGBT mounted X: No brake IGBT C: Safe Stop with Pilz Relay D: Safe Stop with Pilz Safety Relay & Brake IGBT R: Regeneration terminals M: IEC Emergency stop push-button (with Pilz safety relay)[4] N: IEC Emergency stop push-button with brake IGBT and brake terminals [4] P: IEC Emergency stop push-button with regeneration terminals[4]
Display	19	G: Graphical Local Control Panel LCP
Coating PCB	20	C: Coated PCB
Line power option	21	X: No AC line option 3[2]: Line power disconnect and fuse 5[2]: Line power disconnect, fuse and load sharing 7: Fuse A: Fuse and load sharing D: Load sharing E: Line power disconnect, contactor & fuses2) F: Line power circuit breaker, contactor & fuses 2) G: Line power disconnect, contactor, load sharing terminals & fuses2) H: Line power circuit breaker, contactor, load sharing terminals & fuses2) J: Line power circuit breaker & fuses 2) K: Line power circuit breaker, load sharing terminals & fuses 2)
* Requires MCB 112 and MCB 113		

Table 5.5

Description	Pos	Possible choice
Power Terminals & Motor Starters	22	X: No option E 30 A, fuse-protected power terminals F: 30A, fuse-protected power terminals & 2.5-4 A manual motor starter G: 30A, fuse-protected power terminals & 4-6.3 A manual motor starter H: 30A, fuse-protected power terminals & 6.3-10 A manual motor starter J: 30A, fuse-protected power terminals & 10-16 A manual motor starter K: Two 2.5-4 A manual motor starters L: Two 4-6.3 A manual motor starters M: Two 6.3-10 A manual motor starters N: Two 10-16 A manual motor starters
Auxiliary 24 V Supply & External Temperature Monitoring	23	X: No option H: 5A, 24V power supply (customer use) J: External temperature monitoring G: 5A, 24V power supply (customer use) & external temperature monitoring
Software release	24-27	Current software
	24-28	S023: 316 Stainless Steel Backchannel - high power drives only
Software language	28	
1) MCB 113 Extended Relay Card and MCB 112 PTC Thermistor Card required for NAMUR terminals 2) F3 and F4 frames only 3) 380–480/500V only 4) Requires contactor		

Table 5.6

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

Table 5.7

5.2.1 Ordering Numbers: Options and Accessories

Type	Description	Ordering no.	
Miscellaneous hardware			
A5 panel through kit	Panel through kit for frame size A5	130B1028	
B1 panel through kit	Panel through kit for frame size B1	130B1046	
B2 panel through kit	Panel through kit for frame size B2	130B1047	
C1 panel through kit	Panel through kit for frame size C1	130B1048	
C2 panel through kit	Panel through kit for frame size C2	130B1049	
MCF 1xx kit	Mounting brackets frame size A5	130B1080	
MCF 1xx kit	Mounting brackets frame size B1	130B1081	
MCF 1xx kit	Mounting brackets frame size B2	130B1082	
MCF 1xx kit	Mounting brackets frame size C1	130B1083	
MCF 1xx kit	Mounting brackets frame size C2	130B1084	
IP 21/4X top/TYPE 1 kit	Enclosure, frame size A1: IP 21/IP 4X Top/TYPE 1	130B1121	
IP 21/4X top/TYPE 1 kit	Enclosure, frame size A2: IP 21/IP 4X Top/TYPE 1	130B1122	
IP 21/4X top/TYPE 1 kit	Enclosure, frame sizeA3: IP 21/IP 4X Top/TYPE 1	130B1123	
MCF 101 IP21 Kit	IP21/NEMA 1 enclosure Top Cover A2	130B1132	
MCF 101 IP21 Kit	IP21/NEMA 1 enclosure Top Cover A3	130B1133	
MCF 108 Backplate	A5 IP 55/ NEMA 12	130B1098	
MCF 108 Backplate	B11 IP21/ IP55/ NEMA 12	130B3383	
MCF 108 Backplate	B2 IP21/ IP55/ NEMA 12	130B3397	
MCF 108 Backplate	B4 IP20/Chassis	130B4172	
MCF 108 Backplate	C1 IP21/ IP55/ NEMA 12	130B3910	
MCF 108 Backplate	C2 IP21/ IP55/ NEMA 12	130B3911	
MCF 108 Backplate	C3 IP20/Chassis	130B4170	
MCF 108 Backplate	C4 IP20/Chassis	130B4171	
MCF 108 Backplate	A5 IP66/ NEMA 4x stainless steel	130B3242	
MCF 108 Backplate	B1 IP66/ NEMA 4x stainless steel	130B3434	
MCF 108 Backplate	B2 IP66/ NEMA 4x stainless steel	130B3465	
MCF 108 Backplate	C1 IP66/ NEMA 4x stainless steel	130B3468	
MCF 108 Backplate	C2 IP66/ NEMA 4x stainless steel	130B3491	
Profibus top entry	Top entry for D and E frame, enclosure type IP 00 and IP21	176F1742	
Profibus D-Sub 9	D-Sub connector kit for IP20, frame sizes A1, A2 and A3	130B1112	
Profibus shield plate	Profibus shield plate kit for IP20, frame sizes A1, A2 and A3	130B0524	
DC link connector	Terminal block for DC link connection on frame size A2/A3	130B1064	
Terminal blocks	Screw terminal blocks for replacing spring loaded terminals 1 x 10-pin, 1 x 6-pin and 1 x 3-pin connectors	130B1116	
USB cable extension for A5/ B1		130B1155	
USB cable extension for B2/ C1/ C2		130B1156	
Foot-mount frame for flat pack resistors, frame size A2		175U0085	
Foot-mount frame for flat pack resistors, frame size A3		175U0088	
Foot-mount frame for 2 flat pack resistors, frame size A2		175U0087	
Foot-mount frame for 2 flat pack resistors, frame size A3		175U0086	
Ordering numbers for duct cooling kits, NEMA 3R kits, pedestal kits, input plate option kits and Line Power Shield can be found in section High Power Options			
LCP			
LCP 101	Numerical Local Control Panel (NLCP)	130B1124	
LCP 102	Graphical Local Control Panel (GLCP)	130B1107	
LCP cable	Separate LCP cable, 9.8 ft [3 m]	175Z0929	
LCP kit, IP21	Panel mounting kit including graphical LCP, fasteners, 9.8 ft [3 m] cable and gasket	130B1113	
LCP kit, IP21	Panel mounting kit including numerical LCP, fasteners and gasket	130B1114	
LCP kit, IP21	Panel mounting kit for all LCPs including fasteners, 9.8 ft [3 m] cable and gasket	130B1117	
Options for Slot A		**Uncoated**	**Coated**
MCA 101	Profibus option DP V0/V1	130B1100	130B1200
MCA 104	DeviceNet option	130B1102	130B1202
MCA 105	CANopen	130B1103	130B1205
MCA 113	Profibus VLT3000 protocol drive	130B1245	
Options for Slot B			
MCB 101	General purpose Input Output option	130B1125	130B1212
MCB 102	Encoder option	130B1115	130B1203
MCB 103	Resolver option	130B1127	130B1227
MCB 105	Relay option	130B1110	130B1210
MCB 108	Safety PLC interface (DC/DC drive)	130B1120	130B1220
MCB 112	ATEX PTC Thermistor Card		130B1137

Table 5.8

Type	Description	Ordering no.	
Mounting Kits			
Mounting kit for frame size A2 and A3 (1.57 in [40 mm] for one C option)		130B7530	
Mounting kit for frame size A2 and A3 (2.36 in [60 mm] for C0 + C1 option)		130B7531	
Mounting kit for frame size A5		130B7532	
Mounting kit for frame size B, C, D, E and F (except B3)		130B7533	
Mounting kit for frame size B3 (1.57 in [40 mm] for one C option)		130B1413	
Mounting kit for frame size B3 (2.36 in [60 mm] for C0 + C1 option)		130B1414	
Options for Slot C			
MCO 305	Programmable Motion Controller	130B1134	130B1234
MCO 350	Synchronizing controller	130B1152	130B1252
MCO 351	Positioning controller	130B1153	120B1253
MCO 352	Center Winder Controller	130B1165	130B1166
MCB 113	Extended Relay Card	130B1164	130B1264
Option for Slot D			
MCB 107	24V DC backup	130B1108	130B1208
External Options			
Ethernet IP	Ethernet master	175N2584	
PC Software			
MCT 10	MCT 10 Set-up software - 1 user	130B1000	
MCT 10	MCT 10 Set-up software - 5 users	130B1001	
MCT 10	MCT 10 Set-up software - 10 users	130B1002	
MCT 10	MCT 10 Set-up software - 25 users	130B1003	
MCT 10	MCT 10 Set-up software - 50 users	130B1004	
MCT 10	MCT 10 Set-up software - 100 users	130B1005	
MCT 10	MCT 10 Set-up software - unlimited users	130B1006	
Options can be ordered as factory built-in options, see ordering information. For information on serial communication bus and application option compatibility with older software versions, please contact your Danfoss supplier.			

Table 5.9

5.2.2 Ordering Numbers: Spare Parts

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

Table 5.10

5.2.3 Ordering Numbers: Accessory Bags

Type	Description	Ordering no.
Accessory Bags		
Accessory bag A1	Accessory bag, frame size A1	130B1021
Accessory bag A2/A3	Accessory bag, frame size A2/A3	130B1022
Accessory bag A5	Accessory bag, frame size A5	130B1023
Accessory bag A1–A5	Accessory bag, frame size A1-A5 Brake and load sharing connector	130B0633
Accessory bag B1	Accessory bag, frame size B1	130B2060
Accessory bag B2	Accessory bag, frame size B2	130B2061
Accessory bag B3	Accessory bag, frame size B3	130B0980
Accessory bag B4	Accessory bag, frame size B4, 25–30 hp [18.5–22 kW]	130B1300
Accessory bag B4	Accessory bag, frame size B4, 40 hp [30 kW]	130B1301
Accessory bag C1	Accessory bag, frame size C1	130B0046
Accessory bag C2	Accessory bag, frame size C2	130B0047
Accessory bag C3	Accessory bag, frame size C3	130B0981
Accessory bag C4	Accessory bag, frame size C4, 75 hp [55 kW]	130B0982
Accessory bag C4	Accessory bag, frame size C4, 100 hp [75 kW]	130B0983

Table 5.11

5.2.4 Ordering Numbers: High Power Kits

Kit	Description	Ordering Number	Instruction Number
NEMA-3R (Rittal Enclosures)	D3 Frame	176F4600	175R5922
	D4 Frame	176F4601	
	E2 Frame	176F1852	
NEMA-3R (Welded Enclosures)	D3 Frame	176F0296	175R1068
	D4 Frame	176F0295	
	E2 Frame	176F0298	
Pedestal	D Frames	176F1827	175R5642
Back Channel Duct Kit	D3 5.9 ft [1800 mm]	176F1824	175R5640
(Top & Bottom)	D4 5.9 ft [1800 mm]	176F1823	
	D3 78.7 in [2000 mm]	176F1826	
	D4 78.7 in [2000 mm]	176F1825	
	E2 78.7 in [2000 mm]	176F1850	
	E2 7.2 ft [2200 mm]	176F0299	
Back Channel Duct Kit	D3/D4 Frames	176F1775	175R1107
(Top Only)	E2 Frame	176F1776	
IP00 Top & Bottom Covers	D3/D4 Frames	176F1862	175R1106
(Welded Enclosures)	E2 Frame	176F1861	
IP00 Top & Bottom Covers	D3 Frames	176F1781	177R0076
(Rittal Enclosures)	D4 Frames	176F1782	
	E2 Frame	176F1783	
IP00 Motor Cable Clamp	D3 Frame	176F1774	175R1109
	D4 Frame	176F1746	
	E2 Frame	176F1745	
IP00 Terminal Cover	D3/D4 Frame	176F1779	175R1108
line Power Shield	D1/D2 Frames	176F0799	175R5923
	E1 Frame	176F1851	
Input Plates	See Instr		175R5795
Load share	D1/D3 Frame	176F8456	175R5637
	D2/D4 Frame	176F8455	
Top Entry Sub D or Shield Termination	D3/D4/E2 Frames	176F1884	175R5964
IP00 to IP20 Kits	D3/D4 Frames	176F1779	175R1108
	E2 Frames	176F1884	
USB Extension Kit	D Frames	130B1155	177R0091
	E Frames	130B1156	
	F Frames	176F1784	

Table 5.12

5

5.2.5 Ordering Numbers: Brake Resistors 10%

FC 301 - Line power: 200–240 V (T2) - 10% Duty Cycle

FC 301	$P_{m\ (HO)}$	R_{min}	$R_{br,\ nom}$	R_{rec}	$P_{br\ avg}$	Order no.	Period	Cable cross-section[2]*	Therm. relay	Max. brake torque with Rrec*
T2	[kW]	[Ω]	[Ω]	[Ω]	[kW]	175Uxxxx	[s]	[mm2]	[A]	[%]
PK25	0.25	368	408	425	0.095	1841	120	1.5	0.5	154 (160)
PK37	0.37	248	276	310	0.25	1842	120	1.5	0.9	142 (160)
PK55	0.55	166	185	210	0.285	1843	120	1.5	1.2	141 (160)
PK75	0.75	121	135	145	0.065	1820	120	1.5	0.7	149 (160)
P1K1	1.1	81	91.4	90	0.095	1821	120	1.5	1	160 (160)
P1K5	1.5	58.5	66.2	65	0.25	1822	120	1.5	2	160 (160)
P2K2	2.2	40.2	44.6	50	0.285	1823	120	1.5	2.4	143 (160)
P3K0	3	29.1	32.4	35	0.43	1824	120	1.5	2.5	148 (160)
P3K7	3.7	22.5	25.9	25	0.8	1825	120	1.5	5.7	160 (160)

Table 5.13

FC 302 - Line power: 200–240 V (T2) - 10% Duty Cycle

FC 302	$P_{m\ (HO)}$	R_{min}	$R_{br,\ nom}$	R_{rec}	$P_{br\ avg}$	Order no.	Period	Cable cross-section[2]*	Therm. relay	Max. brake torque with Rrec*
T2	[kW]	[Ω]	[Ω]	[Ω]	[kW]	175Uxxxx	[s]	[mm2]	[A]	[%]
PK25	0.25	382	467	425	0.095	1841	120	1.5	0.5	160 (160)
PK37	0.37	279	315	310	0.25	1842	120	1.5	0.9	160 (160)
PK55	0.55	189	211	210	0.285	1843	120	1.5	1.2	160 (160)
PK75	0.75	130	154	145	0.065	1820	120	1.5	0.7	160 (160)
P1K1	1.1	81	104	90	0.095	1821	120	1.5	1	160 (160)
P1K5	1.5	58.5	75.7	65	0.25	1822	120	1.5	2	160 (160)
P2K2	2.2	45	51	50	0.285	1823	120	1.5	2.4	160 (160)
P3K0	3	31.5	37	35	0.43	1824	120	1.5	2.5	160 (160)
P3K7	3.7	22.5	29.6	25	0.8	1825	120	1.5	5.7	160 (160)

Table 5.14

FC 301/FC 302 - Line Power: 200–240 V (T2) - 10% Duty Cycle

AutomationDrive FC 301/FC 302	P_m (HO)	R_{min}	$R_{br.\ nom}$	R_{rec}	$P_{br\ avg}$	Order no.	Period	Cable cross-section[2]*	Therm. relay	Max. brake torque with R_{rec}*
T2	[kW]	[Ω]	[Ω]	[Ω]	[kW]	175Uxxxx	[s]	[mm2]	[A]	[%]
P5K5	5.5	18	20	20	1	1826	120	1.5	7.1	158 (160)
P7K5	7.5	13	14	15	2	1827	120	1.5	11	153 (160)
P11K	11	9	10	10	2.8	1828	120	2.5	17	154 (160)
P15K	15	6	7	7	4	1829	120	4	24	150 (150)
P18K	18.5	5.1	6	6	4.8	1830	120	4	28	150 (150)
P22K	22	4.2	5	4.7	6	1954	300	10	36	150 (150)
P30K	30	3	3.7	3.3	8	1955	300	10	49	150 (150)
P37K	37	2.4	3	2.7	10	1956	300	16	61	150 (150)

Table 5.15

FC 301 - Line power: 380–480 V (T4) - 10% Duty Cycle

FC 301	$P_{m\ (HO)}$	R_{min}	$R_{br.\ nom}$	R_{rec}	$P_{br\ avg}$	Order no.	Period	Cable cross-section[2]*	Therm. relay	Max. brake torque with R_{rec}*
T4	[kW]	[Ω]	[Ω]	[Ω]	[kW]	175Uxxxx	[s]	[mm2]	[A]	[%]
PK37	0.37	620	1098	620	0.065	1840	120	1.5	0.3	160 (160)
PK55	0.55	620	739	620	0.065	1840	120	1.5	0.3	160 (160)
PK75	0.75	485	539	620	0.065	1840	120	1.5	0.3	139 (160)
P1K1	1.1	329	366	425	0.095	1841	120	1.5	0.5	138 (160)
P1K5	1.5	240	266	310	0.25	1842	120	1.5	0.9	138 (160)
P2K2	2.2	161	179	210	0.285	1843	120	1.5	1.2	137 (160)
P3K0	3	117	130	150	0.43	1844	120	1.5	1.7	139 (160)
P4K0	4	87	97	110	0.6	1845	120	1.5	2.3	140 (160)
P5K5	5.5	63	69	80	0.85	1846	120	1.5	3.3	139 (160)
P7K5	7.5	45	50	65	1	1847	120	1.5	3.9	124 (160)
P11K	11	34.9	38.8	40	1.8	1848	120	1.5	7.1	155 (160)
P15K	15	25.3	28.1	30	2.8	1849	120	1.5	9.7	150 (160)
P18K	18.5	20.3	22.6	25	3.5	1850	120	1.5	12	144 (160)
P22K	22	16.9	18.8	20	4	1851	120	1.5	14	150 (160)
P30K	30	13.2	14.7	15	4.8	1852	120	2.5	18	147 (150)
P37K	37	11	12	12	5.5	1853	120	2.5	21	147 (150)
P45K	45	9	10	9.8	15	2008	120	10	39	148 (150)
P55K	55	7	8	7.3	13	0069	120	10	42	150 (150)
P55K	55	6.6	7.9	5.7	14	1958	300	10	50	150 (150)
P75K	75	6.6	5.7	6.3	15	0067	120	10	49	150 (150)
P75K	75	4.2	5.7	4.7	18	1959	300	16	62	150 (150)
P75K	75	4.2	5.7	4.7	29	0077	600	16	79	150 (150)

Table 5.16

FC 302 - Line power: 380–500 V (T5) - 10% Duty Cycle

FC 302	$P_{m\ (HO)}$	R_{min}	$R_{br,\ nom}$	R_{rec}	$P_{br\ avg}$	Order no.	Period	Cable cross-section[2]*	Therm. relay	Max. brake torque with R_{rec}*
T5	[kW]	[Ω]	[Ω]	[Ω]	[kW]	175Uxxxx	[s]	[mm2]	[A]	[%]
PK37	0.37	620	1360	620	0.065	1840	120	1.5	0.3	160 (160)
PK55	0.55	620	915	620	0.065	1840	120	1.5	0.3	160 (160)
PK75	0.75	620	668	620	0.065	1840	120	1.5	0.3	160 (160)
P1K1	1.1	425	453	425	0.095	1841	120	1.5	0.5	160 (160)
P1K5	1.5	310	330	310	0.25	1842	120	1.5	0.9	160 (160)
P2K2	2.2	210	222	210	0.285	1843	120	1.5	1.2	160 (160)
P3K0	3	150	161	150	0.43	1844	120	1.5	1.7	160 (160)
P4K0	4	110	120	110	0.6	1845	120	1.5	2.3	160 (160)
P5K5	5.5	80	86	80	0.85	1846	120	1.5	3.3	160 (160)
P7K5	7.5	65	62	65	1	1847	120	1.5	3.9	160 (160)
P11K	11	40	42.1	40	1.8	1848	120	1.5	7.1	160 (160)
P15K	15	30	30.5	30	2.8	1849	120	1.5	9.7	160 (160)
P18K	18.5	25	24.5	25	3.5	1850	120	1.5	12	160 (160)
P22K	22	20	20.3	20	4	1851	120	1.5	14	150 (160)
P30K	30	15	15.9	15	4.8	1852	120	2.5	18	150 (150)

5

FC 302	$P_{m\ (HO)}$	R_{min}	$R_{br,\ nom}$	R_{rec}	$P_{br\ avg}$	Order no.	Period	Cable cross-section2*	Therm. relay	Max. brake torque with R_{rec}*
P37K	37	12	13	12	5.5	1853	120	2.5	21	150 (150)
P45K	45	10	10	9.8	15	2008	120	10	39	150 (150)
P55K	55	7	9	7.3	13	0069	120	10	42	150 (150)
P55K	55	7.3	8.6	7.3	14	1958	300	10	50	150 (150)
P75K	75	4.7	6.2	4.7	15	0067	120	10	49	150 (150)
P75K	75	4.7	6.2	4.7	18	1959	300	16	62	150 (150)
P75K	75	4.7	6.2	4.7	29	0077	600	16	79	150 (150)
P90K	90	3.8	5.2	3.8	22	1960	300	25	76	150 (150)
P90K	90	3.8	5.2	3.8	36	0078	600	35	97	150 (150)
P110	110	3.2	4.2	3.2	27	1961	300	35	92	150 (150)
P110	110	3	4	3.2	42	0079	600	50	115	150 (150)
P132	132	3	3.5	2.6	32	1962	300	50	111	150 (150)
P160	160	2	2.9	2.1	39	1963	300	70	136	150 (150)
P200	200	2	3	6.6 / 2 = 3.3	28 x 2 = 56	2 x 1061 3*	300	2 x 50 5*	130 4*	106 (150)
P200	200	1.6	2.3	6.6 / 3 = 2.2	28 x 3 = 84	3 x 1061 3*	300	3 x 50 5*	130 4*	150 (150)
P250	250	2.6	1.9	5.2 / 2 = 2.6	36 x 2 = 72	3 x 1062 3*	300	3 x 70 5*	166 4*	108 (150)
P250	250	2.6	1.9	4.2 / 3 = 1.4	50 x 3 = 150	3 x 1064 3*	300	3 x 120 5*	218 4*	150 (150)
P315	315	2.3	1.5	4.2 / 3 = 1.4	50 x 3 = 150	3 x 1064 3*	300	3 x 120 5*	218 4*	97 (150)
P315	315	2.3	1.5	4.2 / 3 = 1.4	50 x 3 = 150	3 x 1064 3*	300	3 x 120 5*	218 4*	150 (150)
P355	355	2.1	1.3	4.2 / 3 = 1.4	50 x 3 = 150	3 x 1064 3*	300	3 x 120 5*	218 4*	94 (150)
P355	355	2.1	1.3	4.2 / 3 = 1.4	50 x 3 = 150	3 x 1064 3*	300	3 x 120 5*	218 4*	150 (150)
P400	400	1.2	1.3	4.2 / 3 = 1.4	50 x 3 = 150	3 x 1064 3*	300	3 x 120 5*	218 4*	135 (135)
P450	450	1.2	1.3	4.2 / 3 = 1.4	50 x 3 = 150	3 x 1064 3*	300	3 x 120 5*	218 4*	120 (120)
P500	500	1.2	1.3	4.2 / 3 = 1.4	50 x 3 = 150	3 x 1064 3*	300	3 x 120 5*	218 4*	108 (108)
P560	560	1.2	1.3	4.2 / 3 = 1.4	50 x 3 = 150	3 x 1064 3*	300	3 x 120 5*	218 4*	96 (96)
P630	630	1.2	1.3	4.2 / 3 = 1.4	50 x 3 = 150	3 x 1064 3*	300	3 x 120 5*	218 4*	85 (85)
P710	710	1.2	1.3	4.2 / 3 = 1.4	50 x 3 = 150	3 x 1064 3*	300	3 x 120 5*	218 4*	76 (76)
P800	800	1.2	1.3	4.2 / 3 = 1.4	50 x 3 = 150	3 x 1064 3*	300	3 x 120 5*	218 4*	67 (67)
P1M0	1000	1.2	1.3	4.2 / 3 = 1.4	50 x 3 = 150	3 x 1064 3*	300	3 x 120 5*	218 4*	54 (54)

Table 5.17

FC 302 - Line power: 525–600 V (T6) - 10% Duty Cycle

FC 302	$P_{m\ (HO)}$	R_{min}	$R_{br,\ nom}$	R_{rec}	$P_{br\ avg}$	Order no.	Period	Cable cross-section2*	Therm. relay	Max. brake torque with R_{rec}*
T6	[kW]	[Ω]	[Ω]	[Ω]	[kW]	175Uxxxx	[s]	[mm2]	[A]	[%]
PK75	0.75	620	904	620	0.1	1840	120	1.5	0.3	160 (160)
P1K1	1.1	550	613	620	0.1	1840	120	1.5	0.3	160 (160)
P1K5	1.5	380	447	425	0.1	1841	120	1.5	0.5	160 (160)
P2K2	2.2	270	301	310	0.3	1842	120	1.5	0.9	160 (160)
P3K0	3	189	218	210	0.3	1843	120	1.5	1.2	160 (160)
P4K0	4	135	162	150	0.4	1844	120	1.5	1.7	160 (160)
P5K5	5.5	99	116	110	0.6	1845	120	1.5	2.3	160 (160)
P7K5	7.5	72	84.5	80	0.9	1846	120	1.5	3.3	160 (160)
P11K	11	40	57	40	2	1848	120	1.5	3.9	160 (160)
P15K	15	36	41.3	40	2	1848	120	1.5	7.1	160 (160)
P18K	18.5	27	33.2	30	2.8	1849	120	1.5	9.7	160 (160)
P22K	22	22.5	27.6	25	3.5	1850	120	1.5	12	150 (150)
P30K	30	18	21.6	20	4	1851	120	1.5	14	150 (150)
P37K	37	13.5	17.3	15	4.8	1852	120	2.5	18	150 (150)
P45K	45	10.8	14.2	12	5.5	1853	120	2.5	21	150 (150)
P55K	55	8.8	11.6	9.8	15	2008	120	10	39	150 (150)
P75K	75	6.6	8.4	7.3	13	0069	120	10	42	150 (150)
P90K	90	4.7	7	4.7	18	1959	300	16	62	150 (150)
P110	110	4.7	5.8	4.7	18	1959	300	16	62	150 (150)
P132	132	4.2	4.8	4.7	18	1959	300	16	62	150 (150)
P160	160	3.4	4	3.8	22	1960	300	25	76	150 (150)
P200	200	2.7	3.2	5.2 / 2 = 2.6	36 x 2 = 72	2 x 1062	300	2 x 70 5*	166	150 (150)
P250	250	2.2	2.5	5.2 / 2 = 2.6	36 x 2 = 72	2 x 1062	300	2 x 70 5*	166	146 (150)
P315	315	1.7	2							(150)
P355	355	1.6	1.8							(150)
P400	400	1.4	1.6							(150)
P450	450	1.2	1.3							(150)
P500	500	1.2	1.3							(150)
P560	560	1.2	1.3							(130)
P670	670	1.2	1.3							(116)
P750	750	1.2	1.3							(103)
P850	850	1.2	1.3							(91)
P1M0	1000	1.2	1.3							(73)
P1M1	1100	1.2	1.3							

Table 5.18

5

FC 302 - Line power: 525–690 V (T7) - 10% Duty Cycle

FC 302	$P_{m\ (HO)}$	R_{min}	$R_{br,\ nom}$	R_{rec}	$P_{br\ avg}$	Order no.	Period	Cable cross-section	Max. brake torque with R_{rec}*
T7	[kW]	[Ω]	[Ω]	[Ω]	[kW]	175Uxxxx	[s]	[mm2]	[%]
P400	400	1.9	2.2	4.2 / 2 = 2.1	50 x 2 = 100	2 x 1064	300	2 x 120	150 (150)
P500	500	1.5	1.7	4.2 / 2 = 2.1	50 x 2 = 100	2 x 1064	300	2 x 120	123 (150)
P560	560	1.4	1.5	4.2 / 2 = 2.1	50 x 2 = 100	2 x 1064	300	2 x 120	118 (150)
P630	630	1.2	1.4	4.2 / 2 = 2.1	50 x 2 = 100	2 x 1064	300	2 x 120	98 (150)
P710	710	1.2	1.3	4.2 / 2 = 2.1	50 x 2 = 100	2 x 1064	300	2 x 120	87 (140)
P800	800	1.2	1.3	4.2 / 2 = 2.1	50 x 2 = 100	2 x 1064	300	2 x 120	77 (124)
P900	900	1.2	1.3	4.2 / 2 = 2.1	50 x 2 = 100	2 x 1064	300	2 x 120	68 (110)
P1M1	1000	1.2	1.3	4.2 / 2 = 2.1	50 x 2 = 100	2 x 1064	300	2 x 120	61 (99)
P1M2	1200	1.2	1.3	4.2 / 2 = 2.1	50 x 2 = 100	2 x 1064	300	2 x 120	51 (83)

Table 5.19

5.2.6 Ordering Numbers: Brake Resistors 40%

FC 301 - Line power: 200–240 V (T2) - 40% Duty Cycle

FC 301	$P_{m\ (HO)}$	R_{min}	$R_{br,\ nom}$	R_{rec}	$P_{br\ avg}$	Order no.	Period	Cable cross-section[2]*	Therm. relay	Max. brake torque with R_{rec}*
T2	[kW]	[Ω]	[Ω]	[Ω]	[kW]	175Uxxxx	[s]	[mm2]	[A]	[%]
PK25	0.25	368	408	425	0.43	1941	120	1.5	1	154 (160)
PK37	0.37	248	276	310	0.80	1942	120	1.5	1.6	142 (160)
PK55	0.55	166	185	210	1.35	1943	120	1.5	2.5	141 (160)
PK75	0.75	121	135	145	0.26	1920	120	1.5	1.3	149 (160)
P1K1	1.1	81	91.4	90	0.43	1921	120	1.5	2.2	160 (160)
P1K5	1.5	58.5	66.2	65	0.80	1922	120	1.5	3.5	160 (160)
P2K2	2.2	40.2	44.6	50	1.00	1923	120	1.5	4.5	143 (160)
P3K0	3	29.1	32.4	35	1.35	1924	120	1.5	6.2	148 (160)
P3K7	3.7	22.5	25.9	25	3.00	1925	120	1.5	11	160 (160)

Table 5.20

FC 302 - Line power: 200–240 V (T2) - 40% Duty Cycle

FC 302	$P_{m\ (HO)}$	R_{min}	$R_{br,\ nom}$	R_{rec}	$P_{br\ avg}$	Order no.	Period	Cable cross-section2*	Therm. relay	Max. brake torque with R_{rec}*
T2	[kW]	[Ω]	[Ω]	[Ω]	[kW]	175Uxxxx	[s]	[mm2]	[A]	[%]
PK25	0.25	382	467	425	0.43	1941	120	1.5	1.0	160 (160)
PK37	0.37	279	315	310	0.80	1942	120	1.5	1.6	160 (160)
PK55	0.55	189	211	210	1.35	1943	120	1.5	2.5	160 (160)
PK75	0.75	130	154	145	0.26	1920	120	1.5	1.3	160 (160)
P1K1	1.1	81	104	90	0.43	1921	120	1.5	2.2	160 (160)
P1K5	1.5	58.5	75.7	65	0.80	1922	120	1.5	3.5	160 (160)
P2K2	2.2	45	51	50	1.00	1923	120	1.5	4.5	160 (160)
P3K0	3	31.5	37	35	1.35	1924	120	1.5	6.2	160 (160)
P3K7	3.7	22.5	29.6	25	3.00	1925	120	1.5	11	160 (160)

Table 5.21

AutomationDrive FC 301/FC 302 - Line Power: 200–240 V (T2) - 40% Duty Cycle

AutomationDrive FC 301/FC 302	$P_{m\ (HO)}$	R_{min}	$R_{br,\ nom}$	R_{rec}	$P_{br\ avg}$	Order no.	Period	Cable cross-section	Therm. relay	Max. brake torque with R_{rec}*
T2	[kW]	[Ω]	[Ω]	[Ω]	[kW]	175Uxxxx	[s]	[mm2]	[A]	[%]
P5K5	5.5	18	20	20	3.5	1926	120	1.5	13	(160)
P7K5	7.5	13	14	15	5	1927	120	2.5	18	(160)
P11K	11	9	10	10	9	1928	120	10	30	(160)
P15K	15	6	7	7	10	1929	120	16	38	(150)
P18K	18.5	5.1	6	6	12.7	1930	120	16	46	(150)
P22K	22	4.2	5							(150)
P30K	30	3	3.7							(150)
P37K	37	2.4	3							(150)

Table 5.22

FC 301 - Line power: 380–480 V (T4) - 40% Duty Cycle

FC 301	$P_{m\ (HO)}$	R_{min}	$R_{br,\ nom}$	R_{rec}	$P_{br\ avg}$	Order no.	Period	Cable cross-section[2]*	Therm. relay	Max. brake torque with R_{rec}*
T4	[kW]	[Ω]	[Ω]	[Ω]	[kW]	175Uxxxx	[s]	[mm2]	[A]	[%]
PK37	0.37	620	1098	620	0.26	1940	120	1.5	0.6	160 (160)
PK55	0.55	620	739	620	0.26	1940	120	1.5	0.6	160 (160)
PK75	0.75	485	539	620	0.26	1940	120	1.5	0.6	139 (160)
P1K1	1.1	329	366	425	0.43	1941	120	1.5	1	138 (160)
P1K5	1.5	240	267	310	0.80	1942	120	1.5	1.6	138 (160)
P2K2	2.2	161	179	210	1.35	1943	120	1.5	2.5	137 (160)
P3K0	3	117	130	150	2.00	1944	120	1.5	3.7	139 (160)
P4K0	4	87	97	110	2.40	1945	120	1.5	4.7	140 (160)
P5K5	5.5	63	69	80	3.00	1946	120	1.5	6.1	139 (160)
P7K5	7.5	45	50	65	4.50	1947	120	1.5	8.3	124 (160)
P11K	11	34.9	38.8	40	5.00	1948	120	1.5	11	155 (160)
P15K	15	25.3	28.1	30	9.30	1949	120	2.5	18	150 (160)
P18K	18.5	20.3	22.6	25	12.70	1950	120	4	23	144 (160)
P22K	22	16.9	18.8	20	13.00	1951	120	4	25	150 (160)
P30K	30	13.2	14.7	15	15.60	1952	120	10	32	147 (150)
P37K	37	10.6	12	12	19.00	1953	120	10	40	147 (150)
P45K	45	8.7	10	9.8	38.00	2007	120	16	62	148 (150)
P55K	55	6.6	8	7.3	38.00	0068	120	25	72	150 (150)
P55K	55	6.6	7.9	5.7						150 (150)
P75K	75	6.6	5.7	6.3	45.00	0066	120	25	87	150 (150)
P75K	75	4.2	5.7	4.7						150 (150)
P75K	75	4.2	5.7	4.7						150 (150)

Table 5.23

FC 302 - Line power: 380–500 V (T5) - 40% Duty Cycle

FC 302	$P_{m\ (HO)}$	R_{min}	$R_{br,\ nom}$	R_{rec}	$P_{br\ avg}$	Order no.	Period	Cable cross-section[2*]	Therm. relay	Max. brake torque with R_{rec}*
T5	[kW]	[Ω]	[Ω]	[Ω]	[kW]	175Uxxxx	[s]	[mm2]	[A]	[%]
PK37	0.37	620	1360	620	0.26	1940	120	1.5	0.6	160 (160)
PK55	0.55	620	915	620	0.26	1940	120	1.5	0.6	160 (160)
PK75	0.75	620	668	620	0.26	1940	120	1.5	0.6	160 (160)
P1K1	1.1	425	453	425	0.43	1941	120	1.5	1	160 (160)
P1K5	1.5	310	330	310	0.80	1942	120	1.5	1.6	160 (160)
P2K2	2.2	210	222	210	1.35	1943	120	1.5	2.5	160 (160)
P3K0	3	150	161	150	2	1944	120	1.5	3.7	160 (160)
P4K0	4	110	120	110	2.4	1945	120	1.5	4.7	160 (160)
P5K5	5.5	80	86	80	3	1946	120	1.5	6.1	160 (160)
P7K5	7.5	65	62	65	4.5	1947	120	1.5	8.3	160 (160)
P11K	11	40	42.1	40	5	1948	120	1.5	11	160 (160)
P15K	15	30	30.5	30	9.3	1949	120	2.5	18	160 (160)
P18K	18.5	25	24.5	25	12.7	1950	120	4	23	160 (160)
P22K	22	20	20.3	20	13	1951	120	4	25	150 (160)
P30K	30	15	15.9	15	15.6	1952	120	10	32	150 (150)
P37K	37	12	13	12	19	1953	120	10	40	150 (150)
P45K	45	10	10	9.8	38	2007	120	16	62	150 (150)
P55K	55	7	9	7.3	38	0068	120	25	72	150 (150)
P55K	55	7.3	8.6							150 (150)
P75K	75	4.7	6.2	4.7	45	0066	120	25	87	150 (150)
P75K	75	4.7	6.2							150 (150)
P75K	75	4.7	6.2							150 (150)
P90K	90	3.8	5.2	7.6 / 2 = 3.8	38 x 2 = 75	2 x 0072 [3*]	600	2 x 70[5*]	140[4*]	150 (150)
P90K	90	3.8	5.2							150 (150)
P110	110	3.2	4.2	6.4 / 2 = 3.2	45 x 2 = 90	2 x 0073[3*]	600	2 x 70[5*]	168[4*]	150 (150)
P110	110	3	4							150 (150)
P132	132	3	4	5.8 / 2 = 2.6	56 x 2 = 112	2 x 0074[3*]	600	2 x 25[5]	186[4]	150 (150)
P160	160	2	3	6.3 / 3 = 2.1	45 x 3 = 135	3 x 0075[3*]	600	3 x 25[5]	252[4]	150 (150)
P200	200	2	3							106 (150)
P200	200	1.6	2.3							150 (150)
P250	250	2.6	1.9							108 (150)
P250	250	2.6	1.9							150 (150)
P315	315	2.3	1.5							97 (150)
P315	315	2.3	1.5							150 (150)
P355	355	2.1	1.3							94 (150)
P355	355	2.1	1.3							150 (150)
P400	400	1.2	1.3							135 (135)
P450	450	1.2	1.3							120 (120)
P500	500	1.2	1.3							108 (108)
P560	560	1.2	1.3							96 (96)
P630	630	1.2	1.3							85 (85)
P710	710	1.2	1.3							76 (76)
P800	800	1.2	1.3							67 (67)
P1M0	1000	1.2	1.3							54 (54)

Table 5.24

5

FC 302 - Line power: 525–600 V (T6) - 40% Duty Cycle

FC 302	$P_{m\ (HO)}$	R_{min}	$R_{br,\ nom}$	R_{rec}	$P_{br\ avg}$	Order no.	Period	Cable cross-section[2]*	Therm. relay	Max. brake torque with R_{rec}*
T6	[kW]	[Ω]	[Ω]	[Ω]	[kW]	175Uxxxx	[s]	[mm2]	[A]	[%]
PK75	0.75	620	905	620	0.26	1940	120	1.5	0.6	160 (160)
P1K1	1.1	550	614	620	0.26	1940	120	1.5	0.6	160 (160)
P1K5	1.5	380	448	425	1	1941	120	1.5	1	160 (160)
P2K2	2.2	270	302	310	1.6	1942	120	1.5	1.6	160 (160)
P3K0	3	189	219	210	2.5	1943	120	1.5	2.5	160 (160)
P4K0	4	135	162	150	3.7	1944	120	1.5	3.7	160 (160)
P5K5	5.5	99	117	110	4.7	1945	120	1.5	4.7	160 (160)
P7K5	7.5	72	84.5	80	6.1	1946	120	1.5	6.1	160 (160)
P11K	11	40	57	40	11	1948	120	1.5	8.3	160 (160)
P15K	15	36	41.3	40	11	1948	120	1.5	11	160 (160)
P18K	18.5	27	33.2	30	18	1949	120	2.5	18	160 (160)
P22K	22	22.5	27.6	25	23	1950	120	4	23	150 (150)
P30K	30	18	21.6	20	25	1951	120	4	25	150 (150)
P37K	37	13.5	17.3	15	32	1952	120	10	32	150 (150)
P45K	45	10.8	14.2	12	40	1953	120	10	40	150 (150)
P55K	55	8.8	11.6	9.8	62	2007	120	16	62	150 (150)
P75K	75	6.6	8.4	7.3	72	0068	120	25	72	150 (150)
P90K	90	4.7	7							150 (150)
P110	110	4.7	5.8							150 (150)
P132	132	4.2	4.8							150 (150)
P160	160	3.4	4							150 (150)
P200	200	2.7	3.2							150 (150)
P250	250	2.2	2.5							146 (150)
P315	315	1.7	2							(150)
P355	355	1.6	1.8							(150)
P400	400	1.4	1.6							(150)
P450	450	1.2	1.3							(150)
P500	500	1.2	1.3							(150)
P560	560	1.2	1.3							(130)
P670	670	1.2	1.3							(116)
P750	750	1.2	1.3							(103)
P850	850	1.2	1.3							(91)
P1M0	1000	1.2	1.3							(73)
P1M1	1100	1.2	1.3							

Table 5.25

FC 302 - Line power: 525–690 V (T7) - 40% Duty Cycle

FC 302	P_m (HO)	R_{min}	$R_{br.\ nom}$	R_{rec}	$P_{br\ avg}$	Order no.	Period	Cable cross-section	Therm. Relay	Max. brake torque with R_{rec}*
T7	[kW]	[Ω]	[Ω]	[Ω]	[kW]	130Bxxxx	[s]	[mm2]	[A]	[%]
P37K	37	18	23.5	22	28	2118	600	6	35	150 (150)
P45K	45	13.5	19.3	18	33	2119	600	10	42	150 (150)
P55K	55	13.5	15.8	15	42	2120	600	16	52	150 (150)
P75K	75	8.8	11.5	11	56	2121	600	25	71	150 (150)
P90K	90	8.8	9.6	9.1	66	2122	600	35	85	146 (150)
P110	110	6.6	7.8	7.5	78	2123	600	50	102	150 (150)
P132	132	4.2	6.5	6.2	96	2124	600	50	124	150 (150)
P160	160	4.2	5.4	5.1	120	2125	600	70	198	150 (150)
P200	200	3.4	4.3	7.8 / 2 = 3.9	2 x 78	2 x 2126 3*	600	2 x 25	200	150 (150)
P250	250	2.3	3.4	6.6 / 2 = 3.3	2 x 90	2 x 2127 3*	600	2 x 35	234	150 (150)
P315	315	2.3	2.7	5.4 / 2 = 2.7	2 x 112	2 x 2128 3*	600	2 x 50	288	150 (150)

Table 5.26

Abbreviations for the Tables

*) Resulting max. brake torque when using R_{rec}. Using the $R_{br,nom}$ will result in maximum brake torque, e.g., of 160%. The value in brackets is the drives max. brake torque

2*) All cabling must comply with national and local regulations on cable cross-sections and ambient temperature. Copper (140°–167°F [60°/75°C]) conductors are recommended.

3*) Order the specified amount of Brake Resistors (e.g., 2 x 1062 = 2 pieces of 175U1062). See table header for the first four characters (175U or 130B).

4*) Rating for each thermistor relay (using one thermistor relay per resistor).

5*) Parallel star connection (see the *Installation* chapter).

6*) Please contact Danfoss for further info.

7*) With Klixon Switch

P_m	: Rated motor size for VLT type
R_{min}	: Minimum permissible brake resistor - by drive
R_{rec}	: Recommended brake resistor (Danfoss)
$P_{b,\ max}$	: Brake resistor rated power as stated by supplier
Therm. relay	: Brake current setting of thermal relay
Code number	: Order numbers for Danfoss Brake Resistors
Cable cross-section	: Recommended minimum value based upon PVC insulated copper cable, 86°F [30°C] ambient temperature with normal heat dissipation
$P_{pbr,avg}$	: Brake resistor average rated power as stages by
$R_{br,avg}$	: The nominal (recommended) resistor value to ensure a braking energy on motor shaft of 160%/110% for 1 minute

Table 5.27

5

5.2.7 Flat Packs

FC 301 - Line power: 200–240 V (T2)

FC 301	$P_{m\ (HO)}$	R_{min}	$R_{br,\ nom}$	Flatpack IP65 for horizontal conveyors		
				Rrec per item	Duty Cycle	Order no.
T2	[kW]	[Ω]	[Ω]	[Ω / W]	%	175Uxxxx
PK25	0.25	368	408	430/100	40	1002
PK37	0.37	248	276	330/100 or 310/200	27 or 55	1003 or 0984
PK55	0.55	166	185	220/100 or 210/200	20 or 37	1004 or 0987
PK75	0.75	121	135	150/100 or 150/200	14 or 27	1005 or 0989
P1K1	1.1	81.0	91.4	100/100 or 100/200	10 or 19	1006 or 0991
P1K5	1.5	58.5	66.2	72/200	14	0992
P2K2	2.2	40.2	44.6	50/200	10	0993
P3K0	3	29.1	32.4	35/200 or 72/200	7 14	0994 or 2 x 0992
P3K7	3.7	22.5	25.9	60/200	11	2 x 0996

Table 5.28

FC 302 Line power: 200–240 V (T2)

FC 302	$P_{m\ (HO)}$	R_{min}	$R_{br.\ nom}$	Flatpack IP65 for horizontal conveyors		
				Rrec per item	Duty Cycle	Order no.
T2	[kW]	[Ω]	[Ω]	[Ω / W]	%	175Uxxxx
PK25	0.25	382	467	430/100	40	1002
PK37	0.37	279	315	330/100 or 310/200	27 or 55	1003 or 0984
PK55	0.55	189	211	220/100 or 210/200	20 or 37	1004 or 0987
PK75	0.75	130	154	150/100 or 150/200	14 or 27	1005 or 0989
P1K1	1.1	81.0	104.4	100/100 or 100/200	10 or 19	1006 or 0991
P1K5	1.5	58.5	75.7	72/200	14	0992
P2K2	2.2	45.0	51.0	50/200	10	0993
P3K0	3	31.5	37.0	35/200 or 72/200	7 or 14	0994 or 2 x 0992
P3K7	3.7	22.5	29.6	60/200	11	2 x 0996

Table 5.29

FC 301 Line power: 380–480 V (T4)

FC 301	$P_{m\ (HO)}$	R_{min}	$R_{br.\ nom}$	Flatpack IP65 for horizontal conveyors		
				Rrec per item	Duty Cycle	Order no.
T4	[kW]	[Ω]	[Ω]	[Ω / W]	%	175Uxxxx
PK37	0.37	620	1098	830/100	30	1000
PK55	0.55	620	739	830/100	20	1000
PK75	0.75	485	539	620/100 or 620/200	14 or 27	1001 or 0982
P1K1	1.1	329	366	430/100 or 430/200	10 or 20	1002 or 0983
P1K5	1.5	240.0	266.7	310/200	14	0984
P2K2	2.2	161.0	179.7	210/200	10	0987
P3K0	3	117.0	130.3	150/200 or 300/200	7 or 14	0989 or 2 x 0985
P4K0	4	87	97	240/200	10	2 x 0986
P5K5	5.5	63	69	160/200	8	2 x 0988
P7K5	7.5	45	50	130/200	6	2 x 0990
P11K	11	34.9	38.8	80/240	5	2 x 0090
P15K	15	25.3	28.1	72/240	4	2 x 0091

Table 5.30

FC 302 Line power: 380–500 V (T5)

FC 302	$P_{m\ (HO)}$	R_{min}	$R_{br.\ nom}$	Flatpack IP65 for horizontal conveyors		
				Rrec per item	Duty Cycle	Order no.
T5	[kW]	[Ω]	[Ω]	[Ω / W]	%	175Uxxxx
PK37	0.37	620	1360	830/100	30	1000
PK55	0.55	620	915	830/100	20	1000
PK75	0.75	620	668	620/100 or 620/200	14 or 27	1001 or 0982
P1K1	1.1	425	453	430/100 or 430/200	10 or 20	1002 or 0983
P1K5	1.5	310.0	330.4	310/200	14	0984
P2K2	2.2	210.0	222.6	210/200	10	0987
P3K0	3	150.0	161.4	150/200 or 300/200	7 14	0989 or 2 x 0985
P4K0	4	110	120	240/200	10	2 x 0986
P5K5	5.5	80	86	160/200	8	2 x 0988
P7K5	7.5	65	62	130/200	6	2 x 0990
P11K	11	40.0	42.1	80/240	5	2 x 0090
P15K	15	30.0	30.5	72/240	4	2 x 0091

Table 5.31

5.2.8 Ordering Numbers: Harmonic Filters

Harmonic filters are used to reduce line harmonics.

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

$I_{AHF,N}$	Typical Motor Used [kW]	Danfoss AHF 005	Danfoss AHF 010	Adjustable frequency drive size
10	0.37–4	175G6600	175G6622	PK37 - P4K0
19	5.5–7.5	175G6601	175G6623	P5K5 - P7K5
26	11	175G6602	175G6624	P11K
35	15–18.5	175G6603	175G6625	P15K - P18K
43	22	175G6604	175G6626	P22K
72	30–37	175G6605	175G6627	P30K - P37K
101	45–55	175G6606	175G6628	P45K - P55K
144	75	175G6607	175G6629	P75K
180	90	175G6608	175G6630	P90K
217	110	175G6609	175G6631	P110
289	132	175G6610	175G6632	P132
324	160	175G6611	175G6633	P160
370	200	175G6688	175G6691	P200
506	250	175G6609 + 175G6610	175G6631 + 175G6632	P250
578	315	2X 175G6610	2X 175G6632	P315
648	355	2X 175G6611	2X 175G6633	P355
694	400	175G6611 + 175G6688	175G6633 + 175G6691	P400
740	450	2X 175G6688	2X 175G6691	P450

Table 5.32 380–415 V, 50Hz

$I_{AHF,N}$	Typical Motor Used [kW]	Danfoss AHF 005	Danfoss AHF 010	Adjustable frequency drive size
10	0.37–4	130B2540	130B2541	PK37 - P4K0
19	5.5–7.5	130B2460	130B2472	P5K5 - P7K5
26	11	130B2461	130B2473	P11K
35	15–18.5	130B2462	130B2474	P15K - P18K
43	22	130B2463	130B2475	P22K
72	30–37	130B2464	130B2476	P30K - P37K
101	45–55	130B2465	130B2477	P45K - P55K
144	75	130B2466	130B2478	P75K
180	90	130B2467	130B2479	P90K
217	110	130B2468	130B2480	P110
289	132	130B2469	130B2481	P132
324	160	130B2470	130B2482	P160
370	200	130B2471	130B2483	P200
506	250	130B2468 + 130B2469	130B2480 + 130B2481	P250
578	315	2X 130B2469	2X 130B2481	P315
648	355	2X 130B2470	2X 130B2482	P355
694	400	130B2470 + 130B2471	130B2482 + 130B2483	P400
740	450	2X 130B2471	2X 130B2483	P450

Table 5.33 380–415V, 60Hz

$I_{AHF,N}$	Typical Motor Used [kW]	Danfoss AHF 005	Danfoss AHF 010	Adjustable frequency drive size
10	6	130B2538	130B2539	PK37-P7K5
19	10–15	175G6612	175G6634	P11K
26	20	175G6613	175G6635	P15K
35	25–30	175G6614	175G6636	P18K - P22K
43	40	175G6615	175G6637	P30K
72	50–60	175G6616	175G6638	P37K - P45K
101	75	175G6617	175G6639	P55K
144	100–125	175G6618	175G6640	P75K - P90K
180	150	175G6619	175G6641	P110
217	200	175G6620	175G6642	P132
289	250	175G6621	175G6643	P160
370	300	175G6690	175G6693	P200
434	350	175G6620 + 175G6620	175G6642 + 175G6642	P250
506	450	175G6620 + 175G6621	175G6642 + 175G6643	P315
578	500	175G6621 + 175G6621	175G6643 + 175G6643	P355
659	550/600	175G6621 + 175G6690	175G6643 + 175G6693	P400
694	600	175G6689 + 175G6690	175G6692 + 175G6693	P450
740	650	175G6690 + 175G6690	175G6693 + 175G6693	P500

Table 5.34 440–480 V, 60 Hz

IAHF	500V Typical Motor Used [kW]	Danfoss AHF 005	Danfoss AHF 010	Adjustable frequency drive size
10	0.75–7.5	175G6644	175G6656	PK75 - P5K5
19	11–15	175G6645	175G6657	P7K5 - P11K
26	18.5–22	175G6646	175G6658	P15K - P18K
35	30	175G6647	175G6659	P22K
43	37	175G6648	175G6660	P30K
72	45–55	175G6649	175G6661	P37K - P45K
101	75	175G6650	175G6662	P55K
144	90–110	175G6651	175G6663	P75K - P90K
180	132	175G6652	175G6664	P110
217	160	175G6653	175G6665	P132
289	200	175G6654	175G6666	P160
324	250	175G6655	175G6667	P200
434	315	175G6653 + 175G6653	175G6665 + 175G6665	P250
506	355	175G6653 + 175G6654	175G6665 + 175G6666	P315
578	400	175G6654 + 175G6654	175G6666 + 175G6666	P355
648	500	175G6655 + 175G6655	175G66967 + 175G6667	P400

Table 5.35 500V, 50 Hz

Matching the adjustable frequency drive and filter is pre-calculated based on 400 V/480 V and on a typical motor load (4-pole) and 160% torque.

IAHF	525 V Typical Motor Used [kW]	Danfoss AHF 005	Danfoss AHF 010	Adjustable frequency drive size, 525–600 V	Adjustable frequency drive size, 525–690 V
10	0.75–7.5	175G6644	175G6656	PK75 - P5K5	
19	11–15	175G6645	175G6657	P7K5 - P11K	
26	18.5–22	175G6646	175G6658	P15K - P18K	
35	30	175G6647	175G6659	P22K	
43	37	175G6648	175G6660	P30K	
72	30–45	175G6649	175G6661	P37K - P45K	P37K - P55K
101	55	175G6650	175G6662	P55K - P75K	P75K
144	75–90	175G6651	175G6663		P90K - P110
180	110	175G6652	175G6664		P132
217	132	175G6653	175G6665		P160
289	160–200	175G6654	175G6666		P200 - P250
360	250	175G6652 + 175G6652	175G6664 + 175G6664		P315
397	300	175G6652 + 175G6653	175G66641 + 175G6665		P355
434	315	175G6653 + 175G6653	175G6665 + 175G6665		P400
506	400	175G6653 + 175G6654	175G6665 + 175G6666		P500
578	450	175G6654 + 175G6654	175G6666 + 175G6666		P560
648	500	175G6655 + 175G6655	175G66967 + 175G6667		P630

Table 5.36

IAHF	690 V Typical Motor Used [kW]	Danfoss AHF 005	Danfoss AHF 010	Adjustable frequency drive size, 525–690 V
43	37	130B2328	130B2293	P37K
72	45–55	130B2330	130B2295	P45K - P55K
101	75–90	130B2331	130B2296	P75K - P90K
144	110	130B2333	130B2298	P110
180	132	130B2334	130B2299	P132
217	160	130B2335	130B2300	P160
288	200–250	130B2333 + 130B2333	130B2301	P200 - P250
324	315	130B2333 + 130B2334	130B2302	P315
365	355	130B2334 + 130B2334	130B2304	P355
397	400	130B2334 + 130B2335	130B2299 + 130B2300	P400
505	500		130B2300 + 130B2301	P500
576	560		130B2301 + 130B2301	P560
612	630		130B2301 + 130B2302	P630
730	710		130B2304 + 130B2304	P710

Table 5.37

Matching the adjustable frequency drive and filter is pre-calculated based on 525 V/690 V and on a typical motor load (4-pole) and 160% torque.

5.2.9 Ordering Numbers: Sine-wave Filter Modules, 200–500 VAC

3 x 240–500 V					Adjustable frequency drive size		
Rated filter current at 50 Hz	Min Switching Frequency [kHz]	Max Output Frequency ([Hz] with Derating	Danfoss IP20	Danfoss IP00	200–240V	380–440V	441–500V
2,5	5	120	130B2439	130B2404	PK25 - PK37	PK37 - PK75	PK37 - PK75
4,5	5	120	130B2441	130B2406	PK55	P1K1 - P1K5	P1K1 - P1K5
8	5	120	130B2443	130B2408	PK75 - P1K5	P2K2 - P3K0	P2K2 - P3K0
10	5	120	130B2444	130B2409		P4K0	P4K0
17	5	120	130B2446	130B2411	P2K2 - P4K0	P5K5 - P7K5	P5K5 - P7K5
24	4	100	130B2447	130B2412	P5K5	P11K	P11K
38	4	100	130B2448	130B2413	P7K5	P15K - P18K	P15K - P18K
48	4	100	130B2307	130B2281	P11K	P22K	P22K
62	3	100	130B2308	130B2282	P15K	P30K	P30K
75	3	100	130B2309	130B2283	P18K	P37K	P37K
115	3	100	130B2310	130B2284	P22K - P30K	P45K - P55K	P55K - P75K
180	3	100	130B2311	130B2285	P37K - P45K	P75K - P90K	P90K - P110
260	3	100	130B2312	130B2286		P110 - P132	P132
410	3	100	130B2313	130B2287		P160 - P200	P160 - P200
480	3	100	130B2314	130B2288		P250	P250
660	2	100	130B2315	130B2289		P315 - P355	P315 - P355
750	2	100	130B2316	130B2290		P400	P400 - P450
880	2	100	130B2317	130B2291		P450 - P500	P500 - P560
1200	2	100	130B2318	130B2292		P560 - P630	P630 - P710
1500	2	100	2X 130B2317	2X 130B2291		P710 - P800	P800

Table 5.38

Matching the adjustable frequency drive and filter is pre-calculated based on 400 V/480 V and on a typical motor load (4-pole) and 160% torque.

NOTE!

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

5.2.10 Ordering Numbers: Sine-Wave Filter Modules, 525–690 VAC

3 x 525–600/690 V					Adjustable frequency drive size	
Rated filter current at 50 Hz	Min Switching Frequency [kHz]	Max Output Frequency ([Hz] with Derating	Danfoss IP20	Danfoss IP00	525–600V	525–690 V
13	2	100	130B2341	130B2321	PK75 - P7K5	
28	2	100	130B2342	130B2322	P11K - P18K	
45	2	100	130B2343	130B2323	P22K - P30K	P37K
76	2	100	130B2344	130B2324	P37K - P45K	P45K - P55K
115	2	100	130B2345	130B2325	P55K - P75K	P75K - P90K
165	2	100	130B2346	130B2326		P110 - P132
260	2	100	130B2347	130B2327		P160 - P200
303	2	100	130B2348	130B2329		P250
430	1.5	100	130B2270	130B2241		P315 - P400
530	1.5	100	130B2271	130B2242		P500
660	1,5	100	130B2381	130B2337		P560 - P630
765	1.5	100	130B2382	130B2338		P710
940	1.5	100	130B2383	130B2339		P800 - P900
1320	1.5	100	130B2384	130B2340		P1M0

Table 5.39

Matching the adjustable frequency drive and filter is pre-calculated based on 525 V/690 V and on a typical motor load (4-pole) and 160% torque.

NOTE!

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

5.2.11 Ordering Numbers: du/dt Filters, 380–480/500V AC

Line power supply 3x380–500V

3 x 380–500 V					Adjustable frequency drive size	
Rated filter current at 50 Hz	Minimum switching frequency [kHz]	Maximum output frequency [Hz] with Derating	Danfoss IP20	Danfoss IP00	380–440V	441–500V
24	4	100	130B2396	130B2385	P11K	P11K
45	4	100	130B2397	130B2386	P15K - P22K	P15K - P22K
75	3	100	130B2398	130B2387	P30K - P37K	P30K - P37K
110	3	100	130B2399	130B2388	P45K - P55K	P45K - P55K
182	3	100	130B2400	130B2389	P75K - P90K	P75K - P90K
280	3	100	130B2401	130B2390	P110 - P132	P110 - P132
400	3	100	130B2402	130B2391	P160 - P200	P160 - P200
500	3	100	130B2277	130B2275	P250	P250
750	2	100	130B2278	130B2276	P315 - P400	P315 - P450
910	2	100	130B2405	130B2393	P450 - P500	P500 - P560
1500	2	100	130B2407	130B2394	P560 - P800	P630 - P800

Table 5.40

5.2.12 Ordering Numbers: du/dt Filters, 525–690V AC

Line power supply 3x525–690V

3 x 525–690 V					Adjustable frequency drive size	
Rated filter current at 50 Hz	Minimum switching frequency [kHz]	Maximum output frequency [Hz] with Derating	Danfoss IP20	Danfoss IP00	525–600 V	525–690 V
28	3	100	130B2423	130B2414	P11K - P18K	
45	2	100	130B2424	130B2415	P22K - P30K	P37K
75	2	100	130B2425	130B2416	P37K - P45K	P45K - P55K
115	2	100	130B2426	130B2417	P55K - P75K	P75K - P90K
165	2	100	130B2427	130B2418		P110 - P132
260	2	100	130B2428	130B2419		P160 - P200
310	2	100	130B2429	130B2420		P250
430	1.5	100	130B2238	130B2235		P315 - P400
530	1.5	100	130B2239	130B2236		P500
630	1.5	100	130B2274	130B2280		P560 - P630
765	1.5	100	130B2430	130B2421		P710
1350	1.5	100	130B2431	130B2422		P800 - P1M0

Table 5.41

6 Mechanical Installation - Frame Size A, B and C

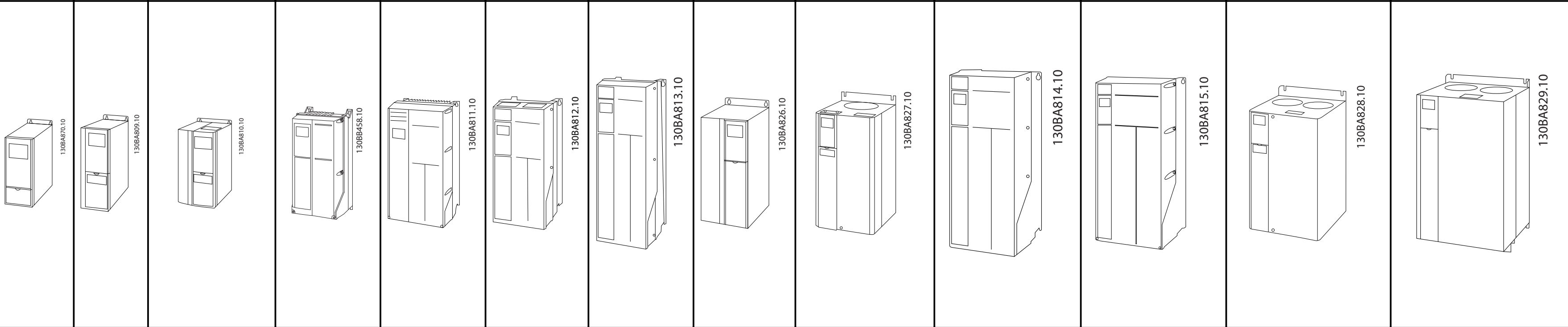
6.1.1 Safety Requirements of Mechanical Installation

WARNING

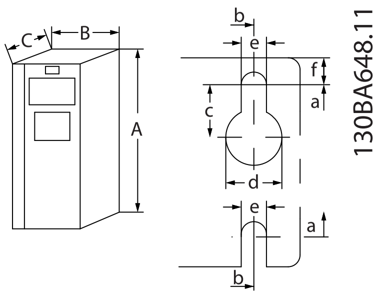
Pay attention to the requirements that apply to integration and the field mounting kit. Observe the information in the list to avoid serious injury or equipment damage, especially when installing large units.

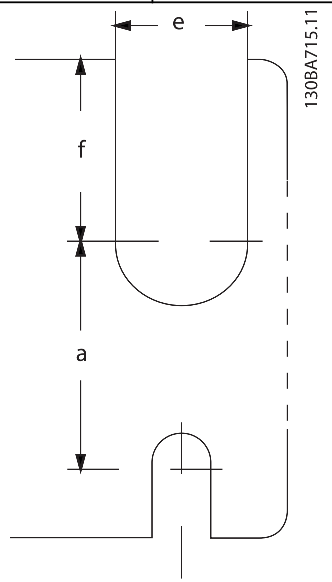
CAUTION

The Adjustable frequency drive is cooled by means of air circulation.
To protect the unit from overheating, it must be ensured that the ambient temperature *does not exceed the maximum temperature stated for the* Adjustable frequency drive and that the 24-hour average temperature *is not exceeded*. Locate the maximum temperature and 24-hour average in the paragraph *Derating for Ambient Temperature*.
If the ambient temperature is in the range of 113°–131°F [45°C–55 °C], derating of the Adjustable frequency drive will become relevant, see *Derating for Ambient Temperature*.
The service life of the Adjustable frequency drive is reduced if derating for ambient temperature is not taken into account.



A1	A2	A3	A4	A5	B1	B2	B3	B4	C1	C2	C3	C4
IP20	IP20/21	IP20/21	IP55/66	IP55/66	IP21/55/66	IP21/55/66	IP20	IP20	IP21/55/66	IP21/55/66	IP20	IP20





Accessory bags containing necessary brackets, screws and connectors are included with the drives upon delivery.	Top and bottom mounting holes (B4, C3 and C4 only)
All measurements in mm. * A5 in IP55/66 only	

Table 6.1

Frame Size		A1	A2		A3		A4	A5	B1	B2	B3	B4	C1	C2	C3	C4
Rated Power [HP]/[kW]	200–240V	0.25–1.5	0.25–2.2		3–3.7		0.25–2.2	0.25–3.7	5.5–7.5	11	5.5–7.5	11–15	15–22	30–37	18.5–22	30–37
	380–480/500V	0.37–1.5	0.37–4.0		5.5–7.5		0.37–4	0.37–7.5	11–15	18.5–22	11–15	18.5–30	30–45	55–75	37–45	55–75
	525–600V				0.75–7.5			0.75–7.5	11–15	18.5–22	11–15	18.5–30	30–45	55–90	37–45	55–90
	525–690V									11–22				30–75		
IP NEMA		20 Chassis	20 Chassis	21 Type 1	20 Chassis	21 Type 1	55/66 Type 12	55/66 Type 12	21/ 55/66 Type 1/Type 12	21/55/66 Type 1/Type 12	20 Chassis	20 Chassis	21/55/66 Type 1/Type 12	21/55/66 Type 1/Type 12	20 Chassis	20 Chassis
Height																
Height of backplate	A	7.87 in [200 mm]	10.55 in [268 mm]	14.76 in [375 mm]	10.55 in [268 mm]	14.76 in [375 mm]	15.35 in [390 mm]	16.54 in [420 mm]	18.90 in [480 mm]	25.59 in [650 mm]	15.71 in [399 mm]	20.47 in [520 mm]	26.77 in [680 mm]	30.32 in [770 mm]	21.65 in [550 mm]	25.98 in [660 mm]
Height with de-coupling plate for serial communication bus cables	A	12.44 in [316 mm]	14.72 in [374 mm]		14.72 in [374 mm]	-	-	-	-	-	16.54 in [420 mm]	23.43 in [595 mm]			24.80 in [630 mm]	31.50 in [800 mm]
Distance between mounting holes	a	7.48 in [190 mm]	10.12 in [257 mm]	13.78 in [350 mm]	10.12 in [257 mm]	13.78 in [350 mm]	15.79 in [401 mm]	15.83 in [402 mm]	17.87 in [454 mm]	24.57 in [624 mm]	14.96 in [380 mm]	19.49 in [495 mm]	25.51 in [648 mm]	29.09 in [739 mm]	20.51 in [521 mm]	24.84 in [631 mm]
Width																
Width of backplate	B	2.95 in [75 mm]	3.54 in [90 mm]	3.54 in [90 mm]	5.12 in [130 mm]	5.12 in [130 mm]	7.87 in [200 mm]	9.53 in [242 mm]	9.53 in [242 mm]	9.53 in [242 mm]	6.50 in [165 mm]	9.06 in [230 mm]	12.13 in [308 mm]	14.57 in [370 mm]	12.13 in [308 mm]	14.57 in [370 mm]
Width of backplate with one C option	B		5.12 in [130 mm]	5.12 in [130 mm]	6.69 in [170 mm]	6.69 in [170 mm]		9.53 in [242 mm]	9.53 in [242 mm]	9.53 in [242 mm]	8.07 in [205 mm]	9.06 in [230 mm]	12.13 in [308 mm]	14.57 in [370 mm]	12.13 in [308 mm]	14.57 in [370 mm]
Width of backplate with two C options	B		5.91 in [150 mm]	5.91 in [150 mm]	7.48 in [190 mm]	7.48 in [190 mm]		9.53 in [242 mm]	9.53 in [242 mm]	9.53 in [242 mm]	8.86 in [225 mm]	9.06 in [230 mm]	12.13 in [308 mm]	14.57 in [370 mm]	12.13 in [308 mm]	14.57 in [370 mm]
Distance between mounting holes	b	2.36 in [60 mm]	2.76 in [70 mm]	2.76 in [70 mm]	4.33 in [110 mm]	4.33 in [110 mm]	6.73 in [171 mm]	8.47 in [215 mm]	8.27 in [210 mm]	8.27 in [210 mm]	5.51 in [140 mm]	7.87 in [200 mm]	10.71 in [272 mm]	13.15 in [334 mm]	10.63 in [270 mm]	12.99 in [330 mm]
Depth																
Depth without option A/B	C	8.15 in [207 mm]	8.07 in [205 mm]	8.15 in [207 mm]	8.07 in [205 mm]	8.15 in [207 mm]	6.89 in [175 mm]	7.68 in [195 mm]	10.24 in [260 mm]	10.24 in [260 mm]	9.80 in [249 mm]	9.53 in [242 mm]	12.21 in [310 mm]	13.19 in [335 mm]	13.11 in [333 mm]	13.11 in [333 mm]
With option A/B	C	8.74 in [222 mm]	8.66 in [220 mm]	8.74 in [222 mm]	8.66 in [220 mm]	8.74 in [222 mm]	6.89 in [175 mm]	7.68 in [195 mm]	10.24 in [260 mm]	10.24 in [260 mm]	10.32 in [262 mm]	9.53 in [242 mm]	12.21 in [310 mm]	13.19 in [335 mm]	13.11 in [333 mm]	13.11 in [333 mm]
Screw holes																
	c	0.24 in [6.0 mm]	0.31 in [8.0 mm]	0.31 in [8.0 mm]	0.31 in [8.0 mm]	0.31 in [8.0 mm]	0.33 in [8.25 mm]	0.33 in [8.25 mm]	0.47 in [12 mm]	0.47 in [12 mm]	0.31 in [8 mm]		0.49 in [12.5 mm]	0.49 in [12.5 mm]		
	d	ø0.35 in. [8 mm]	ø0.43 in [11 mm]	ø0.43 in [11 mm]	ø0.43 in [11 mm]	ø0.43 in [11 mm]	ø0.47 in [12 mm]	ø0.47 in [12 mm]	ø0.75 in [19 mm]	ø0.75 in [19 mm]	0.47 in [12 mm]		ø0.75 in [19 mm]	ø0.75 in [19 mm]		
	e	ø0.20 in [5 mm]	ø0.22 in [5.5 mm]	ø0.22 in [5.5 mm]	ø0.22 in [5.5 mm]	ø0.22 in [5.5 mm]	ø0.26 in [6.5 mm]	ø0.26 in [6.5 mm]	ø0.35 in [9 mm]	ø0.35 in [9 mm]	0.27 in [6.8 mm]	0.34 in [8.5 mm]	ø0.35 in [9 mm]	ø0.35 in [9 mm]	0.34 in [8.5 mm]	0.34 in [8.5 mm]
	f	0.20 in [5 mm]	0.35 in [9 mm]	0.35 in [9 mm]	0.35 in [9 mm]	0.35 in [9 mm]	0.24 in [6 mm]	0.35 in [9 mm]	0.35 in [9 mm]	0.35 in [9 mm]	0.31 in [7.9 mm]	0.59 in [15 mm]	0.39 in [9.8 mm]	0.39 in [9.8 mm]	0.67 in [17 mm]	0.67 in [17 mm]
Max weight		5.95 lbs [2.7 kg]	10.8 lbs [4.9 kg]	11.69 lbs [5.3 kg]	14.55 lbs [6.6 kg]	15.43 lbs [7.0 kg]	21.38 lbs [9.7 kg]	29.76/31.31 lbs [13.5/14.2 kg]	50.71 lbs [23 kg]	59.53 lbs [27 kg]	26.46 lbs [12 kg]	51.81 lbs [23.5 kg]	99.21 lbs [45 kg]	143.30 lbs [65 kg]	77.16 lbs [35 kg]	110.23 lbs [50 kg]
Front cover tightening torque																
Plastic cover (low IP)		Click	Click		Click		-	-	Click	Click	Click	Click	Click	Click	2.0 Nm	2.0 Nm
Metal cover (IP 55/66)		-	-		-		1.5 Nm	1.5 Nm	2.2 Nm	2.2 Nm	-	-	2.2 Nm	2.2 Nm	2.0 Nm	2.0 Nm

Table 6.2

6

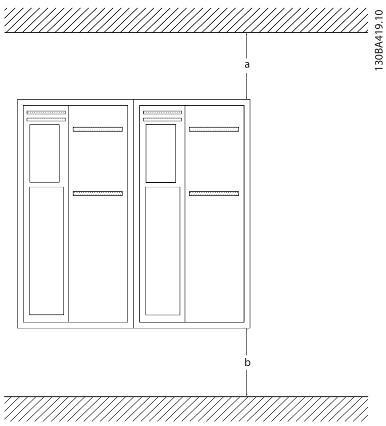
6

6.1.2 Mechanical Mounting

All Frame Sizes allow side-by-side installation except when a *IP21/IP4X/ TYPE 1 Enclosure Kit* is used (see the *Options and Accessories* section of the Design Guide)..

If the IP 21 Enclosure kit is used on frame size A1, A2 or A3, there must be a clearance between the drives of a minimum of 2 in [50 mm].

For optimal cooling conditions, allow a free air passage above and below the adjustable frequency drive. See table below.



Air passage for different frame sizes		
Frame size:	a (ins [mm]):	b (ins [mm]):
A1*/A2/A3/A4/A5/B1	3.94 [100]	3.94 [100]
B2/B3/B4/C1/C3	7.87 [200]	7.87 [200]
C2/C4	8.86 [225]	8.86 [225]

Table 6.3

** FC 301 only*

1. Drill holes in accordance with the measurements given.
2. You must provide screws suitable for the surface on which you want to mount the adjustable frequency drive. Retighten all four screws.

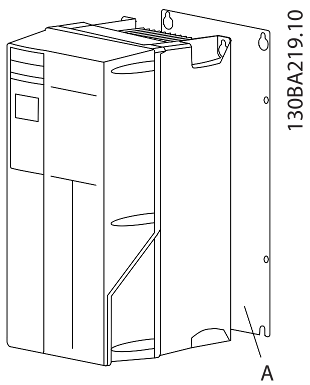


Figure 6.1

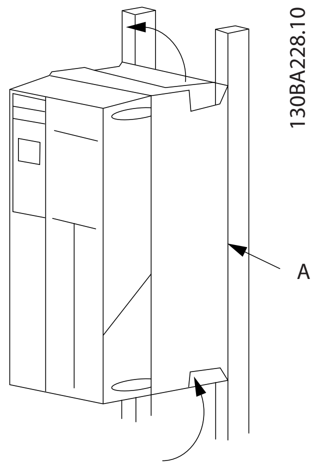


Figure 6.2

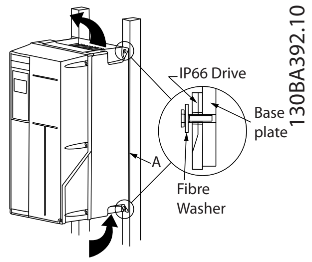


Figure 6.3

When mounting frame sizes A4, A5, B1, B2, C1 and C2 on a non-solid back wall, the drive must be provided with a backplate, “A”, due to insufficient cooling air over the heatsink.

Frame	Tightening torque for covers (Nm)			
	IP20	IP21	IP55	IP66
A1	*	-	-	-
A2	*	*	-	-
A3	*	*	-	-
A4/A5	-	-	2	2
B1	-	*	2,2	2,2
B2	-	*	2,2	2,2
B3	*	-	-	-
B4	2	-	-	-
C1	-	*	2,2	2,2
C2	-	*	2,2	2,2
C3	2	-	-	-
C4	2	-	-	-
* = No screws to tighten - = Does not exist				

Table 6.4

6.1.3 Field Mounting

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

7 Mechanical Installation - Frame size D, E and F

7.1 Pre-installation

7.1.1 Planning the Installation Site

CAUTION

Before performing the installation, it is important to plan the installation of the adjustable frequency drive. Neglecting this may result in extra work during and after installation.

Select the best possible operation site by considering the following (see details on the following pages and in the respective Design Guides):

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

7.1.2 Receiving the Adjustable Frequency Drive

When receiving the adjustable frequency drive, make sure that the packaging is intact, and look for any damage that might have occurred to the unit during transport. If damage has occurred, immediately contact the shipping company to make a damage claim.

7.1.3 Transportation and Unpacking

Before unpacking the adjustable frequency drive, it is recommended to unload it as close as possible to the final installation site.
Remove the box and handle the adjustable frequency drive on the pallet, as long as possible.

7.1.4 Lifting

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

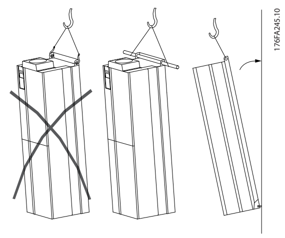


Figure 7.1 Recommended Lifting Method, Frame Sizes D and E.

WARNING

The lifting bar must be able to handle the weight of the Adjustable frequency drive. See *Mechanical Dimensions* for the weight of the different frame sizes. Maximum diameter for bar is 1 in [2.5 cm]. The angle from the top of the drive to the lifting cable should be 60°C or greater.

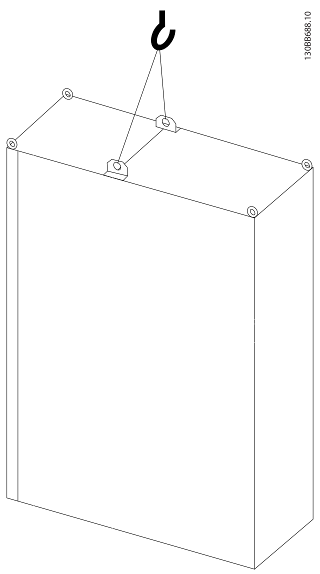


Figure 7.2 Recommended Lifting Method, Frame Sizes F1, F2, F9 and F10

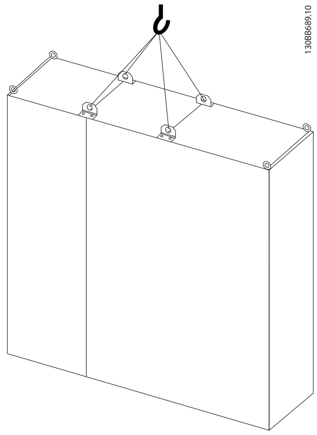


Figure 7.3 Recommended Lifting Method, Frame Sizes F3, F4, F11, F12 and F13

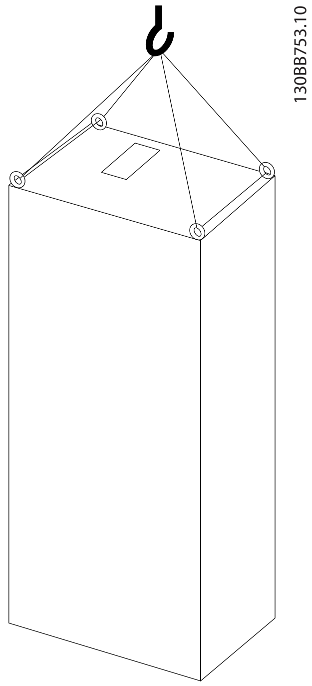


Figure 7.4 Recommended Lifting Method, Frame Sizes F8

NOTE!

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

7.1.5 Mechanical Dimensions

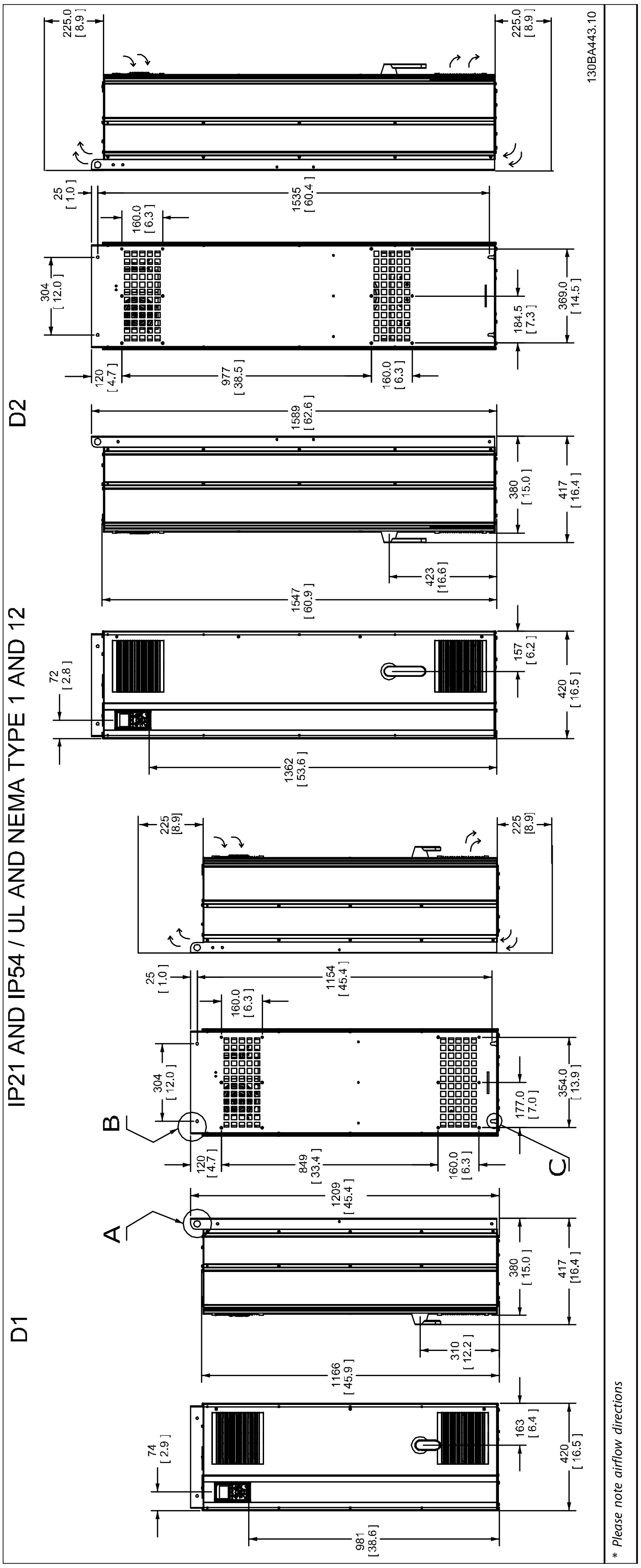


Table 7.1

7

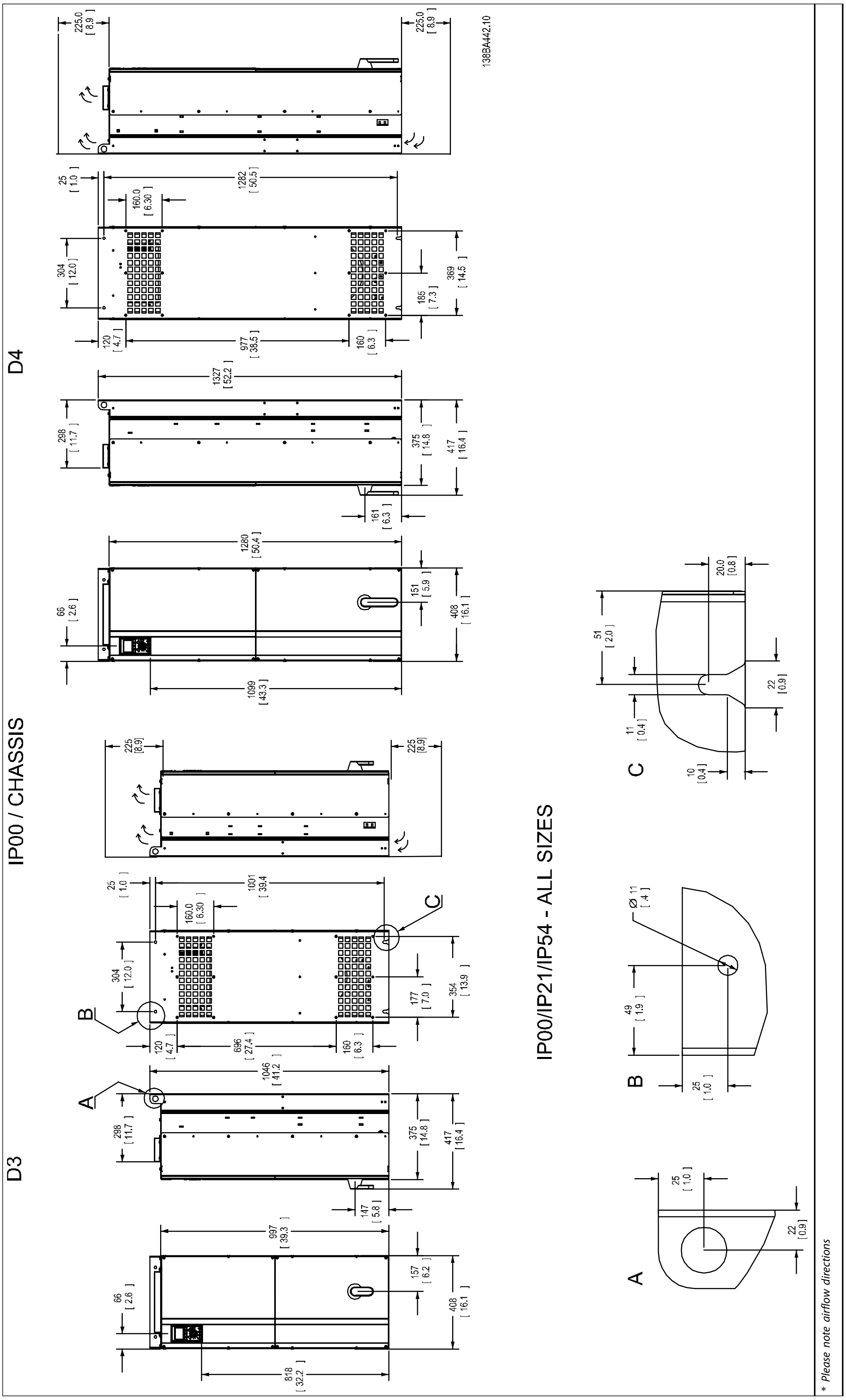
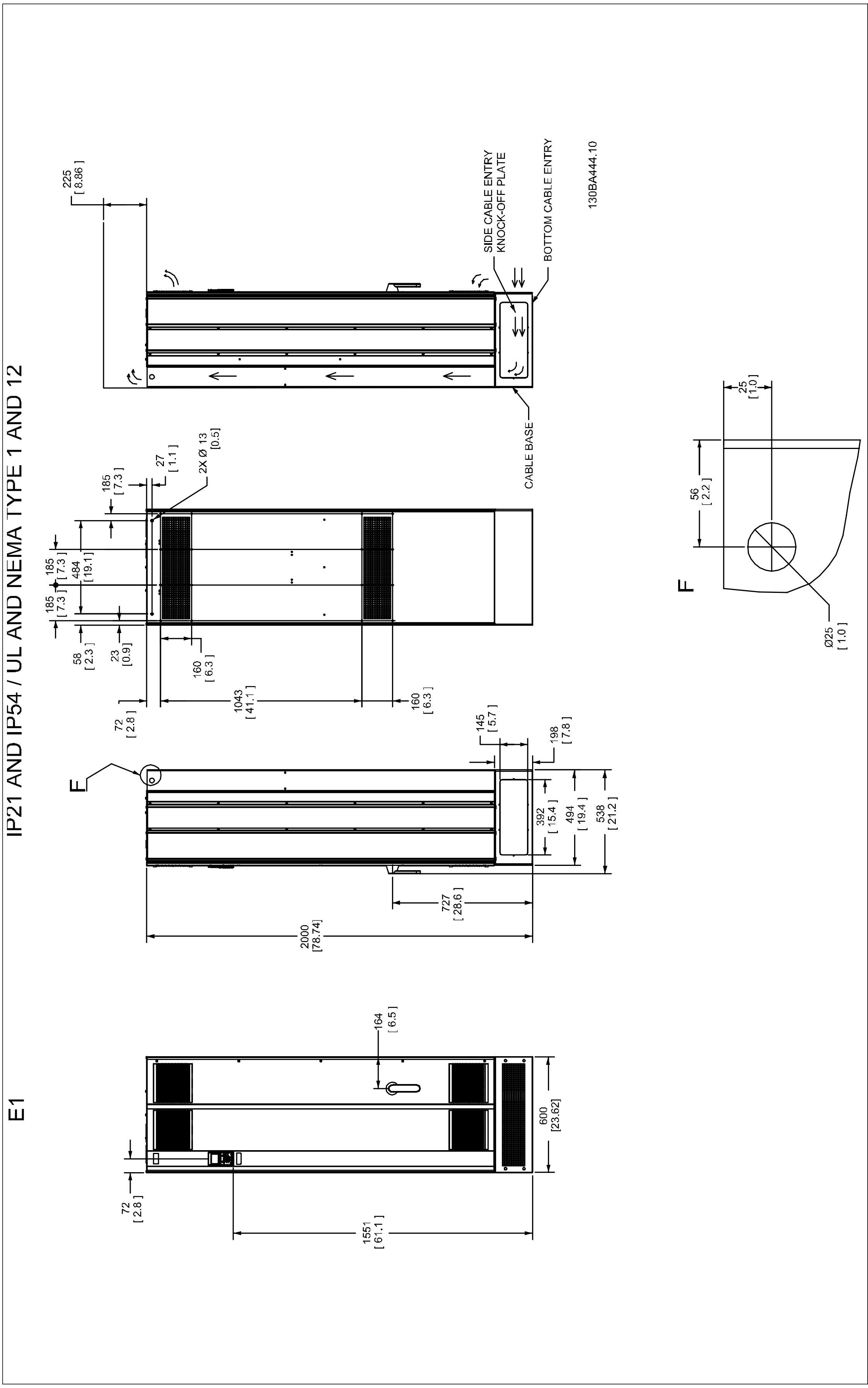
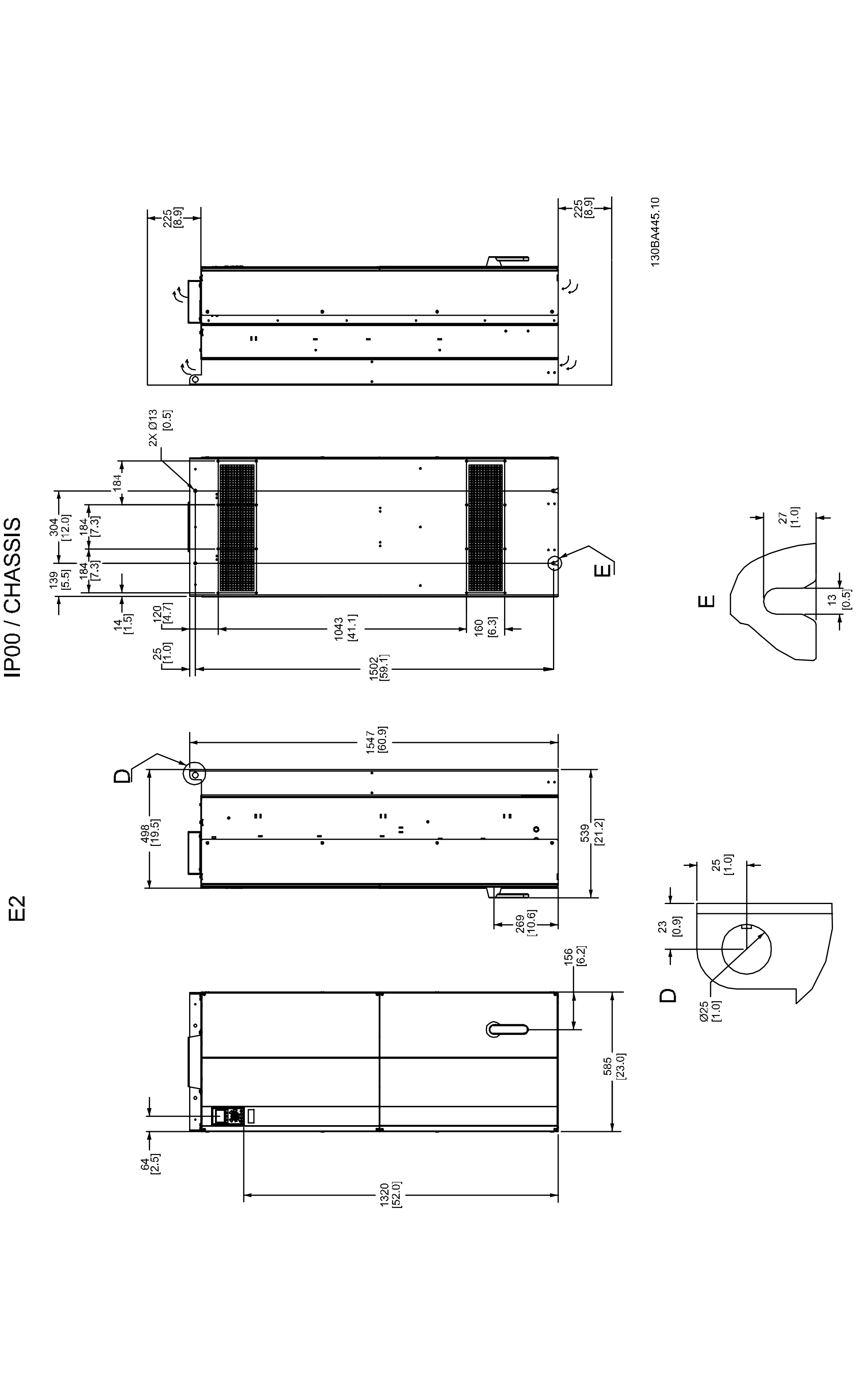

IP00 / CHASSIS
D4
D3
IP00/IP21/IP54 - ALL SIZES
A
B
C
130BA442.10
* Please note airflow directions

Table 7.2



* Please note airflow directions

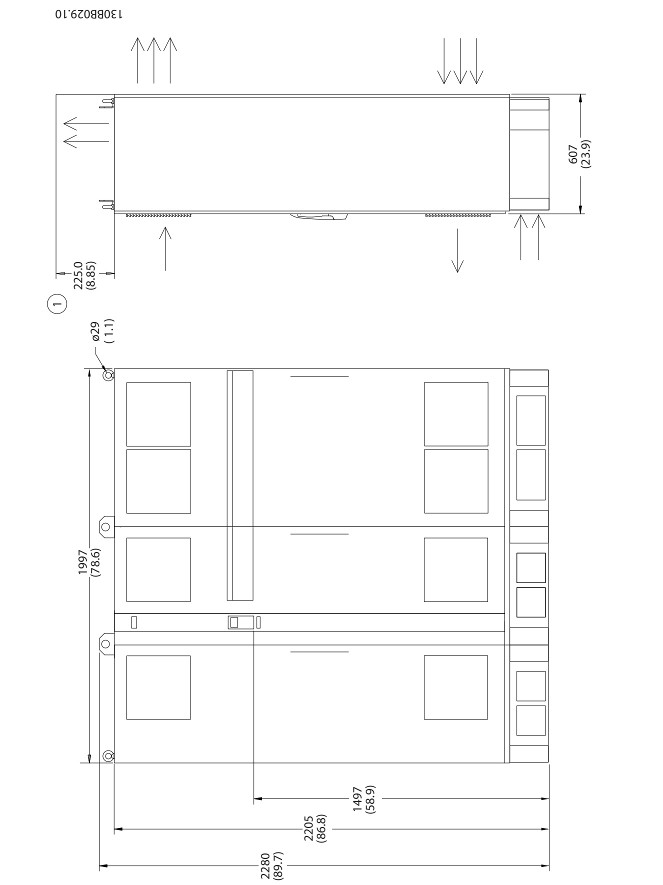
Table 7.3

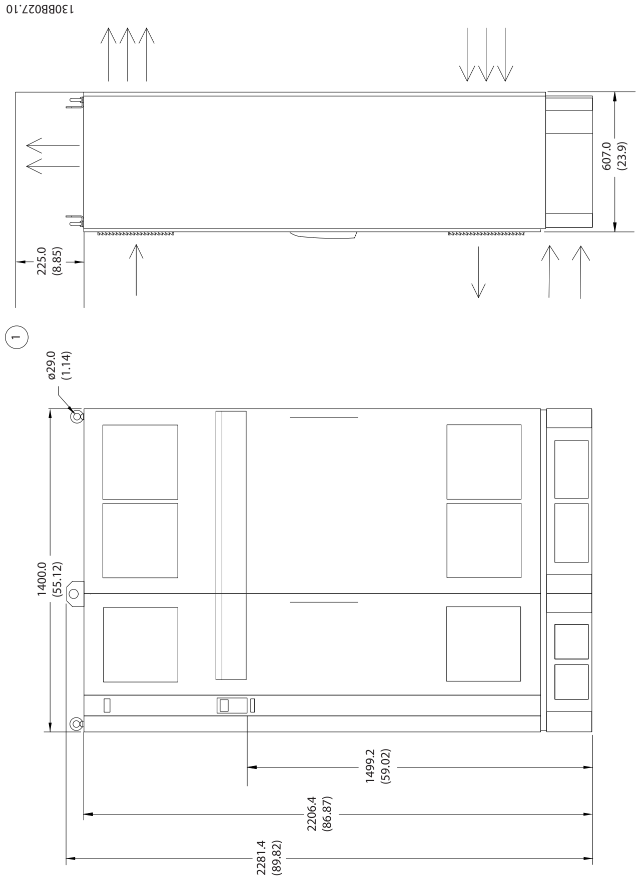


* Please note airflow directions

Table 7.4

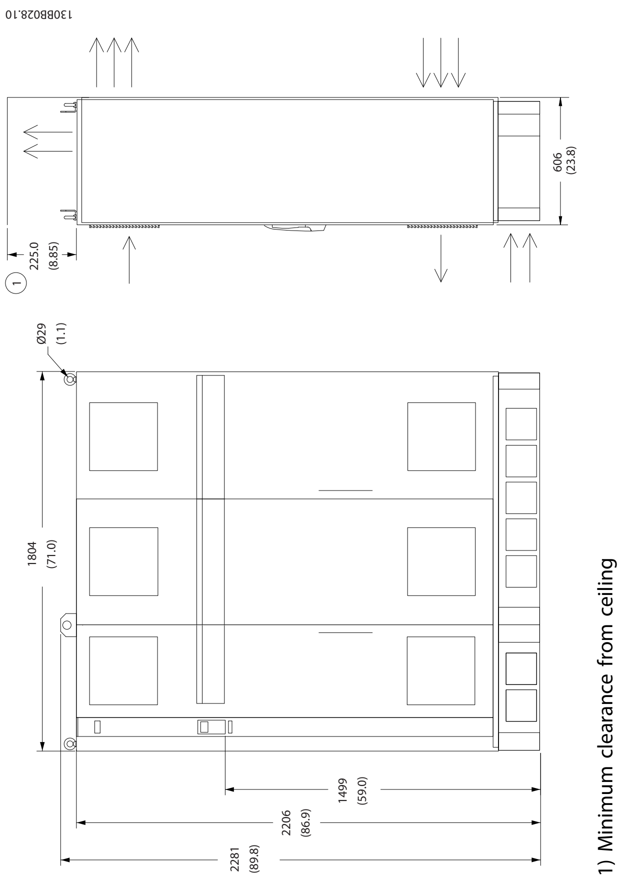
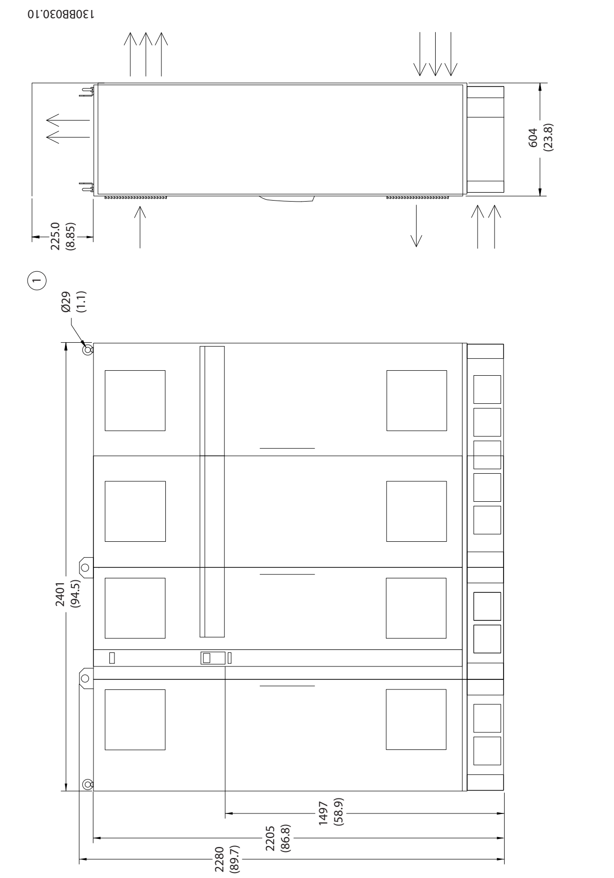
F3	IP21/54 - NEMA 1/12
F1	IP21/54 - NEMA 1/12





1) Minimum clearance from ceiling

Table 7.5

F2	IP21/54 - NEMA 1/12	F4	IP21/54 - NEMA 1/12
			

1) Minimum clearance from ceiling

Table 7.6

Mechanical dimensions, frame size D							
Frame size		D1		D2		D3	D4
		90–110kW (380–500V) 37–132kW (525–690V)		132–200kW (380– 500V) 160–315kW (525–690V)		90–110kW (380–500V) 37–132kW (525–690V)	132–200kW (380–500V) 160–315kW (525–690V)
IP NEMA		21 Type 1	54 Type 12	21 Type 1	54 Type 12	00 Chassis	00 Chassis
Shipping dimensions	Height	25.59 in [650 mm]	25.59 in [650 mm]	25.59 in [650 mm]	25.59 in [650 mm]	25.59 in [650 mm]	25.59 in [650 mm]
	Width	68.11 in [1730 mm]	68.11 in [1730 mm]	68.11 in [1730 mm]	68.11 in [1730 mm]	48.03 in [1220 mm]	58.66 in [1490 mm]
	Depth	22.44 in [570 mm]	22.44 in [570 mm]	22.44 in [570 mm]	22.44 in [570 mm]	22.44 in [570 mm]	22.44 in [570 mm]
Drive dimensions	Height	47.6 in [1209 mm]	47.6 in [1209 mm]	62.56 in [1589 mm]	62.56 in [1589 mm]	41.18 in [1046 mm]	52.24 in [1327 mm]
	Width	16.54 in [420 mm]	16.54 in [420 mm]	16.54 in [420 mm]	16.54 in [420 mm]	16.06 in [408 mm]	16.06 in [408 mm]
	Depth	14.96 in [380 mm]	14.96 in [380 mm]	14.96 in [380 mm]	14.96 in [380 mm]	14.76 in [375 mm]	14.76 in [375 mm]
	Max weight	229.3 lbs [104 kg]	229.3 lbs [104 kg]	332.9 lbs [151 kg]	332.9 lbs [151 kg]	200.62 lbs [91 kg]	304.24 lbs [138 kg]

Table 7.7

Mechanical dimensions, frame sizes E and F							
Frame size		E1	E2	F1	F2	F3	F4
		250–400kW (380–500V) 355–560kW (525–690V)	250–400kW (380–500V) 355 –560kW (525–690V)	450–630kW (380–500V) 630–800kW (525–690V)	710–800kW (380–500V) 900–1200kW (525–690V)	450–630kW (380–500V) 630–800kW (525–690V)	710–800kW (380–500V) 900–1200kW (525–690V)
IP NEMA		21, 54 Type 12	00 Chassis	21, 54 Type 12	21, 54 Type 12	21, 54 Type 12	21, 54 Type 12
Shipping dimensions	Height	31.65 in [840 mm]	32.72 in [831 mm]	91.5 in [2324 mm]	91.5 in [2324 mm]	91.5 in [2324 mm]	91.5 in [2324 mm]
	Width	86.5 in [2197 mm]	67.13 in [1705 mm]	61.77 in [1569 mm]	77.24 in [1962 mm]	85 in [2159 mm]	100.75 in [2559 mm]
	Depth	28.98 in [736 mm]	28.98 in [736 mm]	44.49 in [1130 mm]	44.49 in [1130 mm]	44.49 in [1130 mm]	44.49 in [1130 mm]
Drive dimensions	Height	78.74 in [2000 mm]	60.91 in [1547 mm]	86.8 in [2204 mm]	86.8 in [2204 mm]	86.8 in [2204 mm]	86.8 in [2204 mm]
	Width	23.62 in [600 mm]	23 in [585 mm]	55.1 in [1400 mm]	70.8 in [1800 mm]	78.73 in [2000 mm]	94.5 in [2400 mm]
	Depth	19.45 in [494 mm]	19.61 in [498 mm]	23.9 in [606 mm]	23.9 in [606 mm]	23.9 in [606 mm]	23.9 in [606 mm]
	Max weight	690 lbs [313 kg]	611 lbs [277 kg]	2213 lbs [1004 kg]	2747 lbs [1246 kg]	2863 lbs [1299 kg]	3397 lbs [1541 kg]

Table 7.8

7.1.6 Mechanical Dimensions, 12-Pulse Units

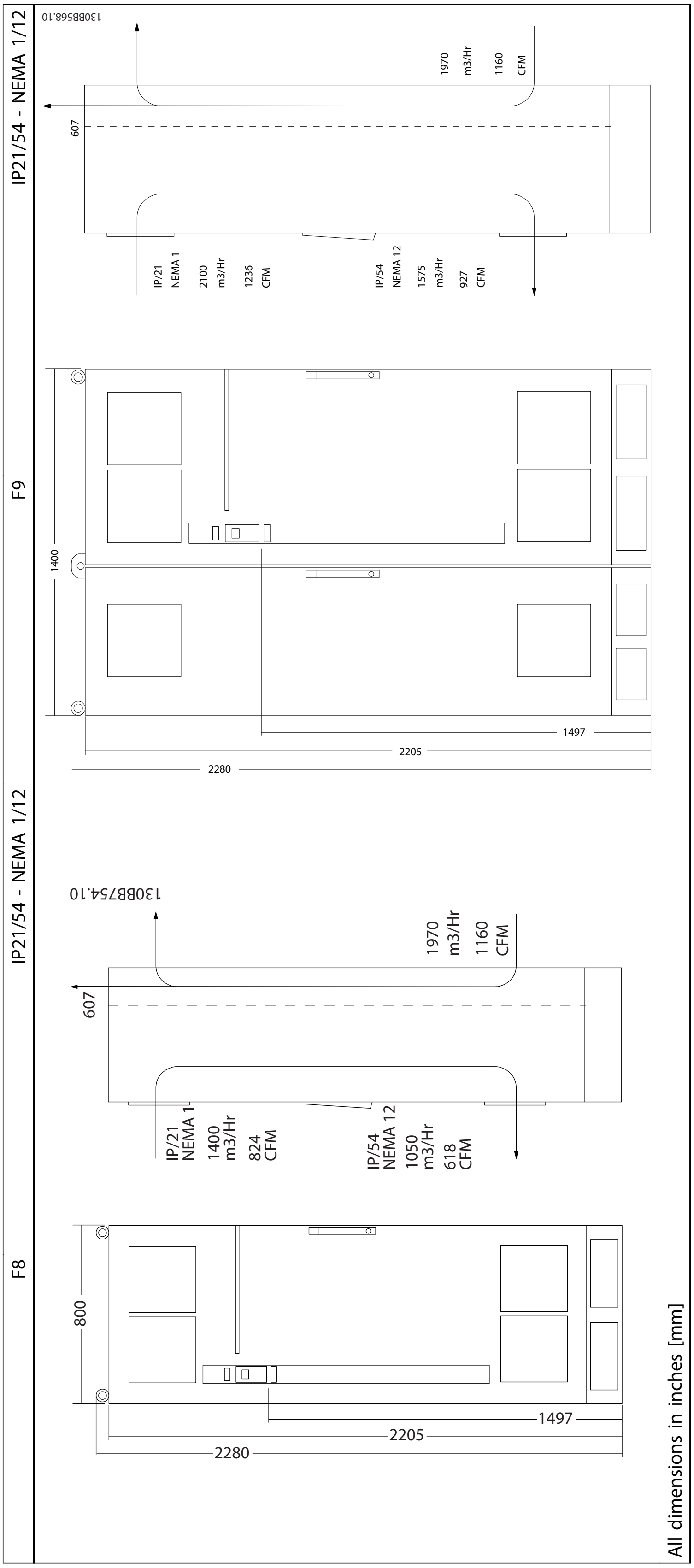


Table 7.9

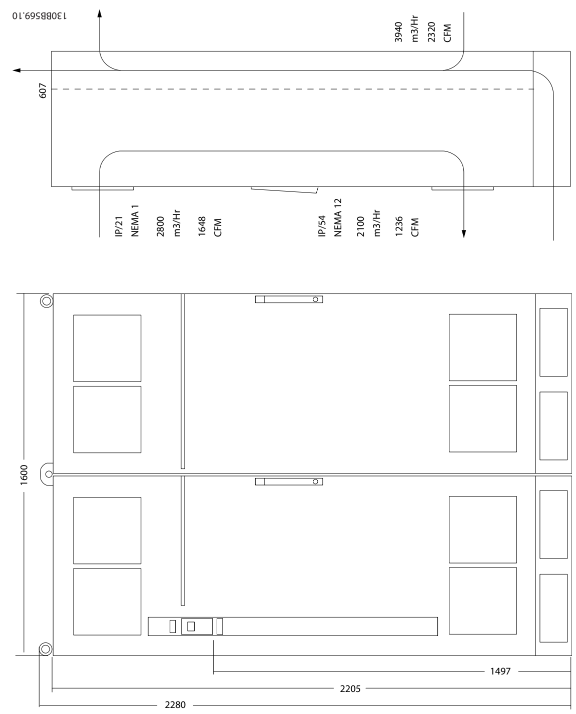
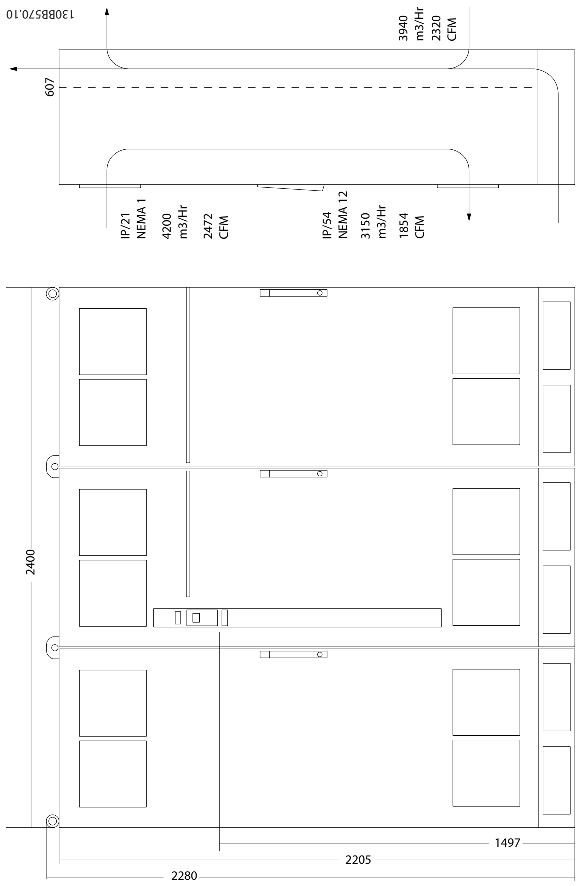
F10	IP21/54 - NEMA 1/12
	
F11	**IP21/54 - NEMA 1/12**
	
All dimensions in inches [mm]	

Table 7.10

7

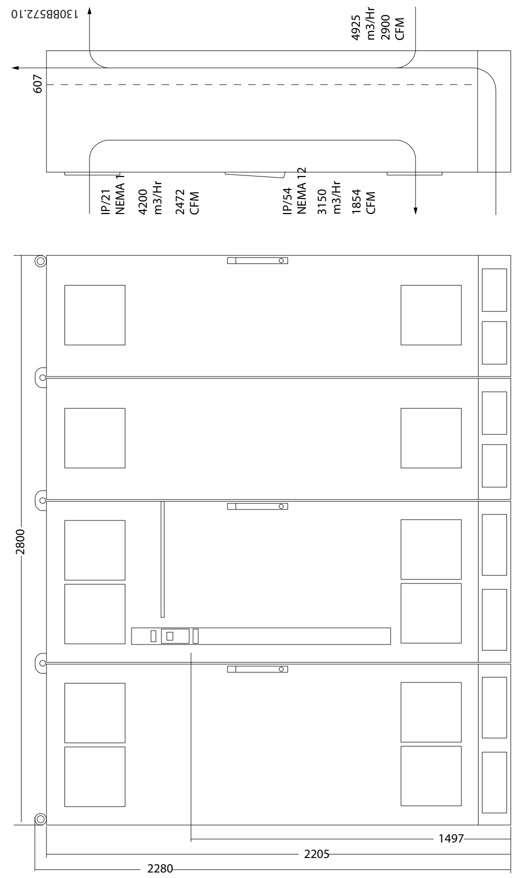
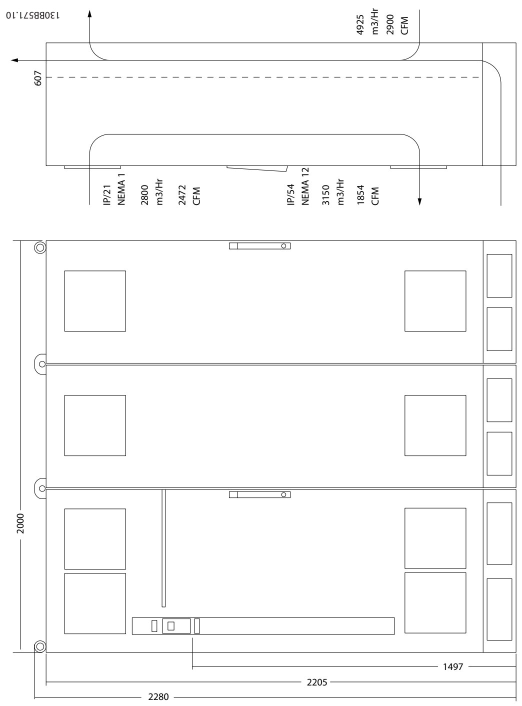
F13	IP21/54 - NEMA 1/12
	
F12	**IP21/54 - NEMA 1/12**
	
All dimensions in inches [mm]	

Table 7.11

Mechanical dimensions, 12-Pulse units, frame sizes F8-F13							
Frame size		F8	F9	F10	F11	F12	F13
High overload rated power - 160% overload torque		250–400kW (380–500V) 355–560kW (525–690V)	250–400kW (380–500V) 355–56kW (525–690V)	450–630kW (380–500V) 630–800kW (525–690V)	450–630kW (380–500V) 630–800kW (525–690V)	710–800kW (380–500V) 900–1200kW (525–690V)	710–800kW (380–500V) 900 –1200kW (525–690V)
IP NEMA		21, 54 Type 1/Type 12	21, 54 Type 1/Type 12	21, 54 Type 1/Type 12	21, 54 Type 1/Type 12	21, 54 Type 1/Type 12	21, 54 Type 1/Type 12
Shipping dimensions ins [mm]	Height	91.49 [2324]	91.49 [2324]	91.49 [2324]	91.49 [2324]	91.49 [2324]	91.49 [2324]
	Width	38.2 [970]	61.73 [1568]	69.3 [1760]	100.75 [2559]	85 [2160]	116.5 [2960]
	Depth	44.5 [1130]	44.5 [1130]	44.5 [1130]	44.5 [1130]	44.5 [1130]	44.5 [1130]
Drive dimensions ins [mm]	Height	86.8 [2204]	86.8 [2204]	86.8 [2204]	86.8 [2204]	86.8 [2204]	86.8 [2204]
	Width Depth	31.50 [800] 23.9 [606]	55.1 [1400] 23.9 [606]	63 [1600] 23.9 [606]	86.6 [2200] 23.9 [606]	78.73 [2000] 23.9 [606]	102.4 [2600] 23.9 [606]
Max weight lbs [kg]		970 [440]	1446 [656]	1940 [880]	2416 [1096]	2253 [1022]	2729 [1238]

Table 7.12

7

7.2 Mechanical Installation

Preparation of the mechanical installation of the adjustable frequency drive must be done carefully to ensure proper results and to avoid additional work during installation. Start by taking a close look at the mechanical drawings at the end of this instruction manual to become familiar with the space demands.

7.2.1 Tools Needed

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

- Drill with 0.39 or 0.47 in [10 or 12 mm] drill.
- Tape measure
- Wrench with relevant metric sockets (7–17 mm [0.275–0.669 ins])
- Extensions to wrench
- Sheet metal punch for conduits or cable connectors in IP 21/Nema 1 and IP 54 units
- Lifting bar to lift the unit (rod or tube max. Ø1 in [25 mm], able to lift minimum 880 lbs [400 kg].
- Crane or other lifting aid to place the adjustable frequency drive in position
- A Torx T50 tool is needed to install the E1 in IP21 and IP54 enclosure types.

7.2.2 General Considerations

Wire access

Ensure that proper cable access is present including the necessary bending allowance. As the IP00 enclosure is open to the bottom cables must be fixed to the back panel of the enclosure where the adjustable frequency drive is mounted, i.e., by using cable clamps.

CAUTION

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

Space

Ensure proper space above and below the adjustable frequency drive to allow airflow and cable access. In addition, space in front of the unit must be considered to allow the panel door to be opened.

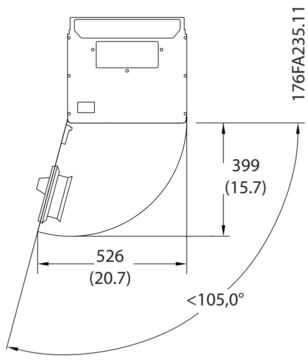


Figure 7.5 Space in front of IP21/IP54 enclosure type, frame size D1 and D2.

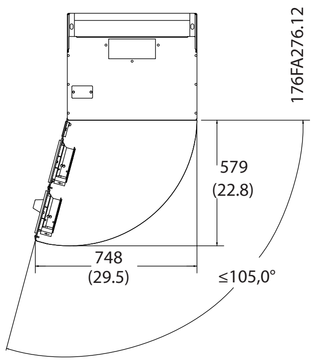


Figure 7.6 Space in front of IP21/IP54 enclosure type, frame size E1.

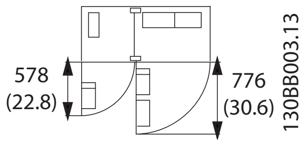


Figure 7.7 Space in front of IP21/IP54 enclosure type, frame size F1

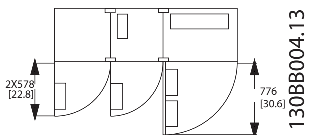


Figure 7.8 Space in front of IP21/IP54 enclosure type, frame size F3

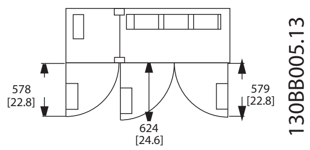


Figure 7.9 Space in front of IP21/IP54 enclosure type, frame size F2

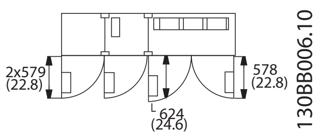


Figure 7.10 Space in front of IP21/IP54 enclosure type, frame size F4

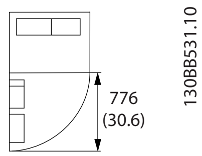


Figure 7.11 Space in front of IP21/IP54 enclosure type, frame size F8

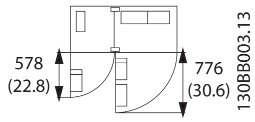


Figure 7.12 Space in front of IP21/IP54 enclosure type, frame size F9

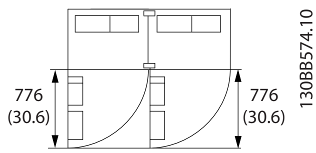


Figure 7.13 Space in front of IP21/IP54 enclosure type, frame size F10

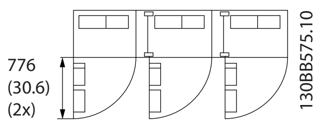


Figure 7.14 Space in front of IP21/IP54 enclosure type, frame size F11

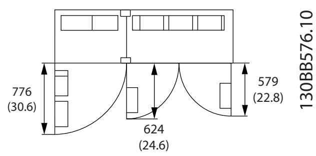


Figure 7.15 Space in front of IP21/IP54 enclosure type, frame size F12

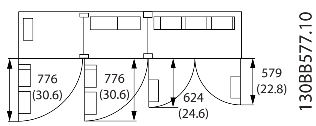


Figure 7.16 Space in front of IP21/IP54 enclosure type, frame size F13

7.2.3 Terminal Locations - Frame size D

Take the following terminal positions into consideration when you design for cable access.

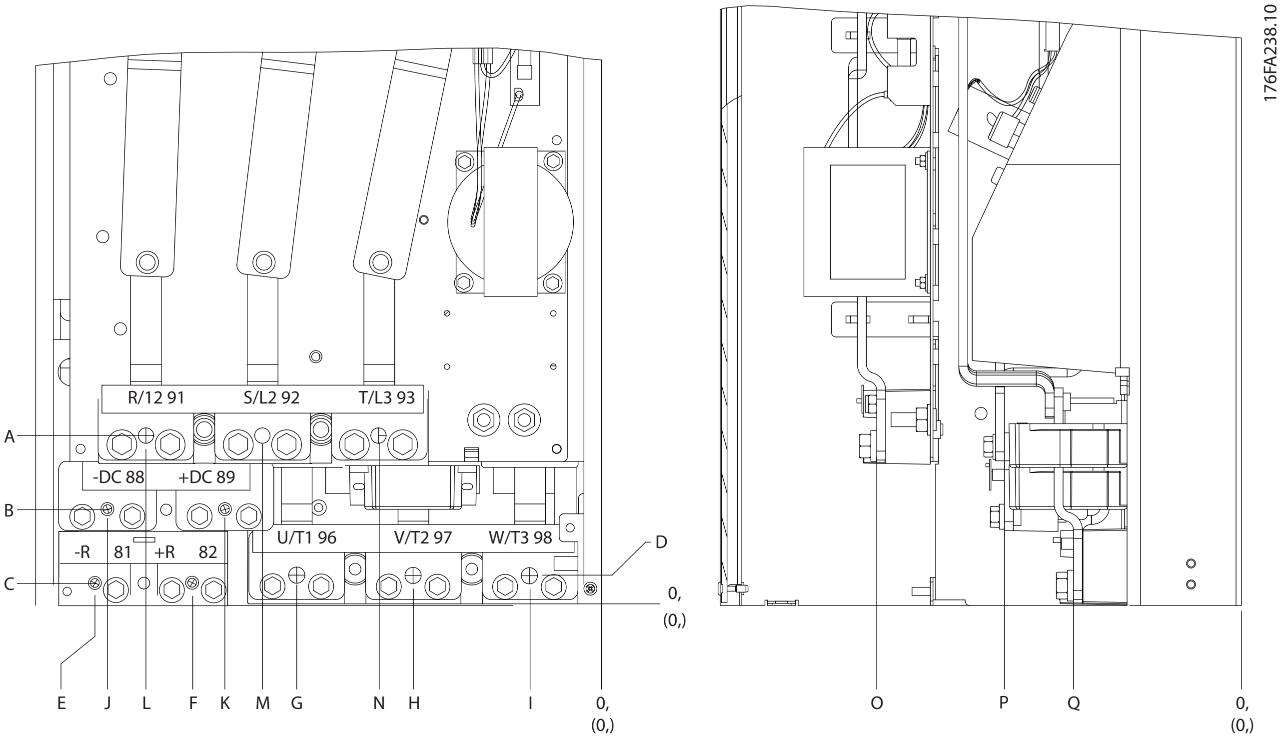


Figure 7.17 Position of power connections, frame size D3 and D4

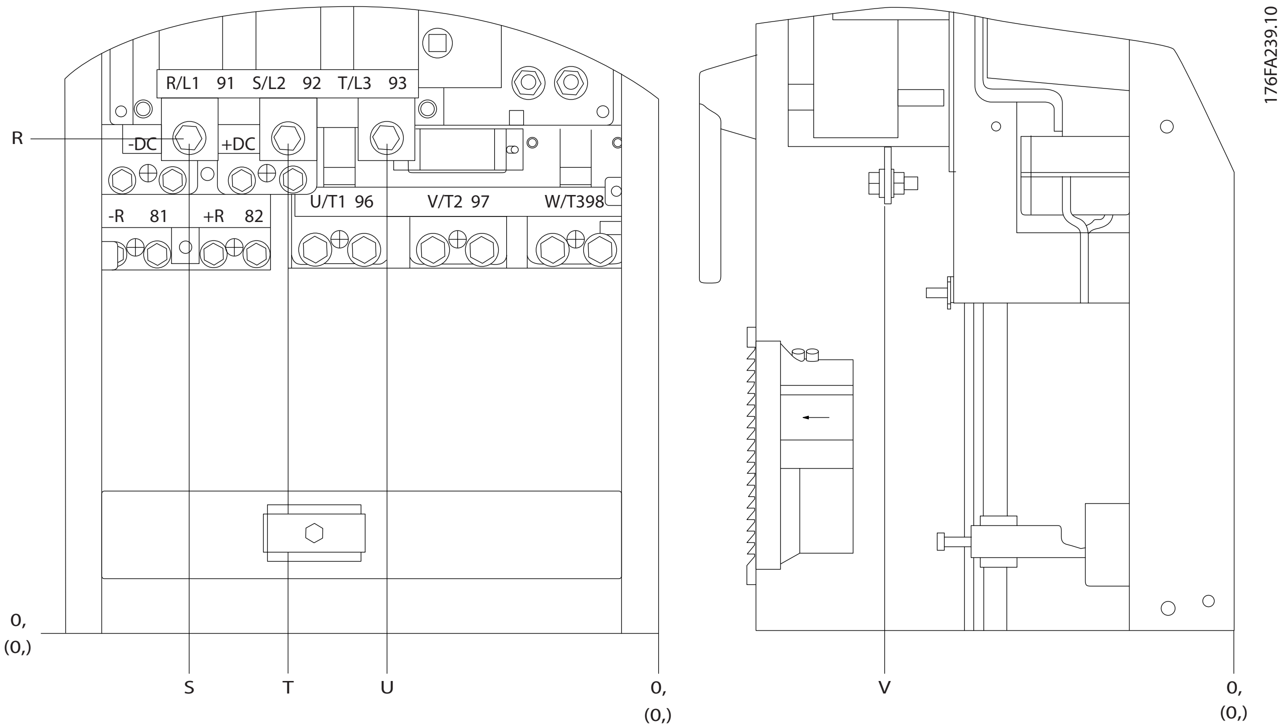


Figure 7.18 Position of power connections with disconnect switch, frame size D1 and D2

Be aware that the power cables are heavy and hard to bend. Give thought to the optimum position of the adjustable frequency drive for ensuring easy installation of the cables.

NOTE!

All D frames are available with standard input terminals or disconnect switch. All terminal dimensions can be found in the following table.

	IP21 (NEMA 1) / IP54 (NEMA 12)		IP00 / Chassis	
	Frame size D1	Frame size D2	Frame size D3	Frame size D4
A	277 (10.9)	379 (14.9)	119 (4.7)	122 (4.8)
B	227 (8.9)	326 (12.8)	68 (2.7)	68 (2.7)
C	173 (6.8)	273 (10.8)	15 (0.6)	16 (0.6)
D	179 (7.0)	279 (11.0)	20.7 (0.8)	22 (0.8)
E	370 (14.6)	370 (14.6)	363 (14.3)	363 (14.3)
F	300 (11.8)	300 (11.8)	293 (11.5)	293 (11.5)
G	222 (8.7)	226 (8.9)	215 (8.4)	218 (8.6)
H	139 (5.4)	142 (5.6)	131 (5.2)	135 (5.3)
I	55 (2.2)	59 (2.3)	48 (1.9)	51 (2.0)
J	354 (13.9)	361 (14.2)	347 (13.6)	354 (13.9)
K	284 (11.2)	277 (10.9)	277 (10.9)	270 (10.6)
L	334 (13.1)	334 (13.1)	326 (12.8)	326 (12.8)
M	250 (9.8)	250 (9.8)	243 (9.6)	243 (9.6)
N	167 (6.6)	167 (6.6)	159 (6.3)	159 (6.3)
O	261 (10.3)	260 (10.3)	261 (10.3)	261 (10.3)
P	170 (6.7)	169 (6.7)	170 (6.7)	170 (6.7)
Q	120 (4.7)	120 (4.7)	120 (4.7)	120 (4.7)
R	256 (10.1)	350 (13.8)	98 (3.8)	93 (3.7)
S	308 (12.1)	332 (13.0)	301 (11.8)	324 (12.8)
T	252 (9.9)	262 (10.3)	245 (9.6)	255 (10.0)
U	196 (7.7)	192 (7.6)	189 (7.4)	185 (7.3)
V	260 (10.2)	273 (10.7)	260 (10.2)	273 (10.7)

Table 7.13 Cable positions as shown in the drawings above. Dimensions in mm (inches).

7.2.4 Terminal Locations - Frame size E

Terminal Locations - E1

Give thought to the following terminal positions when designing the cable access.

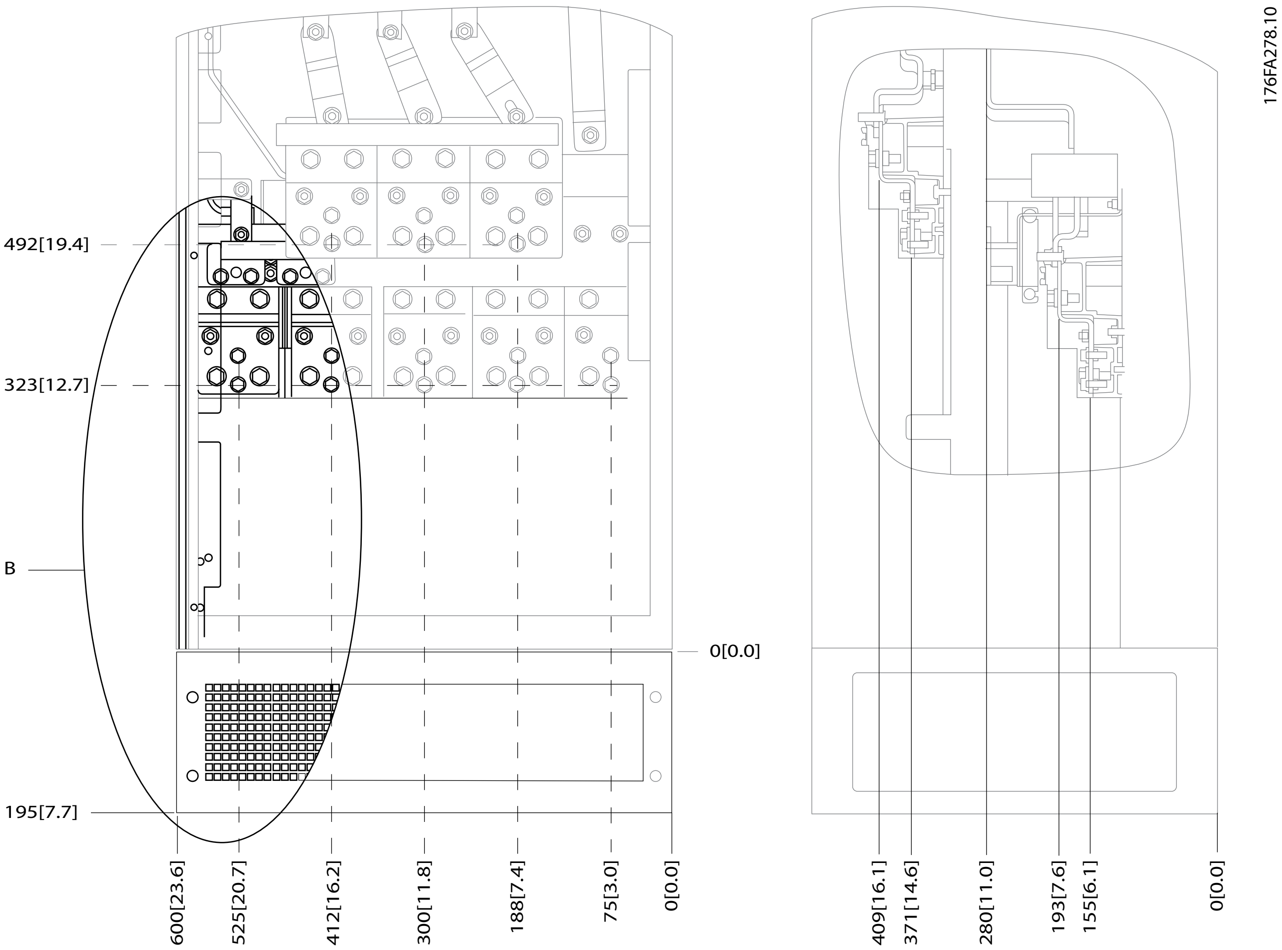


Figure 7.19 IP21 (NEMA Type 1) and IP54 (NEMA Type 12) enclosure power connection positions

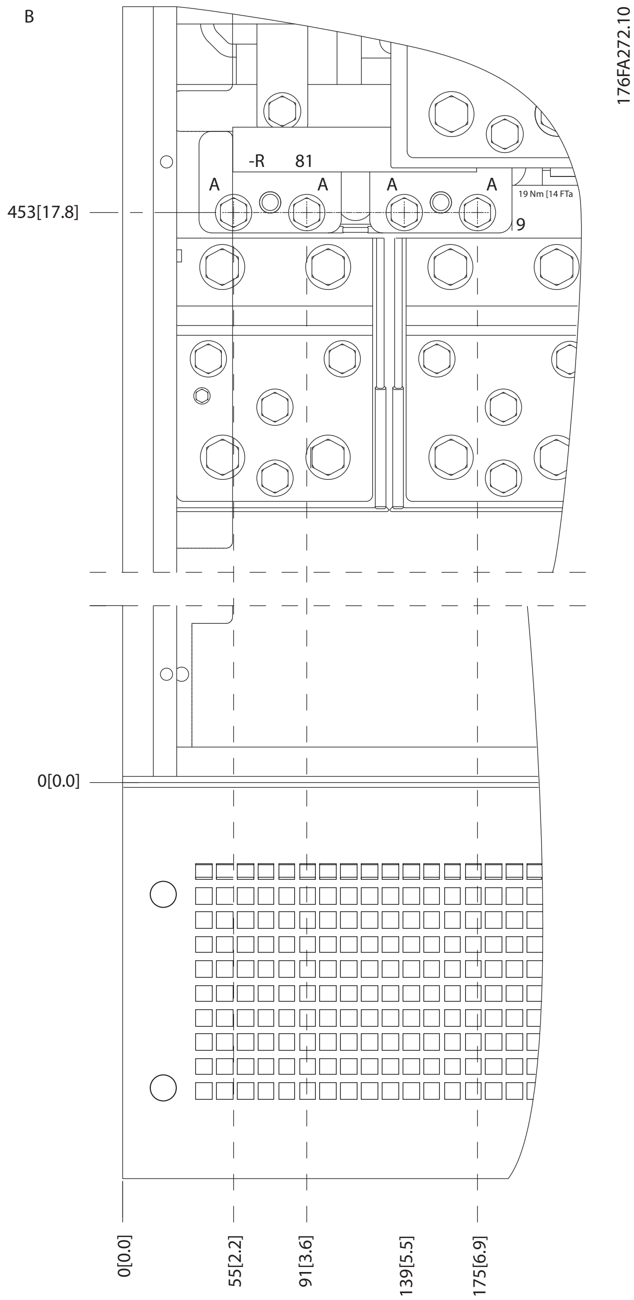


Figure 7.20 IP21 (NEMA type 1) and IP54 (NEMA type 12) enclosure power connection positions (detail B)

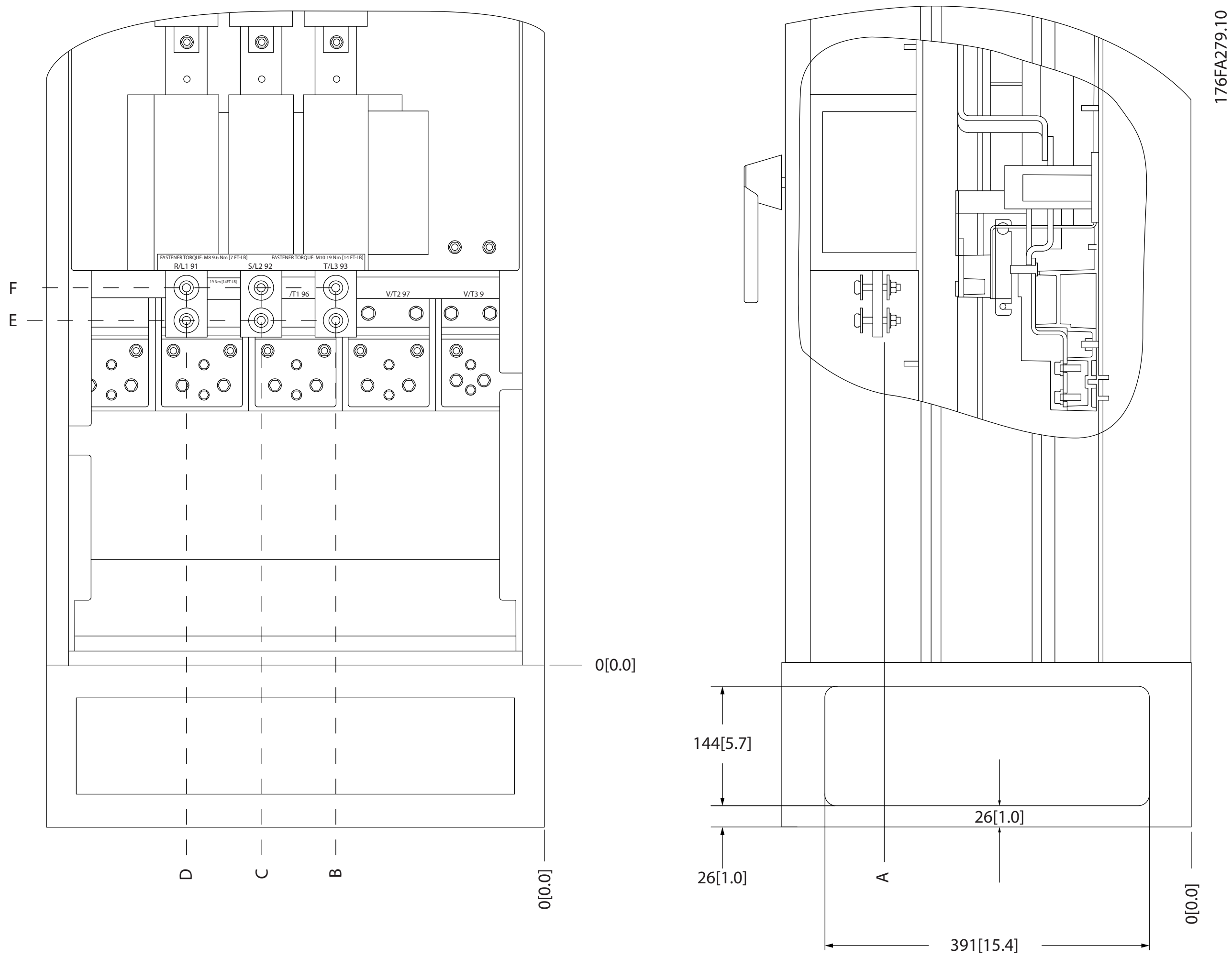


Figure 7.21 IP21 (NEMA type 1) and IP54 (NEMA type 12) enclosure power connection position of disconnect switch

Frame size	Unit type	Dimension for disconnect terminal					
E1	IP54/IP21 UL AND NEMA1/NEMA12						
	350/450 HP [250/315 kW] (400 V) AND 500/600–675/850 HP [355/450–500/630 KW] (690 V)	381 (15.0)	253 (9.9)	253 (9.9)	431 (17.0)	562 (22.1)	N/A
	450/500–550/600 HP [315/355–400/450 kW] (400 V)	371 (14.6)	371 (14.6)	341 (13.4)	431 (17.0)	431 (17.0)	455 (17.9)

Table 7.14

Terminal locations - Frame size E2

Give thought to the following terminal positions when designing the cable access.

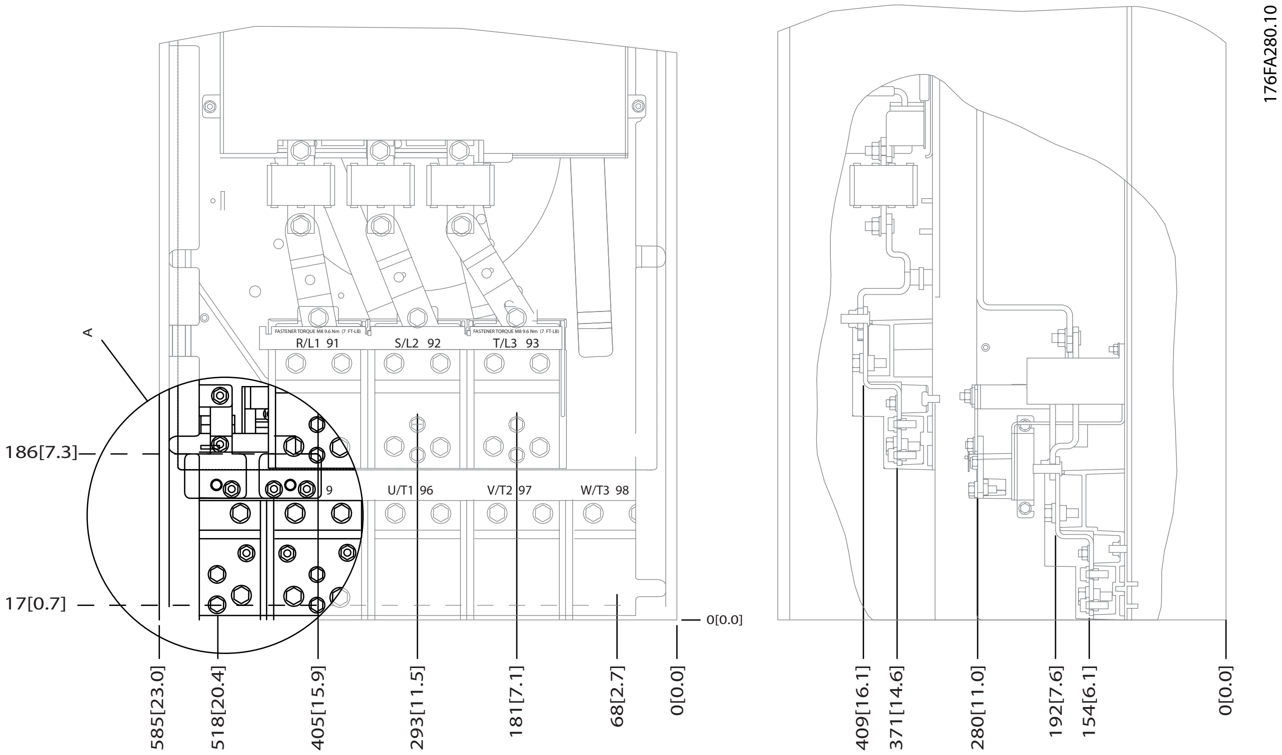


Figure 7.22 IP00 enclosure power connection positions

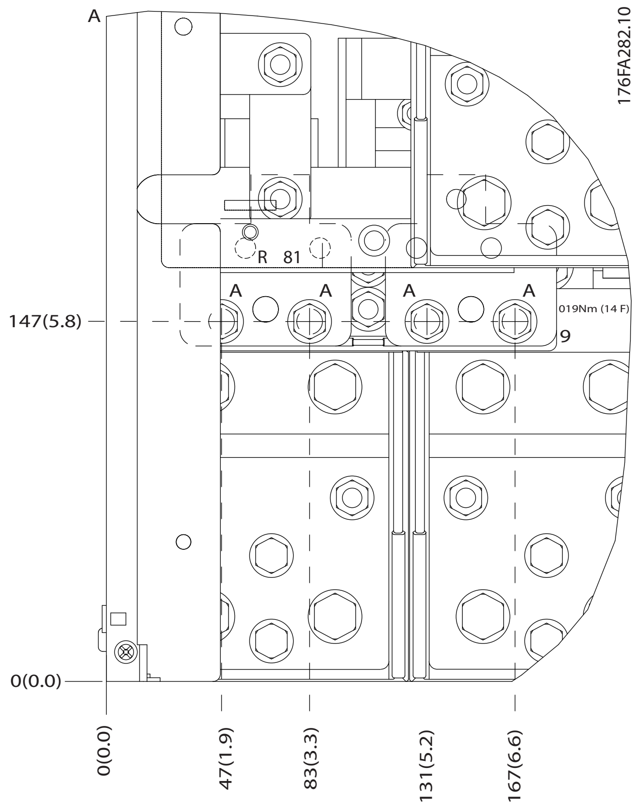


Figure 7.23 IP00 enclosure power connection positions

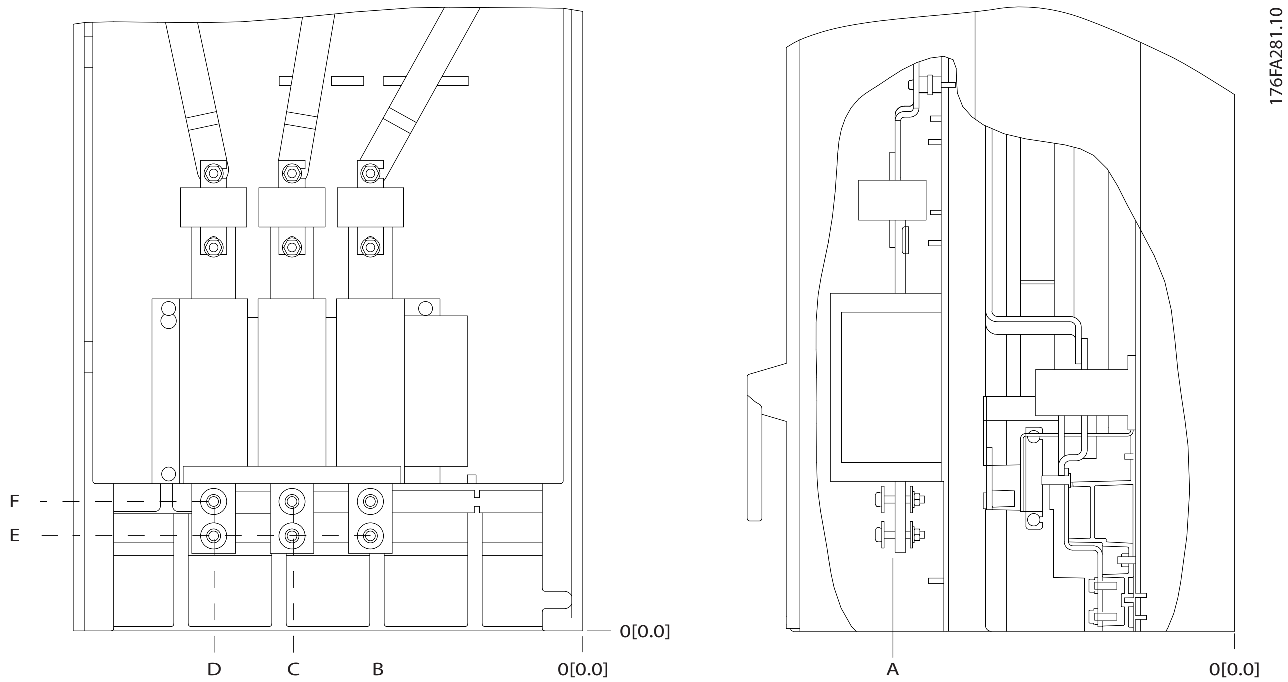


Figure 7.24 IP00 enclosure power connections positions of disconnect switch

Note that the power cables are heavy and difficult to bend. Give thought to the optimum position of the adjustable frequency drive for ensuring easy installation of the cables.
Each terminal allows for the use of up to 4 cables with cable lugs or the use of standard box lug. Ground is connected to relevant termination point in the drive.

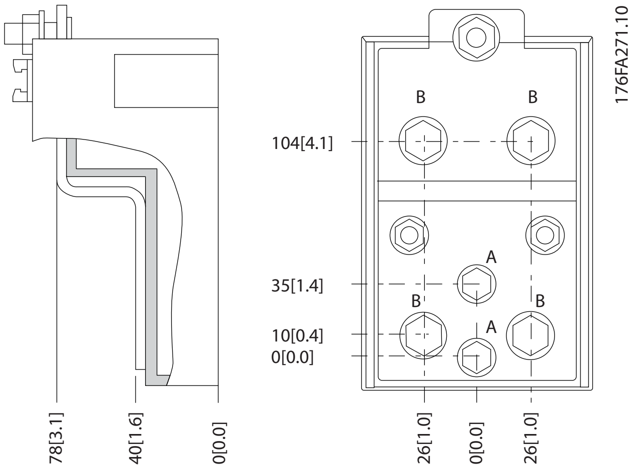


Figure 7.25 Terminal in details

Power connections can be made to positions A or B

Frame size	Unit type	Dimension for disconnect terminal					
	IPOO/CHASSIS	A	B	C	D	E	F
E2	350/450 HP [250/315 kW] (400 V) AND 500/600–675/850 HP [355/450–500/630 KW] (690 V)	381 (15.0)	245 (9.6)	334 (13.1)	423 (16.7)	256 (10.1)	N/A
	450/500–550/600 HP [315/355–400/450 kW] (400 V)	383 (15.1)	244 (9.6)	334 (13.1)	424 (16.7)	109 (4.3)	149 (5.8)

Table 7.15

7

7

7.2.5 Terminal Locations - Frame size F

NOTE!

The F frames have four different sizes, F1, F2, F3 and F4. The F1 and F2 consist of an inverter cabinet on the right and rectifier cabinet on the left. The F3 and F4 have an additional options cabinet left of the rectifier cabinet. The F3 is an F1 with an additional options cabinet. The F4 is an F2 with an additional options cabinet.

Terminal locations - Frame size F1 and F3

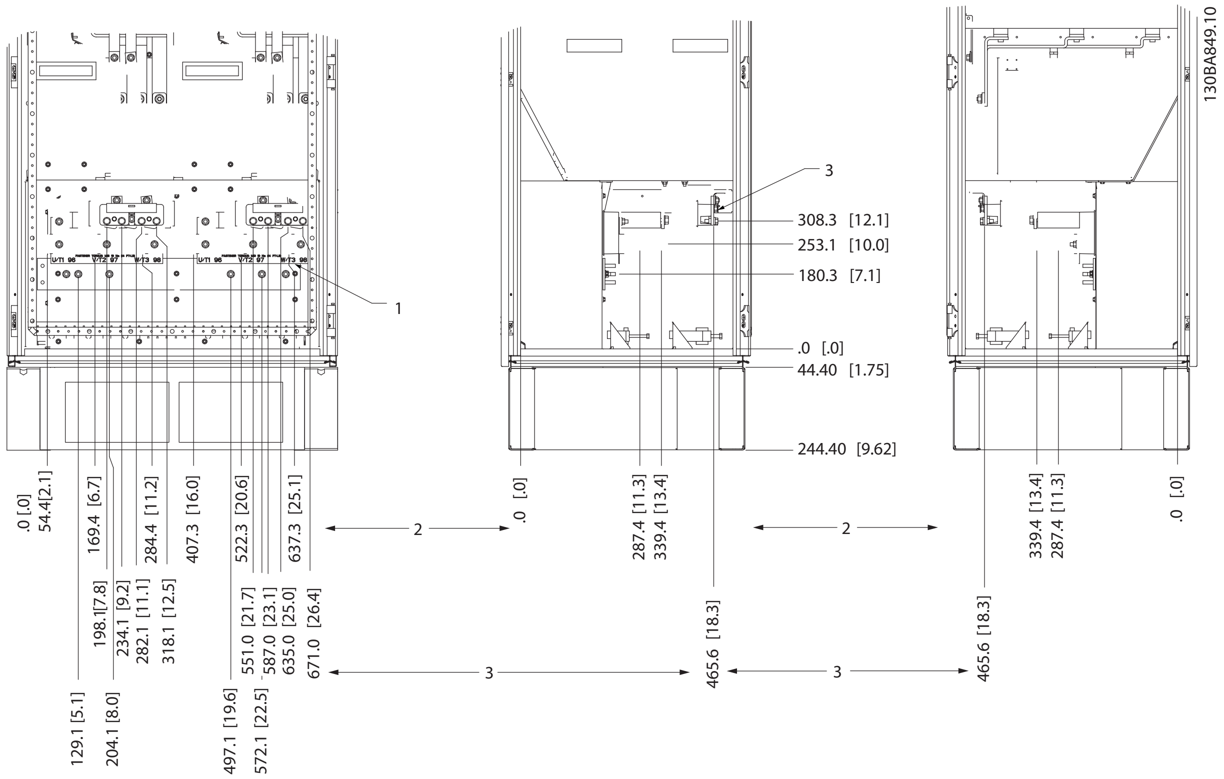


Figure 7.26 Terminal locations - Inverter Cabinet - F1 and F3 (front, left and right side view). The connector plate is 1.65 in [42 mm] below .0 level.

1) Ground bar

2) Motor terminals

3) Brake terminals

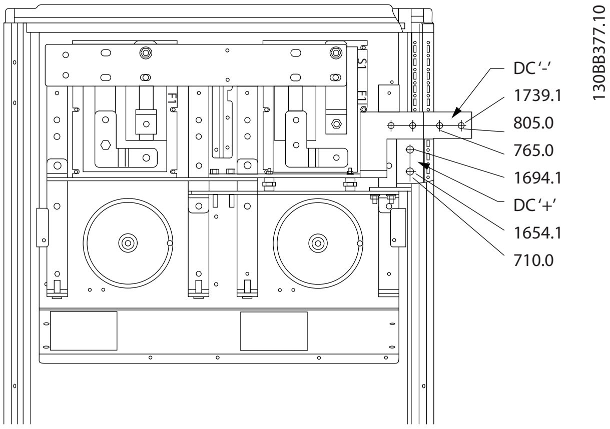


Figure 7.27 Terminal Locations - Regen Terminals - F1 and F3

Terminal locations - Frame size F2 and F4

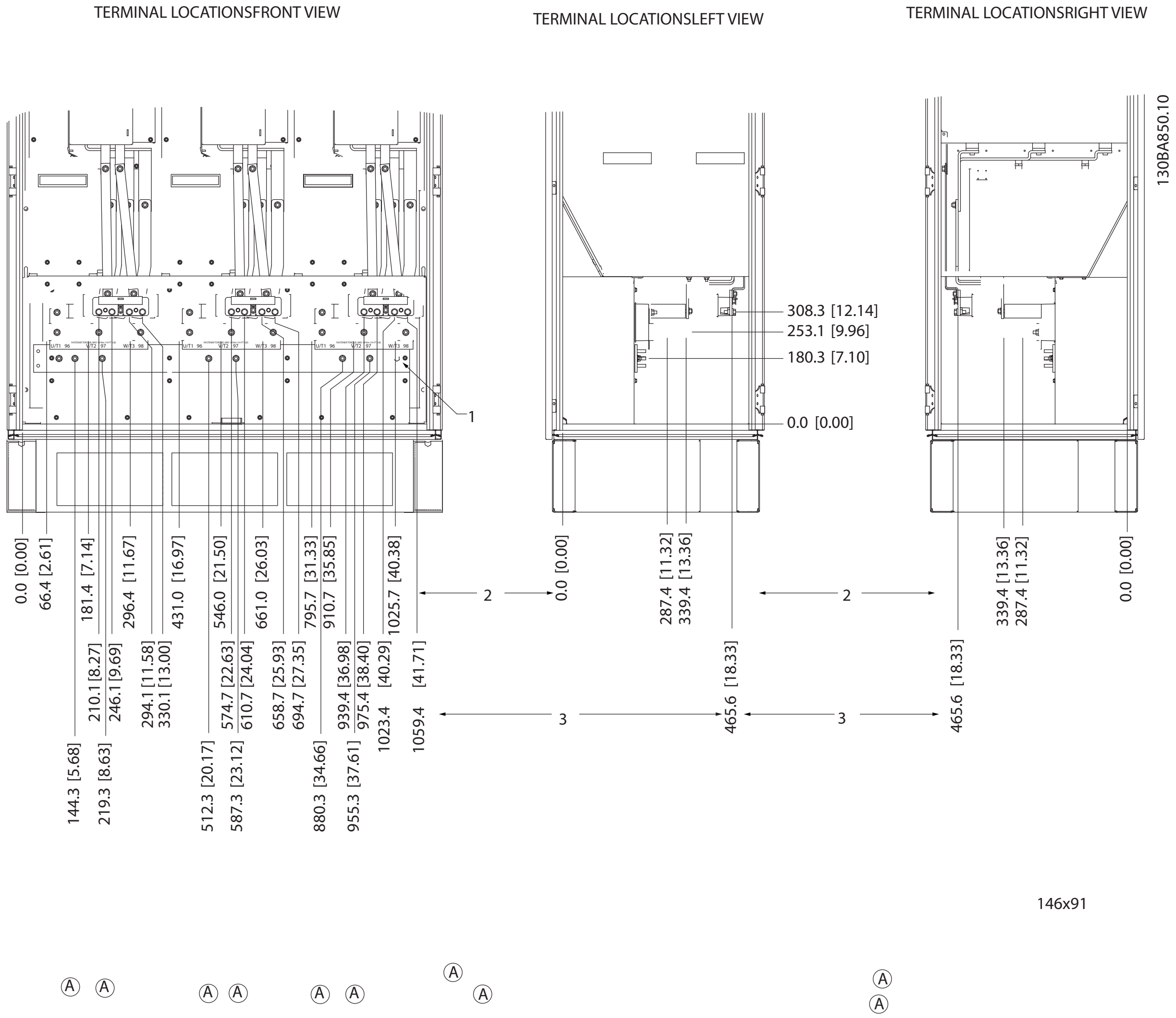


Figure 7.28 Terminal locations - Inverter cabinet - F2 and F4 (front, left and right side view). The connector plate is 1.65 in [42 mm] below .0 level.
1) Ground bar

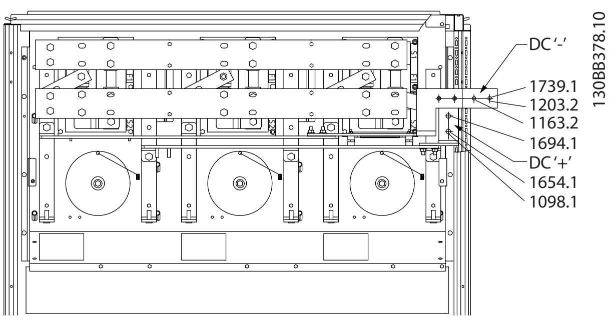
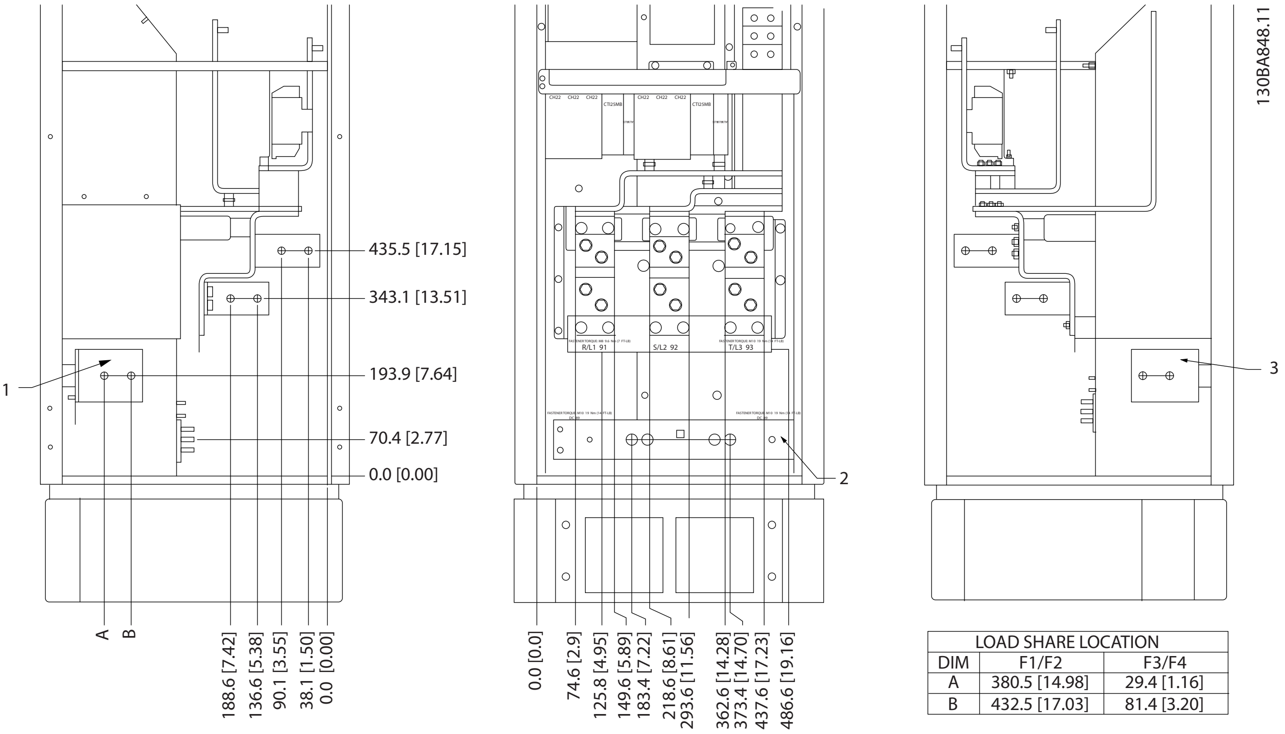


Figure 7.29 Terminal Locations - Regen Terminals - F2 and F4

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



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

Figure 7.30 Terminal locations - Rectifier (left side, front and right side view). The connector plate is 1.65 in [42 mm] below .0 level.

1) Load share Terminal (-)

2) Ground bar

3) Load share Terminal (+)

7

Terminal locations - Options Cabinet (F3 and F4)

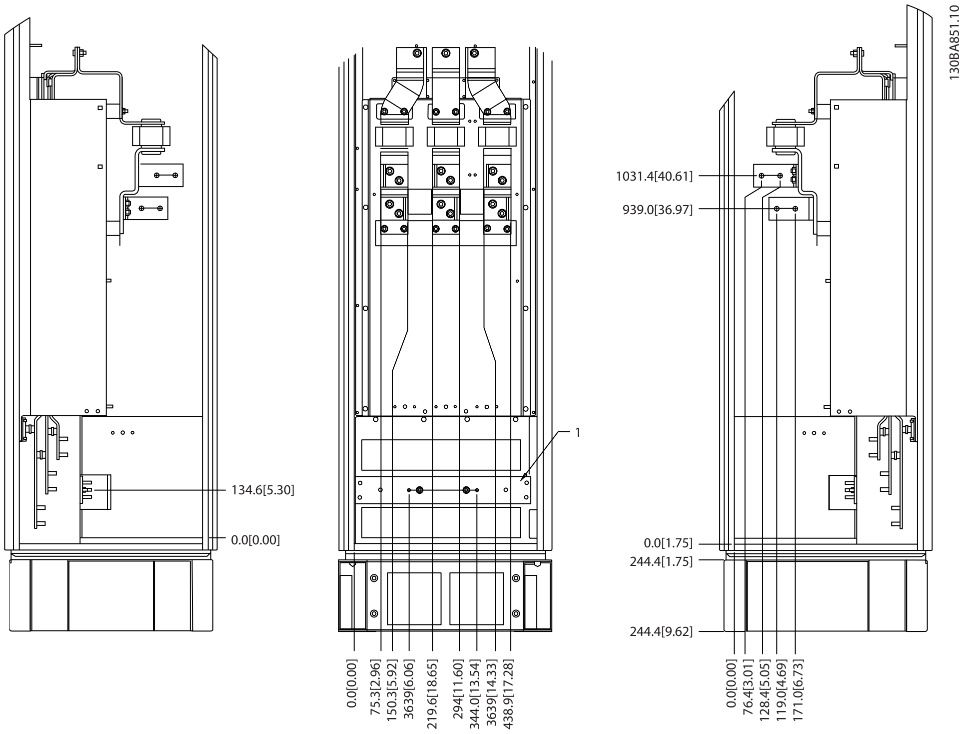


Figure 7.31 Terminal locations - Options cabinet (left side, front and right side view). The connector plate is 1.65 in [42 mm] below .0 level.

1) Ground bar

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

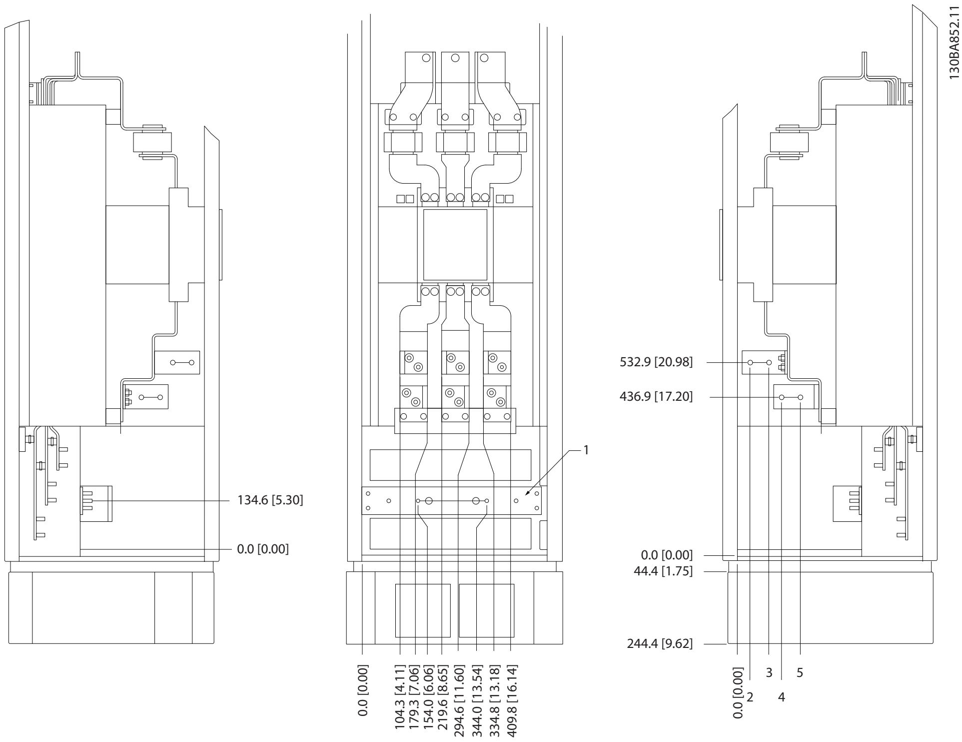


Figure 7.32 Terminal locations - Options cabinet with circuit breaker/ molded case switch (left side, front and right side view). The connector plate is 1.65 in [42 mm] below .0 level.
1) Ground bar

Power size	2	3	4	5
600 hp [450 kW] (480 V), 850–950 hp [630–710 kW] (690 V)	1.37 in [34.9 mm]	3.42 in [86.9 mm]	4.81 in [122.2 mm]	6.86 in [174.2 mm]
675–1075 hp [500–800kW] (480V), 1075–[1350 hp 800–1000kW] (690V)	1.82 in [46.3 mm]	3.87 in [98.3 mm]	4.68 in [119.0 mm]	6.73 in [171.0 mm]

Table 7.16 Dimension for terminal

7

7

7.2.6 Terminal Locations, F8-F13 - 12-Pulse

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

Terminal locations - Inverter and Rectifier Frame size F8 and F9

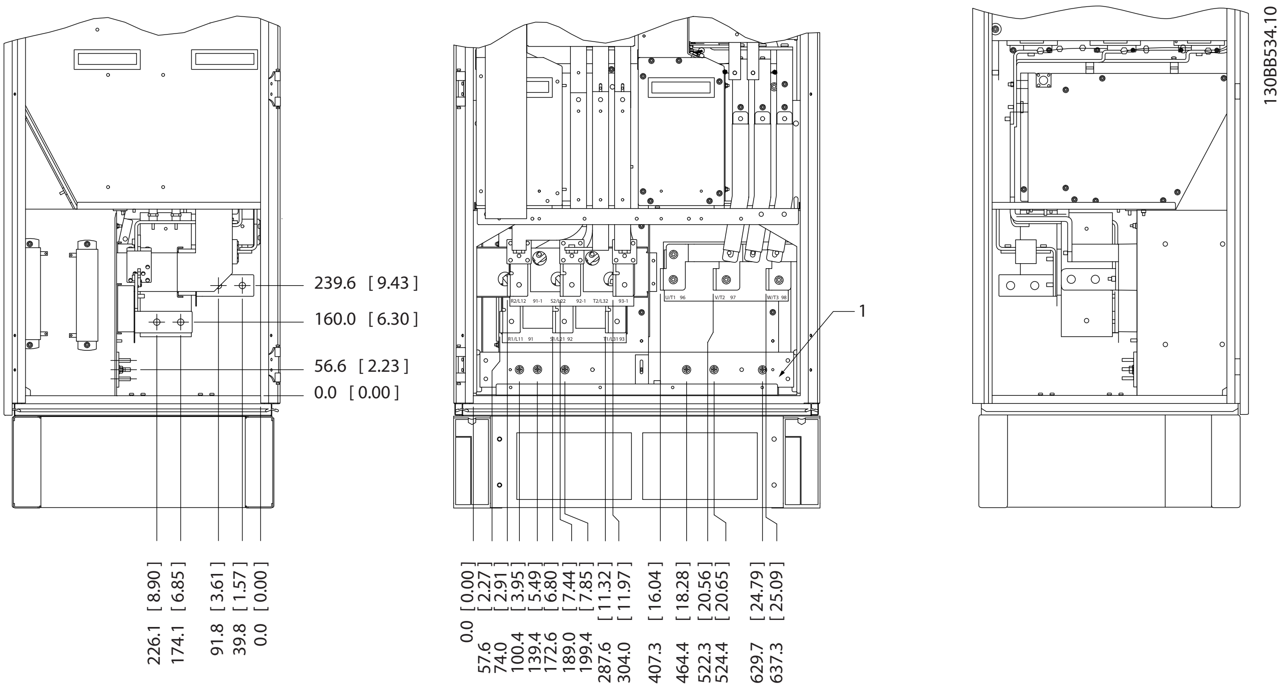


Figure 7.33 Terminal locations - Inverter and Rectifier Cabinet - F8 and F9 (front, left and right side view). The connector plate is 1.65 in [42 mm] below .0 level.

1) Ground bar

Terminal locations - Inverter Frame size F10 and F11

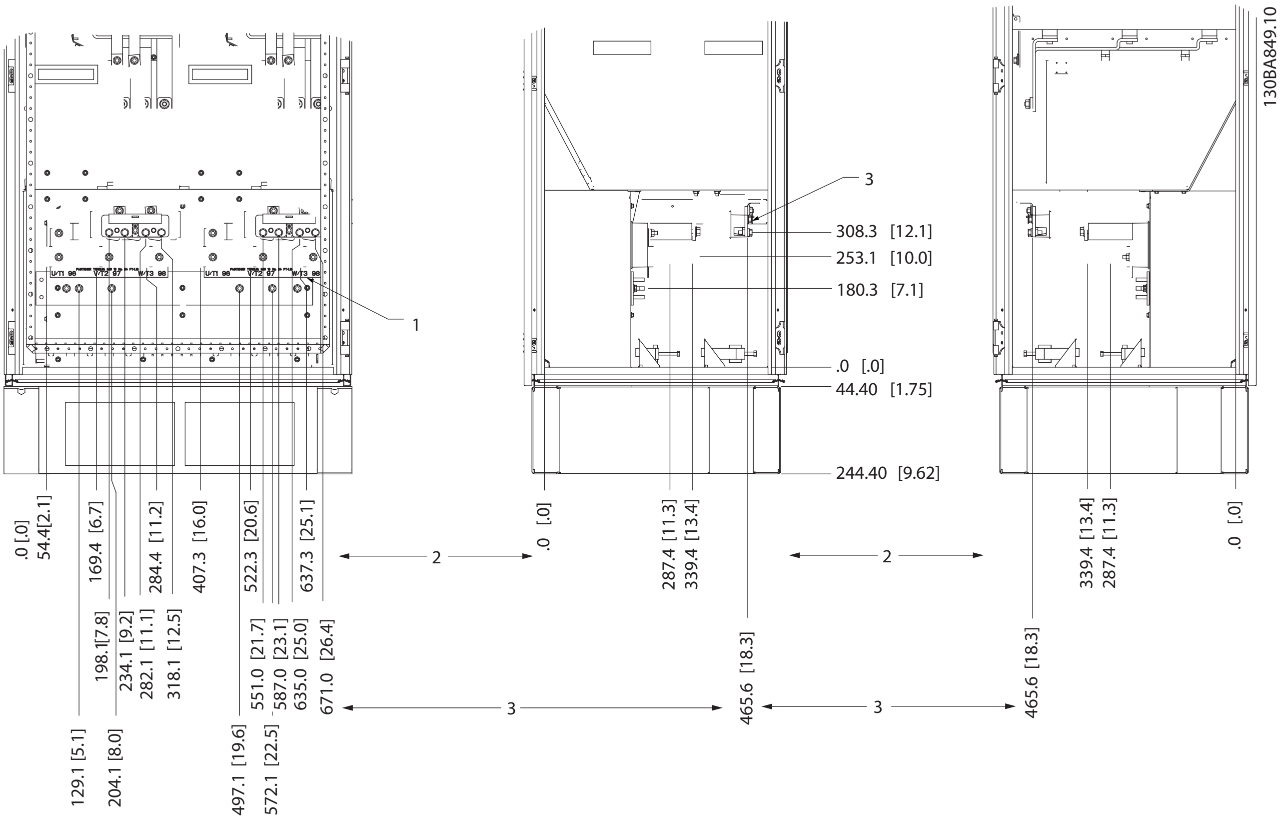


Figure 7.34 Terminal locations - Inverter Cabinet (front, left and right side view). The connector plate is 1.65 in [42 mm] below .0 level.

1) Ground bar

2) Motor terminals

3) Brake terminals

7

Terminal locations - Inverter Frame size F12 and F13

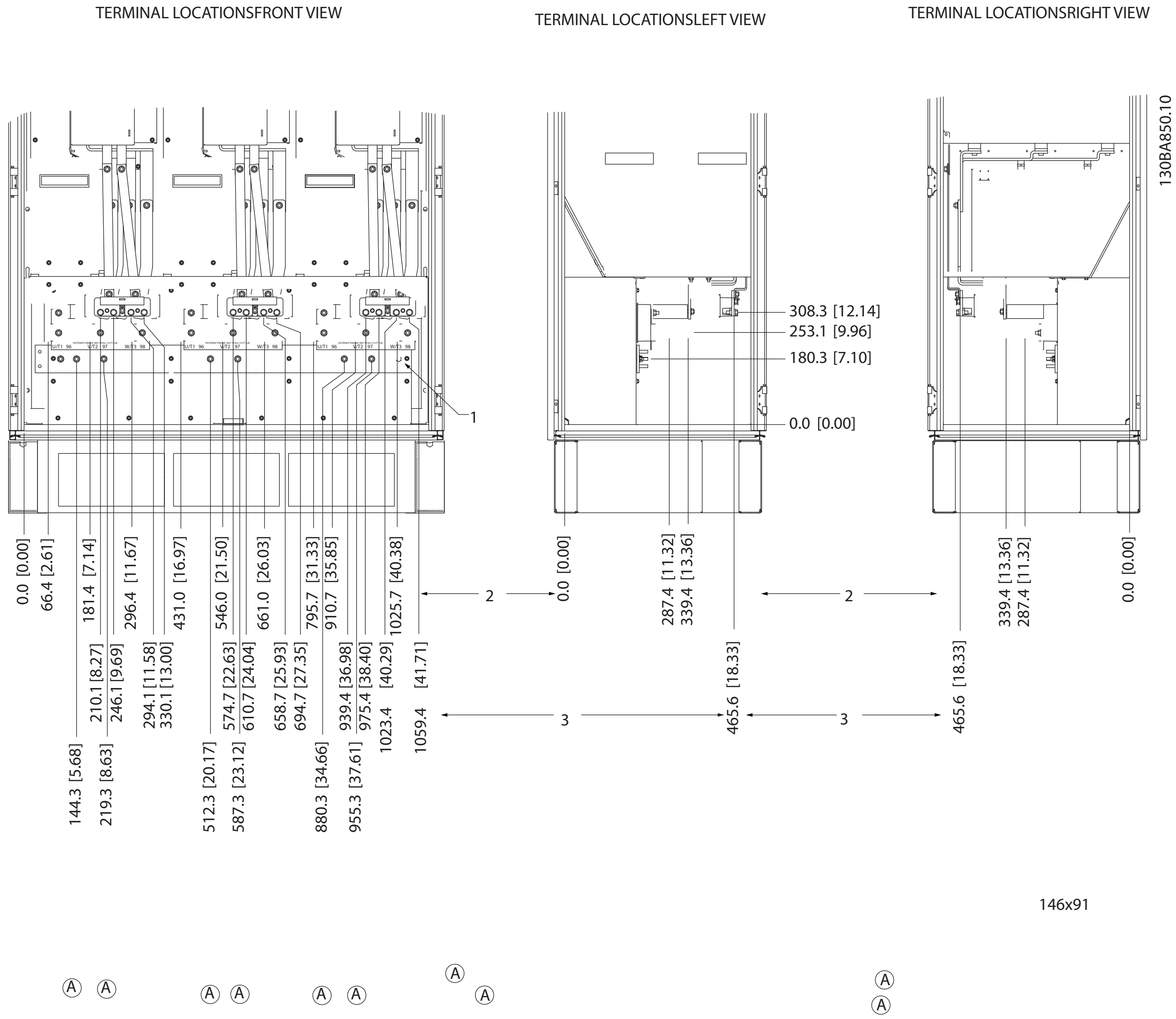


Figure 7.35 Terminal locations - Inverter Cabinet (front, left and right side view). The connector plate is 1.65 in [42 mm] below .0 level.
1) Ground bar

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

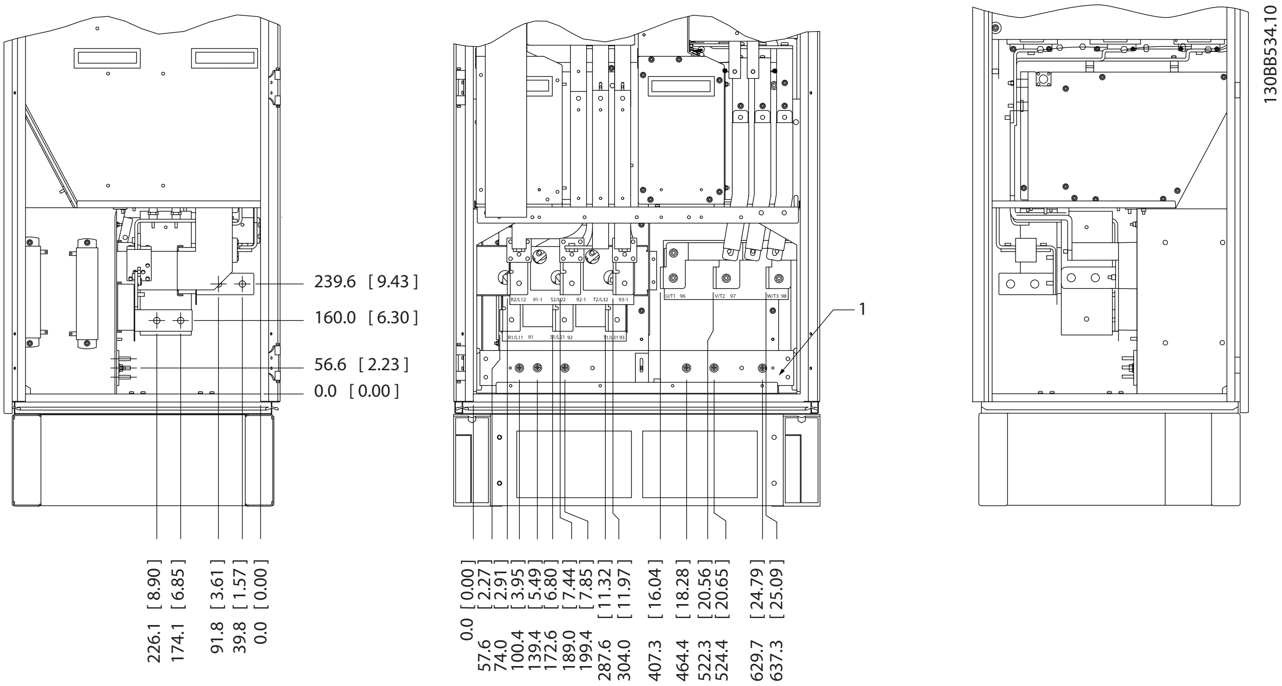


Figure 7.36 Terminal locations - Rectifier (left side, front and right side view). The connector plate is 1.65 in [42 mm] below .0 level.

1) Load share Terminal (-)

2) Ground bar

3) Load share Terminal (+)

Terminal locations - Options Cabinet Frame Size F9

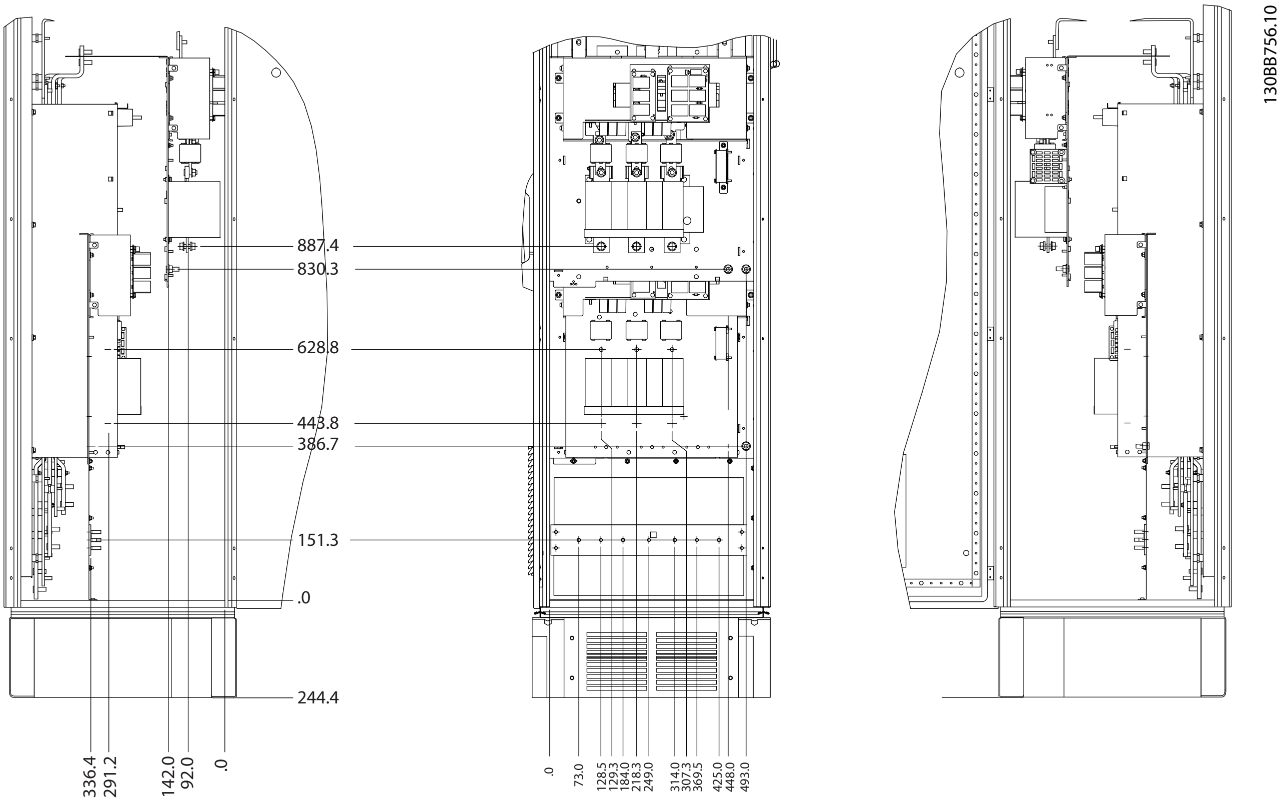


Figure 7.37 Terminal locations - Options cabinet (left side, front and right side view).

Terminal locations - Options Cabinet Frame Size F11/F13

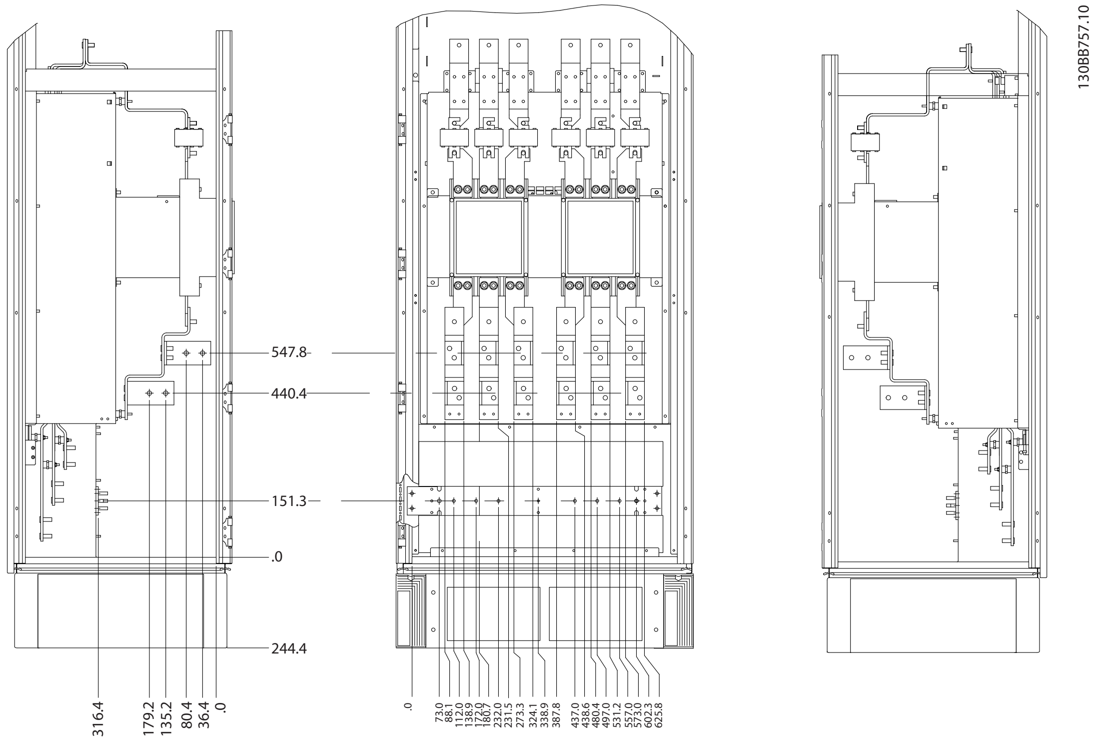


Figure 7.38 Terminal locations - Options cabinet (left side, front and right side view).

7.2.7 Cooling and Airflow

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

Duct cooling
A dedicated option has been developed to optimize installation of IP00/chassis adjustable frequency drives in Rittal TS8 enclosures utilizing the fan of the adjustable frequency drive for forced air cooling of the backchannel. The air out the top of the enclosure could but ducted outside a facility so the heat loses from the backchannel are not dissipated within the control room reducing air-conditioning requirements of the facility.
Please see *Installation of Duct Cooling Kit in Rittal enclosures*, for further information.

Back cooling
The backchannel air can also be ventilated in and out the back of a Rittal TS8 enclosure. This offers a solution where the backchannel could take air from outside the facility and return the heat losses outside the facility thus reducing air-conditioning requirements.

NOTE!

A door fan is required on the enclosure to remove the heat losses not contained in the backchannel of the drive and any additional losses generated from other components installed inside the enclosure. The total required air flow must be calculated so that the appropriate fans can be selected. Some enclosure manufacturers offer software for performing the calculations (i.e., Rittal Therm software). If the VLT is the only heat generating component in the enclosure, the minimum airflow required at an ambient temperature of 113°F [45°C] for the D3 and D4 drives is 391 m^3/h (230 cfm). The minimum airflow required at an ambient temperature of 113°F [45°C] for the E2 drive is 782 m^3/h (460 cfm).

Airflow
The necessary airflow over the heatsink must be ensured. The flow rate is shown below.

Enclosure protection	Frame size	Door fan(s) / Top fan airflow	Heatsink fan(s)
IP21 / NEMA 1 IP54 / NEMA 12	D1 and D2	170 m^3/h (100 cfm)	765 m^3/h (450 cfm)
	E1 P250T5, P355T7, P400T7	340 m^3/h (200 cfm)	1105 m^3/h (650 cfm)
	E1P315-P400T5, P500-P560T7	340 m^3/h (200 cfm)	1445 m^3/h (850 cfm)
IP21 / NEMA 1	F1, F2, F3 and F4	700 m^3/h (412 cfm)*	985 m^3/h (580 cfm)*
IP54 / NEMA 12	F1, F2, F3 and F4	525 m^3/h (309 cfm)*	985 m^3/h (580 cfm)*
IP00 / Chassis	D3 and D4	255 m^3/h (150 cfm)	765 m^3/h (450 cfm)
	E2 P250T5, P355T7, P400T7	255 m^3/h (150 cfm)	1105 m^3/h (650 cfm)
	E2 P315-P400T5, P500-P560T7	255 m^3/h (150 cfm)	1445 m^3/h (850 cfm)
* Airflow per fan. Frame size F contain multiple fans.			

Table 7.17 Heatsink Air Flow

NOTE!

The fan runs for the following reasons:

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

Once the fan is started, it will run for a minimum of 10 minutes.

External ducts

If additional duct work is added externally to the Rittal cabinet, the pressure drop in the ducting must be calculated. Use the charts below to derate the adjustable frequency drive according to the pressure drop.

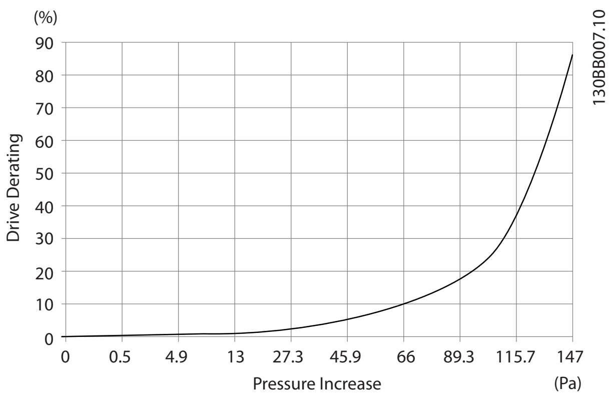


Figure 7.39 D frame Derating vs. Pressure Change
Drive air flow: 450 cfm (765 m³/h)

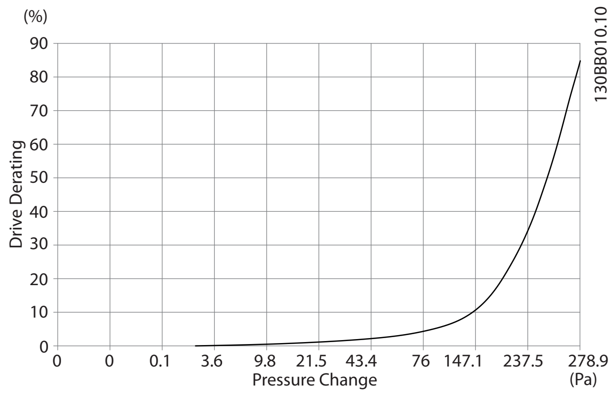


Figure 7.40 E frame Derating vs. Pressure Change (Small Fan), P250T5 and P355T7-P400T7
Drive air flow: 650 cfm (1105 m³/h)

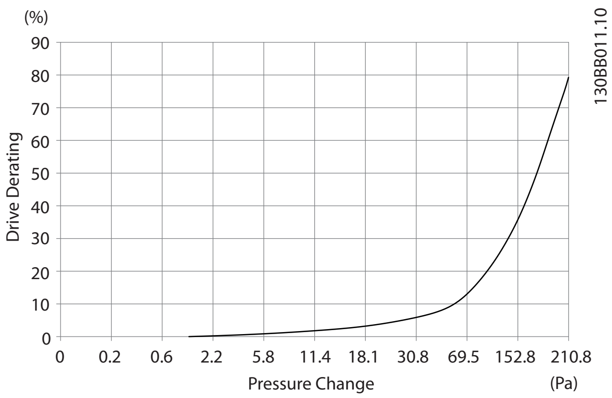


Figure 7.41 E frame Derating vs. Pressure Change (Large Fan), P315T5-P400T5 and P500T7-P560T7
Drive air flow: 850 cfm (1445 m³/h)

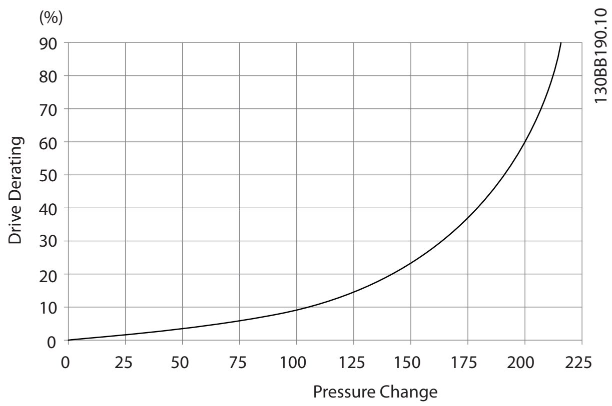


Figure 7.42 F1, F2, F3, F4 frame Derating vs. Pressure Change
Drive air flow: 580 cfm (985 m³/h)

7

7.2.8 Installation on the wall - IP21 (NEMA 1) and IP54 (NEMA 12) Units

This only applies to frame sizes D1 and D2 . Thought must be given to where the unit should be installed.

Take the relevant points into consideration before you select the final installation site:

- Clearance space for cooling
- Clearance for opening the door
- Cable entry clearance from the bottom

Mark the mounting holes carefully using the mounting template on the wall, and drill the holes as indicated. Ensure proper distance to the floor and the ceiling for cooling. A minimum of 8.9 in [225 mm] below the adjustable frequency drive is needed. Mount the bolts at the bottom and lift the adjustable frequency drive up on the bolts. Tilt the adjustable frequency drive against the wall and mount the upper bolts. Tighten all four bolts to secure the adjustable frequency drive against the wall.

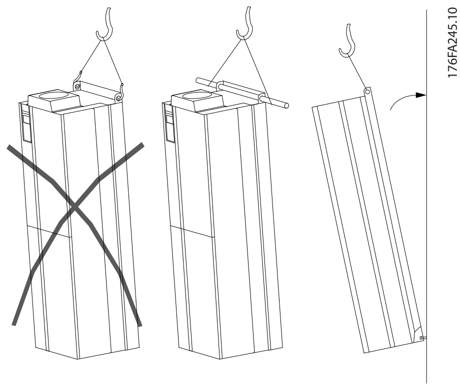


Figure 7.43 Lifting method for mounting drive on wall

7.2.9 Connector/Conduit Entry - IP21 (NEMA 1) and IP54 (NEMA12)

Cables are connected through the connector plate from the bottom. Remove the plate and plan where to place the entry for the connectors or conduits. Prepare holes in the marked area on the drawing.

NOTE!

The connector plate must be fitted to the Adjustable frequency drive to ensure the specified protection degree, as well as ensuring proper cooling of the unit. If the connector plate is not mounted, the Adjustable frequency drive may trip on Alarm 69, Pwr. Card Temp

Cable entries viewed from the bottom of the Adjustable frequency drive - 1) Line power side 2) Motor side

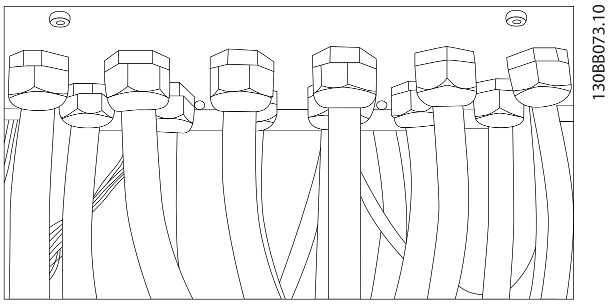


Figure 7.44 Example of Proper Installation of Connector Plate.

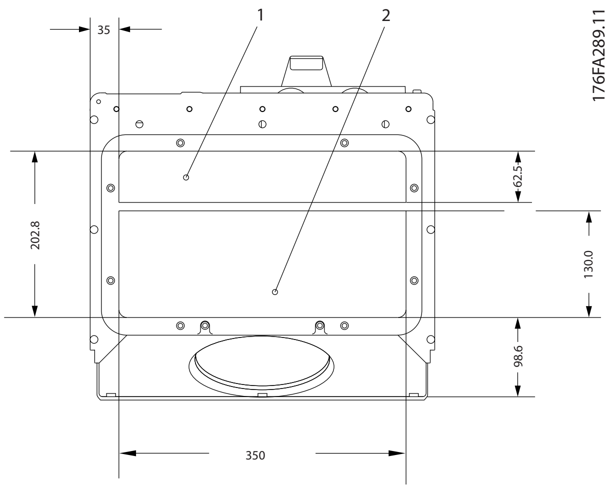


Figure 7.45 Frame Sizes D1 + D2

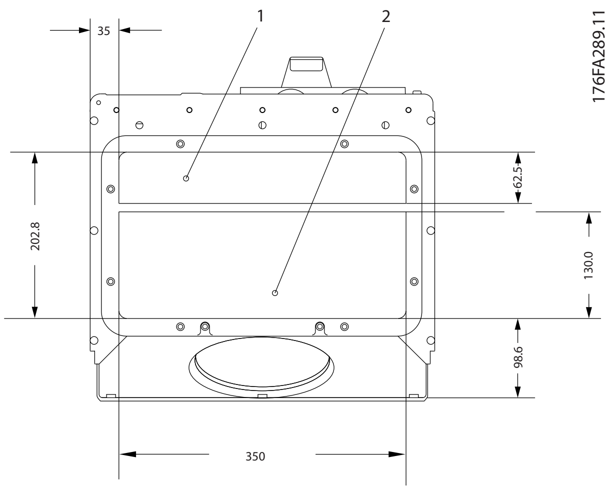


Figure 7.46 Frame Size E1

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

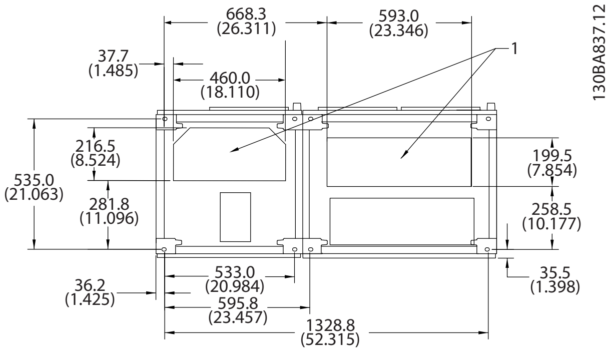


Figure 7.47 Frame Size F1

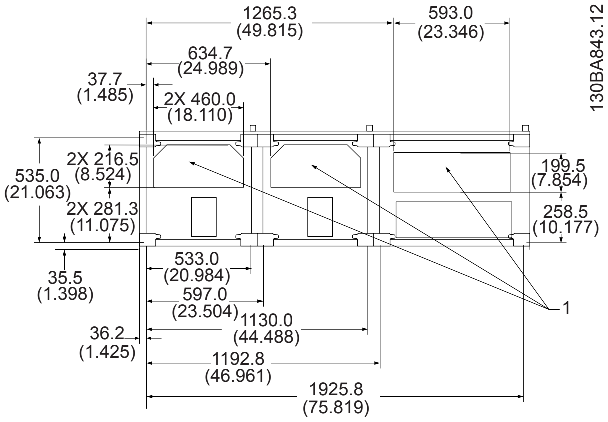


Figure 7.49 Frame Size F3

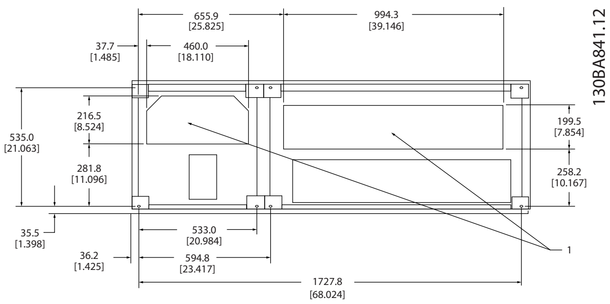


Figure 7.48 Frame Size F2

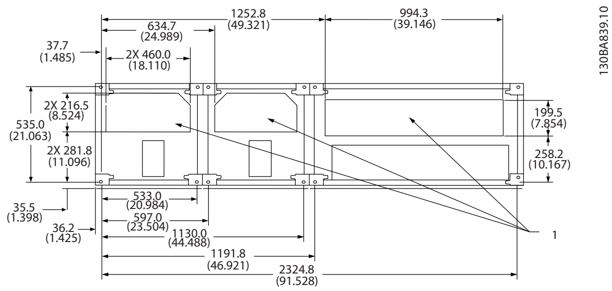


Figure 7.50 Frame Size F4

7

7.2.10 Connector/Conduit Entry, 12-Pulse - IP21 (NEMA 1) and IP54 (NEMA12)

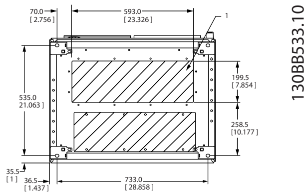
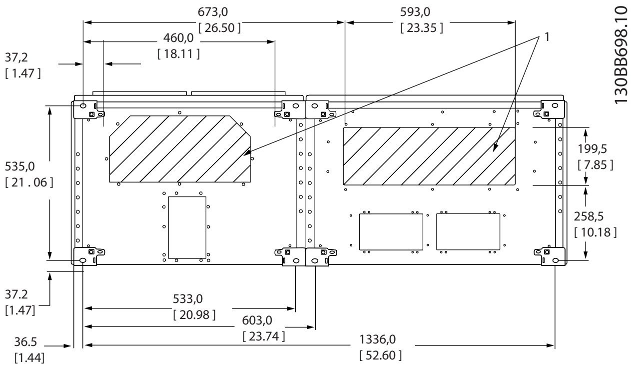
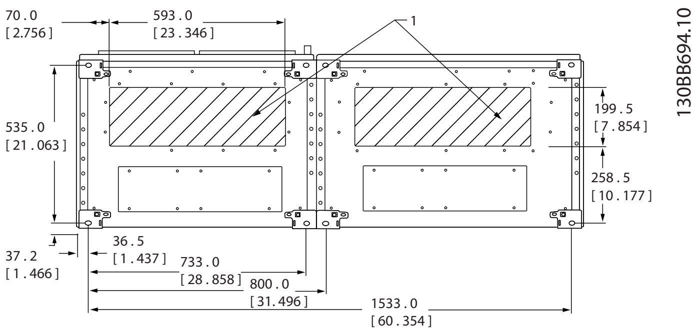
Frame size F8

Frame size F9

Frame size F10


Table 7.18

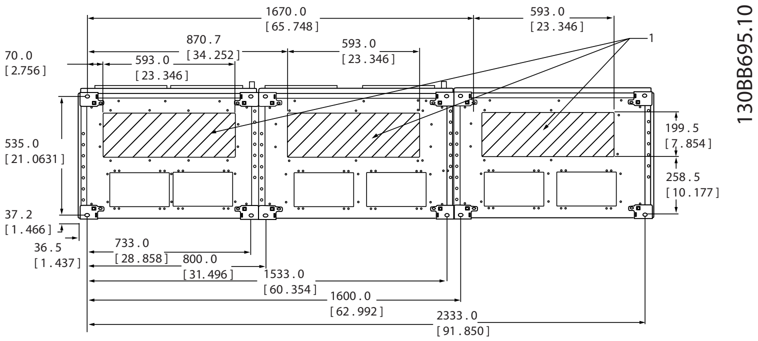
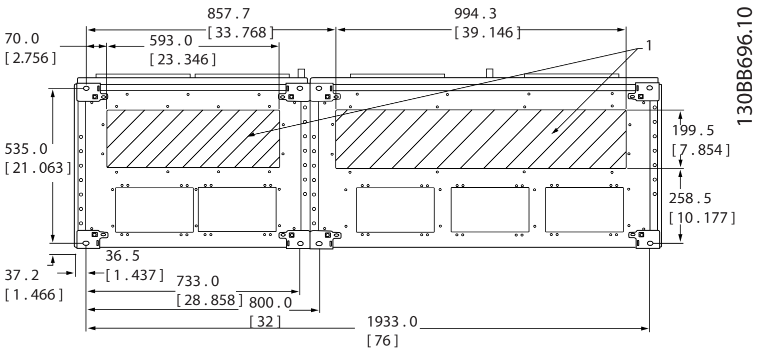
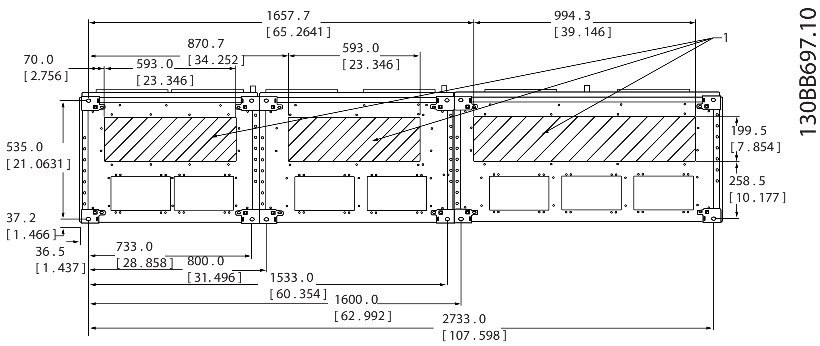
Frame size F11

Frame size F12

Frame size F13

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

Table 7.19

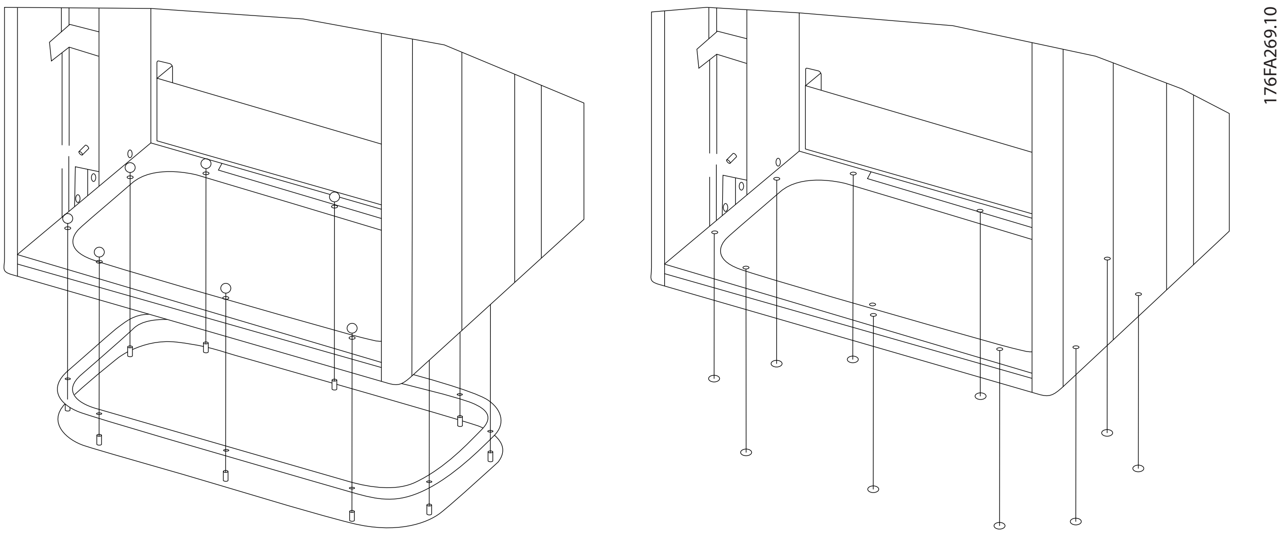


Figure 7.51 Mounting of bottom plate,frame size E1.

The bottom plate of the E1 can be mounted from either inside or outside of the enclosure, allowing flexibility in the installation process, i.e., if mounted from the bottom, the connectors and cables can be mounted before the Adjustable frequency drive is placed on the pedestal.

7.2.11 IP21 Drip Shield Installation (Frame size D1 and D2)

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

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

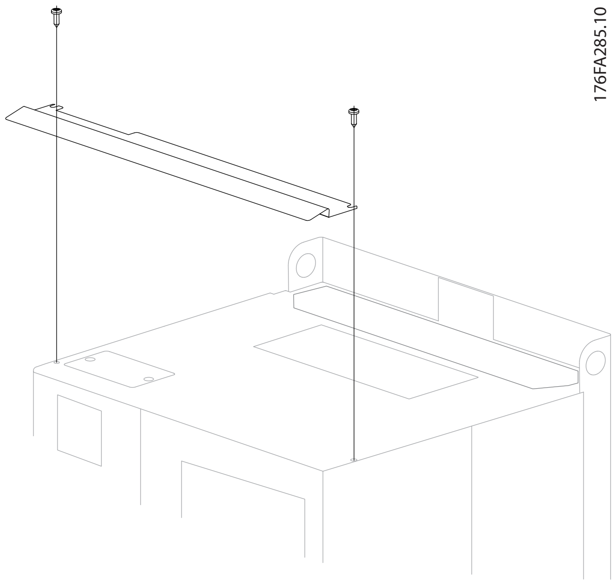


Figure 7.52 Install the drip shield.

8 Electrical Installation

8.1 Connections Frame Sizes A, B and C

NOTE!

Cables General

All cabling must comply with national and local regulations on cable cross-sections and ambient temperature. Copper (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 the softness of the aluminum. It is crucial to keep the connection a gas-tight joint, otherwise the aluminum surface will oxidize again.

Tightening-up Torque					
Frame size	200–240 V	380–500 V	525–690 V	Cable for:	Tightening torque
A1	0.34–2 hp [0.25–1.5 kW]	0.5–2 hp [0.37–1.5 kW]	-	Line power, brake resistor, load sharing, motor cables	0.5-0.6 Nm
A2	0.33-3 hp [0.25-2.2 kW]	0.5–5 hp [0.37–4 kW]	-		
A3	4–5 hp [3–3.7 kW]	7.5–10 hp [5.5-7.5 kW]	-		
A4	0.34–3 hp [0.25–2.2 kW]	0.5–5 hp [0.37–4 kW]			
A5	4–5 hp [3–3.7 kW]	7.5–10 hp [5.5-7.5 kW]	-		
B1	7.5–10 hp [5.5-7.5 kW]	15–20 hp [11–15 kW]	-	Line power, brake resistor, load sharing, motor cables	1.8 Nm
				Relay	0.5-0.6 Nm
				Ground	2-3 Nm
B2	15 hp [11 kW]	25–30 hp [18.5–22 kW]	15–30 hp [11–22 kW]	Line power, brake resistor, load sharing cables	4.5 Nm
				Motor cables	4.5 Nm
				Relay	0.5-0.6 Nm
				Ground	2-3 Nm
B3	7.5–10 hp [5.5-7.5 kW]	15–20 hp [11–15 kW]	-	Line power, brake resistor, load sharing, motor cables	1.8 Nm
				Relay	0.5-0.6 Nm
				Ground	2-3 Nm
B4	15–20 hp [11–15 kW]	25–40 hp [18.5–30 kW]	-	Line power, brake resistor, load sharing, motor cables	4.5 Nm
				Relay	0.5-0.6 Nm
				Ground	2-3 Nm
C1	20–30 hp [15–22 kW]	40–60 hp [30–45 kW]	-	Line power, brake resistor, load sharing cables	10 Nm
				Motor cables	10 Nm
				Relay	0.5-0.6 Nm
				Ground	2-3 Nm
C2	40–50 hp [30–37 kW]	75–100 hp [55–75 kW]	40–100 hp [30–75 kW]	Line power, motor cables	14 Nm (up to 95 mm²) 24 Nm (over 95 mm²)
				Load sharing, brake cables	14 Nm
				Relay	0.5-0.6 Nm
				Ground	2-3 Nm
C3	25–30 hp [18.5–22 kW]	40–50 hp [30–37 kW]	-	Line power, brake resistor, load sharing, motor cables	10 Nm
				Relay	0.5-0.6 Nm
				Ground	2-3 Nm
C4	50–60 hp [37–45 kW]	75–100 hp [55–75 kW]	-	Line power, motor cables	14 Nm (up to 95 mm²) 24 Nm (over 95 mm²)
				Load sharing, brake cables	14 Nm
				Relay	0.5-0.6 Nm
				Ground	2-3 Nm

Table 8.1

8.1.1 Removal of Knockouts for Extra Cables

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

8.1.2 Connection to Line and Grounding

NOTE!

The plug connector for power can be plugged on adjustable frequency drives of up to 10 hp [7.5 kW].

1. Insert the two screws into 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.

NOTE!

Ensure that AC line voltage corresponds to the AC line voltage on the nameplate.

⚠CAUTION

IT Line Power

Do not connect 400V adjustable frequency drives with RFI filters to line power supplies with a voltage between phase and ground of more than 440V.

⚠CAUTION

The ground connection cable cross-section must be at least 10 mm² or 2 x rated line power wires terminated separately according to EN 50178.

The AC line input connection is fitted to the line power switch if this is included.

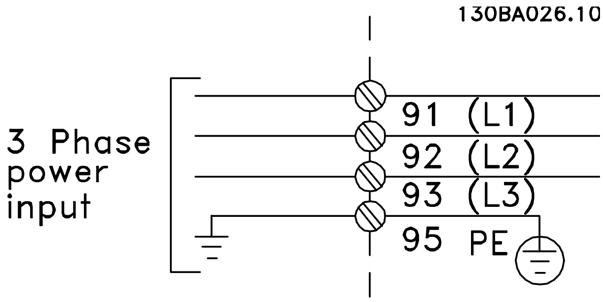


Figure 8.1

AC line input connection for frame sizes A1, A2 and A3:

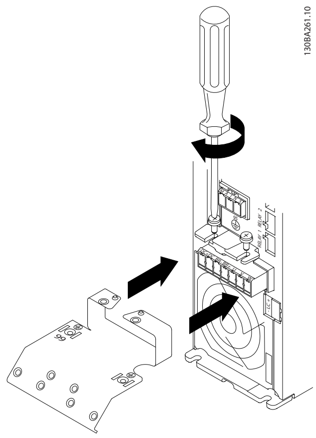


Figure 8.2

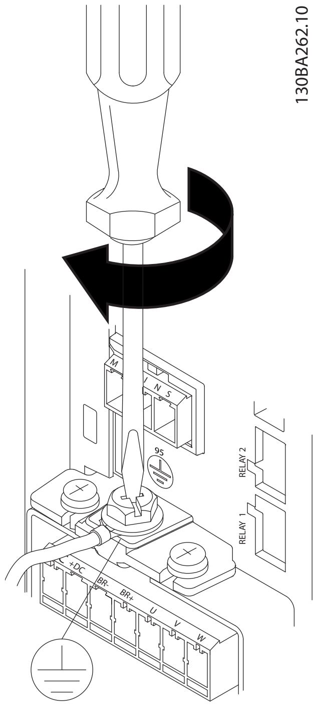


Figure 8.3

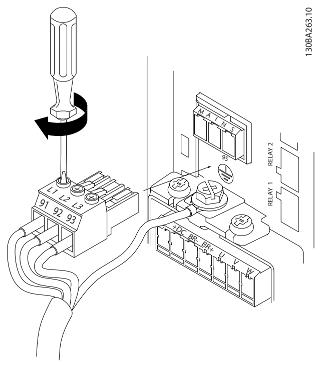


Figure 8.4

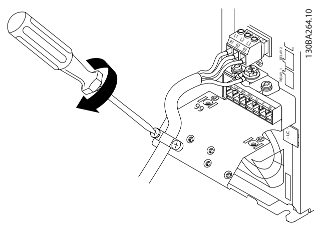


Figure 8.5

Line power connector frame size A4/A5 (IP 55/66)

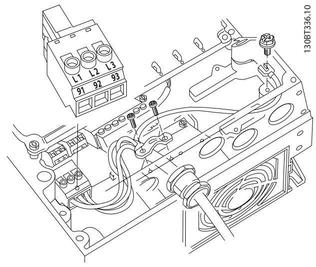


Figure 8.6

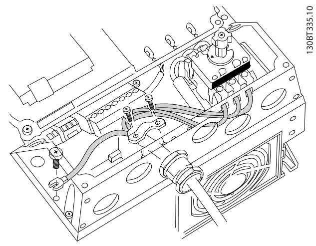


Figure 8.7

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

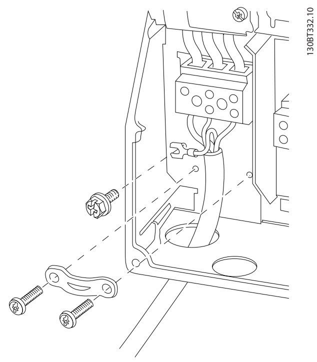


Figure 8.8 AC line input connection frame sizes B1 and B2 (IP 21/NEMA Type 1 and IP 55/66/ NEMA Type 12).

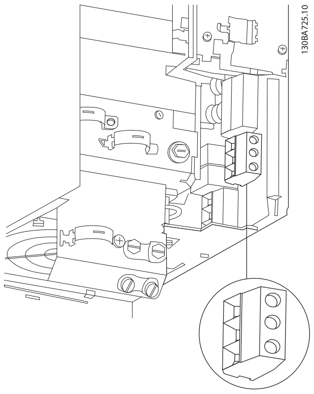


Figure 8.9 AC line input connection size B3 (IP20).

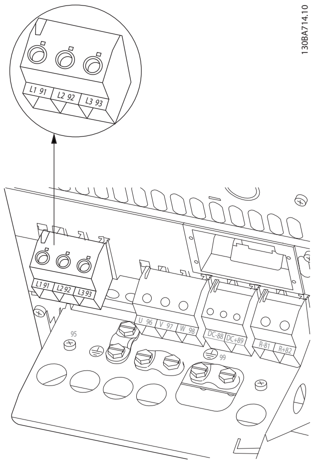


Figure 8.10 AC line input connection size B4 (IP20).

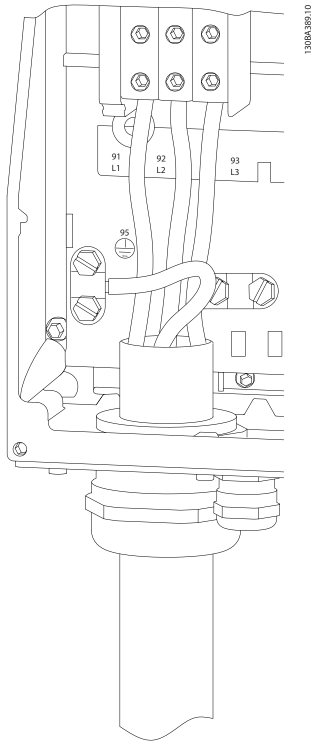


Figure 8.11 AC line input connection size C1 and C2 (IP 21/ NEMA Type 1 and IP 55/66/ NEMA Type 12).

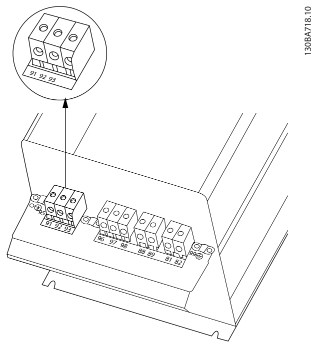


Figure 8.12 AC line input connection size C3 (IP20).

8

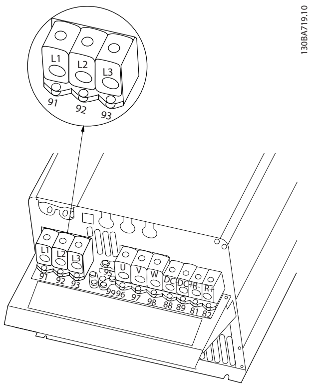


Figure 8.13 AC line input connection size C4 (IP20).

Usually the power cables for line power are non-shielded cables.

8.1.3 Motor Connection

To comply with EMC emission specifications, shielded/ armored cables are recommended. For more information, see *3.5.2 EMC Test Results*.

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

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.
Connect the motor cable screen 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 together with sine-wave filters to reduce the acoustic noise from a motor, the switching frequency must be set according to the sine-wave filter instructions 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.

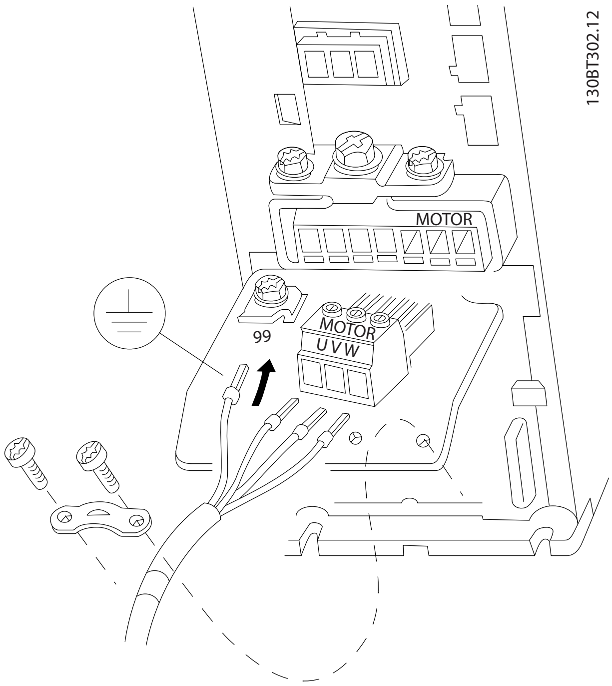


Figure 8.14 Motor connection for A1, A2 and A3

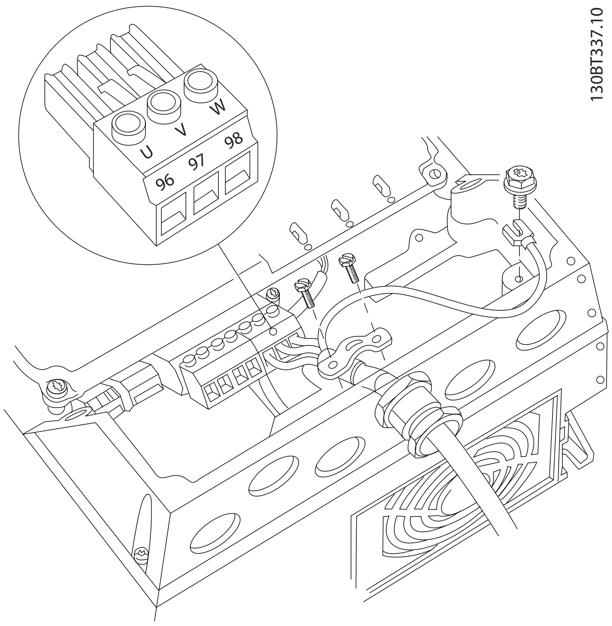


Figure 8.15 Motor connection for size A4/A5 (IP55/66/NEMA Type 12)

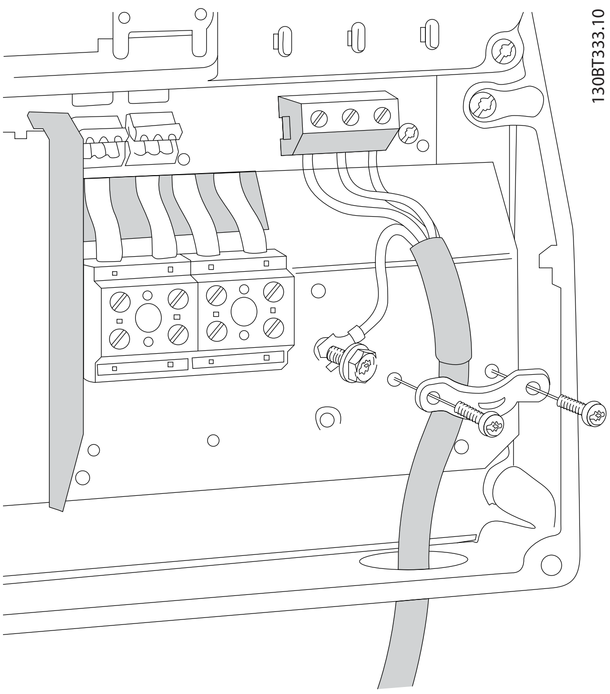


Figure 8.16 Motor connection for size B1 and B2 (IP21/ NEMA Type 1, IP55/ NEMA Type 12 and IP66/ NEMA Type 4X)

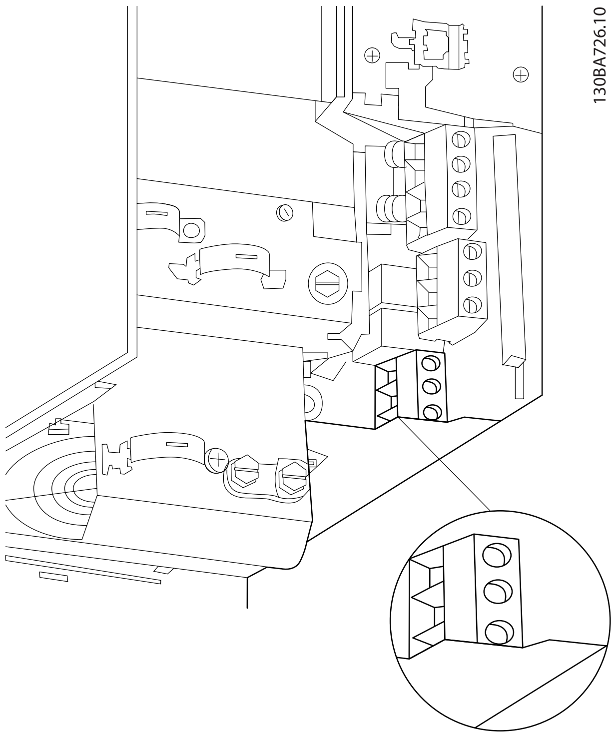


Figure 8.17 Motor connection for size B3.

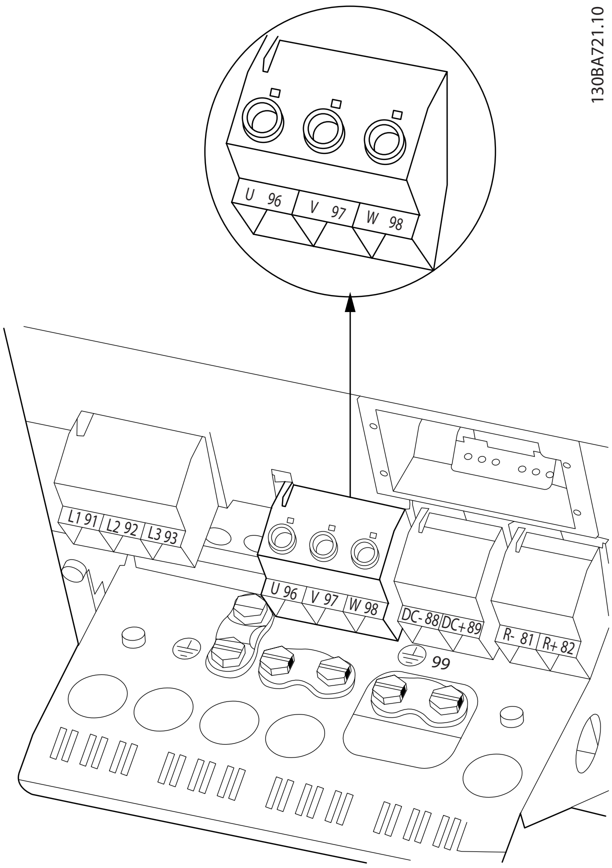


Figure 8.18 Motor connection for frame size B4 .

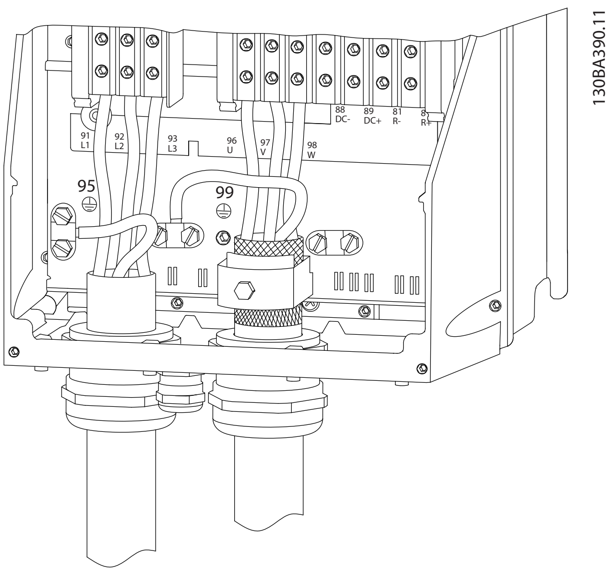


Figure 8.19 Motor connection frame size C1 and C2 (IP21/ NEMA Type 1 and IP55/66/ NEMA Type 12)

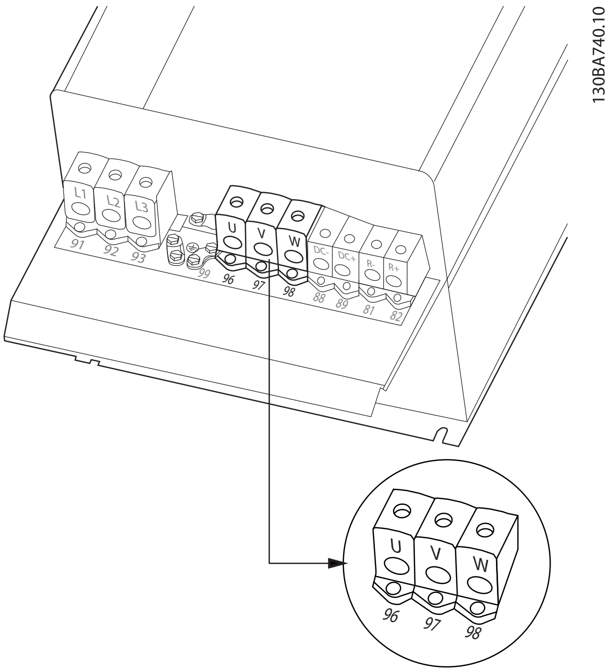


Figure 8.20 Motor connection for frame size C3 and C4.

8

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 8.2

[1)]*Protected Ground Connection*

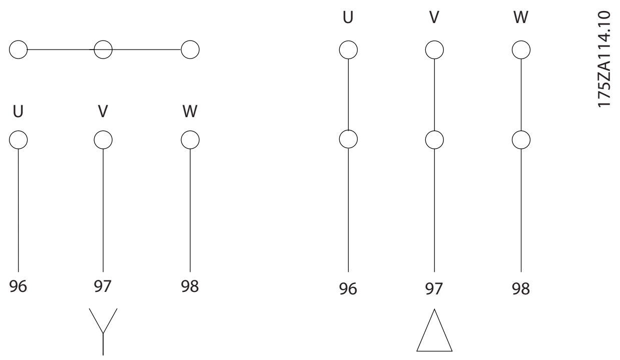


Figure 8.21

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.

Cable entry holes

The suggested use of the holes are purely recommendations, and other solutions are possible. Unused cable entry holes can be sealed with rubber grommets (for IP 21).

* Tolerance ± 0.2 mm

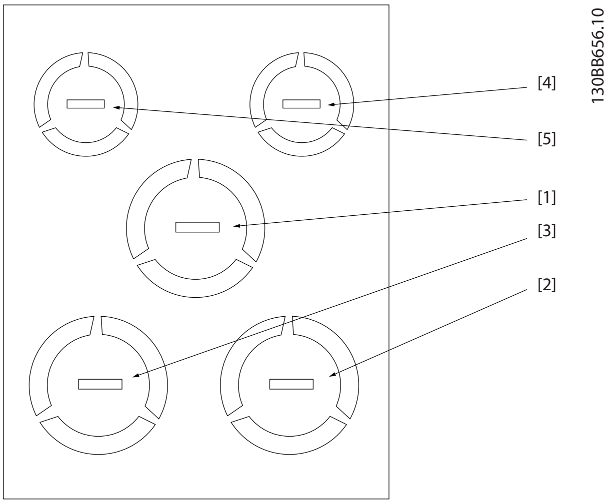


Figure 8.22 A2 - IP21

Hole number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	(in [mm])	
1) Line power	3/4	1.12 [28.4]	M25
2) Motor	3/4	1.12 [28.4]	M25
3) Brake/Load S	3/4	1.12 [28.4]	M25
4) Control Cable	1/2	0.89 [22.5]	M20
5) Control Cable	1/2	0.89 [22.5]	M20

Table 8.3

[1] *Tolerance ± 0.007 in [0.2 mm]*

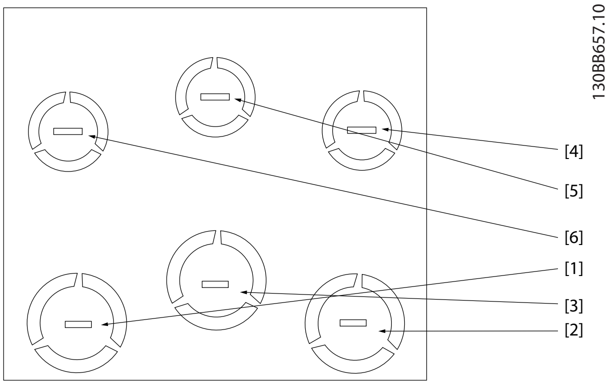


Figure 8.23 A3 - IP21

Hole number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	(in [mm])	
1) Line power	3/4	1.12 [28.4]	M25
2) Motor	3/4	1.12 [28.4]	M25
3) Brake/Load Sharing	3/4	1.12 [28.4]	M25
4) Control Cable	1/2	0.89 [22.5]	M20
5) Control Cable	1/2	0.89 [22.5]	M20
6) Control Cable	1/2	0.89 [22.5]	M20

Table 8.4

[1] *Tolerance ± 0.007 in [0.2 mm]*

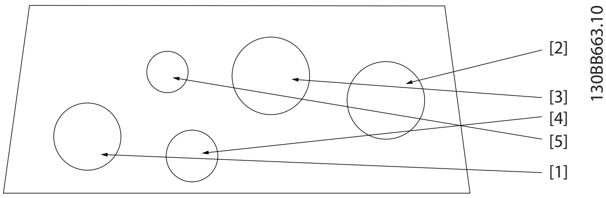


Figure 8.24 A4 - IP55

Hole number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	(in [mm])	
1) Line power	3/4	1.12 [28.4]	M25
2) Motor	3/4	1.12 [28.4]	M25
3) Brake/Load Sharing	3/4	1.12 [28.4]	M25
4) Control Cable	1/2	0.89 [22.5]	M20
5) Removed	-	-	-

Table 8.5

[1] *Tolerance ± 0.007 in [0.2 mm]*

8

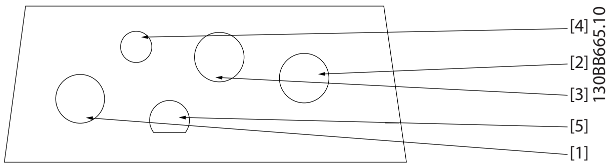


Figure 8.25 A4 - IP55 threaded connector holes

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

Table 8.6

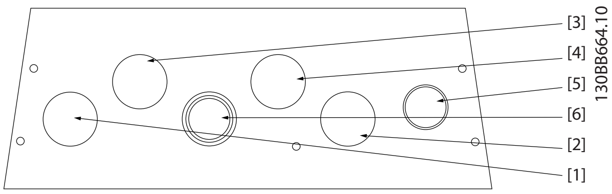


Figure 8.26 A5 - IP55

Hole number and recommended use	Dimensions[1)]		Nearest metric
	UL [in]	(in [mm])	
1) Line power	3/4	1.12 [28.4]	M25
2) Motor	3/4	1.12 [28.4]	M25
3) Brake/Load Sharing	3/4	1.12 [28.4]	M25
4) Control Cable	3/4	1.12 [28.4]	M25
5) Control Cable[2)]	3/4	1.12 [28.4]	M25
6) Control Cable [2)]	3/4	1.12 [28.4]	M25

Table 8.7

[1)] *Tolerance ± 0.007 in [0.2 mm]*

[2)] *Knock-out hole*

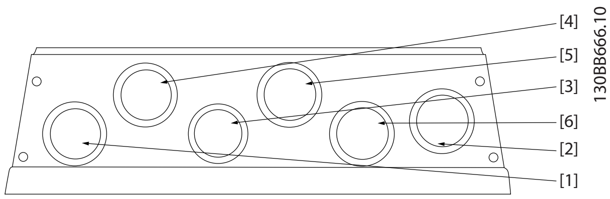


Figure 8.27 A5- IP55 threaded connector holes

Hole number and recommended use	Dimensions
1) Line power	M25
2) Motor	M25
3) Brake/Load S	1.12 in [28.4 mm][1)]
4) Control Cable	M25
5) Control Cable	M25
6) Control Cable	M25

Table 8.8

[1)] *Knock-out hole*

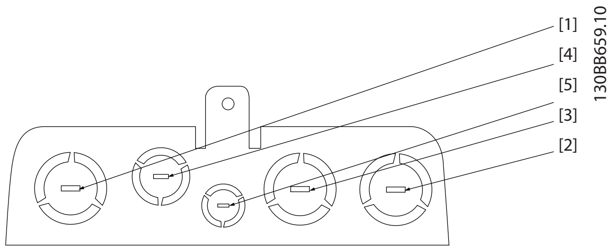


Figure 8.28 B1 - IP21

Hole number and recommended use	Dimensions[1)]		Nearest metric
	UL [in]	(in [mm])	
1) Line power	1	1.37 [34.7]	M32
2) Motor	1	1.37 [34.7]	M32
3) Brake/Load Sharing	1	1.37 [34.7]	M32
4) Control Cable	1	1.37 [34.7]	M32
5) Control Cable	1/2	0.89 [22.5]	M20

Table 8.9

[1)] *Tolerance ± 0.007 in [0.2 mm]*

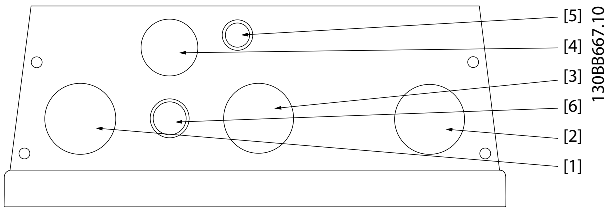


Figure 8.29 B1 - IP55

Hole number and recommended use	Dimensions[1)]		Nearest metric
	UL [in]	(in [mm])	
1) Line power	1	1.37 [34.7]	M32
2) Motor	1	1.37 [34.7]	M32
3) Brake/Load Sharing	1	1.37 [34.7]	M32
4) Control Cable	3/4	1.12 [28.4]	M25
5) Control Cable	1/2	0.89 [22.5]	M20
5) Control Cable[2)]	1/2	0.89 [22.5]	M20

Table 8.10

[1)] *Tolerance ± 0.007 in [0.2 mm]*

[2)] *Knock-out hole*

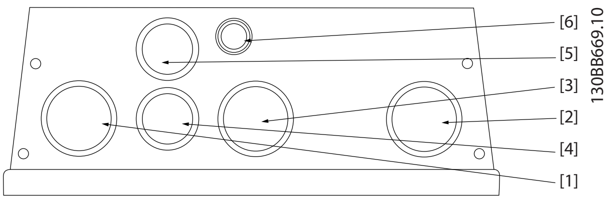


Figure 8.30 B1 - IP55 threaded connector holes

Hole number and recommended use	Dimensions
1) Line power	M32
2) Motor	M32
3) Brake/Load Sharing	M32
4) Control Cable	M25
5) Control Cable	M25
6) Control Cable	0.89 in [22.5 mm] [1)]

Table 8.11

[1)] *Knock-out hole*

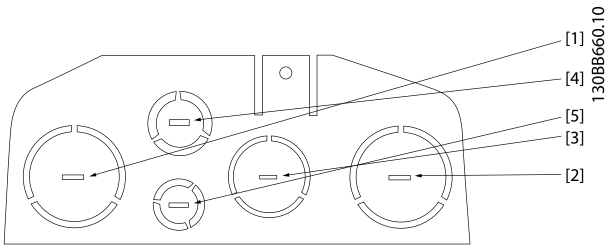


Figure 8.31 B2 - IP21

Hole number and recommended use	Dimensions[1)]		Nearest metric
	UL [in]	(in [mm])	
1) Line power	1 1/4	1.74 [44.2]	M40
2) Motor	1 1/4	1.74 [44.2]	M40
3) Brake/Load Sharing	1	1.37 [34.7]	M32
4) Control Cable	3/4	1.12 [28.4]	M25
5) Control Cable	1/2	0.89 [22.5]	M20

Table 8.12

[1)] *Tolerance ± 0.007 in [0.2 mm]*

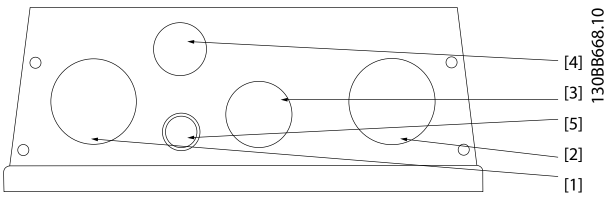


Figure 8.32 B2 - IP55

Hole number and recommended use	Dimensions[1)]		Nearest metric
	UL [in]	(in [mm])	
1) Line power	1 1/4	1.74 [44.2]	M40
2) Motor	1 1/4	1.74 [44.2]	M40
3) Brake/Load Sharing	1	1.37 [34.7]	M32
4) Control Cable	3/4	1.12 [28.4]	M25
5) Control Cable[2)]	1/2	0.89 [22.5]	M20

Table 8.13

[1)] *Tolerance ± 0.007 in [0.2 mm]*

[2)] *Knock-out hole*

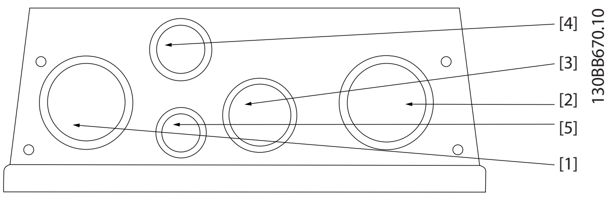


Figure 8.33 B2 - IP55 threaded connector holes

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

Table 8.14

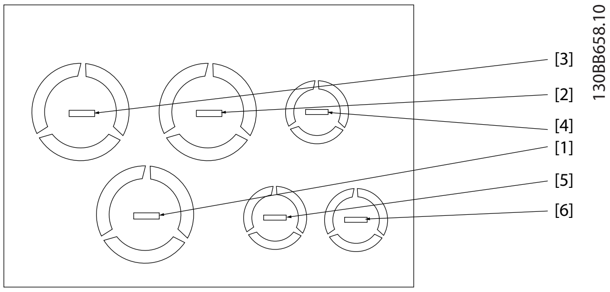


Figure 8.34 B3 - IP21

Hole number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	(in [mm])	
1) Line power	1	1.37 [34.7]	M32
2) Motor	1	1.37 [34.7]	M32
3) Brake/Load Sharing	1	1.37 [34.7]	M32
4) Control Cable	1/2	0.89 [22.5]	M20
5) Control Cable	1/2	0.89 [22.5]	M20
6) Control Cable	1/2	0.89 [22.5]	M20

Table 8.15

[1] *Tolerance ± 0.007 in [0.2 mm]*

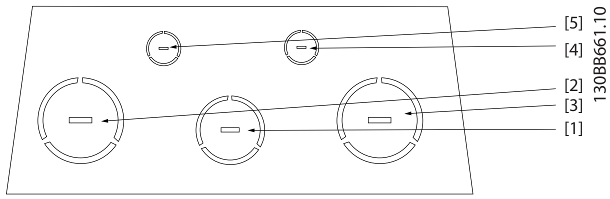


Figure 8.35 C1 - IP21

Hole number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	(in [mm])	
1) Line power	2	2.49 [63.3]	M63
2) Motor	2	2.49 [63.3]	M63
3) Brake/Load Sharing	1 1/2	1.98 [50.2]	M50
4) Control Cable	3/4	1.12 [28.4]	M25
5) Control Cable	1/2	0.89 [22.5]	M20

Table 8.16

[1] *Tolerance ± 0.007 in [0.2 mm]*

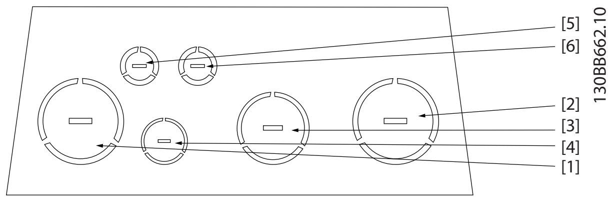


Figure 8.36 C2 - IP21

Hole number and recommended use	Dimensions[1]		Nearest metric
	UL [in]	(in [mm])	
1) Line power	2	2.49 [63.3]	M63
2) Motor	2	2.49 [63.3]	M63
3) Brake/Load Sharing	1 1/2	1.98 [50.2]	M50
4) Control Cable	3/4	1.12 [28.4]	M25
5) Control Cable	1/2	0.89 [22.5]	M20
6) Control Cable	1/2	0.89 [22.5]	M20

Table 8.17

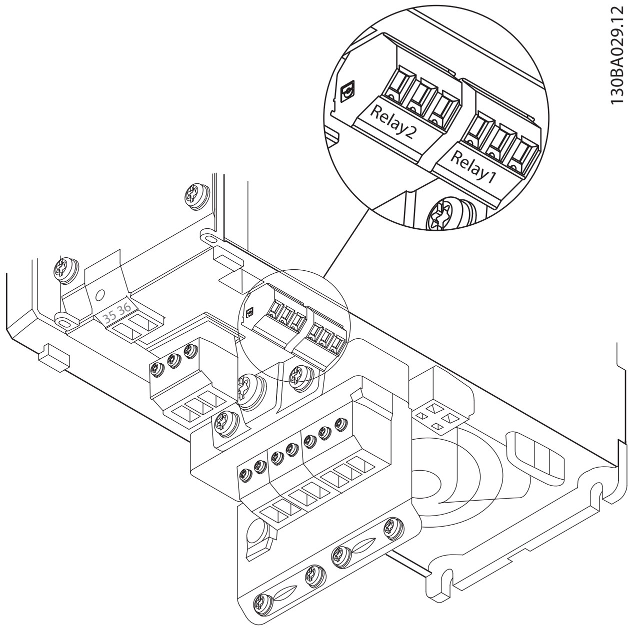
[1] *Tolerance ± 0.007 in [0.2 mm]*

8.1.4 Relay Connection

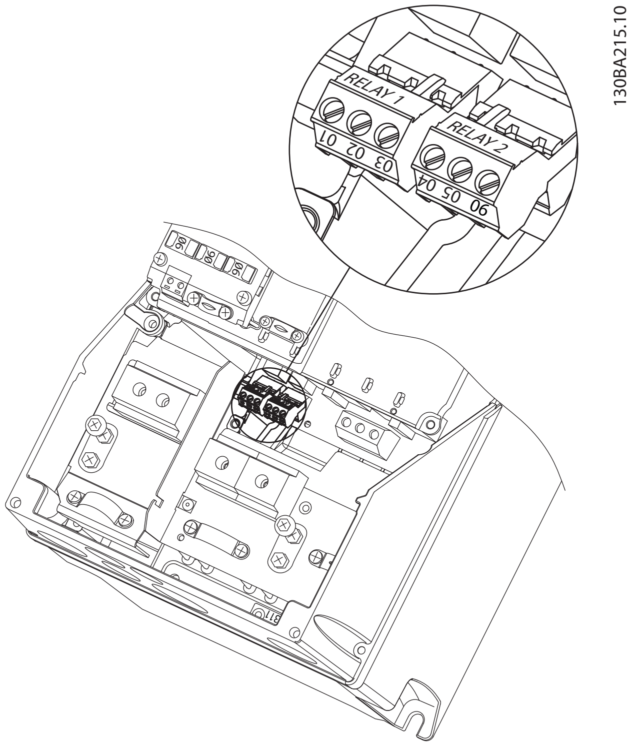
To set relay output, see parameter group 5-4* Relays.

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

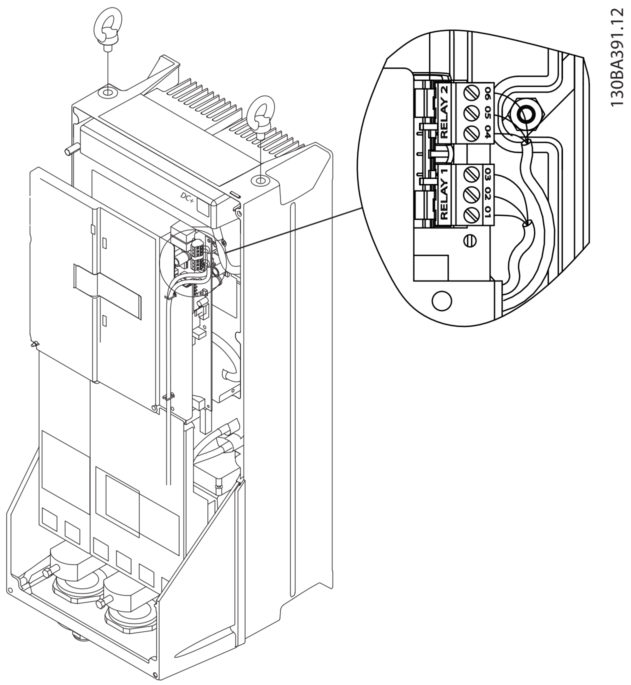
Table 8.18



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



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



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

Table 8.19

8.2 Connections - Frame Sizes D, E and F

8.2.1 Torque

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

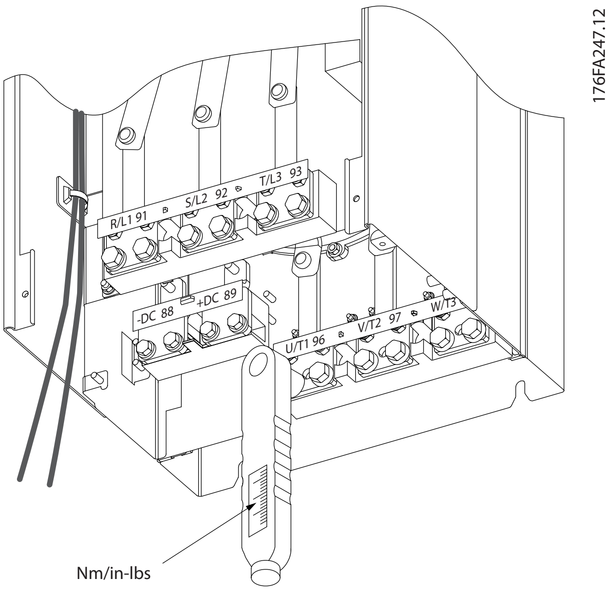


Figure 8.37 Always use a torque wrench to tighten the bolts.

Frame size	Terminal	Torque	Bolt size
D	Line power Motor	19–40 Nm (168–354 in-lbs)	M10
	Load sharing Brake	8.5–20.5 Nm (75–181 in-lbs)	M8
E	Line power Motor Load sharing	19–40 Nm (168–354 in-lbs)	M10
	Brake	8.5–20.5 Nm (75–181 in-lbs)	M8
F	Line power Motor	19–40 Nm (168–354 in-lbs)	M10
	Load sharing Brake Regen	19–40 Nm (168–354 in-lbs) 8.5–20.5 Nm (75–181 in-lbs) 8.5–20.5 Nm (75–181 in-lbs)	M10 M8 M8

Table 8.20 Torque for terminals

8.2.2 Power Connections

Cabling and Fusing

Cables General

All cabling must comply with national and local regulations on cable cross-sections and ambient temperature. UL applications require 167°F [75°C] copper conductors. 167°F [75°C] and 194°F [90°C] copper conductors are thermally acceptable for the adjustable frequency drive to use in non-UL applications.

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

For protection of the adjustable frequency drive, the recommended fuses must be used or the unit must be with built-in fuses. Recommended fuses can be seen in the tables of the fuse section. Always ensure that proper fusing is done according to local regulations.

The AC line input connections are fitted to the line power switch if this is included.

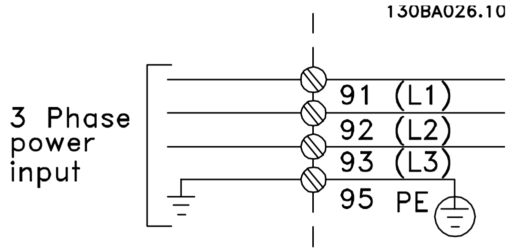


Figure 8.38

The motor cable must be shielded/armored. If an unshielded/unarmored cable is used, some EMC requirements are not complied with. Use a shielded/armored motor cable to comply with EMC emission specifications. For more information, see *EMC specifications* in the *Design Guide*.

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

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.

8

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

Make the shield connections with the largest possible surface area (cable clamp). This is done by using the supplied installation devices within the adjustable frequency drive.

Cable-length and cross-section:
The adjustable frequency drive has been EMC tested with a given length of cable. Keep the motor cable as short as possible to reduce the noise level and leakage currents.

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

8

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 8.21

[1)]*Protected Ground Connection*

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

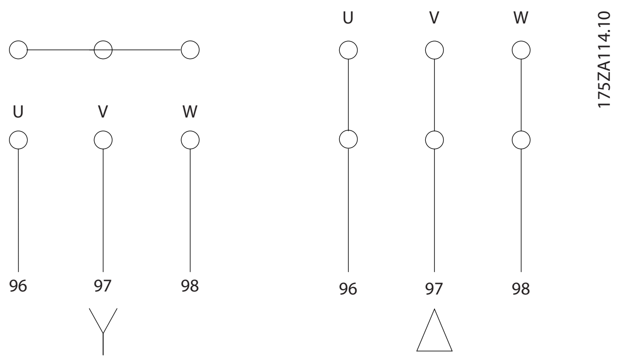


Figure 8.39

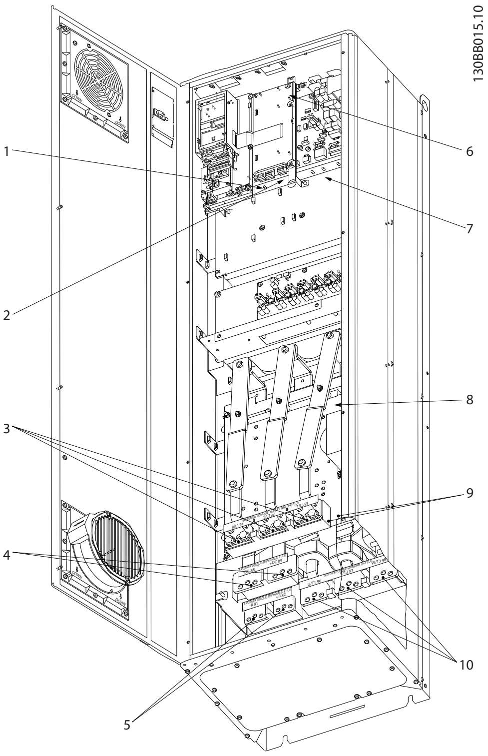


Figure 8.40 Compact IP 21 (NEMA 1) and IP 54 (NEMA 12), frame size D1

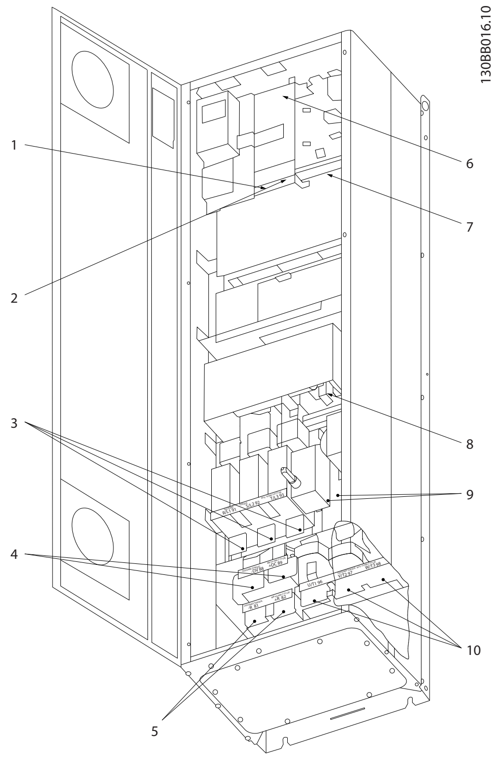


Figure 8.41 Compact IP 21 (NEMA 1) and IP 54 (NEMA 12) with disconnect, fuse and RFI filter, frame size D2

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

Table 8.22

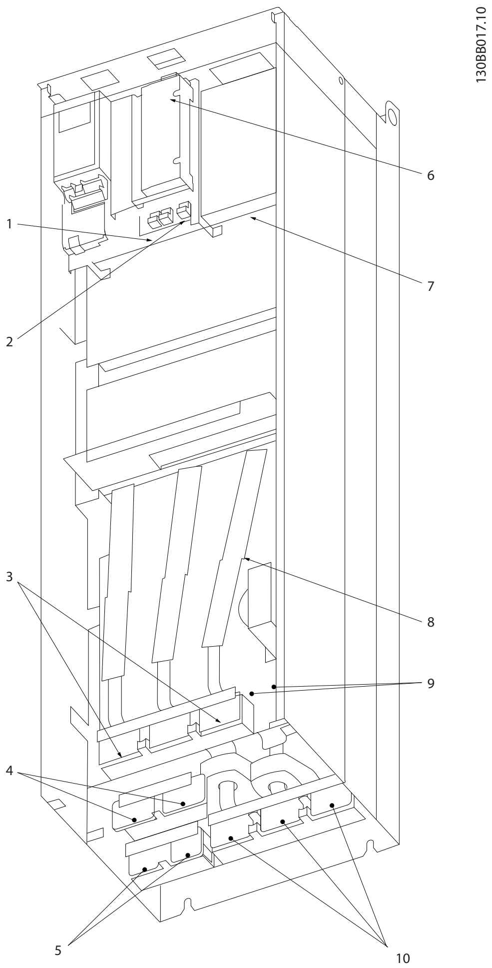


Figure 8.42 Compact IP 00 (Chassis), frame size D3

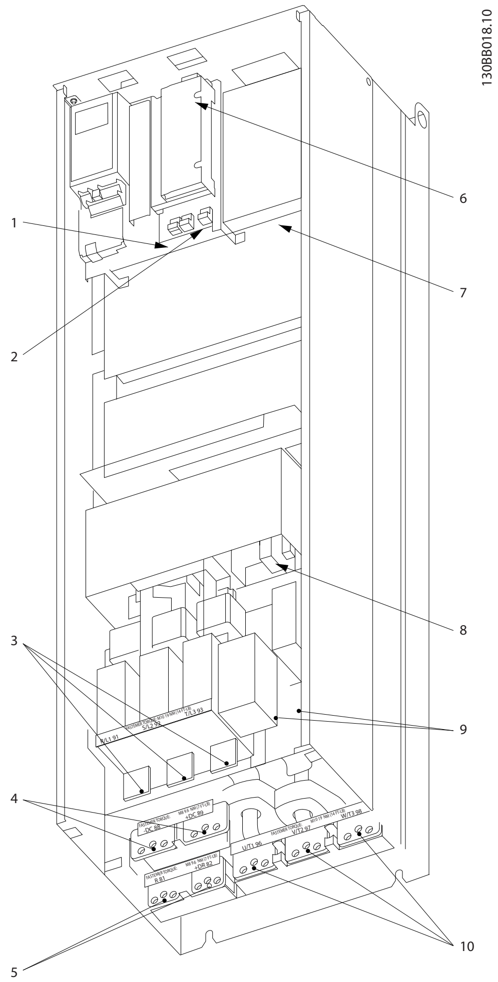


Figure 8.43 Compact IP 00 (Chassis) with disconnect, fuse and RFI filter, frame size D4

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

Table 8.23

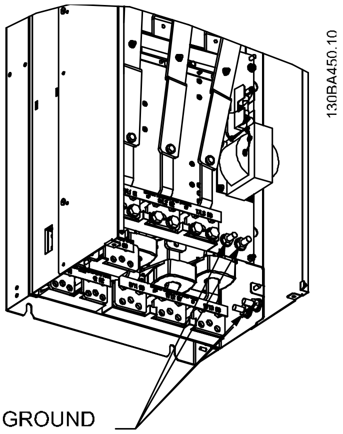


Figure 8.44 Position of ground terminals IP00, frame sizes D

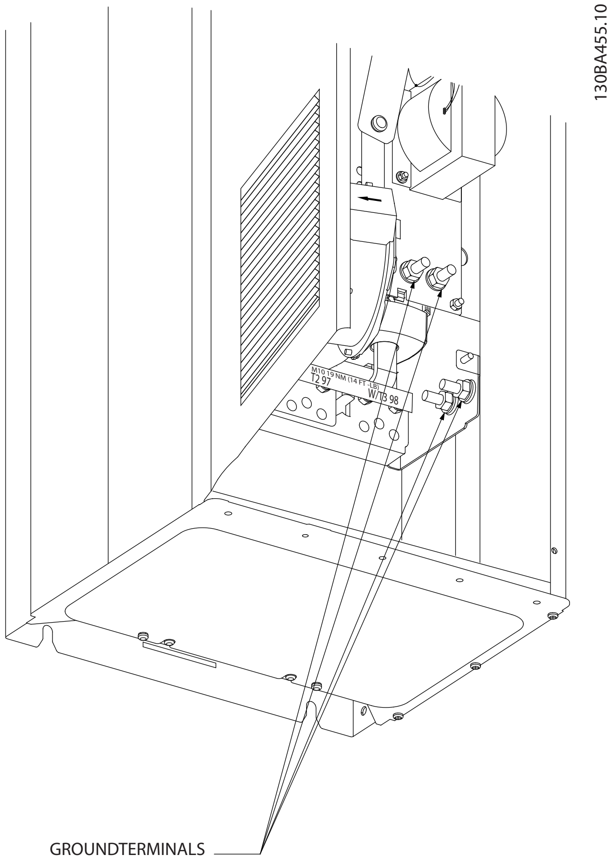


Figure 8.45 Position of ground terminals IP21 (NEMA type 1) and IP54 (NEMA type 12)

NOTE!

D2 and D4 shown as examples. D1 and D3 are equivalent.

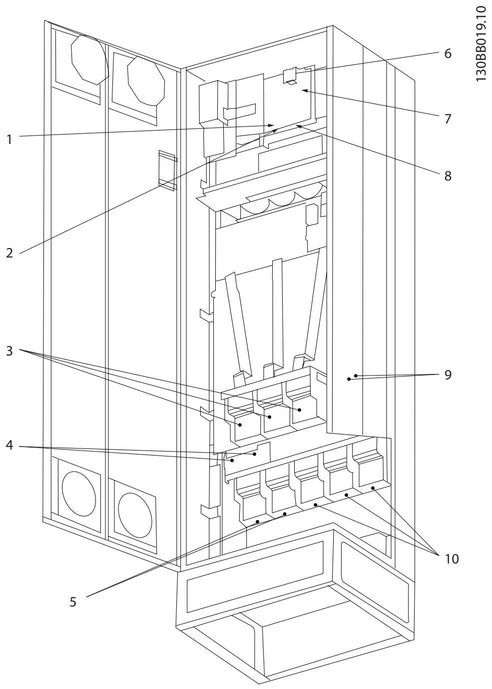


Figure 8.46 Compact IP 21 (NEMA 1) and IP 54 (NEMA 12) frame size E1

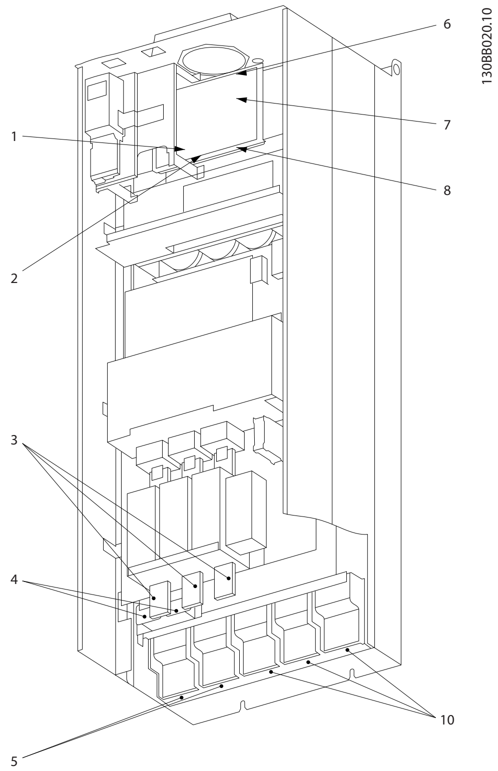


Figure 8.47 Compact IP 00 (Chassis) with disconnect, fuse and RFI filter, frame size E2

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

Table 8.24

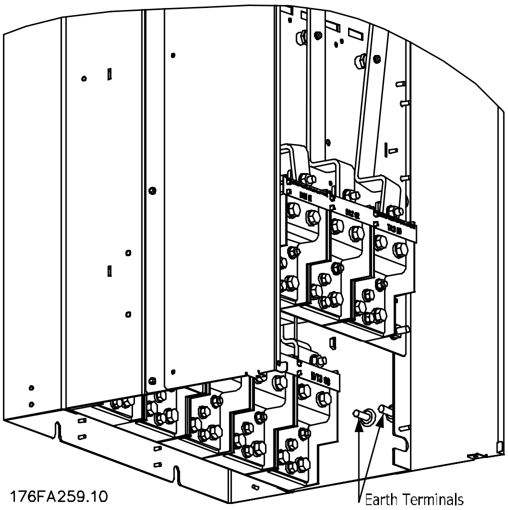


Figure 8.48 Position of ground terminals IP00, frame sizes E

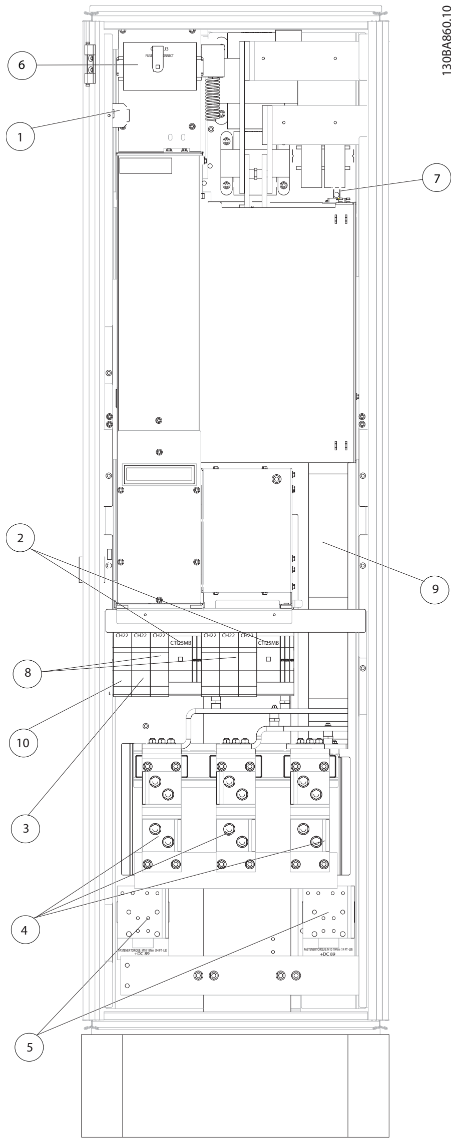


Figure 8.49 Rectifier Cabinet, frame size F1, F2, F3 and F4

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

Table 8.25

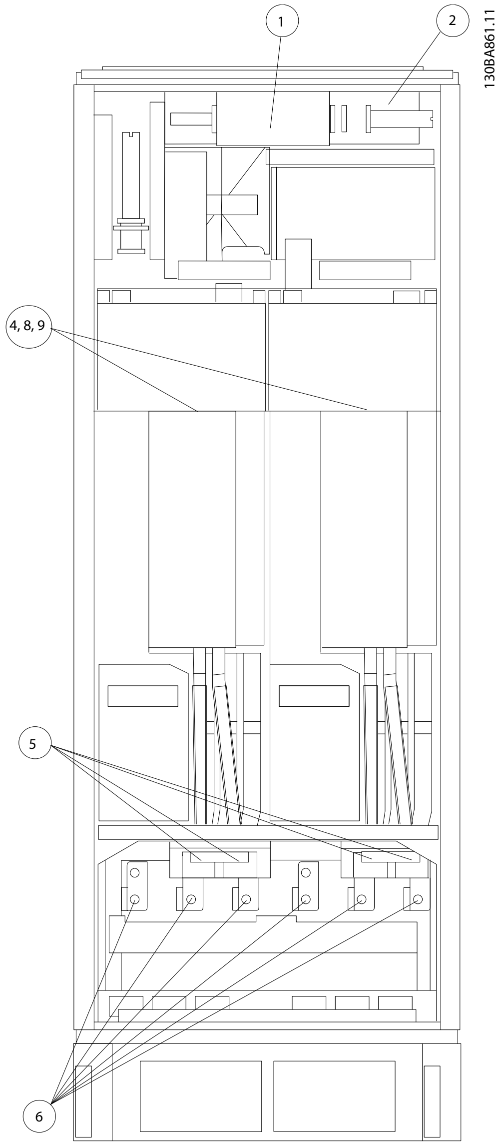
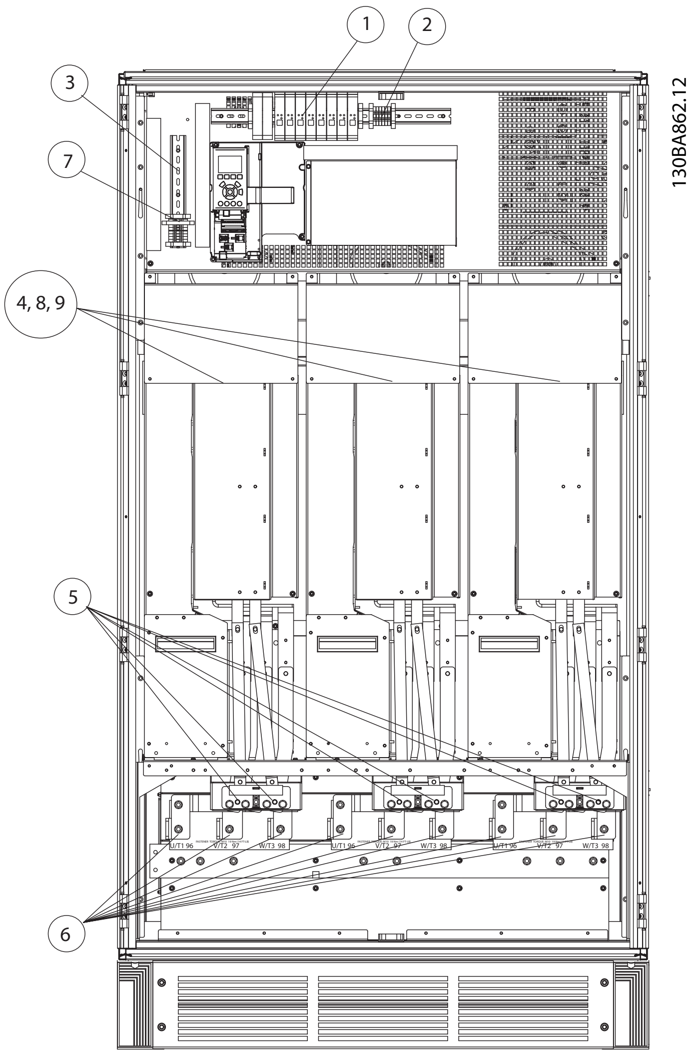


Figure 8.50 Inverter Cabinet, frame size F1 and F3

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

Table 8.26



8

Figure 8.51 Inverter Cabinet, frame size F2 and F4

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

Table 8.27

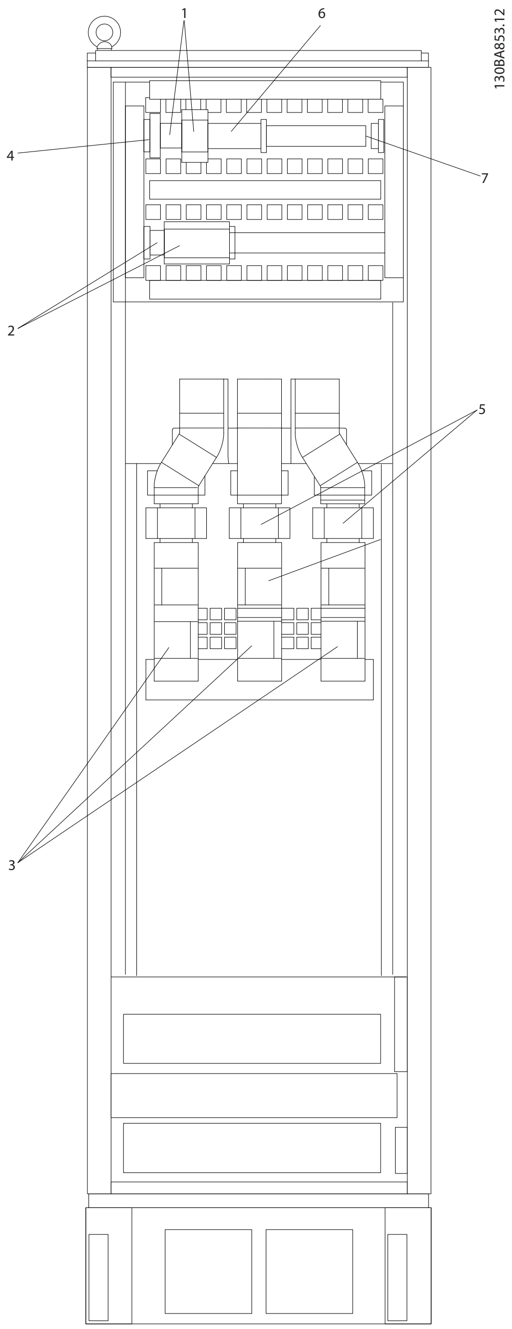


Figure 8.52 Options Cabinet, frame size F3 and F4

1)	Pilz Relay Terminal				4)	Safety Relay Coil Fuse with PILS Relay
2)	RCD or IRM Terminal					See fuse tables for part numbers
3)	Line power				5)	Line Fuses, F3 and F4 (3 pieces)
	R	S	T			See fuse tables for part numbers
	91	92	93		6)	Contactor Relay Coil (230 VAC). N/C and N/O Aux Contacts
	L1	L2	L3		7)	Circuit Breaker Shunt Trip Control Terminals (230 VAC or 230 VDC)

Table 8.28

8.2.3 Power Connections 12-Pulse Drives

Cabling and Fusing

NOTE!

Cables General

All cabling must comply with national and local regulations on cable cross-sections and ambient temperature. UL applications require that 167°F [75°C] copper conductors. 167°F [75°C] and 194°C] copper conductors are thermally acceptable for the adjustable frequency drive to use in non-UL applications.

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

For protection of the adjustable frequency drive, the recommended fuses must be used or the unit must have built-in fuses. Recommended fuses can be seen in the tables of the fuse section. Always ensure that proper fusing is installed according to local regulations.

The AC line input connection is fitted to the line power switch if this is included.

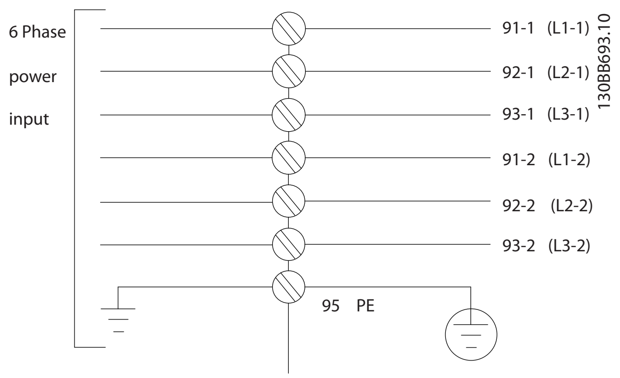


Figure 8.53

NOTE!

The motor cable must be shielded/armored. If an unshielded/unarmored cable is used, some EMC requirements are not complied with. Use a shielded/armored motor cable to comply with EMC emission specifications. For more information, see *EMC specifications* in the *Design Guide*.

See for correct dimensioning of motor cable cross-section and length.

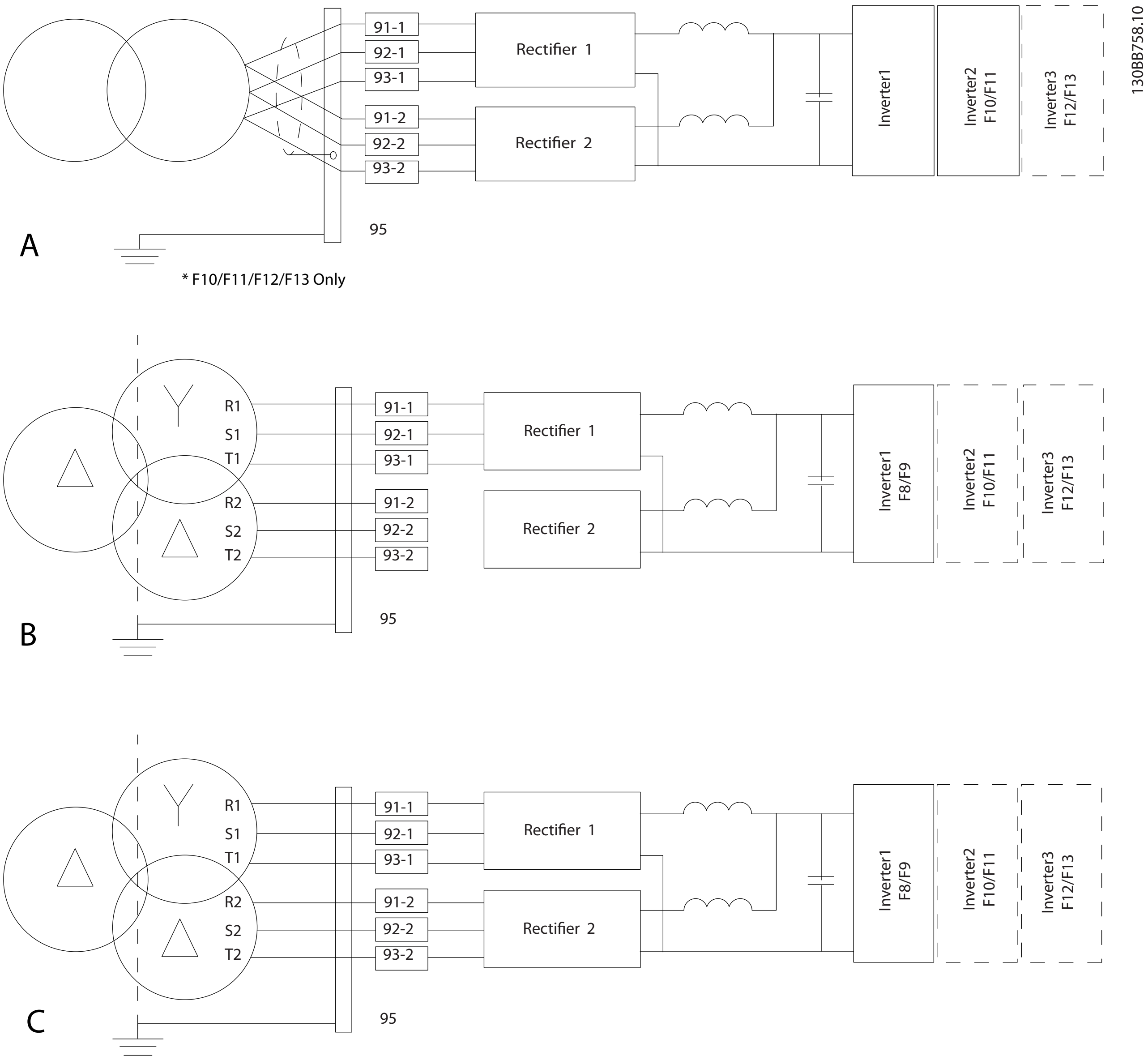


Figure 8.54

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

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

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

Notes:

1) Parallel connection shown. A single 3-phase cable may be used with sufficient carrying capability. Shorting busbars must be installed.

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

3) Suitable for IT and TN AC line input connections.

4) In the unlikely event that one of the 6-pulse modular rectifiers becomes inoperable, it is possible to operate the drive at reduced load with a single 6-pulse rectifier. Contact factory for reconnection details.

5) No paralleling of line power cabling is shown here.

Shielding of cables:
Avoid installation with twisted shield ends (pigtails), as 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.

Connect the motor cable shield to both the de-coupling plate of the adjustable frequency drive and to the metal housing of the motor.

Make the shield connections with the largest possible surface area (cable clamp). This is done by using the supplied installation devices within the adjustable frequency drive.

Cable-length and cross-section:
The adjustable frequency drive has been EMC tested with a given length of cable. Keep the motor cable as short as possible to reduce the noise level and leakage currents.

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

Term. no.	96	97	98	99	
	U	V	W	PE[1]	Motor voltage 0–100% of 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 8.29

[1] *Protected Ground Connection*

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.

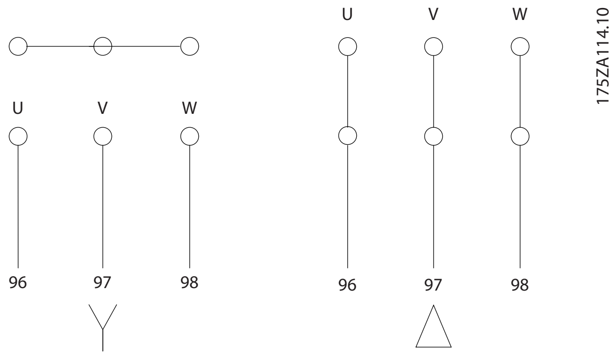


Figure 8.55

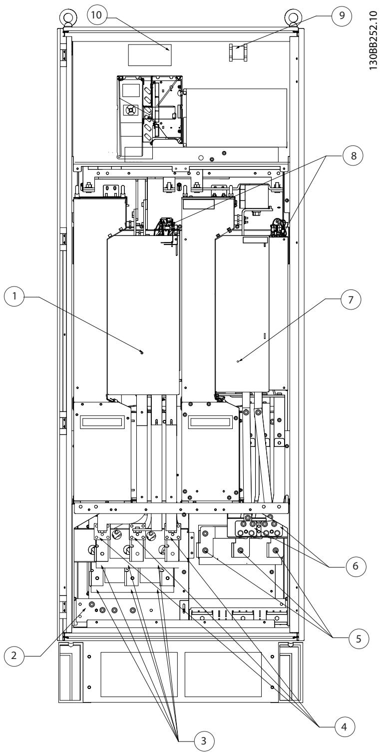


Figure 8.56 Rectifier and Inverter Cabinet, frame size F8 and F9

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

Table 8.30

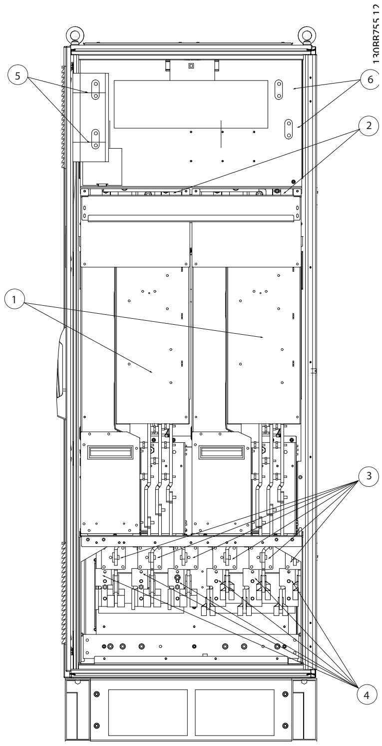


Figure 8.57 Rectifier Cabinet, frame size F10 and F12

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

Table 8.31

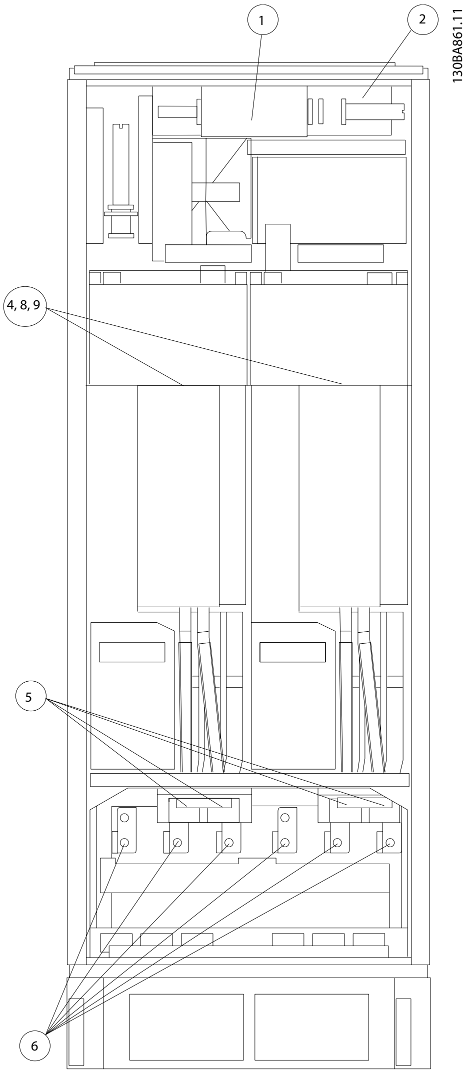


Figure 8.58 Inverter Cabinet, frame size F10 and F11

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

Table 8.32

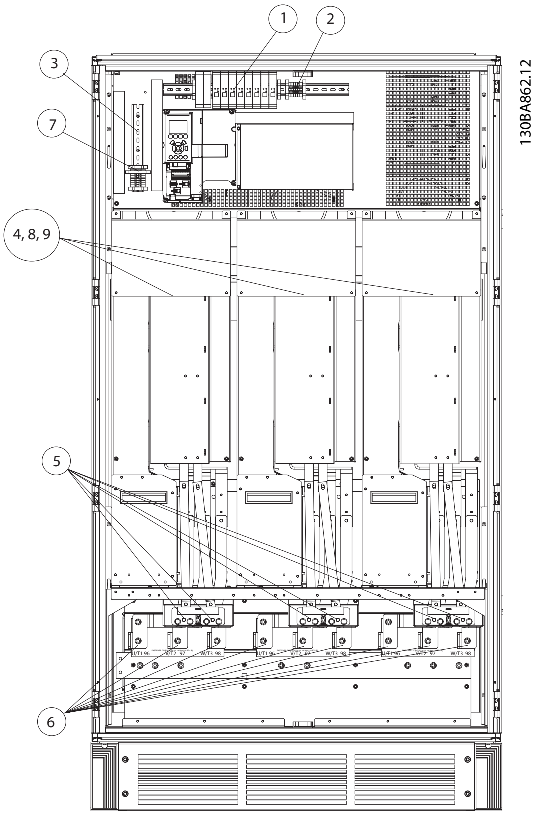


Figure 8.59 Inverter Cabinet, frame size F12 and F13

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

Table 8.33

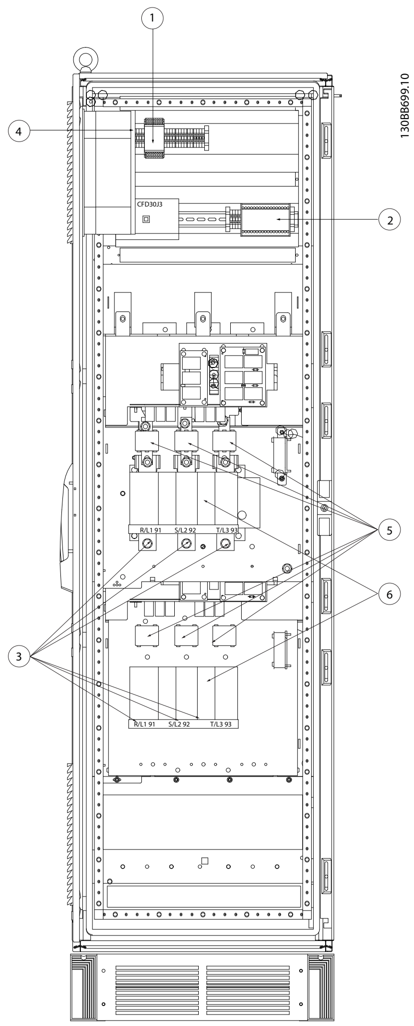


Figure 8.60 Options Cabinet, frame size F9

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

Table 8.34

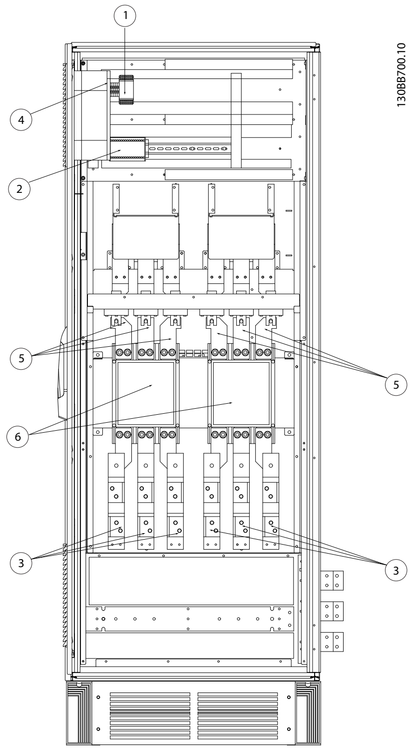


Figure 8.61 Options Cabinet, frame size F11 and F13

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

Table 8.35

8.2.4 Shielding against Electrical Noise

Before mounting the line power cable, mount the EMC metal cover to ensure best EMC performance.

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

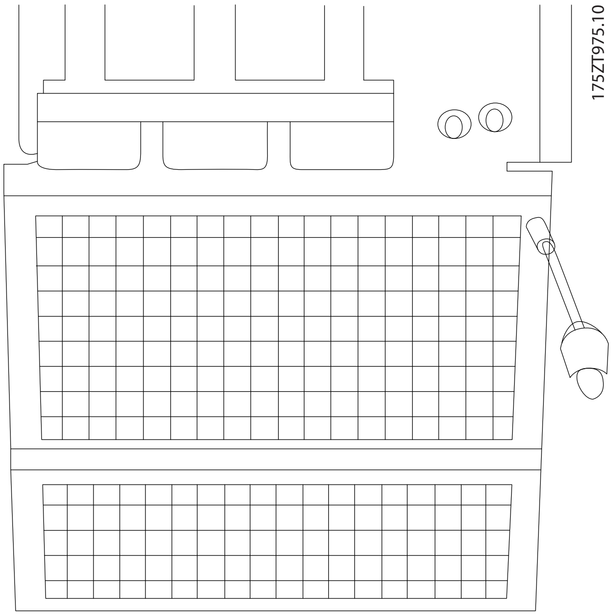


Figure 8.62 Mount the EMC shield.

8.2.5 External Fan Supply

Frame size D, E, F

If the Adjustable frequency drive is supplied by DC or if the fan must run independently of the power supply, an external power supply can be applied. The connection is made on the power card.

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

Table 8.36

The connector located on the power card provides the AC line voltage connection for the cooling fans. The fans are factory-equipped to be supplied from a common AC line (jumpers between 100-102 and 101-103). If an external supply is needed, the jumpers are removed and the supply is connected to terminals 100 and 101. A 5 Amp fuse should be used for protection. In UL applications, this should be a LittleFuse KLK-5 or equivalent.

8.3 Fuses

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

NOTE!

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

WARNING

Personnel and property must be protected against the consequence of internal component break-down in the Adjustable frequency drive.

Branch Circuit Protection

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

NOTE!

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

Short-circuit protection:

Danfoss recommends using the fuses/circuit breakers mentioned below to protect service personnel and property in case of component break-down in the Adjustable frequency drive.

8

8.3.1 Recommendations

WARNING

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

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

If fuses/circuit breakers are chosen according as recommended, possible damage to the Adjustable frequency drive will be limited to mainly damage inside the unit.

For further information, please see Application Note *Fuses and Circuit Breakers*, MN.90.TX.YY

8.3.2 CE Compliance

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

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

Enclosure	FC 300 Power	Recommended fuse size	Recommended Max. fuse	Recommended circuit breaker	Max. trip level
Size	[kW]			Moeller	[A]
A1	0.25–1.5	gG-10	gG-25	PKZM0-16	16
A2	0.25–2.2	gG-10 (0.25–1.5) gG-16 (2.2)	gG-25	PKZM0-25	25
A3	3.0–3.7	gG-16 (3) gG-20 (3.7)	gG-32	PKZM0-25	25
B3	5.5	gG-25	gG-63	PKZM4-50	50
B4	7.5–1.5	gG-32 (7.5) gG-50 (11) gG-63 (15)	gG-125	NZMB1-A100	100
C3	18.5–22	gG-80 (18.5) aR-125 (22)	gG-150 (18.5) aR-160 (22)	NZMB2-A200	150
C4	30–37	aR-160 (30) aR-200 (37)	aR-200 (30) aR-250 (37)	NZMB2-A250	250
A4	0.25–2.2	gG-10 (0.25–1.5) gG-16 (2.2)	gG-32	PKZM0-25	25
A5	0.25–3.7	gG-10 (0.25–1.5) gG-16 (2.2–3) gG-20 (3.7)	gG-32	PKZM0-25	25
B1	5.5–7.5	gG-25 (5.5) gG-32 (7.5)	gG-80	PKZM4-63	63
B2	11	gG-50	gG-100	NZMB1-A100	100
C1	15-22	gG-63 (15) gG-80 (18.5) gG-100 (22)	gG-160 (15–18.5) aR-160 (22)	NZMB2-A200	160
C2	30–37	aR-160 (30) aR-200 (37)	aR-200 (30) aR-250 (37)	NZMB2-A250	250

Table 8.37 200–240V, Frame Sizes A, B and C

Enclosure	FC 300 Power	Recommended fuse size	Recommended Max. fuse	Recommended circuit breaker	Max. trip level
Size	[kW]			Moeller	[A]
A1	0.37–1.5	gG-10	gG-25	PKZM0-16	16
A2	0.37–4.0	gG-10 (0.37–3) gG-16 (4)	gG-25	PKZM0-25	25
A3	5.5–7.5	gG-16	gG-32	PKZM0-25	25
B3	11–15	gG-40	gG-63	PKZM4-50	50
B4	18.5–30	gG-50 (18.5) gG-63 (22) gG-80 (30)	gG-125	NZMB1-A100	100
C3	37–45	gG-100 (37) gG-160 (45)	gG-150 (37) gG-160 (45)	NZMB2-A200	150
C4	55–75	aR-200 (55) aR-250 (75)	aR-250	NZMB2-A250	250
A4	0.37–4	gG-10 (0.37–3) gG-16 (4)	gG-32	PKZM0-25	25
A5	0.37–7.5	gG-10 (0.37–3) gG-16 (4–7.5)	gG-32	PKZM0-25	25
B1	11–15	gG-40	gG-80	PKZM4-63	63
B2	18.5–22	gG-50 (18.5) gG-63 (22)	gG-100	NZMB1-A100	100
C1	30–45	gG-80 (30) gG-100 (37) gG-160 (45)	gG-160	NZMB2-A200	160
C2	55–75	aR-200 (55) aR-250 (75)	aR-250	NZMB2-A250	250
D	90–200	gG-300 (90) gG-350 (110) gG-400 (132) gG-500 (160) gG-630 (200)	gG-300 (90) gG-350 (110) gG-400 (132) gG-500 (160) gG-630 (200)	-	-
E	250–400	aR-700 (250) aR-900 (315–400)	aR-700 (250) aR-900 (315–400)	-	-
F	450–800	aR-1600 (450–500) aR-2000 (7560–630) aR-2500 (710–800)	aR-1600 (450–500) aR-2000 (560–630) aR-2500 (710–800)	-	-

Table 8.38 380–500V, Frame Sizes A, B, C, D, E and F

Enclosure	FC 300 Power	Recommended fuse size	Recommended Max. fuse	Recommended circuit breaker	Max. trip level
Size	[kW]			Moeller	[A]
A2	0.75–4.0	gG-10	gG-25	PKZM0-25	25
A3	5.5–7.5	gG-10 (5.5) gG-16 (7.5)	gG-32	PKZM0-25	25
B3	11–15	gG-25 (11) gG-32 (15)	gG-63	PKZM4-50	50
B4	18.5–30	gG-40 (18.5) gG-50 (22) gG-63 (30)	gG-125	NZMB1-A100	100
C3	37–45	gG-63 (37) gG-100 (45)	gG-150	NZMB2-A200	150
C4	55–75	aR-160 (55) aR-200 (75)	aR-250	NZMB2-A250	250
A5	0.75–7.5	gG-10 (0.75–5.5) gG-16 (7.5)	gG-32	PKZM0-25	25
B1	11-18	gG-25 (11) gG-32 (15) gG-40 (18.5)	gG-80	PKZM4-63	63
B2	22–30	gG-50 (22) gG-63 (30)	gG-100	NZMB1-A100	100
C1	37–55	gG-63 (37) gG-100 (45) aR-160 (55)	gG-160 (37–45) aR-250 (55)	NZMB2-A200	160
C2	75	aR-200 (75)	aR-250	NZMB2-A250	250

Table 8.39 525–600V, Frame Sizes A, B and C

8

Enclosure	FC 300 Power	Recommended fuse size	Recommended Max. fuse	Recommended circuit breaker	Max. trip level
Size	[kW]			Moeller	[A]
B2	11 15 18 22	gG-25 (11) gG-32 (15) gG-32 (18) gG-40 (22)	gG-63	-	-
C2	30 37 45 55 75	gG-63 (30) gG-63 (37) gG-80 (45) gG-100 (55) gG-125 (75)	gG-80 (30) gG-100 (37) gG-125 (45) gG-160 (55–75)	-	-
D	37-315	gG-125 (37) gG-160 (45) gG-200 (55–75) aR-250 (90) aR-315 (110) aR-350 (132–160) aR-400 (200) aR-500 (250) aR-550 (315)	gG-125 (37) gG-160 (45) gG-200 (55–75) aR-250 (90) aR-315 (110) aR-350 (132–160) aR-400 (200) aR-500 (250) aR-550 (315)	-	-
E	355-560	aR-700 (355–400) aR-900 (500–560)	aR-700 (355–400) aR-900 (500–560)	-	-
F	630-1200	aR-1600 (630–900) aR-2000 (1000) aR-2500 (1200)	aR-1600 (630–900) aR-2000 (1000) aR-2500 (1200)	-	-

Table 8.40 525–690V, Frame Sizes B, C, D, E and F

UL Compliance

Fuses or circuit breakers are mandatory to comply with NEC 2009. We recommend using a selection of the following.

The fuses below are suitable for use on a circuit capable of delivering 100,000 Arms (symmetrical), 240V, or 480V, or 500V, or 600V depending on the Adjustable frequency drive voltage rating. With the proper fusing, the drive Short Circuit Current Rating (SCCR) is 100,000 Arms.

	Recommended max. fuse					
FC 300 Power	Bussmann	Bussmann	Bussmann	Bussmann	Bussmann	Bussmann
[kW]	Type RK1 [1)]	Type J	Type T	Type CC	Type CC	Type CC
0.25–0.37	KTN-R-05	JKS-05	JJN-05	FNQ-R-5	KTK-R-5	LP-CC-5
0.55–1.1	KTN-R-10	JKS-10	JJN-10	FNQ-R-10	KTK-R-10	LP-CC-10
1.5	KTN-R-15	JKS-15	JJN-15	FNQ-R-15	KTK-R-15	LP-CC-15
2.2	KTN-R-20	JKS-20	JJN-20	FNQ-R-20	KTK-R-20	LP-CC-20
3.0	KTN-R-25	JKS-25	JJN-25	FNQ-R-25	KTK-R-25	LP-CC-25
3.7	KTN-R-30	JKS-30	JJN-30	FNQ-R-30	KTK-R-30	LP-CC-30
5.5	KTN-R-50	KS-50	JJN-50	-	-	-
7.5	KTN-R-60	JKS-60	JJN-60	-	-	-
11	KTN-R-80	JKS-80	JJN-80	-	-	-
15–18.5	KTN-R-125	JKS-125	JJN-125	-	-	-
22	KTN-R-150	JKS-150	JJN-150	-	-	-
30	KTN-R-200	JKS-200	JJN-200	-	-	-
37	KTN-R-250	JKS-250	JJN-250	-	-	-

Table 8.41 200–240V, Frame Sizes A, B and C

	Recommended max. fuse			
FC 300 Power	SIBA	Littel fuse	Ferraz-Shawmut	Ferraz-Shawmut
[kW]	Type RK1	Type RK1	Type CC	Type RK1[3)]
0.25–0.37	5017906-005	KLN-R-05	ATM-R-05	A2K-05-R
0.55–1.1	5017906-010	KLN-R-10	ATM-R-10	A2K-10-R
1.5	5017906-016	KLN-R-15	ATM-R-15	A2K-15-R
2.2	5017906-020	KLN-R-20	ATM-R-20	A2K-20-R
3.0	5017906-025	KLN-R-25	ATM-R-25	A2K-25-R
3.7	5012406-032	KLN-R-30	ATM-R-30	A2K-30-R
5.5	5014006-050	KLN-R-50	-	A2K-50-R
7.5	5014006-063	KLN-R-60	-	A2K-60-R
11	5014006-080	KLN-R-80	-	A2K-80-R
15–18.5	2028220-125	KLN-R-125	-	A2K-125-R
22	2028220-150	KLN-R-150	-	A2K-150-R
30	2028220-200	KLN-R-200	-	A2K-200-R
37	2028220-250	KLN-R-250	-	A2K-250-R

Table 8.42 200–240V, Frame Sizes A, B and C

	Recommended max. fuse			
FC 300	Bussmann	Littel fuse	Ferraz-Shawmut	Ferraz-Shawmut
[kW]	Type JFHR2 2)	JFHR2	JFHR2 4)	J
0.25–0.37	FWX-5	-	-	HSJ-6
0.55–1.1	FWX-10	-	-	HSJ-10
1.5	FWX-15	-	-	HSJ-15
2.2	FWX-20	-	-	HSJ-20
3.0	FWX-25	-	-	HSJ-25
3.7	FWX-30	-	-	HSJ-30
5.5	FWX-50	-	-	HSJ-50
7.5	FWX-60	-	-	HSJ-60
11	FWX-80	-	-	HSJ-80
15–18.5	FWX-125	-	-	HSJ-125
22	FWX-150	L25S-150	A25X-150	HSJ-150
30	FWX-200	L25S-200	A25X-200	HSJ-200
37	FWX-250	L25S-250	A25X-250	HSJ-250

Table 8.43 200–240V, Frame Sizes A, B and C

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

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

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

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

	Recommended max. fuse					
FC 300	Bussmann	Bussmann	Bussmann	Bussmann	Bussmann	Bussmann
[kW]	Type RK1	Type J	Type T	Type CC	Type CC	Type CC
0.37–1.1	KTS-R-6	JKS-6	JJS-6	FNQ-R-6	KTK-R-6	LP-CC-6
1.5–2.2	KTS-R-10	JKS-10	JJS-10	FNQ-R-10	KTK-R-10	LP-CC-10
3	KTS-R-15	JKS-15	JJS-15	FNQ-R-15	KTK-R-15	LP-CC-15
4	KTS-R-20	JKS-20	JJS-20	FNQ-R-20	KTK-R-20	LP-CC-20
5.5	KTS-R-25	JKS-25	JJS-25	FNQ-R-25	KTK-R-25	LP-CC-25
7.5	KTS-R-30	JKS-30	JJS-30	FNQ-R-30	KTK-R-30	LP-CC-30
11	KTS-R-40	JKS-40	JJS-40	-	-	-
15	KTS-R-50	JKS-50	JJS-50	-	-	-
18	KTS-R-60	JKS-60	JJS-60	-	-	-
22	KTS-R-80	JKS-80	JJS-80	-	-	-
30	KTS-R-100	JKS-100	JJS-100	-	-	-
37	KTS-R-125	JKS-125	JJS-125	-	-	-
45	KTS-R-150	JKS-150	JJS-150	-	-	-
55	KTS-R-200	JKS-200	JJS-200	-	-	-
75	KTS-R-250	JKS-250	JJS-250	-	-	-

Table 8.44 380–500V, Frame Sizes A, B and C

	Recommended max. fuse			
FC 302	SIBA	Littel fuse	Ferraz-Shawmut	Ferraz-Shawmut
[kW]	Type RK1	Type RK1	Type CC	Type RK1
0.37–1.1	5017906-006	KLS-R-6	ATM-R-6	A6K-6-R
1.5–2.2	5017906-010	KLS-R-10	ATM-R-10	A6K-10-R
3	5017906-016	KLS-R-15	ATM-R-15	A6K-15-R
4	5017906-020	KLS-R-20	ATM-R-20	A6K-20-R
5.5	5017906-025	KLS-R-25	ATM-R-25	A6K-25-R
7.5	5012406-032	KLS-R-30	ATM-R-30	A6K-30-R
11	5014006-040	KLS-R-40	-	A6K-40-R
15	5014006-050	KLS-R-50	-	A6K-50-R
18	5014006-063	KLS-R-60	-	A6K-60-R
22	2028220-100	KLS-R-80	-	A6K-80-R
30	2028220-125	KLS-R-100	-	A6K-100-R
37	2028220-125	KLS-R-125	-	A6K-125-R
45	2028220-160	KLS-R-150	-	A6K-150-R
55	2028220-200	KLS-R-200	-	A6K-200-R
75	2028220-250	KLS-R-250	-	A6K-250-R

Table 8.45 380–500V, Frame Sizes A, B and C

	Recommended max. fuse			
FC 302	Bussmann	Ferraz-Shawmut	Ferraz-Shawmut	Littel fuse
[kW]	JFHR2	J	JFHR2 1)	JFHR2
0.37–1.1	FWH-6	HSJ-6	-	-
1.5–2.2	FWH-10	HSJ-10	-	-
3	FWH-15	HSJ-15	-	-
4	FWH-20	HSJ-20	-	-
5.5	FWH-25	HSJ-25	-	-
7.5	FWH-30	HSJ-30	-	-
11	FWH-40	HSJ-40	-	-
15	FWH-50	HSJ-50	-	-
18	FWH-60	HSJ-60	-	-
22	FWH-80	HSJ-80	-	-
30	FWH-100	HSJ-100	-	-
37	FWH-125	HSJ-125	-	-
45	FWH-150	HSJ-150	-	-
55	FWH-200	HSJ-200	A50-P-225	L50-S-225
75	FWH-250	HSJ-250	A50-P-250	L50-S-250

Table 8.46 380–500V, Frame Sizes A, B and C

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

	Recommended max. fuse					
FC 302	Bussmann	Bussmann	Bussmann	Bussmann	Bussmann	Bussmann
[kW]	Type RK1	Type J	Type T	Type CC	Type CC	Type CC
0.75–1.1	KTS-R-5	JKS-5	JJS-6	FNQ-R-5	KTK-R-5	LP-CC-5
1.5–2.2	KTS-R-10	JKS-10	JJS-10	FNQ-R-10	KTK-R-10	LP-CC-10
3	KTS-R15	JKS-15	JJS-15	FNQ-R-15	KTK-R-15	LP-CC-15
4	KTS-R20	JKS-20	JJS-20	FNQ-R-20	KTK-R-20	LP-CC-20
5.5	KTS-R-25	JKS-25	JJS-25	FNQ-R-25	KTK-R-25	LP-CC-25
7.5	KTS-R-30	JKS-30	JJS-30	FNQ-R-30	KTK-R-30	LP-CC-30
11	KTS-R-35	JKS-35	JJS-35	-	-	-
15	KTS-R-45	JKS-45	JJS-45	-	-	-
18	KTS-R-50	JKS-50	JJS-50	-	-	-
22	KTS-R-60	JKS-60	JJS-60	-	-	-
30	KTS-R-80	JKS-80	JJS-80	-	-	-
37	KTS-R-100	JKS-100	JJS-100	-	-	-
45	KTS-R-125	JKS-125	JJS-125	-	-	-
55	KTS-R-150	JKS-150	JJS-150	-	-	-
75	KTS-R-175	JKS-175	JJS-175	-	-	-

Table 8.47 525–600V, Frame Sizes A, B and C

	Recommended max. fuse			
FC 302	SIBA	Littel fuse	Ferraz-Shawmut	Ferraz-Shawmut
[kW]	Type RK1	Type RK1	Type RK1	J
0.75–1.1	5017906-005	KLS-R-005	A6K-5-R	HSJ-6
1.5–2.2	5017906-010	KLS-R-010	A6K-10-R	HSJ-10
3	5017906-016	KLS-R-015	A6K-15-R	HSJ-15
4	5017906-020	KLS-R-020	A6K-20-R	HSJ-20
5.5	5017906-025	KLS-R-025	A6K-25-R	HSJ-25
7.5	5017906-030	KLS-R-030	A6K-30-R	HSJ-30
11	5014006-040	KLS-R-035	A6K-35-R	HSJ-35
15	5014006-050	KLS-R-045	A6K-45-R	HSJ-45
18	5014006-050	KLS-R-050	A6K-50-R	HSJ-50
22	5014006-063	KLS-R-060	A6K-60-R	HSJ-60
30	5014006-080	KLS-R-075	A6K-80-R	HSJ-80
37	5014006-100	KLS-R-100	A6K-100-R	HSJ-100
45	2028220-125	KLS-R-125	A6K-125-R	HSJ-125
55	2028220-150	KLS-R-150	A6K-150-R	HSJ-150
75	2028220-200	KLS-R-175	A6K-175-R	HSJ-175

Table 8.48 525–600V, Frame Sizes A, B and C

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

	Recommended max. fuse							
FC 302 [kW]	Max. prefuse	Bussmann E52273 RK1/JDDZ	Bussmann E4273 J/JDDZ	Bussmann E4273 T/JDDZ	SIBA E180276 RK1/JDDZ	LittelFuse E81895 RK1/JDDZ	Ferraz-Shawmut E163267/E2137 RK1/JDDZ	Ferraz-Shawmut E2137 J/HSJ
11	30 A	KTS-R-30	JKS-30	JKJS-30	5017906-030	KLS-R-030	A6K-30-R	HST-30
15–18.5	45 A	KTS-R-45	JKS-45	JJS-45	5014006-050	KLS-R-045	A6K-45-R	HST-45
22	60 A	KTS-R-60	JKS-60	JJS-60	5014006-063	KLS-R-060	A6K-60-R	HST-60
30	80 A	KTS-R-80	JKS-80	JJS-80	5014006-080	KLS-R-075	A6K-80-R	HST-80
37	90 A	KTS-R-90	JKS-90	JJS-90	5014006-100	KLS-R-090	A6K-90-R	HST-90
45	100 A	KTS-R-100	JKS-100	JJS-100	5014006-100	KLS-R-100	A6K-100-R	HST-100
55	125 A	KTS-R-125	JKS-125	JJS-125	2028220-125	KLS-150	A6K-125-R	HST-125
75	150 A	KTS-R-150	JKS-150	JJS-150	2028220-150	KLS-175	A6K-150-R	HST-150
* UL compliance only 525–600V								

Table 8.49 525–690V*, Frame Sizes B and C

FC 302 [kW]	Recommended Drive External Fuse Bussmann PN	Rating	Drive Internal Option Bussmann PN	Alternate External Bussmann PN	Alternate External Bussmann PN	Alternate External Siba PN	Alternate External Littlefuse PN	Alternate External Ferraz-Shawmut PN
90	170M3017	315A, 700V	170M3018	FWH-300	JJS-300	2028220-315	L50-S-300	A50-P-300
110	170M3018	350A, 700V	170M3018	FWH-350	JJS-350	2028220-315	L50-S-350	A50-P-350
132	170M4012	400A, 700V	170M4016	FWH-400	JJS-400	206xx32-400	L50-S-400	A50-P-400
160	170M4014	500A, 700V	170M4016	FWH-500	JJS-500	206xx32-500	L50-S-500	A50-P-500
200	170M4016	630A, 700V	170M4016	FWH-600	JJS-600	206xx32-600	L50-S-600	A50-P-600

Table 8.50 380–480/500V, Frame Size D, Line Fuse

FC 302 [kW]	Recommended Drive External Fuse Bussmann PN	Rating	Drive Internal Option Bussmann PN	Alternate External Siba PN	Alternate External Ferraz-Shawmut PN
250	170M4017	700A, 700V	170M4017	20 610 32.700	6.9URD31D08A0700
315	170M6013	900A, 700V	170M6013	22 610 32.900	6.9URD33D08A0900
355	170M6013	900A, 700V	170M6013	22 610 32.900	6.9URD33D08A0900
400	170M6013	900A, 700V	170M6013	22 610 32.900	6.9URD33D08A0900

Table 8.51 380–480/500V, Frame Size E, Line Fuse

FC 302 [kW]	Recommended Drive External Fuse Bussmann PN	Rating	Drive Internal Option Bussmann PN	Alternate Siba PN
450	170M7081	1600A, 700V	170M7082	20 695 32.1600
500	170M7081	1600A, 700V	170M7082	20 695 32.1600
560	170M7082	2000A, 700V	170M7082	20 695 32.2000
630	170M7082	2000A, 700V	170M7082	20 695 32.2000
710	170M7083	2500A, 700V	170M7083	20 695 32.2500
800	170M7083	2500A, 700V	170M7083	20 695 32.2500

Table 8.52 380–480/500V, Frame Size F, Line Fuse

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

Table 8.53 380–480/500V, Frame Size F, Inverter Module DC Link Fuses

FC 302 [kW]	Recommended Drive External Fuse Bussmann PN	Rating	Drive Internal Option Bussmann PN	Alternate External Siba PN	Alternate External Ferraz-Shawmut PN
37	170M3013	125A, 700V	170M3015	2061032,125	6.9URD30D08A0125
45	170M3014	160A, 700V	170M3015	2061032,16	6.9URD30D08A0160
55	170M3015	200A, 700V	170M3015	2061032,2	6.9URD30D08A0200
75	170M3015	200A, 700V	170M3015	2061032,2	6.9URD30D08A0200
90	170M3016	250A, 700V	170M3018	2061032,25	6.9URD30D08A0250
110	170M3017	315A, 700V	170M3018	2061032,315	6.9URD30D08A0315
132	170M3018	350A, 700V	170M3018	2061032,35	6.9URD30D08A0350
160	170M4011	350A, 700V	170M5011	2061032,35	6.9URD30D08A0350
200	170M4012	400A, 700V	170M5011	2061032,4	6.9URD30D08A0400
250	170M4014	500A, 700V	170M5011	2061032,5	6.9URD30D08A0500
315	170M5011	550A, 700V	170M5011	2062032,55	6.9URD32D08A0550

Table 8.54 525–690V, Frame Size D, Line Fuse

FC 302 [kW]	Recommended Drive External Fuse Bussmann PN	Rating	Drive Internal Option Bussmann PN	Alternate External Siba PN	Alternate External Ferraz-Shawmut PN
355	170M4017	700A, 700V	170M4017	20 610 32.700	6.9URD31D08A0700
400	170M4017	700A, 700V	170M4017	20 610 32.700	6.9URD31D08A0700
500	170M6013	900A, 700V	170M6013	22 610 32.900	6.9URD33D08A0900
560	170M6013	900A, 700V	170M6013	22 610 32.900	6.9URD33D08A0900

Table 8.55 525–690V, Frame Size E, Line Fuse

FC 302 [kW]	Recommended Drive External Fuse Bussmann PN	Rating	Drive Internal Option Bussmann PN	Alternate Siba PN
630	170M7081	1600A, 700V	170M7082	20 695 32.1600
710	170M7081	1600A, 700V	170M7082	20 695 32.1600
800	170M7081	1600A, 700V	170M7082	20 695 32.1600
900	170M7081	1600A, 700V	170M7082	20 695 32.1600
1000	170M7082	2000A, 700V	170M7082	20 695 32.2000
1200	170M7083	2500A, 700V	170M7083	20 695 32.2500

Table 8.56 525–690V, Frame Size F, Line Fuse

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

Table 8.57 525–690V, Frame Size F, Inverter Module DC Link Fuses

*170M fuses from Bussmann shown use the -/80 visual indicator; -TN/80 Type T, -/110 or TN/110 Type T indicator fuses of the same size and amperage may be substituted for external use
**Any minimum 500V UL listed fuse with associated current rating may be used to meet UL requirements.

Supplementary fuses

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

Table 8.58 SMPS Fuse

Size/Type	Bussmann PN*	LittelFuse	Rating
P90K-P250, 380–500V	KTK-4		4 A, 600V
P37K-P400, 525–690V	KTK-4		4 A, 600V
P315-P800, 380–500V		KLK-15	15A, 600V
P500-P1M2, 525–690V		KLK-15	15A, 600V

Table 8.59 Fan Fuses

	Size/Type	Bussmann PN*	Rating	Alternative Fuses
2.5–4.0 A Fuse	P450-P800, 380–500V	LPJ-6 SP or SPI	6 A, 600V	Any listed Class J Dual Element, Time Delay, 6 A
	P630-P1M2, 525–690V	LPJ-10 SP or SPI	10 A, 600V	Any listed Class J Dual Element, Time Delay, 10 A
4.0–6.3 A Fuse	P450-P800, 380–500V	LPJ-10 SP or SPI	10 A, 600V	Any listed Class J Dual Element, Time Delay, 10 A
	P630-P1M2, 525–690V	LPJ-15 SP or SPI	15 A, 600V	Any listed Class J Dual Element, Time Delay, 15 A
6.3–10 A Fuse	P450-P800600–1200 HP, 380–500V	LPJ-15 SP or SPI	15 A, 600V	Any listed Class J Dual Element, Time Delay, 15 A
	P630-P1M2, 525–690V	LPJ-20 SP or SPI	20 A, 600V	Any listed Class J Dual Element, Time Delay, 20 A
10–16 A Fuse	P450-P800, 380–500V	LPJ-25 SP or SPI	25 A, 600V	Any listed Class J Dual Element, Time Delay, 25 A
	P630-P1M2, 525–690V	LPJ-20 SP or SPI	20 A, 600V	Any listed Class J Dual Element, Time Delay, 20 A

Table 8.60 Manual Motor Controller Fuses

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

Table 8.61 30 A Fuse Protected Terminal Fuse

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

Table 8.62 Control Transformer Fuse

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

Table 8.63 NAMUR Fuse

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

Table 8.64 Safety Relay Coil Fuse with PILZ Relay

The fuses below are suitable for use on a circuit capable of delivering 100,000 Arms (symmetrical), 240 V, or 480 V, or 500 V, or 600 V depending on the drive voltage rating. With the proper fusing, the drive Short Circuit Current Rating (SCCR) is 100,000 Arms.

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

Table 8.65 Line Fuses, 380–500V

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

Table 8.66 Line Fuses, 525–690V

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

Table 8.67 Inverter Module DC Link Fuses, 380–500V

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

Table 8.68 Inverter Module DC Link Fuses, 525–690V

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

Supplementary fuses

	Size/Type	Bussmann PN*	Rating	Alternative Fuses
2.5–4.0 A Fuse	P450-P800, 380–500 V	LPJ-6 SP or SPI	6 A, 600 V	Any listed Class J Dual Element, Time Delay, 6 A
	P630-P1M2, 525–690 V	LPJ-10 SP or SPI	10 A, 600 V	Any listed Class J Dual Element, Time Delay, 10 A
4.0–6.3 A Fuse	P450-P800, 380–500 V	LPJ-10 SP or SPI	10 A, 600 V	Any listed Class J Dual Element, Time Delay, 10 A
	P630-P1M2, 525–690 V	LPJ-15 SP or SPI	15 A, 600 V	Any listed Class J Dual Element, Time Delay, 15 A
6.3–10 A Fuse	P450-P800600–1200 HP, 380–500 V	LPJ-15 SP or SPI	15 A, 600 V	Any listed Class J Dual Element, Time Delay, 15 A
	P630-P1M2, 525–690 V	LPJ-20 SP or SPI	20 A, 600 V	Any listed Class J Dual Element, Time Delay, 20 A
10–16 A Fuse	P450-P800, 380–500 V	LPJ-25 SP or SPI	25 A, 600 V	Any listed Class J Dual Element, Time Delay, 25 A
	P630-P1M2, 525–690 V	LPJ-20 SP or SPI	20 A, 600 V	Any listed Class J Dual Element, Time Delay, 20 A

Table 8.69 Manual Motor Controller Fuses

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

Table 8.70 SMPS Fuse

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

Table 8.71 Fan Fuses

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

Table 8.72 30 A Fuse Protected Terminal Fuse

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

Table 8.73 Control Transformer Fuse

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

Table 8.74 NAMUR Fuse

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

Table 8.75 Safety Relay Coil Fuse with Pilz Relay

8

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

Table 8.76 F-Frame Circuit Breakers

8.4 Disconnectors, Circuit Breakers and Contactors

8.4.1 Line Power Disconnectors

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

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

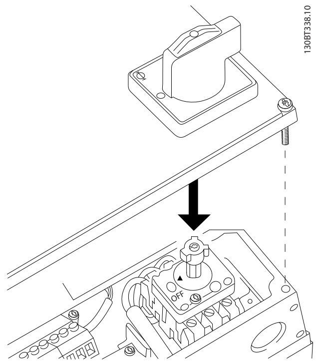


Figure 8.63

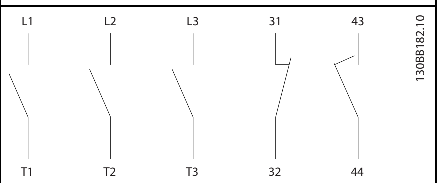
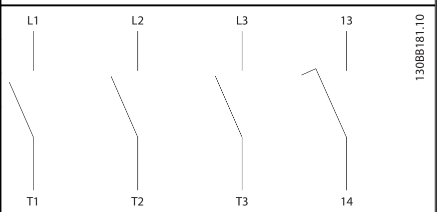
Frame size	Type	Terminal connections
A5	Kraus&Naimer KG20A T303	
B1	Kraus&Naimer KG64 T303	
B2	Kraus&Naimer KG64 T303	
C1 37 kW	Kraus&Naimer KG100 T303	
C1 45–55 kW	Kraus&Naimer KG105 T303	
C2 75 kW	Kraus&Naimer KG160 T303	
C2 90 kW	Kraus&Naimer KG250 T303	

Table 8.77

8.4.2 Line Power Disconnectors - Frame Size D, E and F

Frame size	Power	Type
380–500V		
D1/D3	P90K-P110	ABB OT200U12-91
D2/D4	P132-P200	ABB OT400U12-91
E1/E2	P250	ABB OETL-NF600A
E1/E2	P315-P400	ABB OETL-NF800A
F3	P450	Merlin Gerin NPJF36000S12AAYP
F3	P500-P630	Merlin Gerin NRKF36000S20AAYP
F4	P710-P800	Merlin Gerin NRKF36000S20AAYP
525–690 V		
D1/D3	P90K-P132	ABB OT200U12-91
D2/D4	P160-P315	ABB OT400U12-91
E1/E2	P355-P560	ABB OETL-NF600A
F3	P630-P710	Merlin Gerin NPJF36000S12AAYP
F3	P800	Merlin Gerin NRKF36000S20AAYP
F4	P900-P1M2	Merlin Gerin NRKF36000S20AAYP

Table 8.78

8.4.3 Line Power Disconnectors, 12-Pulse

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

Table 8.79

8.4.4 F-Frame Line Power Contactors

Frame size	Power & Voltage	Type
F3	P450-P500 380–500 V & P630-P800 525–690 V	Eaton XTCE650N22A
F3	P560 380–500 V	Eaton XTCE820N22A
F3	P630380–500V	Eaton XTCEC14P22B
F4	P900 525–690 V	Eaton XTCE820N22A
F4	P710-P800 380–500V & P1M2 525–690V	Eaton XTCEC14P22B

Table 8.80

WARNING

Customer supplied 230V supply required for line power contactors.

8.5 Additional Motor Information

8.5.1 Motor Cable

The motor must be connected to terminals U/T1/96, V/T2/97, W/T3/98. Ground to terminal 99. All types of 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:

Terminal No.	Function
96, 97, 98, 99	Line power U/T1, V/T2, W/T3 Ground

Table 8.81

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

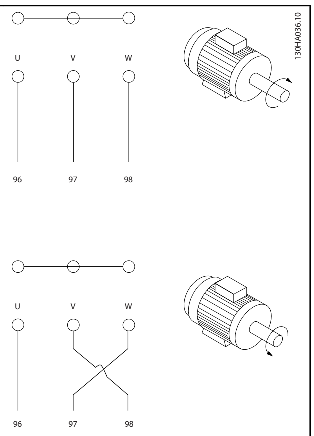


Table 8.82

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

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

F frame Requirements

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

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

Output junction box requirements: The length, a minimum of 8 ft [2.5 m], and quantity of cables must be equal from each inverter module to the common terminal in the junction box.

NOTE!

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

8.5.2 Motor Thermal Protection

The electronic thermal relay in the adjustable frequency drive has received UL-approval for single motor protection, when *1-90 Motor Thermal Protection*is set for *ETR Trip* and *1-24 Motor Current* is set to the rated motor current (see motor nameplate).
For thermal motor protection, it is also possible to use the MCB 112 PTC thermistor card option. This card provides an ATEX certificate to protect motors in explosion hazard areas, Zone 1/21 and Zone 2/22. Please refer to the *Design Guide* for further information.

8.5.3 Parallel Connection of Motors

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

- It is recommended to run applications with parallel motors in U/F mode par. 1-01 [0]. Set the U/F graph in par. 1-55 and 1-56.
- 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.
- If motor sizes are widely different in winding resistance, starting problems may arise due to too low motor voltage at low speed.
- The electronic thermal relay (ETR) of the frequency inverter cannot be used as motor protection for the individual motor. Provide further motor protection, e.g., by thermistors in each motor winding or individual thermal relays. (Circuit breakers are not suitable as protection devices).

8

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

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

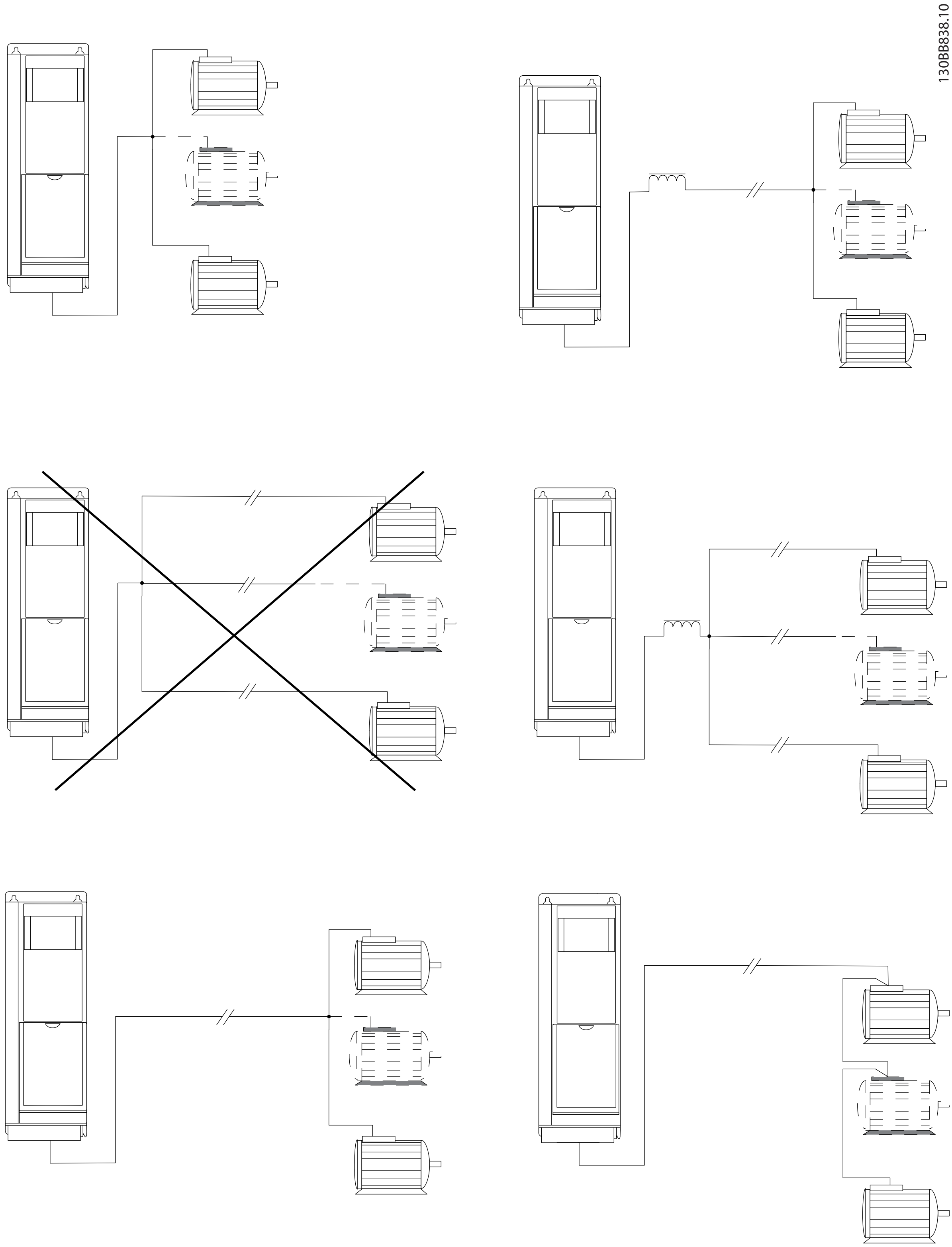


Figure 8.64

b) Be aware of the maximum motor cable length specified in *Table 8.83*.

c, f) The total motor cable length specified in section 4.5, *General Specifications*, is valid as long as the parallel cables are kept short (less than 32 ft [10 m] each).
d, e) Consider voltage drop across the motor cables.

Frame Size	Power Size [kW]	Voltage [V]	1 cable (ft [m])	2 cables (ft [m])	3 cables (ft [m])	4 cables (ft [m])
A1, A2, A5	0.37–0.75	400	492 [150]	147 [45]	26 [8]	19 [6]
		500	492 [150]	22 [7]	13 [4]	9 [3]
A2, A5	1.1–1.5	400	492 [150]	147 [45]	65 [20]	26 [8]
		500	492 [150]	147 [45]	16 [5]	13 [4]
A2, A5	2.2–4	400	492 [150]	147 [45]	65 [20]	36 [11]
		500	492 [150]	147 [45]	65 [20]	19 [6]
A3, A5	5.5–7.5	400	492 [150]	147 [45]	65 [20]	36 [11]
		500	492 [150]	147 [45]	65 [20]	36 [11]
B1, B2, B3, B4,	11–75	400	492 [150]	246 [75]	164 [50]	121 [37]
C1, C2, C3, C4		500	492 [150]	246 [75]	164 [50]	121 [37]

Table 8.83

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

The electronic thermal relay (ETR) of the adjustable frequency drive cannot be used as motor protection for the individual motor of systems with parallel-connected motors. Provide further motor protection with, for example, thermistors in each motor or individual thermal relays (circuit breakers are not a suitable means of protection).

8.5.4 Motor Insulation

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

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

Table 8.84

8.5.5 Motor Bearing Currents

All motors installed with FC 302 125 hp [90 kW] or higher power drives should have NDE (Non-Drive End) insulated bearings installed to eliminate circulating bearing currents. To minimize DE (Drive End) bearing and shaft currents proper grounding of the drive, motor, driven machine, and motor to the driven machine is required.

Standard Mitigation Strategies:

1. Use an insulated bearing
2. Apply rigorous installation procedures
    - Ensure the motor and load motor are aligned
    - Strictly follow the EMC Installation guideline
    - Reinforce the PE so the high frequency impedance is lower in the PE than the input power leads.
    - Provide a good high frequency connection between the motor and the adjustable frequency drive for instance by shielded cable which has a 360° connection in the motor and the adjustable frequency drive.
    - 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.

- 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

8.6 Control Cables and Terminals

8.6.1 Access to Control Terminals

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

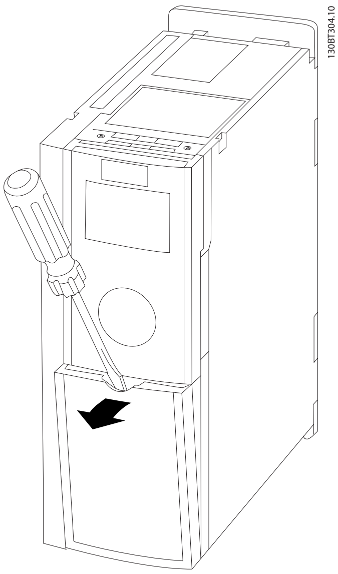


Figure 8.65 Frame sizes A1, A2, A3, B3, B4, C3 and C4

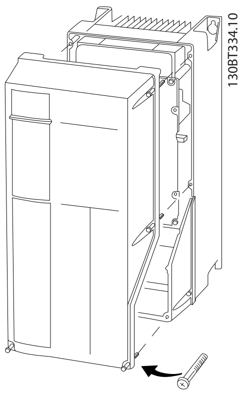


Figure 8.66 Frame sizes A5, B1, B2, C1 and C2

8.6.2 Control Cable Routing

Tie down all control wires to the designated control cable routing as shown in the picture. Remember to connect the shields in a proper way to ensure optimum electrical immunity.

Serial communication bus connection
Connections are made to the relevant options on the control card. For details, see the relevant serial communication bus instruction. The cable must be placed in the provided path inside the adjustable frequency drive and tied down together with other control wires (see pictures).

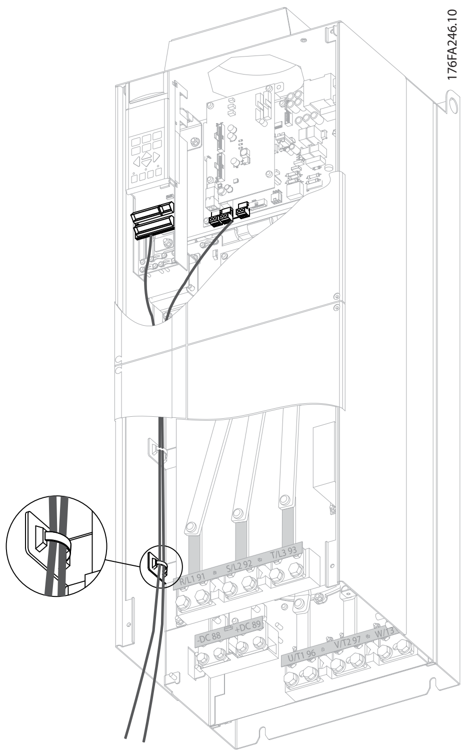


Figure 8.67 Control card wiring path for the D3. Control card wiring for the D1, D2, D4, E1 and E2 use the same path.

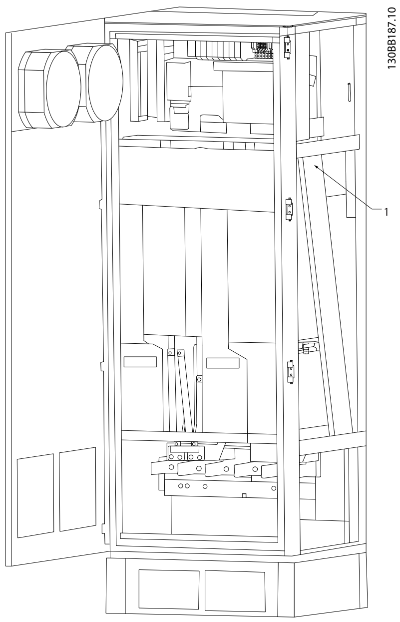


Figure 8.68 Control card wiring path for the F1/F3. Control card wiring for the F2/F4 use the same path.

In the chassis (IP00) and NEMA 1 units, it is also possible to connect the serial communication bus from the top of the unit as shown in the following pictures. On the NEMA 1 unit, a coverplate must be removed.
Kit number for serial communication bus top connection: 176F1742

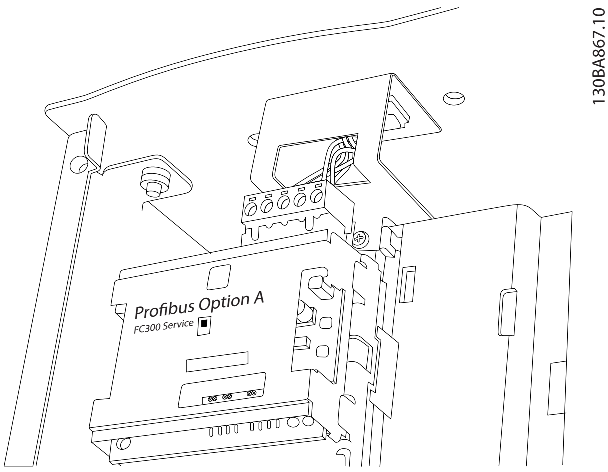


Figure 8.69 Top connection for serial communication bus.

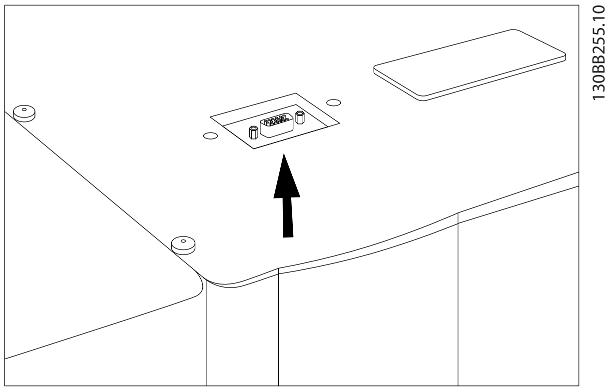


Figure 8.70

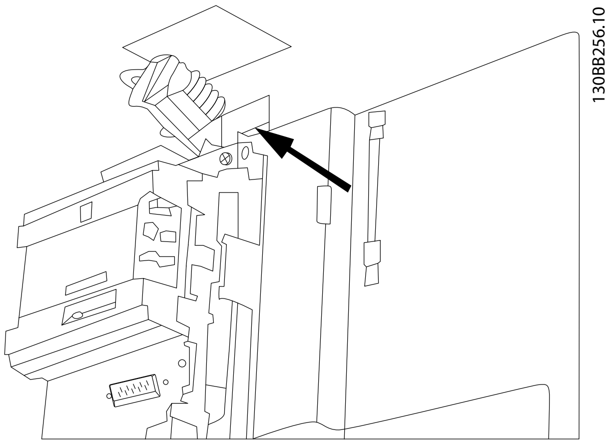


Figure 8.71

Installation of 24 Volt external DC Supply

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

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

Table 8.85

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

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

8.6.3 Control Terminals

Control Terminals, FC 301

Drawing reference numbers:

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

Control Terminals, FC 302

Drawing reference numbers:

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

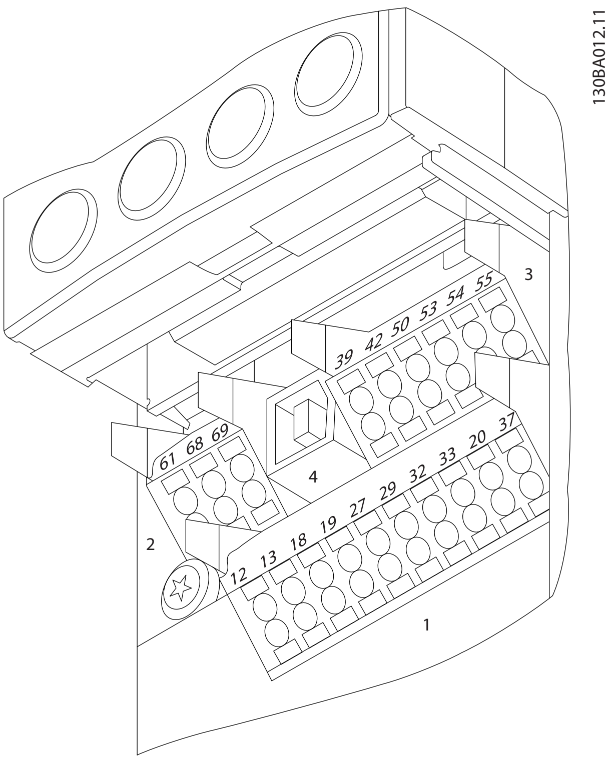


Figure 8.72 Control terminals (all frame sizes)

8.6.4 Switches S201, S202 and S801

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

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

See drawing *Diagram showing all electrical terminals* in section *Electrical Installation.*

Default setting:

S201 (A53) = OFF (voltage input)

S202 (A54) = OFF (voltage input)

S801 (Bus termination) = OFF

NOTE!

When changing the function of S201, S202 or S801, be careful not to force the switch over. It is recommended to remove the LCP fixture (cradle) when operating the switches. The switches must not be operated while the adjustable frequency drive is powered.

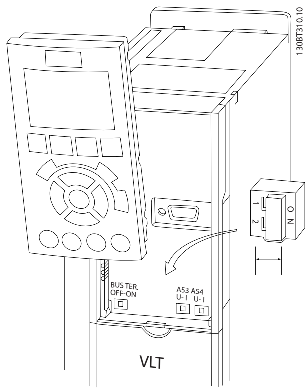


Figure 8.73

8.6.5 Electrical Installation, Control Terminals

To mount the cable to the terminal:

1. Strip insulation of 0.34–0.39 in [9–10 mm]
2. Insert a screwdriver[1)] in the square hole.
3. Insert the cable in the adjacent circular hole.
4. Remove the screwdriver. The cable is now mounted to the terminal.

To remove the cable from the terminal:

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

[1)] Max. 0.015 x 0.1 in [0.4 x 2.5 mm]

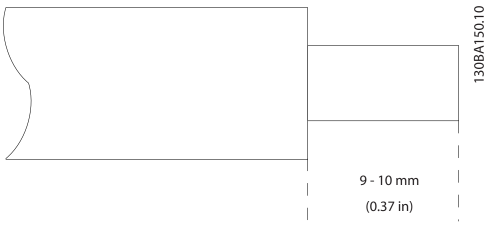


Figure 8.74 1.

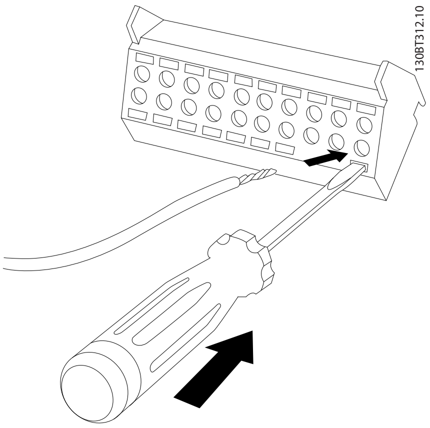


Figure 8.75 2.

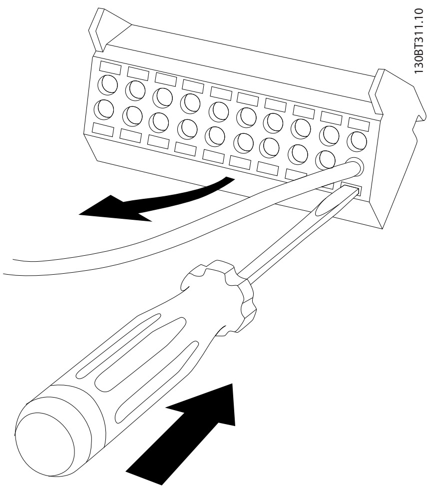


Figure 8.76 3.

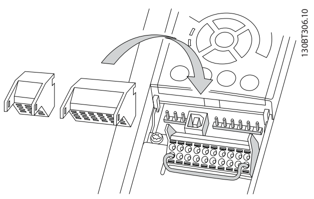


Figure 8.77

8.6.6 Basic Wiring Example

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

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

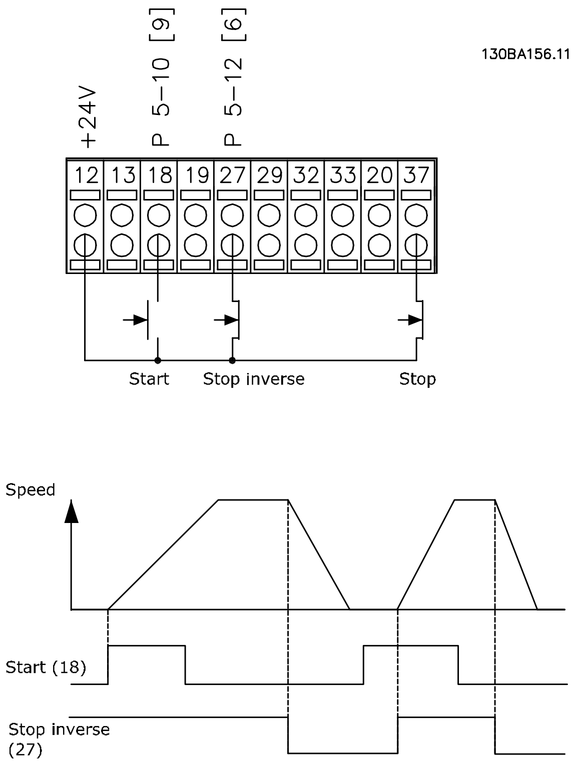


Figure 8.78

8.6.7 Electrical Installation, Control Cables

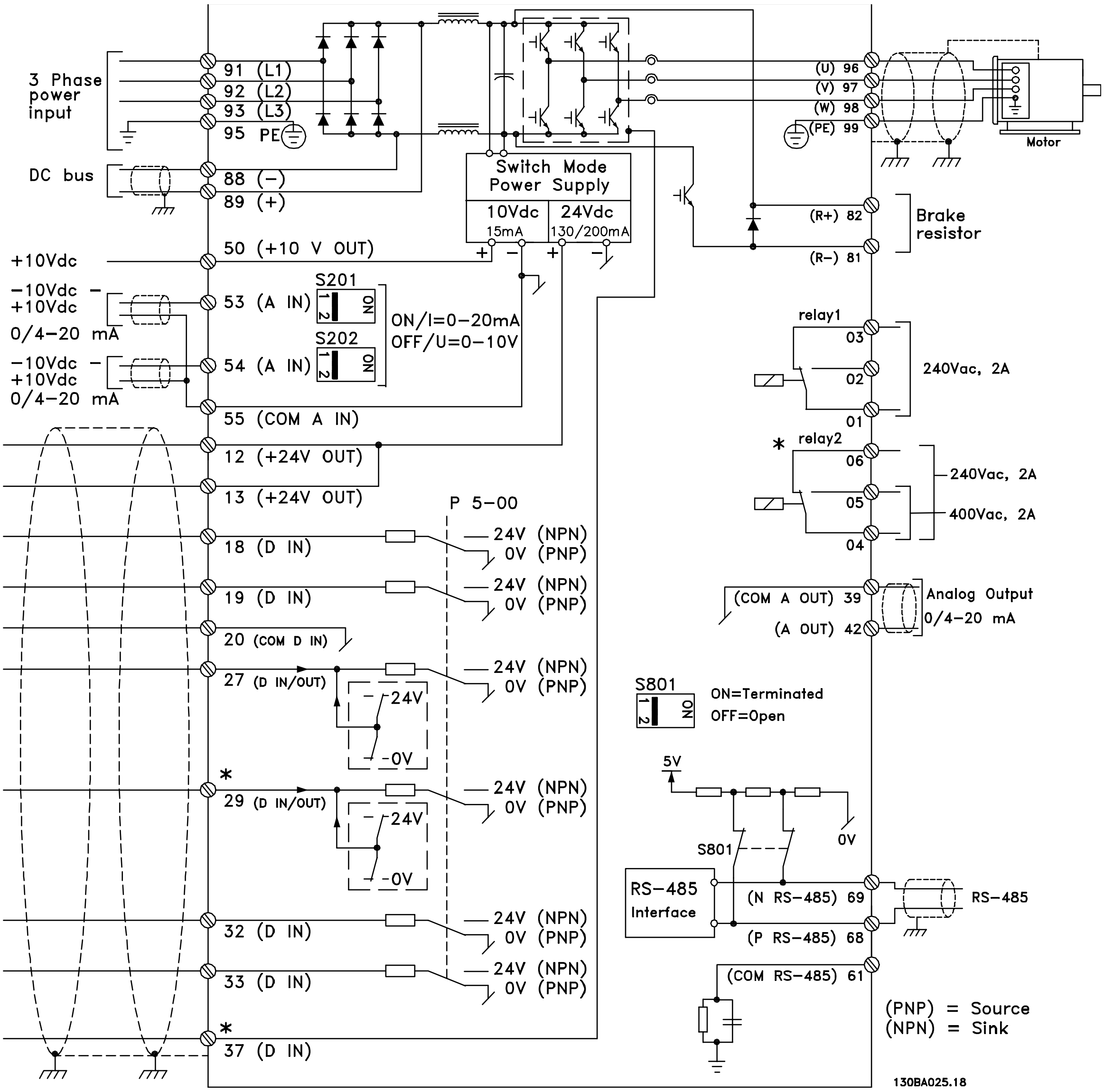


Figure 8.79 Diagram showing all electrical terminals without options.

A = analog, D = digital

Terminal 37 is used for Safe Stop. For instructions on Safe Stop installation, please refer to the section *Safe Stop Installation* of the Design Guide.

* Terminal 37 is not included in FC 301 (Except FC 301 A1, which includes Safe Stop).

Relay 2 and Terminal 29, have no function in FC 301.

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

Input polarity of control terminals

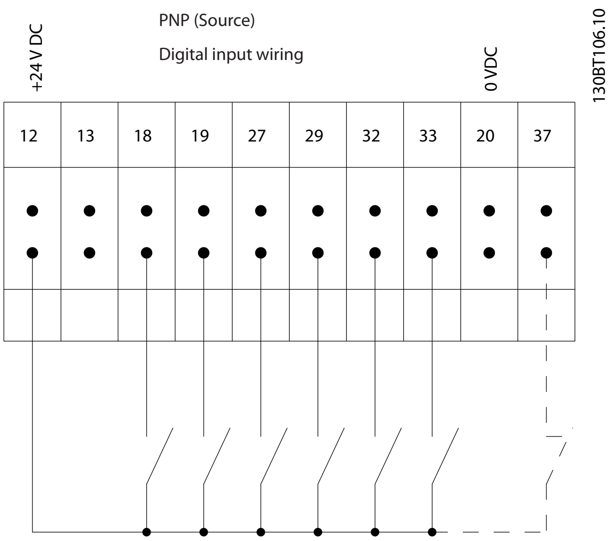


Figure 8.80

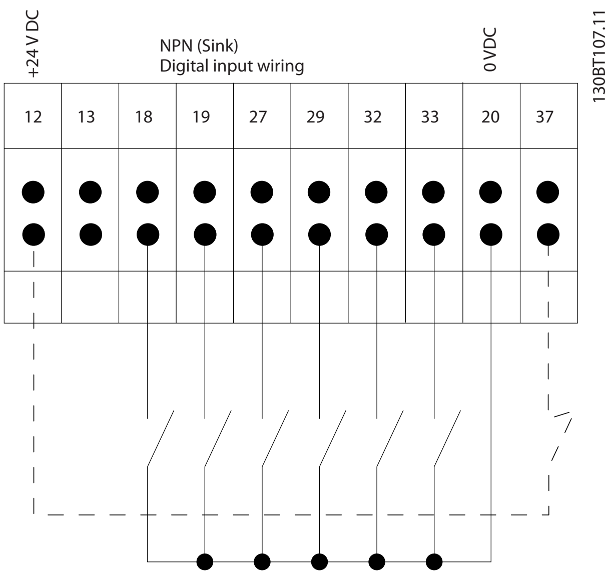


Figure 8.81

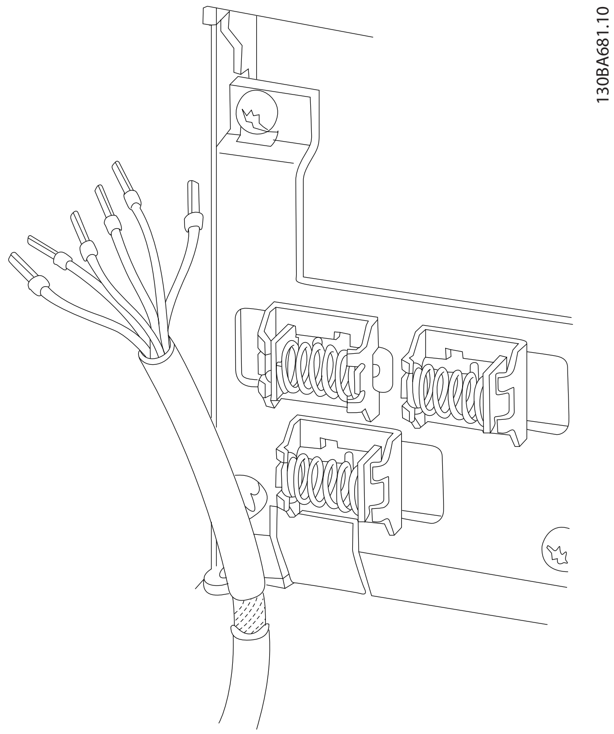


Figure 8.82

To comply with EMC emission specifications, shielded/ armored cables are recommended. If a non-shielded/ unarmored cable is used, see section *Power and Control Wiring for Non-shielded Cables*.. For more information, see EMC Test Results.

8.6.8 12-Pulse Control Cables

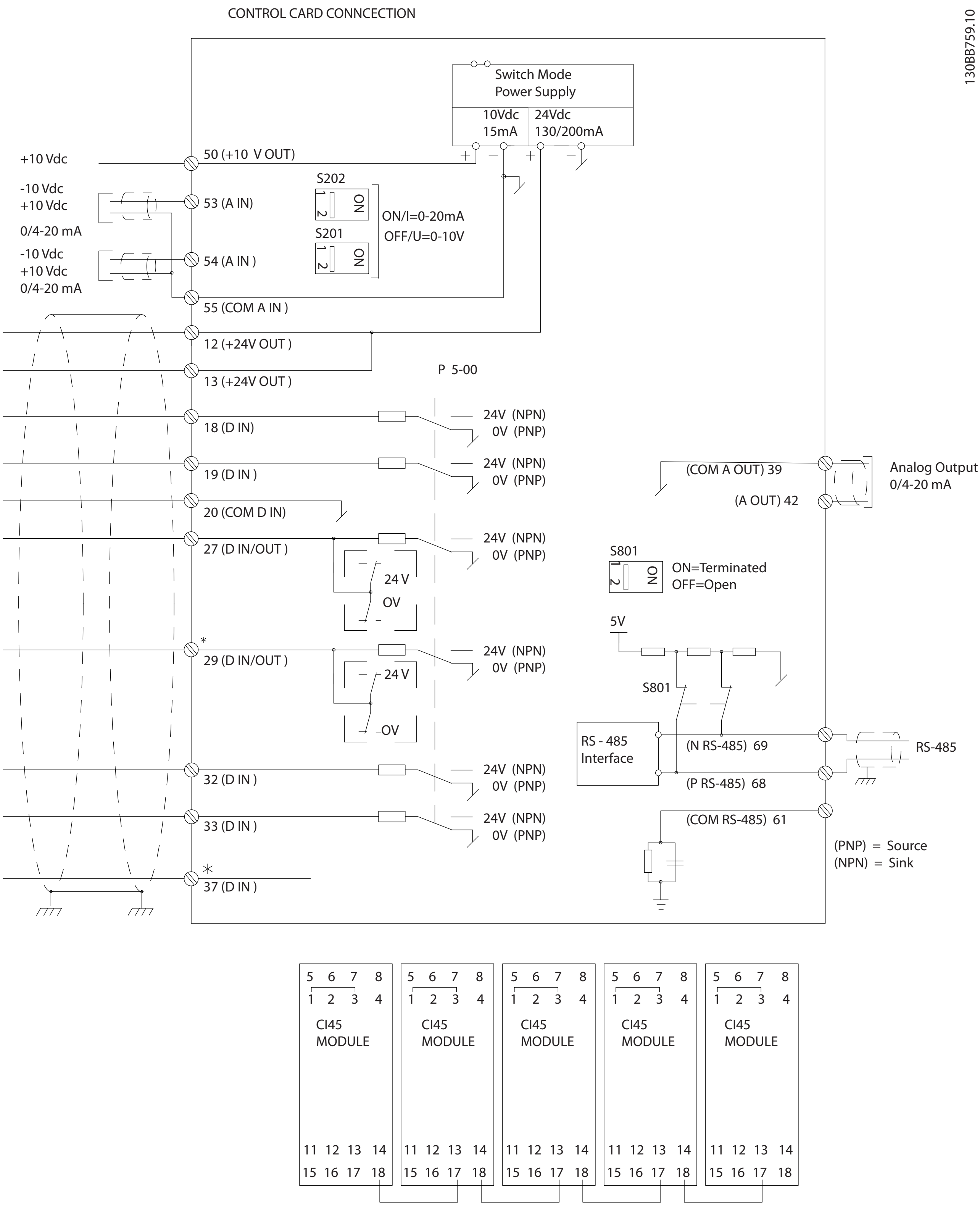


Figure 8.83

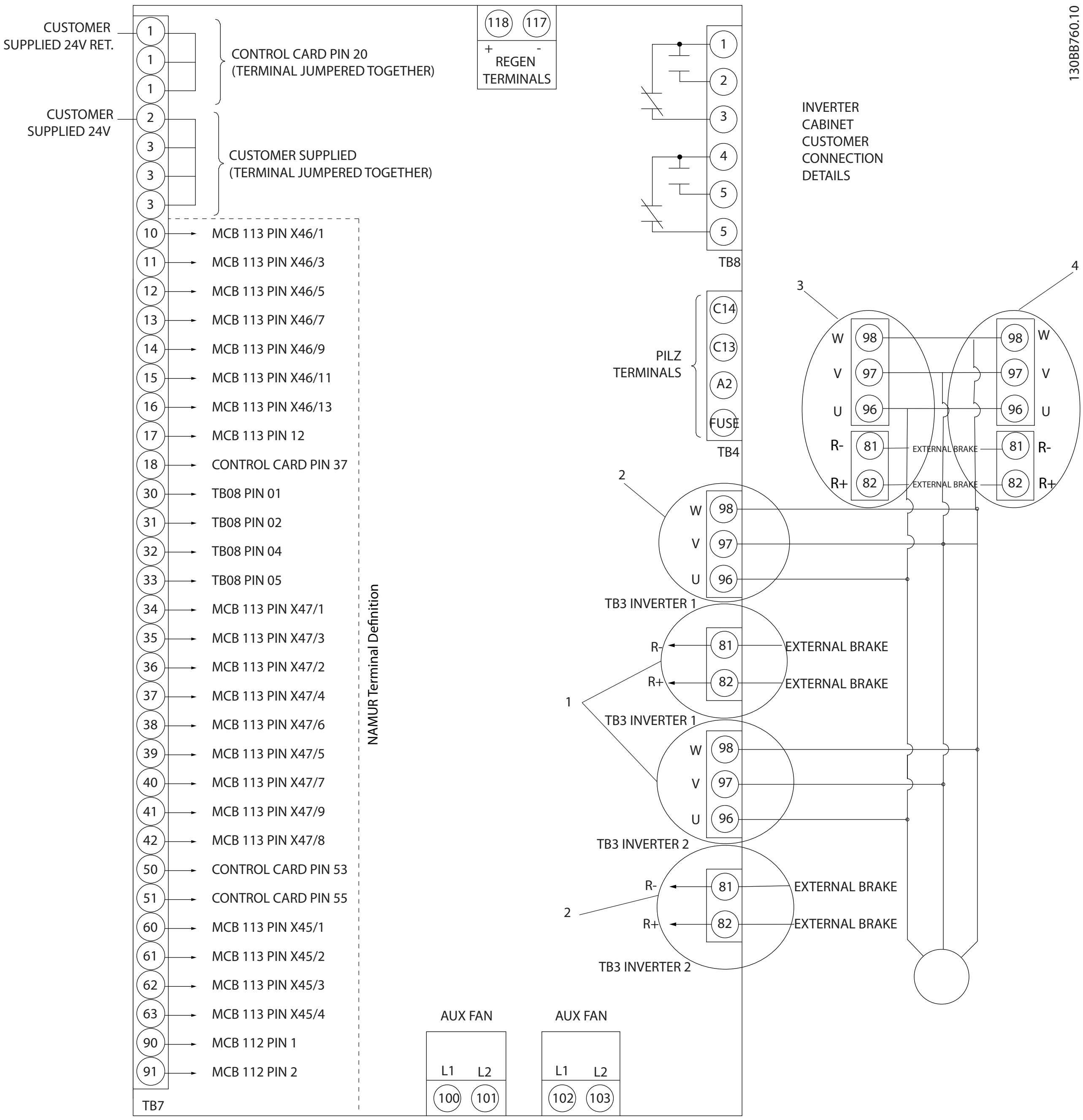


Figure 8.84 Diagram showing all electrical terminals without options

Terminal 37 is the input to be used for Safe Stop. For instructions on safe stop installation, refer to the section *Safe Stop Installation* in the adjustable frequency drive Design Guide. See also sections Safe Stop and Safe Stop Installation.

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

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

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

In rare cases, very long control cables and analog signals may, depending on installation, result in 50/60 Hz ground loops due to noise from line power supply cables.

If this occurs, it may be necessary to break the shield or insert a 100 nF capacitor between shield and chassis.

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

Input polarity of control terminals

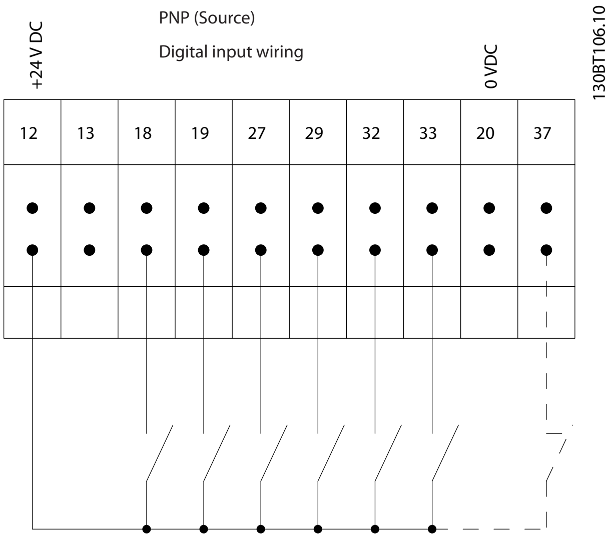


Figure 8.85

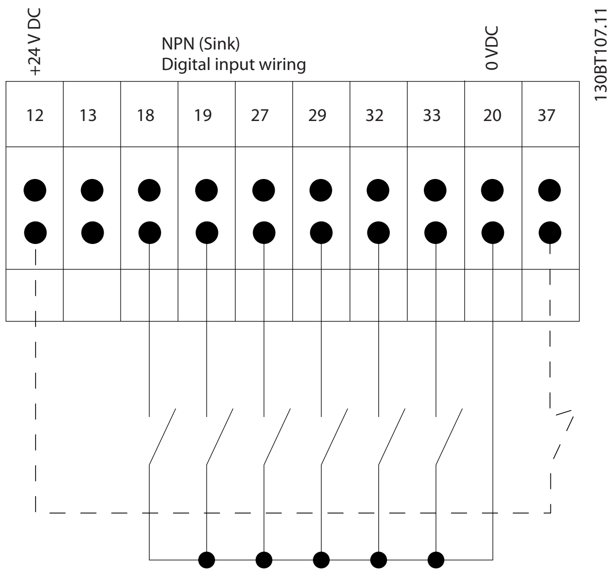


Figure 8.86

NOTE!

Control cables must be shielded/armored.

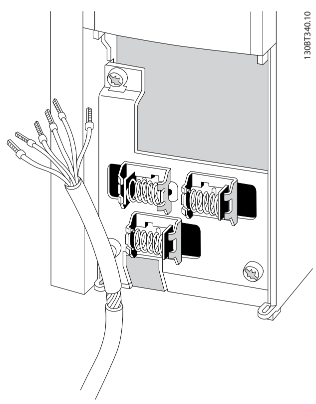


Figure 8.87

Connect the wires as described in the Instruction Manual for the adjustable frequency drive. Remember to connect the shields in a proper way to ensure optimum electrical immunity.

8.6.9 Relay Output

Relay 1

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

Relay 2 (Not FC 301)

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

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

Additional relay outputs by using option module MCB 105.

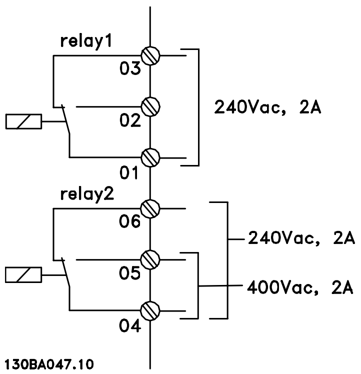


Figure 8.88

8.6.10 Brake Resistor Temperature Switch

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

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

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

Table 8.86

NOTE!

If the temperature of the brake resistor gets too high and the thermal switch drops out, the Adjustable frequency drive will stop braking. The motor will start coasting.

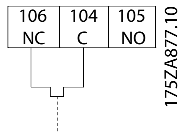


Figure 8.89

8.7 Additional Connections

8.7.1 DC Bus Connection

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

Terminal numbers used:	88, 89

Table 8.87

Please contact Danfoss if you require further information.

8.7.2 Load Sharing

Terminal No.	Function
88, 89	Load sharing

Table 8.88

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.

Please note that voltages up to 1099 V DC may occur on the terminals.
Load sharing calls for extra equipment and safety considerations. For further information, see load sharing Instructions MI.50.NX.YY.

Please note that a line power disconnect may not isolate the adjustable frequency drive due to DC link connection

8.7.3 Installation of Brake Cable

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

No.	Function
81, 82	Brake resistor terminals

Table 8.89

See Brake instructions, MI.90.FX.YY and MI.50.SX.YY for more information about safe installation.

NOTE!

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

⚠CAUTION

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

Frame size F Requirements

The brake resistor(s) must be connected to the brake terminals in each inverter module.

8.7.4 How to Connect a PC to the Adjustable Frequency Drive

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

USB is a serial bus utilizing 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 the Instruction Manual "Connection to Line Power and Grounding" 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. This reduces the ground potential difference but does not eliminate all potential differences due to the ground and shield connected in the PC USB port.

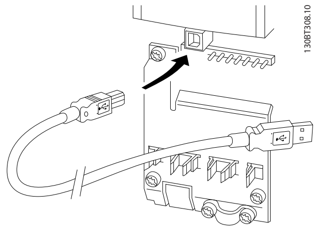


Figure 8.90 USB connection.

8.7.5 The FC 300 PC 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. Choose "Copy".
5. Select the "project" section.
6. Choose "Paste".
7. Choose "Save as"

All parameters are now stored.

Data transfer from PC to 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. Choose "Open" – stored files will be shown
4. Open the appropriate file
5. Choose "Write to drive"

All parameters are now transferred to the drive.

A separate manual for MCT 10 Set-up Software, MG. 10.RX.YY, is available.

8.8.1 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 380–500V 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 line power and the motor connection if the leakage currents are too high.

8.8.2 Grounding

The following basic issues need to be considered when installing an adjustable frequency drive, so as to obtain electromagnetic compatibility (EMC).

- Safety grounding: Please note that the adjustable frequency drive has a high leakage current and must be grounded appropriately for safety reasons. Always follow local safety regulations.
- High-frequency grounding: Keep the ground wire connections as short as possible.

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

8.8.3 Safety Ground Connection

The Adjustable frequency drive has a high leakage current and must be grounded appropriately for safety reasons according to EN 50178.

WARNING

The ground leakage current from the Adjustable frequency drive exceeds 3.5 mA. To ensure a good mechanical connection from the ground cable to the ground connection (terminal 95), the cable cross-section must be at least 0.016 in² [10 mm²] or two rated ground wires terminated separately.

8.9 EMC-correct Installation

8.9.1 Electrical Installation - EMC Precautions

The following is a guideline for good engineering practice when installing adjustable frequency drives. Follow these guidelines to comply with EN 61800-3 *First environment*. If the installation is in EN 61800-3 *Second environment,* i.e., industrial networks, or in an installation with its own transformer, deviation from these guidelines is allowed but not recommended. See also paragraphs *CE Labeling, General Aspects of EMC Emission* and *EMC Test Results*.

Good engineering practice to ensure EMC-correct electrical installation:

- Use only braided shielded/armored motor cables and braided shielded/armored control cables. The shield should provide a minimum coverage of 80%. The shield material must be metal, not limited to, but typically, copper, aluminum, steel or lead. There are no special requirements for the line cable.
- Installations using rigid metal conduits are not required to contain shielded cable, but the motor cable must be installed in conduit separate from the control and line cables. Full connection of the conduit from the drive to the motor is required. The EMC performance of flexible conduits varies greatly, and information from the manufacturer must therefore be obtained.
- Connect the shield/armor/conduit to ground at both ends for motor cables as well as for control cables. In some cases, it is not possible to connect the shield at both ends. If so, connect the shield at the Adjustable frequency drive. See also *Grounding of Braided Shielded/Armored Control Cables*.
- Avoid terminating the shield/armor with twisted ends (pigtails). It increases the high frequency impedance of the shield, which reduces its effectiveness at high frequencies. Use low impedance cable clamps or EMC cable connectors instead.
- Avoid using unshielded/unarmored motor or control cables inside cabinets housing the drive(s), whenever this can be avoided.

Leave the shield as close to the connectors as possible.

Figure 8.91 shows an example of an EMC-compliant electrical installation of an IP 20 Adjustable frequency drive. The Adjustable frequency drive is fitted in an installation cabinet with an output contactor and connected to a PLC, which is installed in a separate cabinet. Other ways of performing the installation may result in an equally effective EMC performance, provided the above guidelines for engineering practice are followed.

If the installation is not carried out according to the guidelines, and if non-shielded cables and control wires are used, some emission requirements will not be fulfilled, although the immunity requirements will be. See the paragraph *EMC test results*.

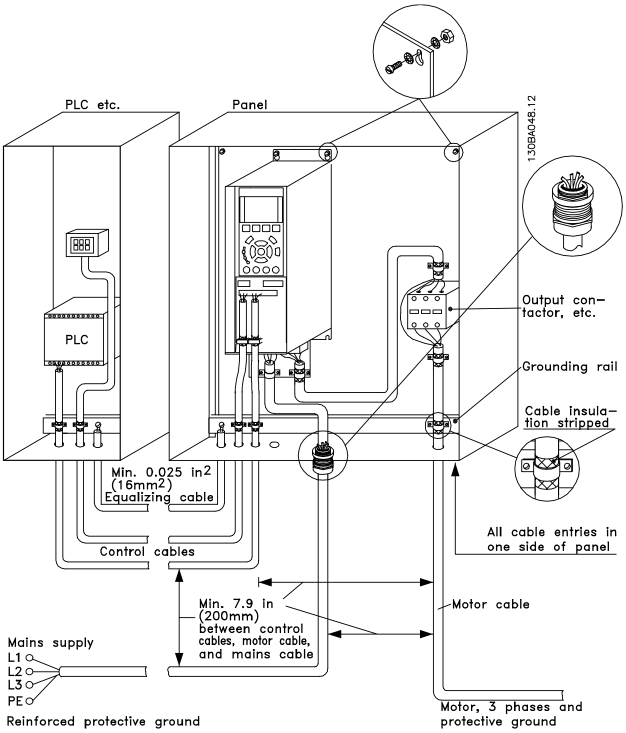


Figure 8.91 EMC-compatible Electrical Installation of a Adjustable Frequency Drive in Cabinet.

8

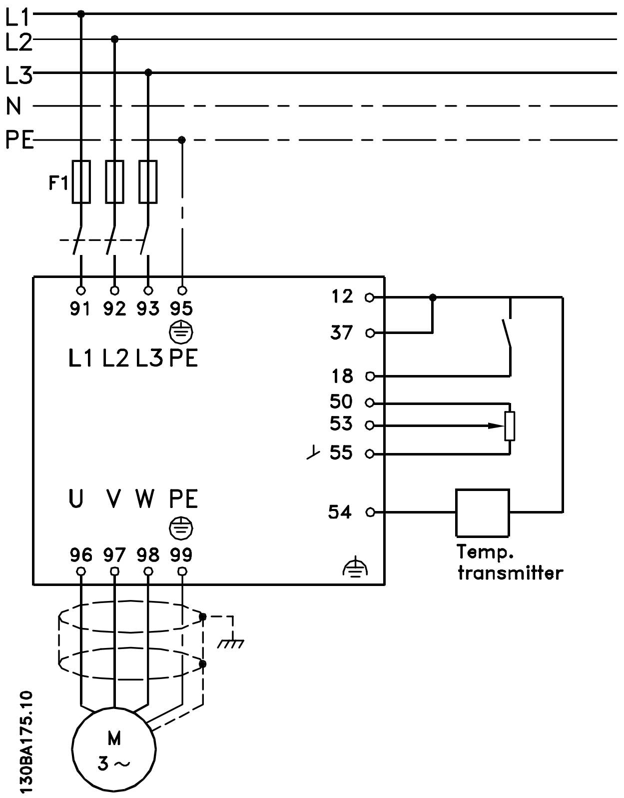


Figure 8.92 Electrical Connection Diagram.

8.9.2 Use of EMC-Correct Cables

Danfoss recommends braided shielded/armored cables to optimize EMC immunity of the control cables and the EMC emission from the motor cables.

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

Transfer impedance (Z_T) is rarely stated by cable manufacturers, but it is often possible to estimate transfer impedance (Z_T) by assessing the physical design of the cable.

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

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

a. Aluminum-clad with copper wire.

b. Twisted copper wire or armored steel wire cable.

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

d. Double-layer braided copper wire.

e. Twin layer of braided copper wire with a magnetic, shielded/armored intermediate layer.

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

g. Lead cable with 0.043 in [1.1 mm] wall thickness.

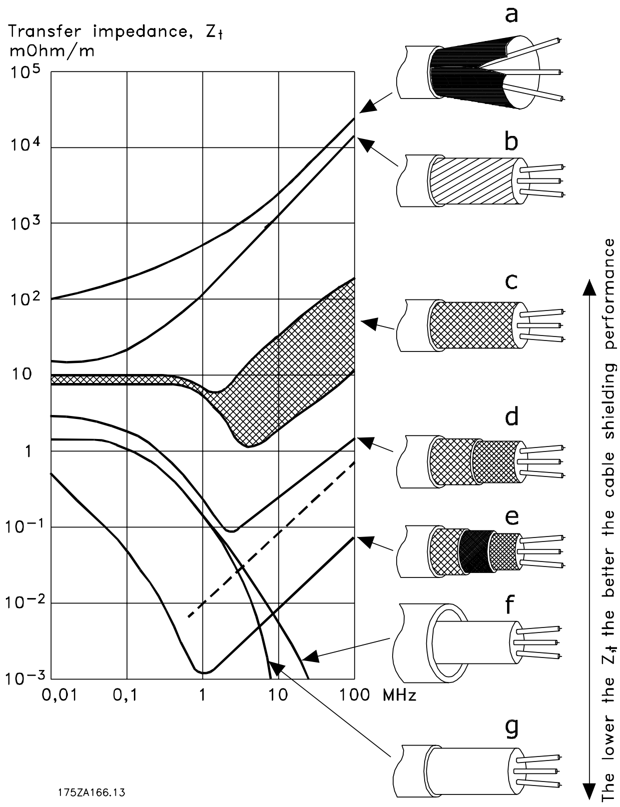


Figure 8.93

8.9.3 Grounding of Shielded Control Cables

Correct shielding

The preferred method in most cases is to secure control and serial communication cables with shielding clamps provided at both ends to ensure best possible high frequency cable contact.

If the ground potential between the adjustable frequency drive and the PLC is different, electric noise may occur that will disturb the entire system. Solve this problem by fitting an equalizing cable next to the control cable. Minimum cable cross-section: 16 mm^2.

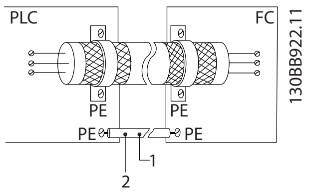


Figure 8.94

50/60Hz ground loops

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

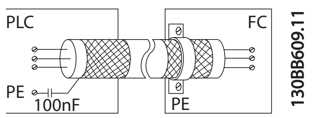


Figure 8.95

Avoid EMC noise on serial communication

This terminal is grounded via an internal RC link. Use twisted-pair cables to reduce interference between conductors. The recommended method is shown below:

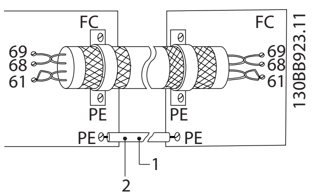


Figure 8.96

Alternatively, the connection to terminal 61 can be omitted:

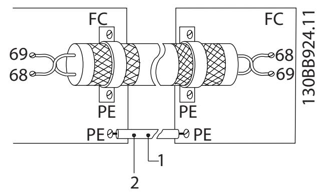


Figure 8.97

8.9.4 RFI Switch

Line power supply isolated from ground

If the adjustable frequency drive is supplied from an isolated line power source (IT line power, floating delta and grounded delta) or TT/TN-S line power with grounded leg, the RFI switch is recommended to be turned off (OFF) 1) via *14-50 RFI 1* on the drive and *14-50 RFI 1* on the filter. For further reference, see IEC 364-3. In case optimum EMC performance is needed, parallel motors are connected or the motor cable length is greater than 82 ft [25 m], it is recommended to set *14-50 RFI 1* to [ON].

1) Not available for 525–600/690V adjustable frequency drives in frame sizes D, E and F.

In OFF, the internal RFI capacities (filter capacitors) between the chassis and the intermediate circuit are cut off to avoid damage to the intermediate circuit and to reduce the ground capacity currents (according to IEC 61800-3).

Please also refer to the application note VLT on IT line power, MN.90.CX.02. It is important to use isolation monitors that are capable for use together with power electronics (IEC 61557-8).

8.10.1 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 Hz	250 Hz	350 Hz

Table 8.90

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

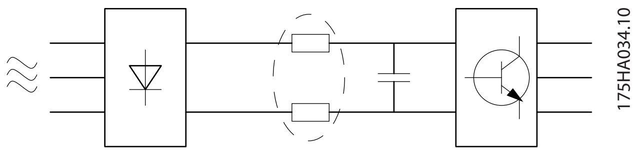


Figure 8.98

NOTE!

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

Harmonic currents compared to the RMS input current:

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

Table 8.91

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%.

8.10.2 The Effect of Harmonics in a Power Distribution System

In *Figure 8.99*, 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.

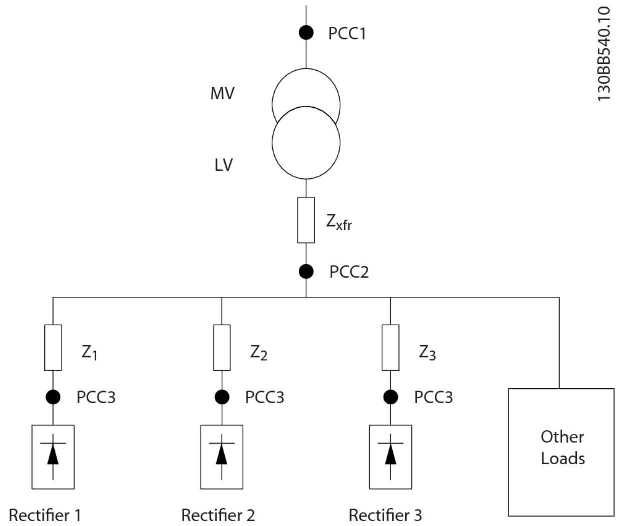


Figure 8.99 Small Distribution System

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

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

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

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

The negative effect of harmonics is twofold

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

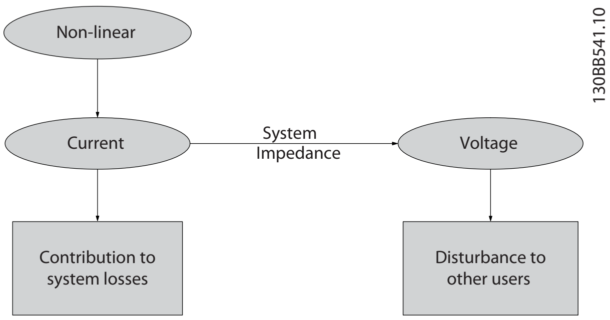


Figure 8.100

8.10.3 Harmonic Limitation Standards and Requirements

The requirements for harmonic limitation can be:

- Application specific requirements
- Standards that must be observed

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

Example: a 250kVA transformer with two 150 hp [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 will be undersized if both motors are supplied with an adjustable frequency drive. Using additional means of harmonic reduction within the installation or choosing 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 AHF005/010 Design Guide for specific details on each standard.

8.10.4 Harmonic Mitigation

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

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

The choice of the right solution depends on several factors:

- The grid (background distortion, 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.)

8.10.5 Harmonic Calculation

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

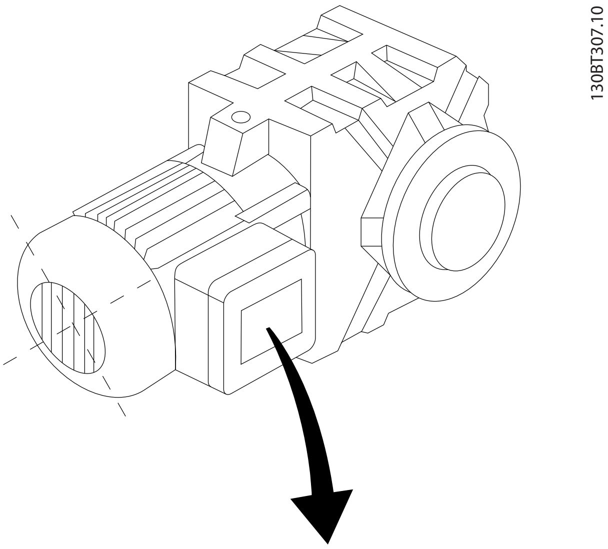
8.11 Residual Current Device - FC 300 DG

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

8.12 Final Set-up and Test

To test the set-up and ensure that the adjustable frequency drive is running, follow these steps.

Step 1. Locate the motor nameplate
The motor is either star- (Y) or delta-connected (Δ). This information is located on the motor nameplate data.



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

Figure 8.101

Step 2. Enter the motor nameplate data in this parameter list.
To access this list, first press the [QUICK MENU] key, then select “Q2 Quick Set-up”.

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

Step 3. Activate the Automatic Motor Adaptation (AMA)

Performing an AMA will ensure optimum performance. The AMA measures the values from the motor model equivalent diagram.

1. Connect terminal 37 to terminal 12 (if terminal 37 is available).
2. Connect terminal 27 to terminal 12 or set *5-12 Terminal 27 Digital Input* to 'No function'.
3. Activate the AMA *1-29 Automatic Motor Adaptation (AMA)*.
4. Choose between complete or reduced AMA. If a sine-wave filter is mounted, run only the reduced AMA, or remove the sine-wave filter during the AMA procedure.
5. Press the [OK] key. The display shows “Press [Hand on] to start”.
6. Press the [Hand on] key. A progress bar indicates if the AMA is in progress.

Stop the AMA during operation

1. Press the [OFF] key - the adjustable frequency drive enters into alarm mode and the display shows that the AMA was terminated by the user.

Successful AMA

1. The display shows “Press [OK] to finish AMA”.
2. Press the [OK] key to exit the AMA state.

Unsuccessful AMA

1. The adjustable frequency drive enters into alarm mode. A description of the alarm can be found in the *Warnings and Alarms* chapter.
2. "Report Value” in the [Alarm Log] shows the last measuring sequence carried out by the AMA before the adjustable frequency drive entered alarm mode. This number along with the description of the alarm will assist you in trouble-shooting. If you contact Danfoss for service, make sure to mention the number and alarm description.

An unsuccessful AMA is often caused by incorrectly registered motor nameplate data or a difference between the motor power size and the adjustable frequency drive power size that is too large.

Step 4. Set speed limit and ramp times

Set up the desired limits for speed and ramp time:

3-02 Minimum Reference

3-03 Maximum Reference

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

8

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

3-41 Ramp 1 Ramp-up Time

3-42 Ramp 1 Ramp-down Time

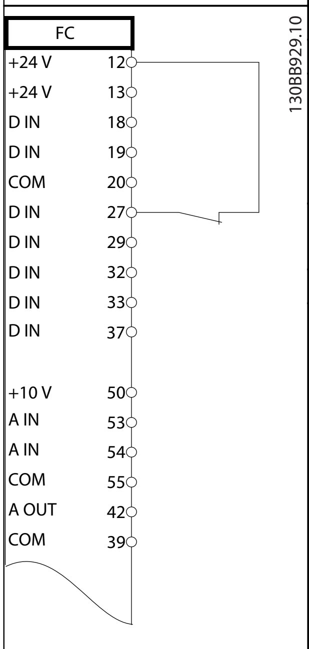
9 Application Examples

NOTE!

A jumper wire may be required between terminal 12 (or 13) and terminal 27 for the Adjustable frequency drive to operate when using factory default programming values. See for details.

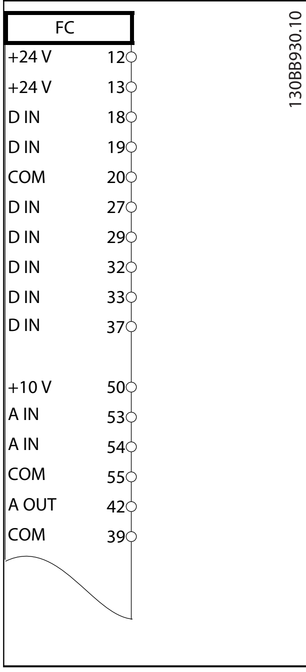
The examples in this section are intended as a quick reference for common applications.

- 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.



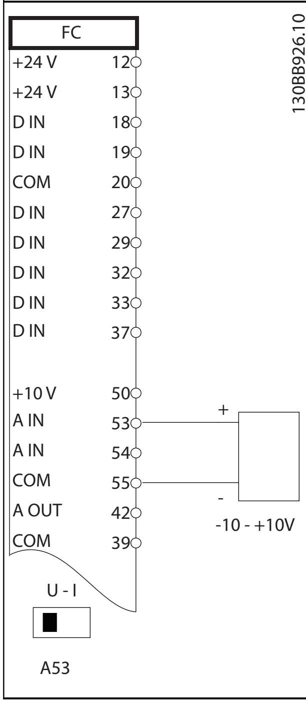
Parameters	
Function	**Setting**
1-29 Automatic Motor Adaptation (AMA)	[1] Enable complete AMA
5-12 Terminal 27 Digital Input	[2]* Coast inverse
* = Default Value	
Notes/comments: Parameter group 1-2* must be set according to motor	

Table 9.1 AMA with T27 Connected



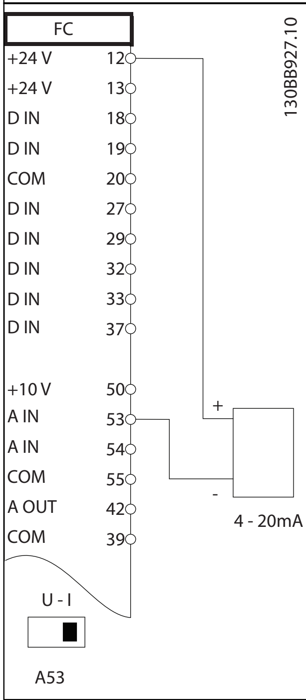
Parameters	
Function	**Setting**
1-29 Automatic Motor Adaptation (AMA)	[1] Enable complete AMA
5-12 Terminal 27 Digital Input	[0] No operation
* = Default Value	
Notes/comments: Parameter group 1-2* must be set according to motor	

Table 9.2 AMA without T27 Connected



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

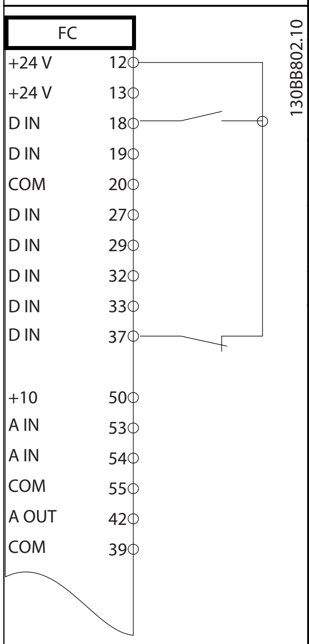
Table 9.3 Analog Speed Reference (Voltage)



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

Notes/comments:

Table 9.4 Analog Speed Reference (Current)



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 9.5 Start/Stop Command with Safe Stop

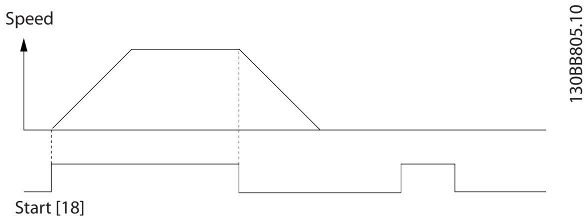
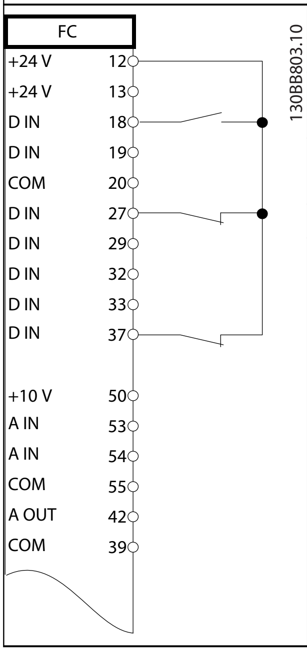


Figure 9.1



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 9.6 Pulse Start/Stop

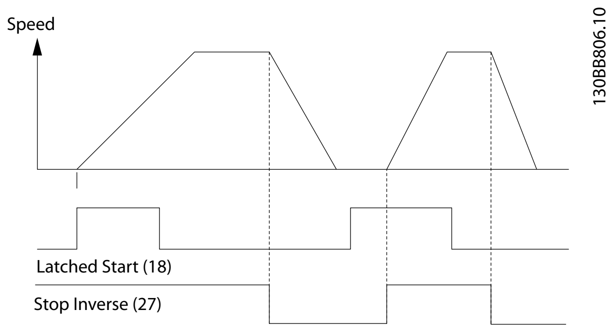
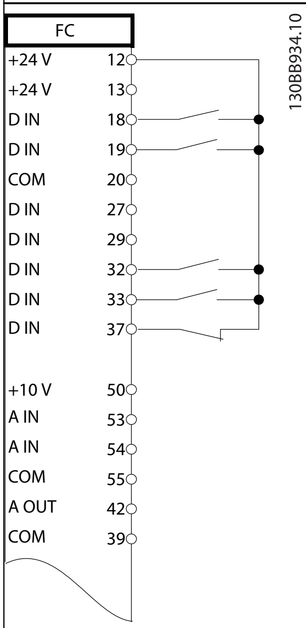
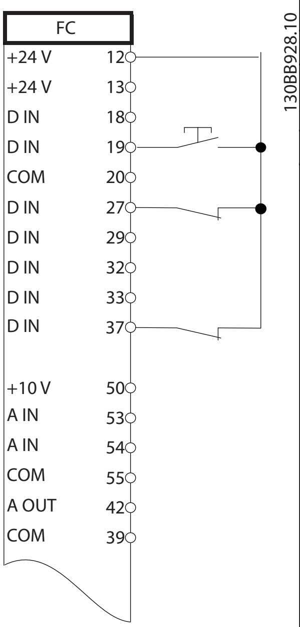


Figure 9.2



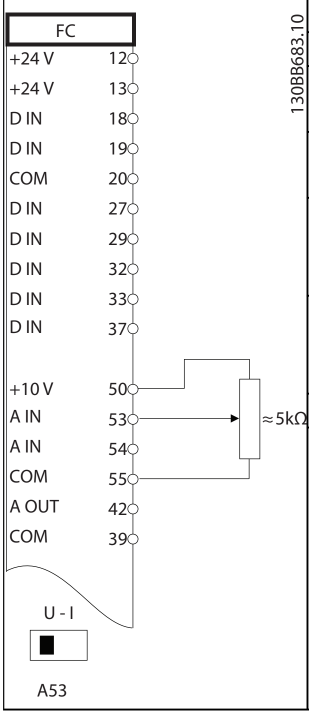
Parameters	
Function	**Setting**
5-10 Terminal 18 Digital Input	[8] Start
5-11 Terminal 19 Digital Input	[10] Reversing*
5-12 Terminal 27 Digital Input	[0] No operation
5-14 Terminal 32 Digital Input	[16] Preset ref bit 0
5-15 Terminal 33 Digital Input	[17] Preset ref bit 1
3-10 Preset Reference	
Preset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

Table 9.7 Start/Stop with Reversing and Four Preset Speeds



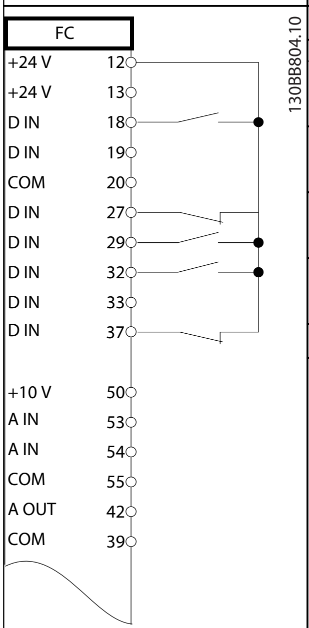
Parameters	
Function	**Setting**
5-11 Terminal 19 Digital Input	[1] Reset
* = Default Value	
Notes/comments:	

Table 9.8 External Alarm Reset



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

Table 9.9 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 9.10 Speed Up/Down

9

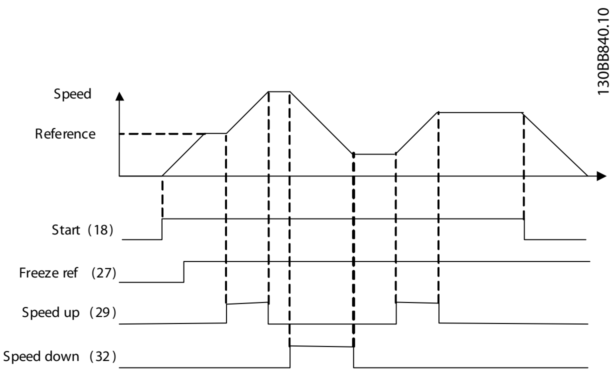


Figure 9.3

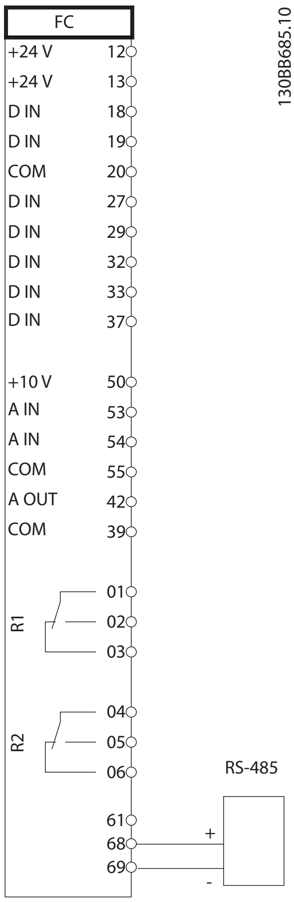
	Parameters	
	Function	Setting
		
	8-30 Protocol	FC*
	8-31 Address	1*
	8-32 Baud Rate	9600*
	* = Default Value	
	Notes/comments: Select protocol, address and baud rate in the above mentioned parameters.	

Table 9.11 RS-485 Network Connection

CAUTION

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

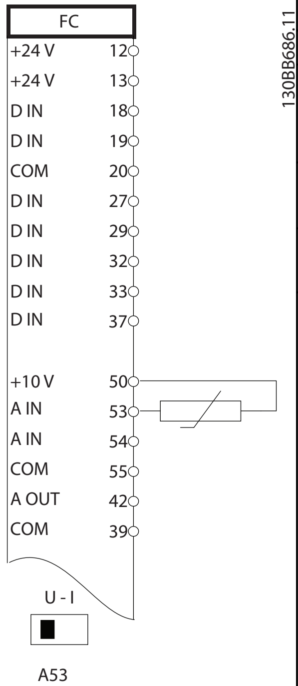
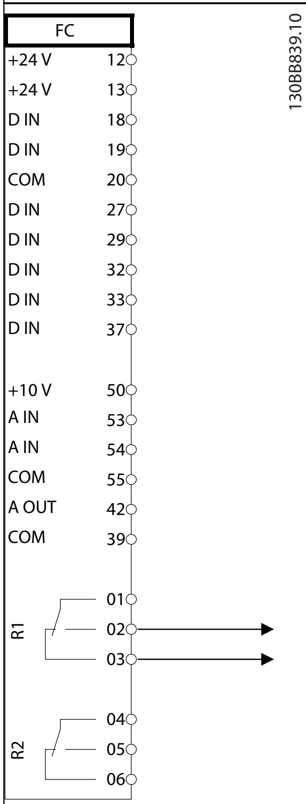
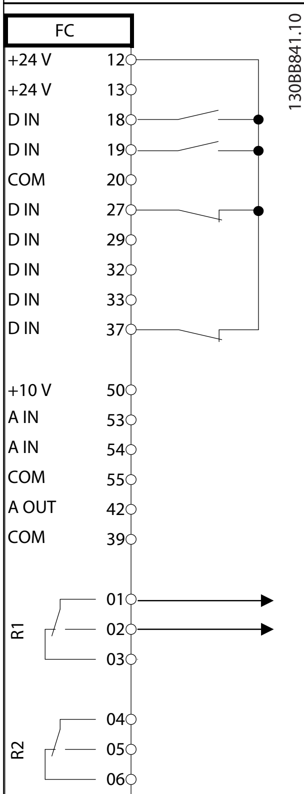
	Parameters	
	Function	Setting
		
	1-90 Motor Thermal Protection	[2] Thermistor trip
	1-93 Thermistor Source	[1] Analog input 53
	* = Default Value	
	Notes/comments: If only a warning is desired, *1-90 Motor Thermal Protection* should be set to [1] *Thermistor warning*.	

Table 9.12 Motor Thermistor



Parameters	
Function	**Setting**
4-30 Motor Feedback Loss Function	[1] Warning
4-31 Motor Feedback Speed Error	100 RPM
4-32 Motor Feedback Loss Timeout	5 sec
7-00 Speed PID Feedback Source	[2] MCB 102
17-11 Resolution (PPR)	1024*
13-00 SL Controller Mode	[1] On
13-01 Start Event	[19] Warning
13-02 Stop Event	[44] Reset key
13-10 Comparator Operand	[21] Warning no.
13-11 Comparator Operator	[1] ≈*
13-12 Comparator Value	90
13-51 SL Controller Event	[22] Comparator 0
13-52 SL Controller Action	[32] Set digital out A low
5-40 Function Relay	[80] SL digital output A
* = Default Value	
Notes/comments: If the limit in the feedback monitor is exceeded, Warning 90 will be issued. The SLC monitors Warning 90 and if Warning 90 becomes TRUE, then Relay 1 is triggered. External equipment may then indicate that service may be required. If the feedback error goes below the limit again within 5 sec., then the drive continues and the warning disappears. But Relay 1 will still be triggered until [Reset] on the LCP.	

Table 9.13 Using SLC to Set a Relay



Parameters	
Function	**Setting**
5-40 Function Relay	[32] Mech. brake ctrl.
5-10 Terminal 18 Digital Input	[8] Start*
5-11 Terminal 19 Digital Input	[11] Start reversing
1-71 Start Delay	0.2
1-72 Start Function	[5] VVC+/ FLUX Clockwise
1-76 Start Current	Im,n
2-20 Release Brake Current	App. dependent
2-21 Activate Brake Speed [RPM]	Half of nominal slip of the motor
* = Default Value	
Notes/comments:	

Table 9.14 Mechanical Brake Control

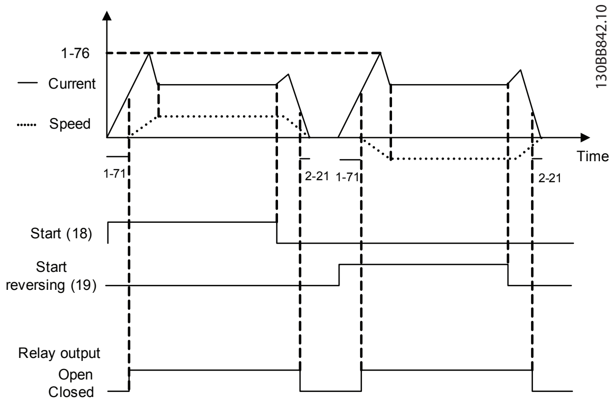


Figure 9.4

9.1.1 Encoder Connection

The purpose of this guideline is to ease the set-up of encoder connection to the adjustable frequency drive. Before setting up the encoder, the basic settings for a closed-loop speed control system will be shown.
See also *10.2 Encoder Option MCB 102*

Encoder connection to the adjustable frequency drive

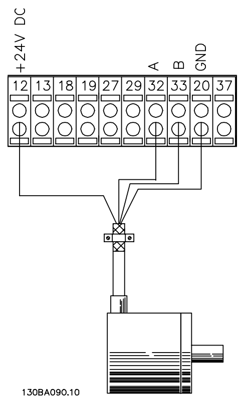


Figure 9.5

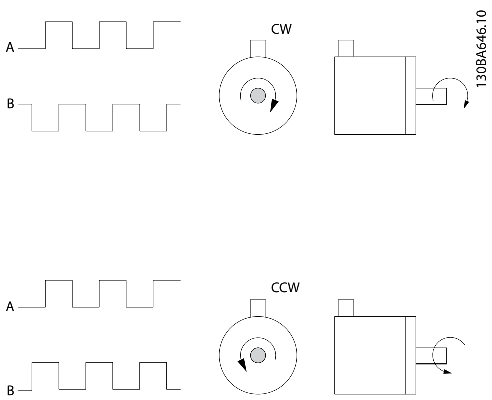


Figure 9.6 24V incremental encoder. Max. cable length 16 ft [5 m]

9.1.2 Encoder Direction

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

9.1.3 Closed-loop Drive System

A drive system usually consists of more elements such as:

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

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

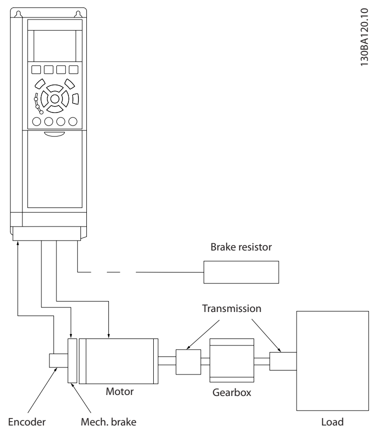


Figure 9.7 Basic Set-up for FC 302 Closed-loop Speed Control

9.1.4 Programming of Torque Limit and Stop

In applications with an external electro-mechanical brake, such as hoisting applications, it is possible to stop the 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, see paragraph *Control of Mechanical Brake*. Program terminal 27 to Coast, inverse [2] or Coast and Reset, inverse [3], and program terminal 29 to Terminal mode 29 Output [1] and Torque limit & stop [27].

Description:
If a stop command is active via terminal 18 and the 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 Torque limit and stop [27]) is activated. The signal to terminal 27 changes from 'logic 1' to 'logic 0', and the motor starts to coast, thereby ensuring that the hoist stops even if the 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 Start [8]
- Quickstop via terminal 27
  5-12 Terminal 27 Digital Input Coasting Stop, Inverse [2]
- Terminal 29 Output
  5-02 Terminal 29 Mode Terminal 29 Mode Output [1]
  5-31 Terminal 29 digital Output Torque Limit & Stop [27]
- Relay output [0] (Relay 1)
  5-40 Function Relay Mechanical Brake Control [32]

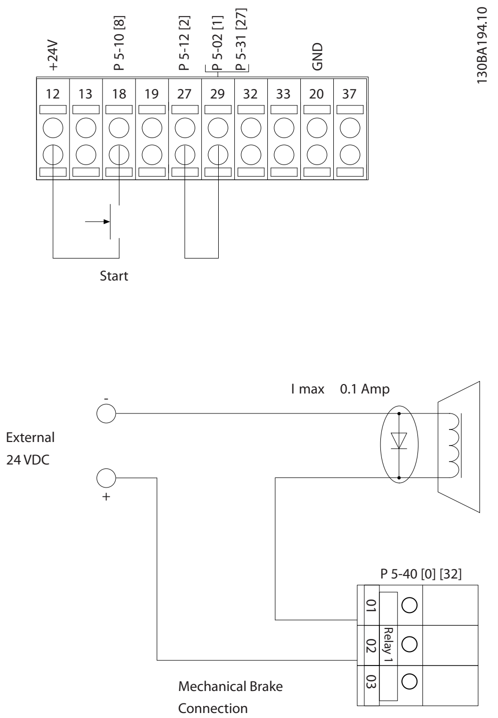


Figure 9.8

9

10 Options and Accessories

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

10.1.1 Mounting of Option Modules in Slot A

Slot A position is dedicated to serial communication bus options. For further information, see the Instruction Manual.

10.1.2 Mounting of Option Modules in Slot B

The power to the adjustable frequency drive must be disconnected.

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

- Remove the LCP (Local Control Panel), the terminal cover, and the LCP frame from the adjustable frequency drive.
- Fit the MCB10x option card into slot B.
- Connect the control cables and fasten the cables with the enclosed cable strips.
  * Remove the knock-out in the extended LCP frame, so that the option will fit under the extended LCP frame.
- Fit the extended LCP frame and terminal cover.
- Fit the LCP or blind cover in the extended LCP frame.
- Connect power to the adjustable frequency drive.
- Set up the input/output functions in the corresponding parameters, as mentioned in *4.5 General Specifications*.

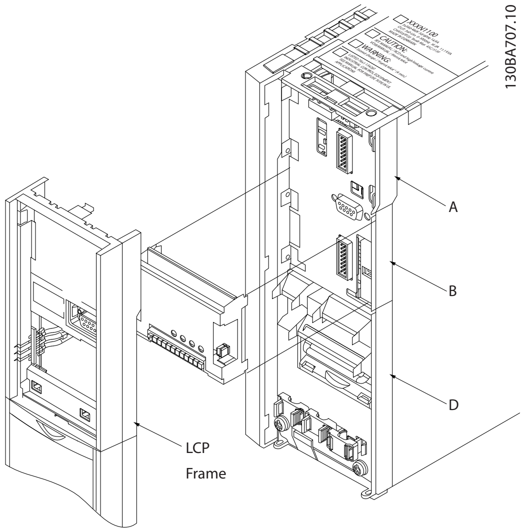


Figure 10.1 Frame sizes A2, A3 and B3

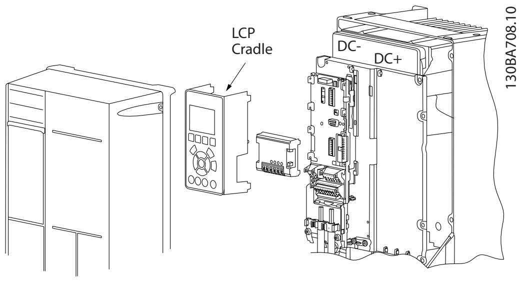


Figure 10.2 Frame sizes A5, B1, B2, B4, C1, C2, C3 and C4

10.1.3 Mounting of Options in Slot C

The power to the adjustable frequency drive must be disconnected.

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

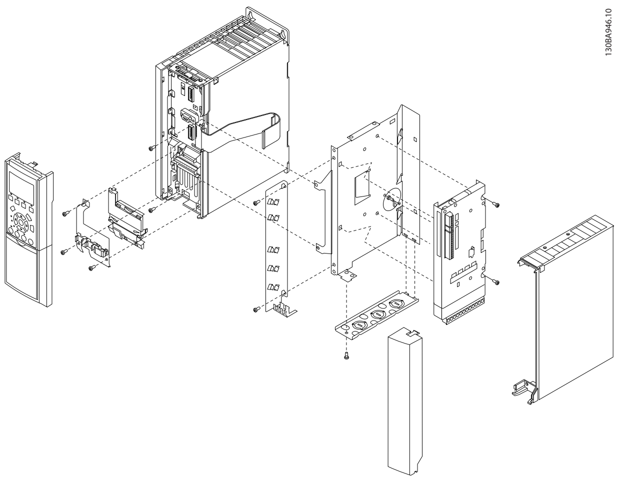


Figure 10.3 Frame sizes A2, A3 and B3

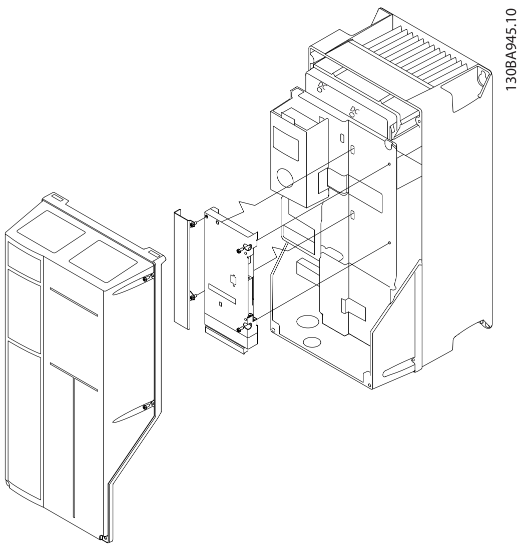


Figure 10.4 Frame sizes A5, B1, B2, B4, C1, C2, C3 and C4

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

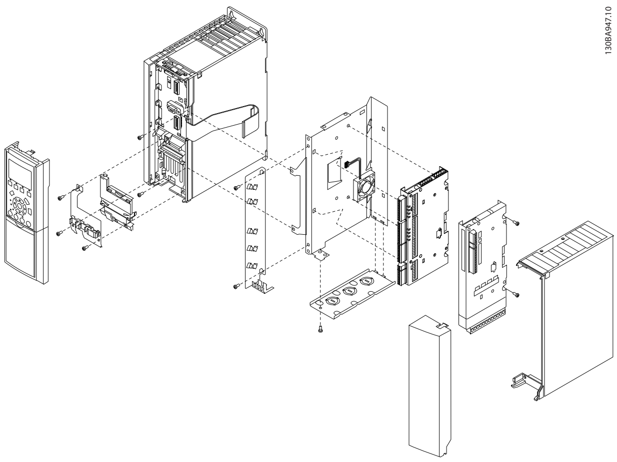


Figure 10.5 Frame sizes A2, A3 and B3

10.2 General Purpose Input Output Module MCB 101

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

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

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

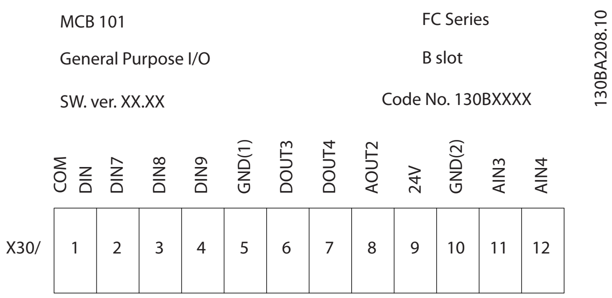


Figure 10.6

10.2.1 Galvanic Isolation in the MCB 101

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

If the digital inputs 7, 8 or 9 are to be switched by use of the internal 24V power supply (terminal 9), the connection between terminal 1 and 5 which is illustrated in the drawing must be established.

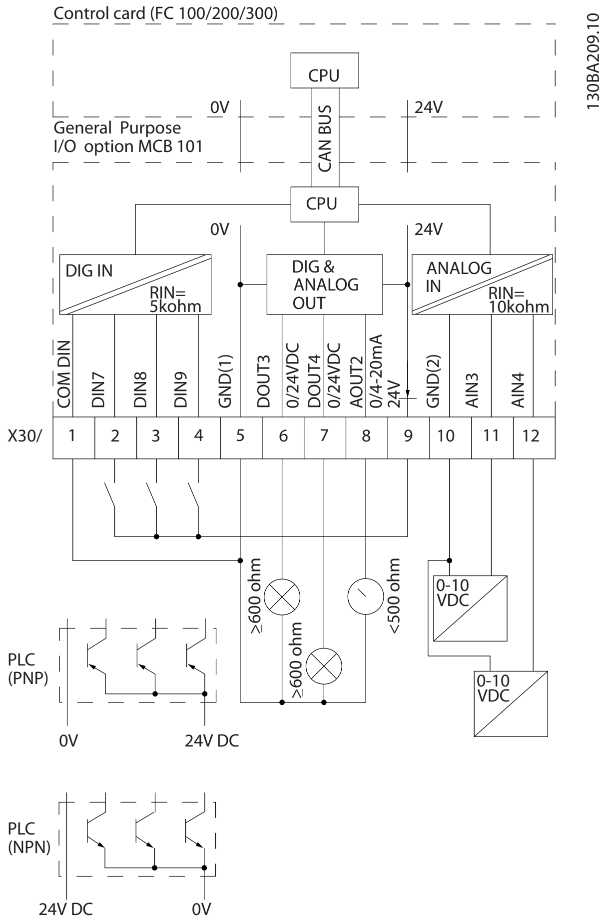


Figure 10.7 Principle Diagram

10.2.2 Digital Inputs - Terminal X30/1-4:

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

10.2.3 Analog Inputs - Terminal X30/11, 12:

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

10.2.4 Digital Outputs - Terminal X30/6, 7:

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

10.2.5 Analog Output - Terminal X30/8:

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

10.3 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-xx

Used for

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

Supported encoder types:
Incremental encoder: 5 V TTL type, RS422, max. frequency: 410kHz
Incremental encoder: 1Vpp, sine-cosine
Hiperface® Encoder: Absolute and Sine-Cosine (Stegmann/SICK)
EnDat encoder: Absolute and Sine-Cosine (Heidenhain)
Supports version 2.1
SSI encoder: Absolute
Encoder monitor:
The 4 encoder channels (A, B, Z and D) are monitored, open and short circuit can be detected. There is a green LED for each channel which lights up when the channel is OK.

NOTE!

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

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

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

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

Connector Designation X31	Incremental Encoder (please refer to Graphic A)	SinCos Encoder Hiperface® (please refer to Graphic B)	EnDat Encoder	SSI Encoder	Description
1	NC			24V*	24V Output (21-25V, I_{max}:125mA)
2	NC	8 Vcc			8V Output (7-12V, I_{max}: 200mA)
3	5 VCC		5 VCC	5V*	5V Output (5V ± 5%, I_{max}: 200mA)
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. 5V on X31.5-12					
* Supply for encoder: see data on encoder					

Table 10.1

10

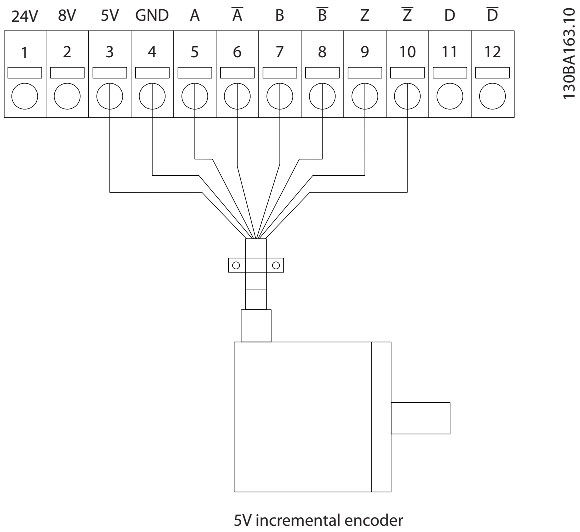


Figure 10.8

Max. cable length 492 ft [150 m].

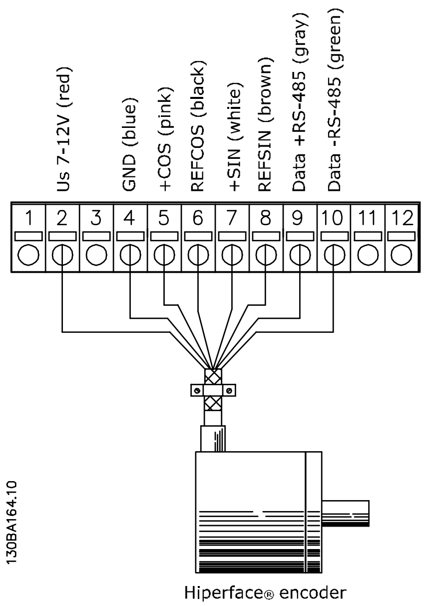


Figure 10.9

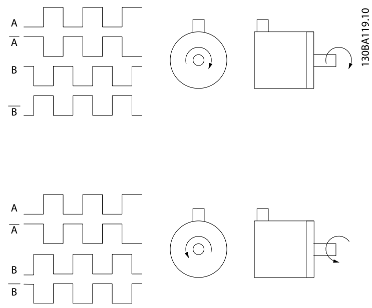


Figure 10.10

10.4 Resolver Option MCB 103

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

When Resolver option is ordered separately the kit includes:

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

Selection of parameters: 17-5x resolver interface.

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

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

Table 10.2

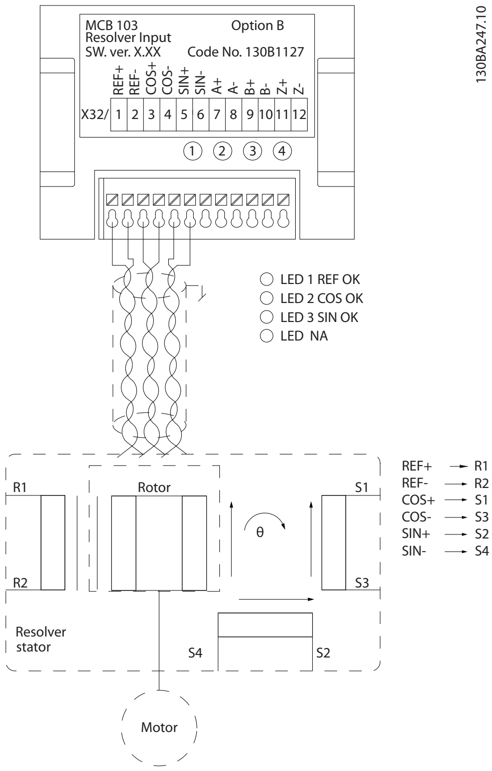


Figure 10.11

NOTE!

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

LED indicators

LED 1 is on when the reference signal is OK to resolver
LED 2 is on when 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 *Warning* or *Trip*.

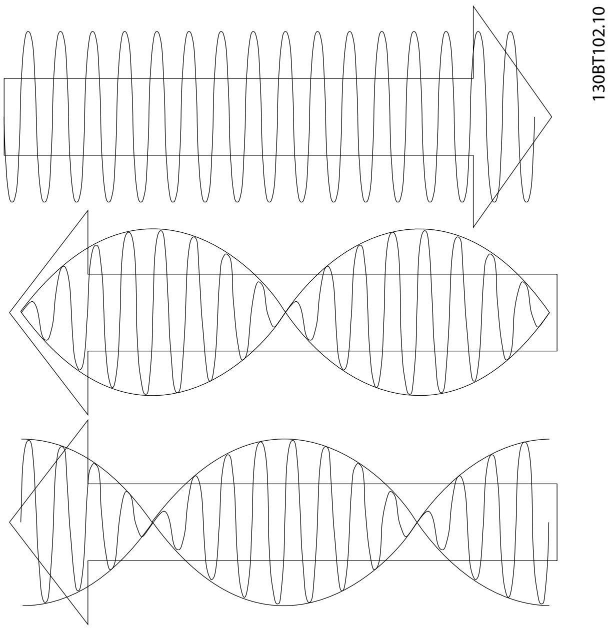


Figure 10.12

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 490 ft [150 m] when a twisted-pair type of cable is used.

NOTE!

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

NOTE!

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

NOTE!

Always use shielded motor cables and brake chopper cables.

1-00 Configuration Mode	Speed closed-loop [1]
1-01 Motor Control Principle	Flux with feedback [3]
1-10 Motor Construction	PM, non-salient SPM [1]
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	Enabled [1]

Table 10.3 Adjust following parameters

10.5 Relay Option MCB 105

The MCB 105 option includes 3 pieces of SPDT contacts and must be fitted into option slot B.

Electrical Data:	
Max terminal load (AC-1) 1) (Resistive load)	240V AC 2A
Max terminal load (AC-15)1) (Inductive load @ cosφ 0.4)	240 V AC 0.2A
Max terminal load (DC-1)1) (Resistive load)	24V DC 1 A
Max terminal load (DC-13)1) (Inductive load)	24V DC 0.1 A
Min terminal load (DC)	5V 10mA
Max switching rate at rated load/min load	6 min^{-1}/20 sec^{-1}

1) IEC 947 part 4 and 5

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

- Relay Module MCB 105
- Enlarged LCP fixture and enlarged terminal cover
- Label for covering access to switches S201, S202 and S801
- Cable strips for fastening cables to relay module

The relay option does not support FC 302 adjustable frequency drives manufactured before week 50/2004.

Min. software version: 2.03 (*15-43 Software Version*).

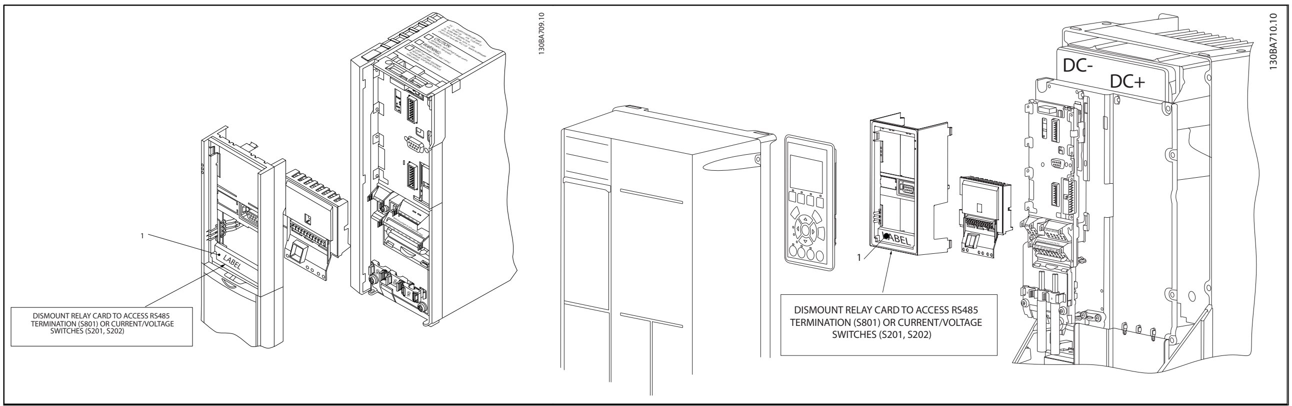


Table 10.4

A2-A3-B3	A5-B1-B2-B4-C1-C2-C3-C4
1) **IMPORTANT!** The label MUST be placed on the LCP frame as shown (UL approved).	

Table 10.5

WARNING

Warning Dual supply

How to add the MCB 105 option:

- The power to the adjustable frequency drive must be disconnected.
- The power to the live part connections on relay terminals must be disconnected.
- Remove the LCP, the terminal cover and the LCP fixture from the adjustable frequency drive.
- Fit the MCB 105 option in slot B.
- Connect the control cables and fasten the cables with the enclosed cable strips.
- Make sure the length of the stripped wire is correct (see the following drawing).
- Do not mix live parts (high voltage) with control signals (PELV).
- Fit the enlarged LCP fixture and enlarged terminal cover.
- Replace the LCP.
- Connect power to the adjustable frequency drive.
- Select the relay functions in *5-40 Function Relay* [6-8], *5-41 On Delay, Relay* [6-8] and *5-42 Off Delay, Relay* [6-8].

NOTE!

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

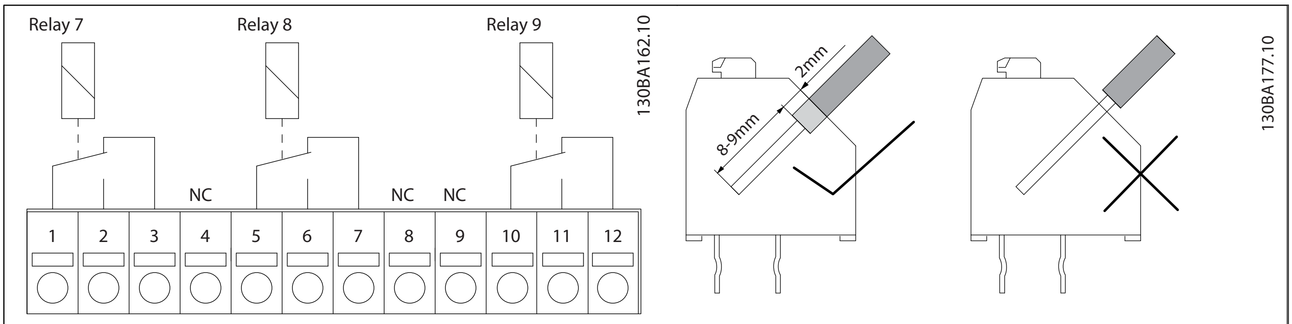


Table 10.6

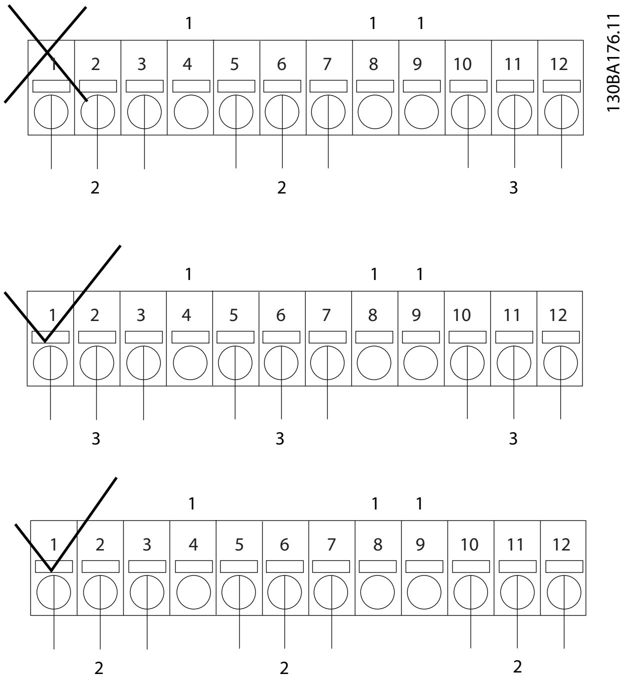


Figure 10.13

⚠WARNING

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

10.6 24V Backup Option MCB 107

External 24V DC Supply

An external 24V DC supply can be installed for low-voltage supply to the control card and any option card installed. This enables full operation of the LCP (including the parameter setting) without connection to line power.

External 24V DC supply specification:	
Input voltage range	24V DC ±15% (max. 37V in 10 sec.)
Max. input current	2.2A
Average input current for FC 302	0.9 A
Max cable length	246 ft [75 m]
Input capacitance load	< 10uF
Power-up delay	< 0.6 sec.

The inputs are protected.

Terminal numbers:

Terminal 35: - external 24V DC supply.

Terminal 36: + external 24V DC supply.

Follow these steps:

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

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

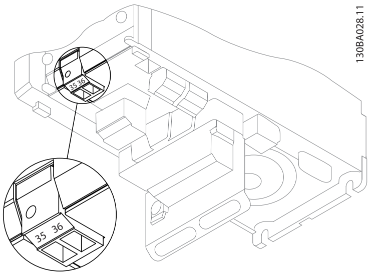


Figure 10.14 Connection to 24V backup supply on frame sizes A2 and A3.

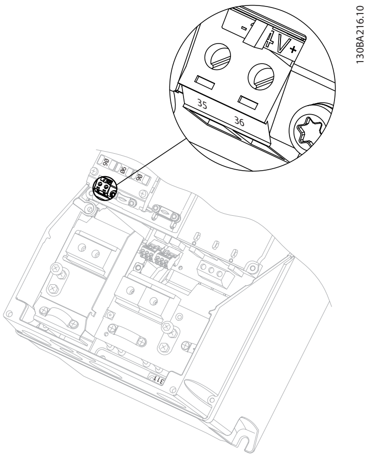


Figure 10.15 Connection to 24V backup supply on frame sizes A5, B1, B2, C1 and C2.

10.7 MCB 112 PTC Thermistor Card

The option makes it possible to monitor the temperature of an electrical motor through a galvanically-isolated PTC thermistor input. It is a B option for FC 302 with safe stop.

For information on mounting and installation of the option, please see *10.1.2 Mounting of Option Modules in Slot B* earlier in this section. See also *9 Application Examples* for different application possibilities.

X44/ 1 and X44/ 2 are the thermistor inputs, X44/ 12 will enable safe stop of the FC 302 (T-37) if the thermistor values make it necessary and X44/ 10 will inform the FC 302 that a request for safe stop came from the in order to ensure suitable alarm handling. One of the digital Inputs of the FC 302 (or a DI of a mounted option) must be set to PTC Card 1 [80] in order to use the information from X44/ 10. *5-19 Terminal 37 Safe Stop* Terminal 37 Safe Stop must be configured to the desired safe stop functionality (default is Safe Stop Alarm).

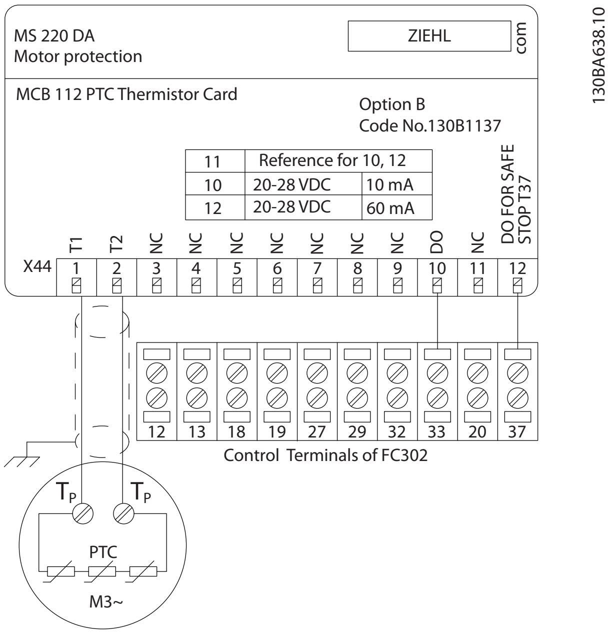


Figure 10.16

ATEX Certification with FC 302

The has been certified for ATEX which means that the FC 302 together with the can now be used with motors in potentially explosive atmospheres. See the Instruction Manual for the for more information.

	ATmosphère EXplosive (ATEX)

Table 10.7

Electrical Data

Resistor connection:	
PTC compliant with DIN 44081 and DIN 44082.	
Number	1..6 resistors in series
Shut-off value	3.3Ω.... 3.65Ω ... 3.85Ω
Reset value	1.7Ω .... 1.8Ω ... 1.95Ω
Trigger tolerance	± 10°F [6°C]
Collective resistance of the sensor loop	< 1.65Ω
Terminal voltage	≤ 2.5V for R ≤ 3.65Ω, ≤ 9V for R = ∞
Sensor current	≤ 1mA
Short circuit	20Ω ≤ R ≤ 40Ω
Power consumption	60 mA

Testing conditions:	
EN 60 947-8	
Measurement voltage surge resistance	6000V
Overvoltage category	III
Pollution degree	2
Measurement isolation voltage Vbis	690V
Reliable galvanic isolation until Vi	500 V
Perm. ambient temperature	-4°F [-20°C] ... 140°F [+60°C]
	EN 60068-2-1 Dry heat
Moisture	5–95%, no condensation permissible
EMC resistance	EN61000-6-2
EMC emissions	EN61000-6-4
Vibration resistance	10–1000Hz 1.14g
Shock resistance	50g

Safety system values:	
EN 61508 for Tu = 167°F [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	

10.8 MCB 113 Extended Relay Card

The MCB 113 adds seven digital inputs, two analog outputs and four SPDT relays to the standard I/O of the drive for increased flexibility and to comply with the German NAMUR NE37 recommendations.
The MCB 113 is a standard C1 option for the Danfoss VLT® AutomationDrive and is automatically detected after mounting.
For information on mounting and installation of the option, please see *Mounting of Option Modules in Slot C1* earlier in this chapter.

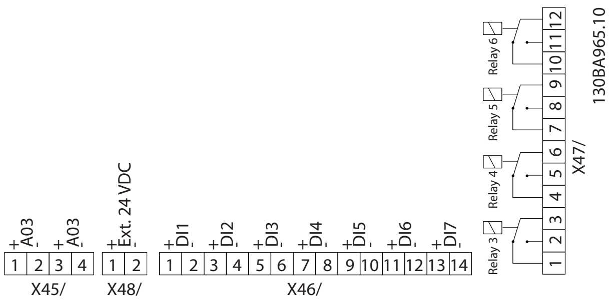


Figure 10.17 Electrical connections of MCB 113

MCB 113 can be connected to an external 24V on X58/ in order to ensure galvanic isolation between the VLT® AutomationDrive and the option card. If galvanic isolation is not needed, the option card can be supplied through internal 24 V from the drive.

NOTE!

It is OK to combine 24V signals with high voltage signals in the relays as long as there is one unused relay in between.

To setup MCB 113, use parameter groups 5-1* (Digital input), 6-7* (Analog output 3), 6-8* (Analog output 4), 14-8* (Options), 5-4* (Relays) and 16-6* (Inputs and Outputs).

NOTE!

In par. 5-4* Array [2] is relay 3, array [3] is relay 4, array [4] is relay 5 and array [5] is relay 6

Electrical Data

Relays:	
Numbers	4 SPDT
Load at 250V AC/ 30V DC	8A
Load at 250V AC/ 30V DC with cos = 0.4	3.5A
Overvoltage category (contact - ground)	III
Overvoltage category (contact - contact)	II
Combination of 250V and 24V signals	Possible with one unused relay in between
Maximum thru-put delay	10ms
Isolated from ground/chassis for use on IT line power systems	

Digital Inputs:	
Numbers	7
Range	0/24V
Mode	PNP/NPN
Input impedance	4kW
Low trigger level	6.4V
High trigger level	17V
Maximum thru-put delay	10ms

Analog Outputs:	
Numbers	2
Range	0/4–20mA
Resolution	11 bit
Linearity	<0.2%

Analog Outputs:	
Numbers	2
Range	0/4–20mA
Resolution	11 bit
Linearity	<0.2%

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

10.9 Brake Resistors

In applications where the motor is used as a brake, energy is generated in the motor and send back into the Adjustable frequency drive. If the energy cannot be transported back to the motor, it will increase the voltage in the drive DC line. In applications with frequent braking and/or high inertia loads, this increase may lead to an overvoltage trip in the drive, and ultimately, 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 the section *Control with brake function* for the dimensioning of brake resistors. Code numbers can be found in *5 How to Order*.

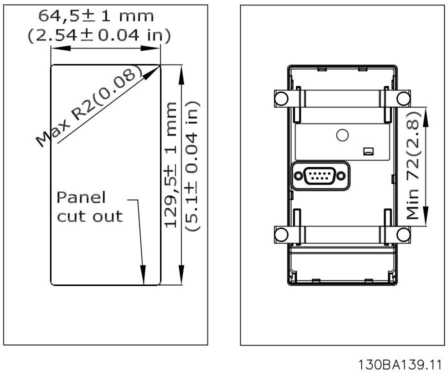


Figure 10.18

10

10.10 LCP Panel Mounting Kit

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

Technical data	
Enclosure:	IP66 front
Max. cable length between and unit:	10 ft [3 m]
Communication std:	RS485

Table 10.8

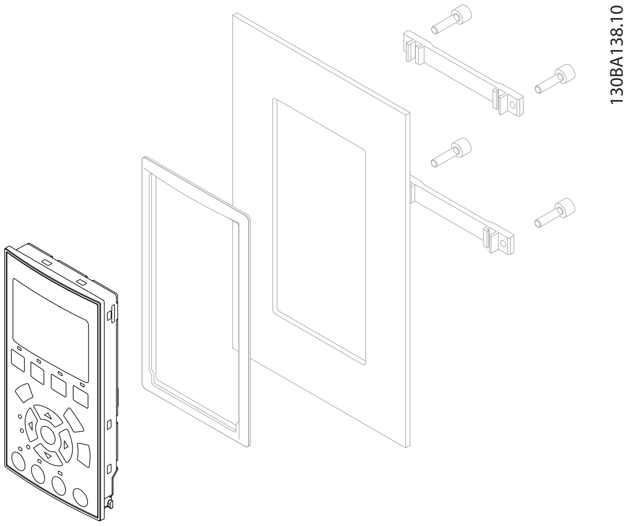
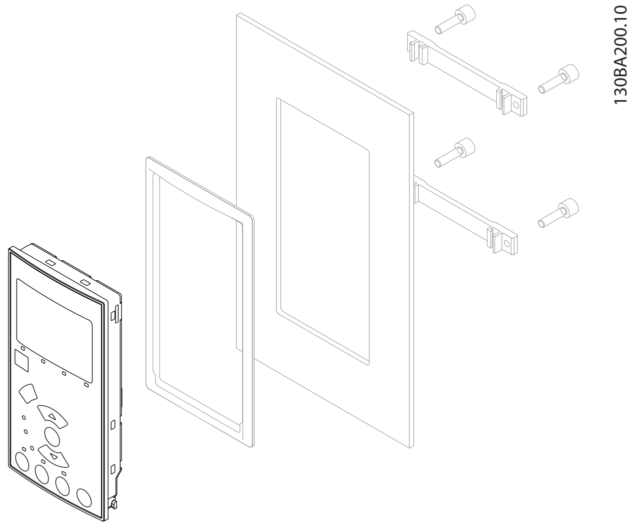
Ordering no. 130B1113	Ordering no. 130B1114
 **Figure 10.19 LCP Kit with Graphical LCP, Fasteners, 9.8 ft [3 m] Cable and Gasket.**	 **Figure 10.19 LCP Kit with Numerical LCP, Fasteners and Gasket.**
LCP Kit without LCP is also available. Ordering number: 130B1117 For IP55 units, the ordering number is 130B1129.	

Table 10.9

10.11 IP21/IP 4X/ TYPE 1 Enclosure Kit

IP20/IP 4X top/ TYPE 1 is an optional enclosure element available for IP 20 Compact units.
If the enclosure kit is used, an IP 20 unit is upgraded to comply with enclosure IP 21/ 4X top/TYPE 1.

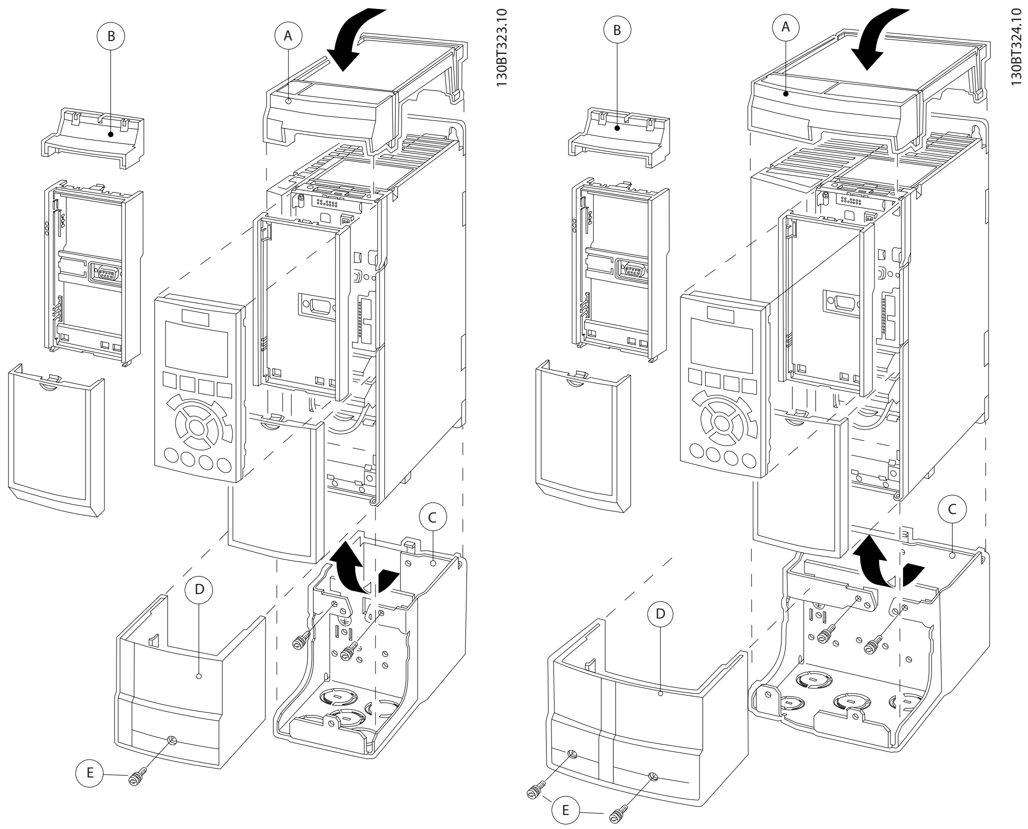
The IP 4X top can be applied to all standard IP 20 FC 30X variants.

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

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 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



A2 Enclosure | A3 Enclosure

Table 10.10

Dimensions			
Enclosure type	Height (in [mm]) A	Width (in [mm]) B	Depth (in [mm]) C*
A2	14.6 [372]	3.5 [90]	8.1 [205]
A3	14.6 [372]	5.1 [130]	8.1 [205]
B3	18.7 [475]	6.5 [165]	9.8 [249]
B4	26.4 [670]	10 [255]	9.7 [246]
C3	29.7 [755]	13 [329]	13.3 [337]
C4	37.4 [950]	15.4 [391]	13.3 [337]
* If option A/B is used, the depth will increase (see section Mechanical Dimensions for details)			

Table 10.11

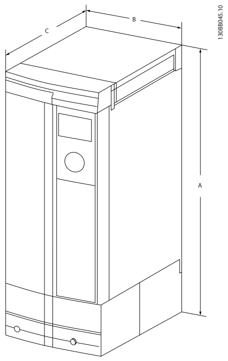
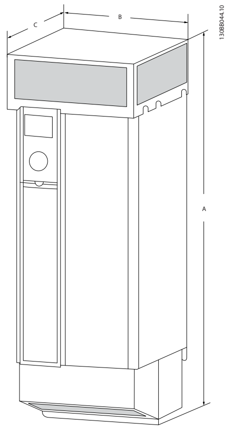
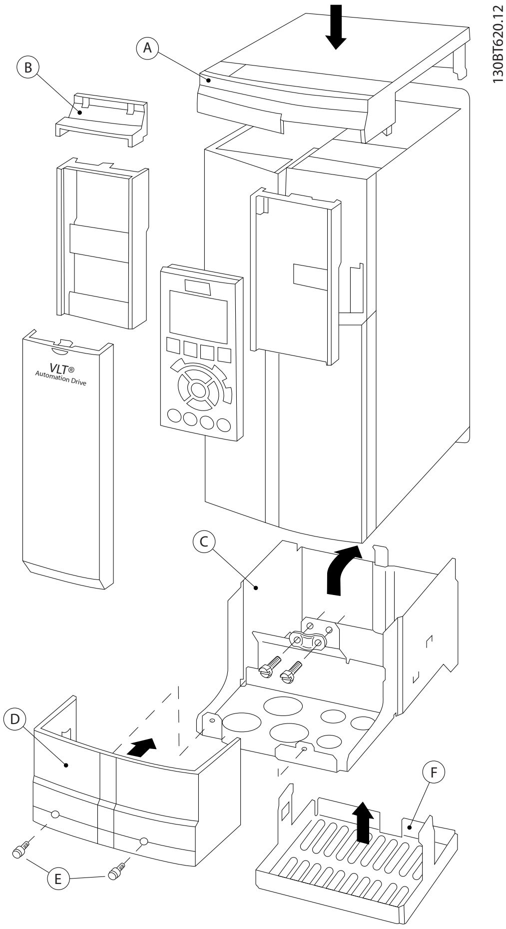
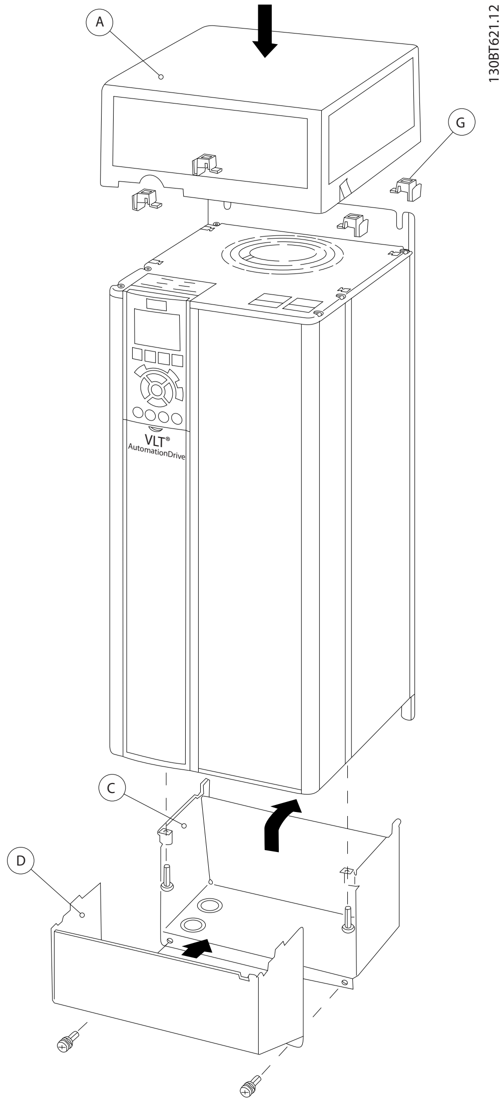
	
A2, A3, B3	B4, C3, C4

Table 10.12

A – Top cover
B – Brim
C – Base part
D – Base cover
E – Screw(s)
F - Fan cover
G - Top clip
When option module A and/or option module B is/are used, the brim (B) must be fitted to the top cover (A).



B3 Enclosure



B4 - C3 - C4 Enclosure

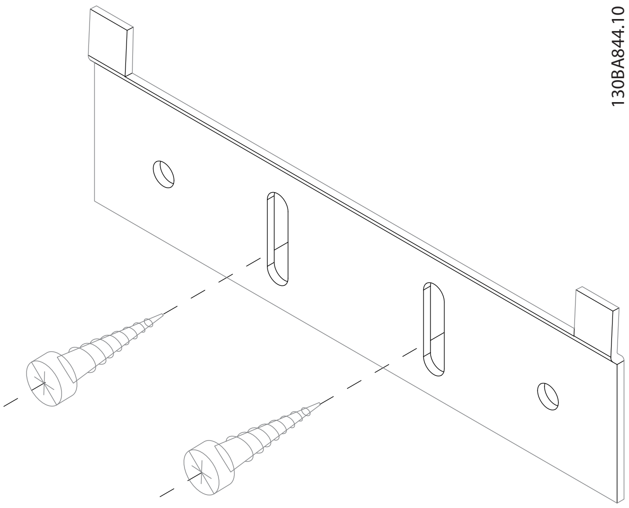
Table 10.13

NOTE!

Side-by-side installation is not possible when using the *IP 21/ IP 4X/ TYPE 1 Enclosure Kit*

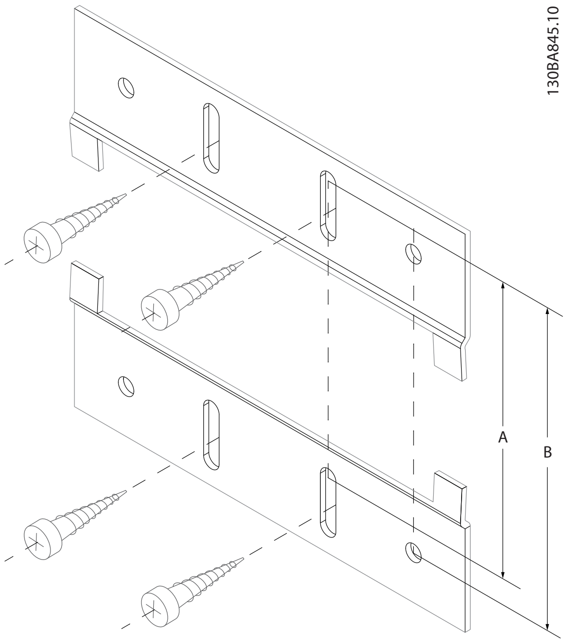
10.12 Mounting Bracket for Frame Size A5, B1, B2, C1 and C2

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



Step 1

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

Measure distance A or B, and position the upper bracket, but do not tighten it. See dimensions below

Table 10.14

Frame size	A5	B1	B2	B3	B4
IP	55/66	21/55/66	21/55/66	21/55/66	21/55/66
A (ins [mm])	18.9 [480]	21.1 [535]	27.8 [705]	28.7 [730]	32.3 [820]
B (ins [mm])	19.5 [495]	21.7 [550]	28.3 [720]	29.3 [745]	32.9 [835]
Ordering number	130B1080	130B1081	130B1082	130B1083	130B1084

Table 10.15

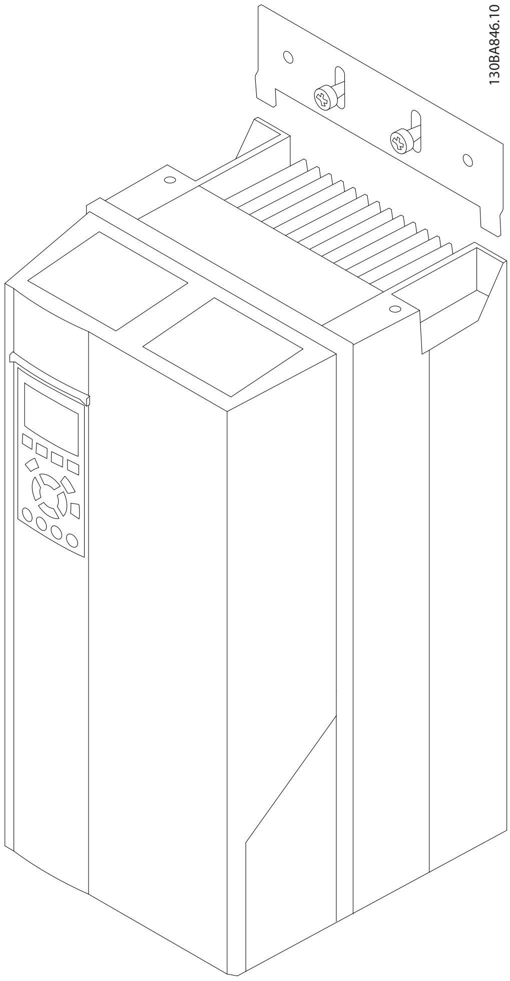
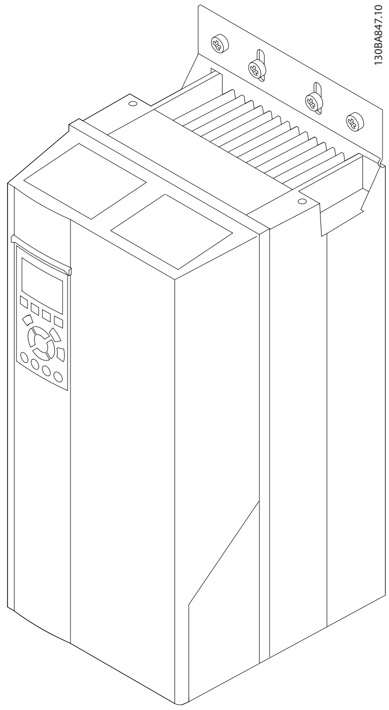
 **Step 3** Place the adjustable frequency drive in the lower bracket, and lift the upper one. When the adjustable frequency drive is in place, lower the upper bracket.	 **Step 4** Now tighten the screws. For extra security, drill and mount screws in all holes.

Table 10.16

10.13 Sine-wave Filters

When a motor is controlled by an adjustable frequency drive, resonance noise will be heard from the motor. This noise, which is the result of the design of the motor, arises every time an inverter switch in the 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 can supply a sine-wave filter to dampen the acoustic motor noise.

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

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

10.14 High Power Options

Ordering numbers for High Power options can be found in the *How to Order* section. The kits are described in the FC 300 High Power Instruction Manual, *MG.33.UX.YY*.

10.14.1 Frame Size F Options

Space Heaters and Thermostat
Mounted on the cabinet interior of frame size F adjustable frequency drives, space heaters controlled via automatic thermostat help control humidity inside the enclosure, extending the lifetime of drive components in damp environments. The thermostat default settings turn on the heaters at 10°C (50°F) and turn them off at 15.6°C (60°F).

Cabinet Light with Power Outlet
A light mounted on the cabinet interior of frame size F adjustable frequency drives increases visibility during servicing and maintenance. The housing light includes a power outlet for temporarily powering tools or other devices, available in two voltages:

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

Transformer Tap Set-up
If the Cabinet Light & Outlet and/or the Space Heaters & Thermostat are installed Transformer T1 requires it taps to be set to the proper input voltage. A 380–480/ 500V drive will initially be set to the 525V tap and a 525–690V drive will be set to the 690V tap to insure no overvoltage of secondary equipment occurs if the tap is not changed prior to power being applied. See the table below to set the proper tap at terminal T1 located in the rectifier cabinet. For location in the drive, see illustration of rectifier in *8.2.2 Power Connections*.

Input Voltage Range	Tap to Select
380–440 V	400V
441–490 V	460V
491–550 V	525V
551–625 V	575V
626–660 V	660V
661–690 V	690V

Table 10.17

NAMUR Terminals
NAMUR is an international association of automation technology users in process industries, primarily in the chemical and pharmaceutical industries, in Germany. Selection of this option provides terminals organized and labeled to the specifications of the NAMUR standard for drive input and output terminals. This requires MCB 112 PTC Thermistor Card and MCB 113 Extended Relay Card.

RCD (Residual Current Device)
Uses the core balance method to monitor ground fault currents in grounded and high-resistance grounded systems (TN and TT systems in IEC terminology). There is a pre-warning (50% of main alarm setpoint) and a main alarm setpoint. Associated with each setpoint is an SPDT alarm relay for external use. Requires an external “window-type” current transformer (supplied and installed by customer).

- Integrated into the drive’s safe-stop circuit
- IEC 60755 Type B device monitors AC, pulsed DC, and pure DC ground fault currents
- LED bar graph indicator of the ground fault current level from 10–100% of the setpoint
- Fault memory
- TEST / RESET button

Insulation Resistance Monitor (IRM)
Monitors the insulation resistance in ungrounded systems (IT systems in IEC terminology) between the system phase conductors and ground. There is an ohmic pre-warning and a main alarm setpoint for the insulation level. Associated with each setpoint is an SPDT alarm relay for external use. Note: only one insulation resistance monitor can be connected to each ungrounded (IT) system.

- Integrated into the drive’s safe-stop circuit
- LCD display of the ohmic value of the insulation resistance
- Fault Memory

- INFO, TEST and RESET buttons

IEC Emergency Stop with Pilz Safety Relay
Includes a redundant 4-wire emergency stop pushbutton mounted on the front of the enclosure and a Pilz relay that monitors it in conjunction with the drive's safe stop circuit and the line power contactor located in the options cabinet.

Safe Stop + Pilz Relay
Provides a solution for the "Emergency Stop" option without the contactor in F-Frame drives.

Manual Motor Starters
Provides 3-phase power for electric blowers often required for larger motors. Power for the starters is provided from the load side of any supplied contactor, circuit breaker, or disconnect switch. Power is fused before each motor starter, and is off when the incoming power to the drive is off. Up to two starters are allowed (one if a 30 A, fuse-protected circuit is ordered). Integrated into the drive's safe-stop circuit.
Unit features include:

- Operation switch (on/off)
- Short-circuit and overload protection with test function
- Manual reset function

30 Ampere, Fuse-protected Terminals

- 3-phase power matching incoming AC line voltage for powering auxiliary customer equipment
- Not available if two manual motor starters are selected
- Terminals are off when the incoming power to the drive is off
- Power for the fused protected terminals will be provided from the load side of any supplied contactor, circuit breaker, or disconnect switch.

24 VDC Power Supply

- 5 amp, 120W, 24V DC
- Protected against output overcurrent, overload, short circuits and overtemperature
- For powering customer-supplied accessory devices such as sensors, PLC I/O, contactors, temperature probes, LEDs and/or other electronic hardware
- Diagnostics include a dry DC-ok contact, a green DC-ok LED and a red overload LED

External Temperature Monitoring
Designed for monitoring temperatures of external system components, such as the motor windings and/or bearings. Includes five universal input modules. The modules are integrated into the drive's safe-stop circuit and can be monitored via a serial communication bus network (requires the purchase of a separate module/bus coupler).

<u>Universal inputs (5)</u>
Signal types:

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

Additional features:

- One universal output, configurable for analog voltage or analog current
- Two output relays (N.O.)
- Dual-line LC display and LED diagnostics
- Sensor lead wire break, short-circuit and incorrect polarity detection
- Interface set-up software

11 RS-485 Installation and Set-up

11.1 Overview

RS485 is a two-wire bus interface compatible with multi-drop network topology, i.e., nodes can be connected as a bus, or via drop cables from a common trunk line. A total of 32 nodes can be connected to one network segment. Repeaters divide network segments. Please note that each repeater functions as a node within the segment in which it is installed. Each node connected within a given network must have a unique node address across all segments. Terminate each segment at both ends using either the termination switch (S801) of the adjustable frequency drives or a biased termination resistor network. Always use shielded twisted pair (STP) cable for bus cabling, and always follow good common installation practice.
Low-impedance ground connection of the shield at every node is important, including at high frequencies. Thus, connect a large surface of the shield to ground, for example, with a cable clamp or a conductive cable 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: 120Ω
Cable length: Max. 3,937 ft [1200 m] (including drop lines)
Max. 1,640 ft [500 m] station-to-station

Table 11.1

11.2 Network Connection

One or more adjustable frequency drives can be connected to a control (or master) using the RS485 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 *8.9.3 Grounding of Shielded Control Cables*

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

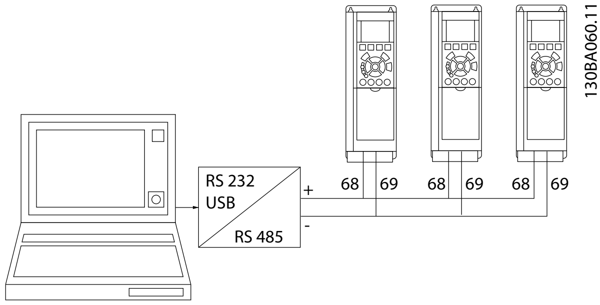


Figure 11.1

In order 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.

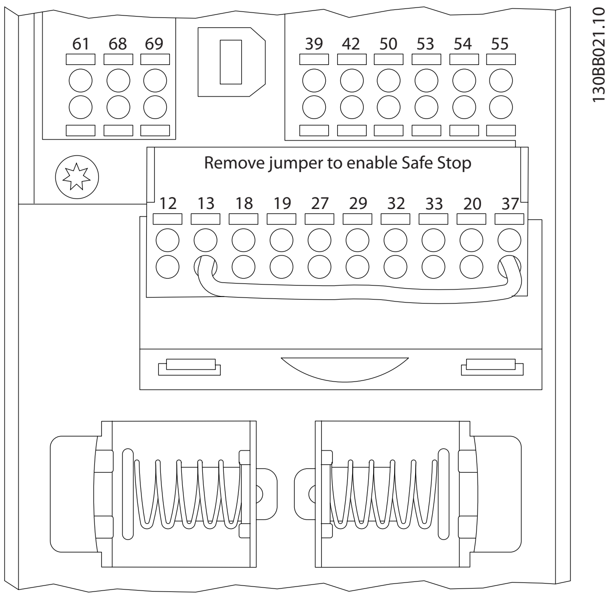


Figure 11.2 Control Card Terminals

11.3 Bus Termination

The RS485 bus must be terminated by a resistor network at both ends. For this purpose, set switch S801 on the control card to "ON".
For more information, see *8.6.4 Switches S201, S202 and S801* .

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

11.4.1 EMC Precautions

The following EMC precautions are recommended in order to achieve interference-free operation of the RS485 network.

Relevant national and local regulations, for example regarding protective ground connection, must be observed. The RS485 communication cable must be kept away from motor and brake resistor cables to avoid coupling of high frequency noise from one cable to another. Normally a distance of 200mm (8 inches) is sufficient, but keeping the greatest possible distance between the cables is generally recommended, especially where cables run in parallel over long distances. When crossing is unavoidable, the RS485 cable must cross motor and brake resistor cables at an angle of 90 degrees.

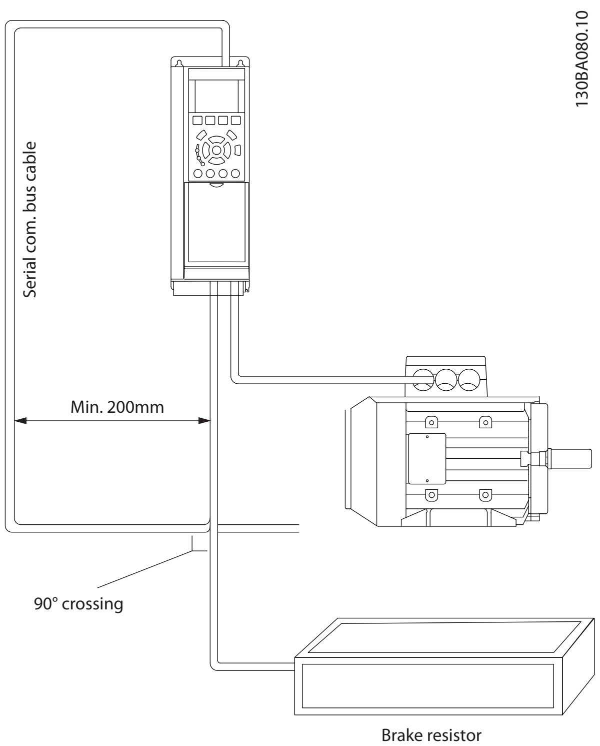


Figure 11.3

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

The physical layer is RS485, thus utilizing the RS485 port built into the 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.

11.5 Network Configuration

11.5.1 FC 300 Adjustable Frequency Drive Set-up

Set the following parameters to enable the Adjustable Frequency protocol for the adjustable frequency drive.

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

Table 11.2

11.6 Adjustable frequency drive Protocol Message Framing Structure - FC 300

11.6.1 Content of a Character (byte)

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

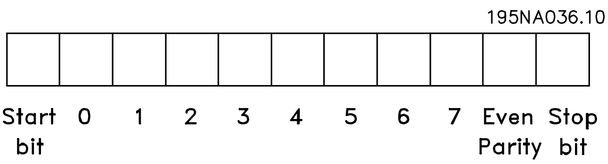


Figure 11.4

11.6.2 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 telegram) follows.

A data control byte (BCC) completes the telegram.

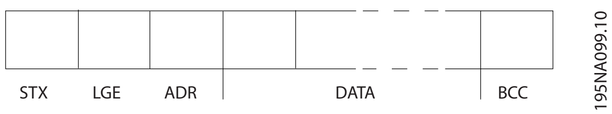


Figure 11.5

11.6.3 Length (LGE)

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

The length of telegrams with 4 data bytes is	LGE = 4 + 1 + 1 = 6 bytes
The length of telegrams with 12 data bytes is	LGE = 12 + 1 + 1 = 14 bytes
The length of telegrams containing texts is	10[1)]+n bytes

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

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

11.6.5 Data Control Byte (BCC)

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

11.6.6 The Data Field

The structure of data blocks depends on the type of . There are three types, and the type applies for both control telegrams (master=>slave) and response telegrams (slave=>master).

The three types of are:

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

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

11

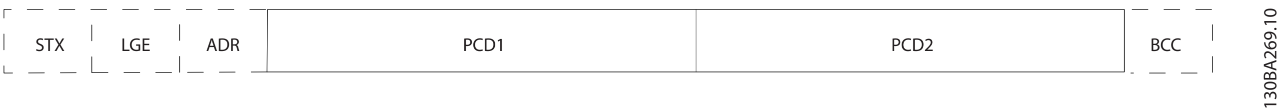


Figure 11.6

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

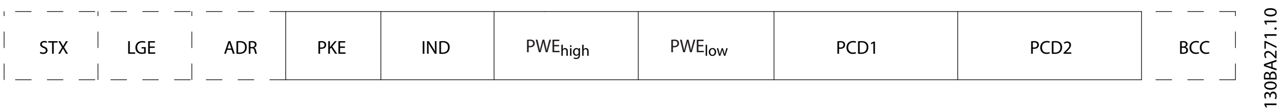


Figure 11.7

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

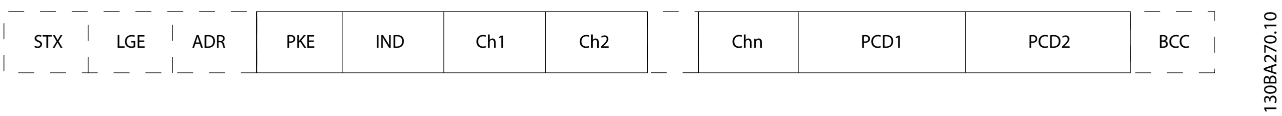


Figure 11.8

11.6.7 The PKE Field

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

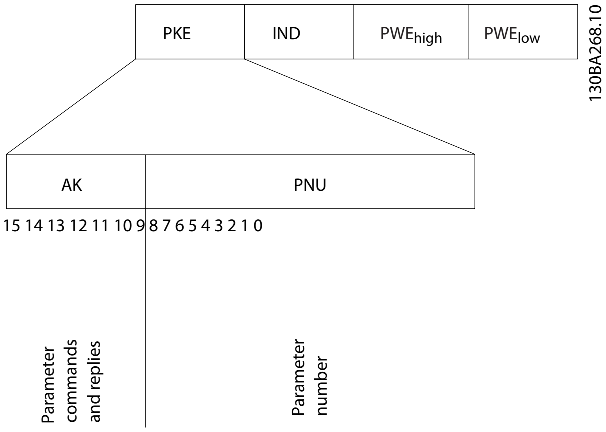


Figure 11.9

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

Parameter commands master ⇒ slave				
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 11.3

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

Table 11.4

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

PWE low (Hex)	Fault Report
0	The parameter number used does not exit.
1	There is no write access to the defined parameter
2	Data value exceeds the parameter's limits
3	The sub index used does not exit.
4	The parameter is not the array type.
5	The data type does not match the defined parameter
11	Data change in the defined parameter is not possible in the 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 the factory set-up is selected.

Table 11.5

11.6.8 Parameter Number (PNU)

Bits no. 0-11 transfer parameter numbers. The function of the relevant parameter is defined in the parameter description in the Programming Guide, MG.33.MX.YY.

11.6.9 Index (IND)

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

Only the low byte is used as an index.

11.6.10 Parameter Value (PWE)

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

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

15-40 FC Type to *15-53 Power Card Serial Number* contain data type 9.

For example, read the unit size and AC line voltage range in *15-40 FC Type*. When a text string is transferred (read), the length of the is variable, and the texts are of different lengths. The length is defined in the second byte of the , 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".

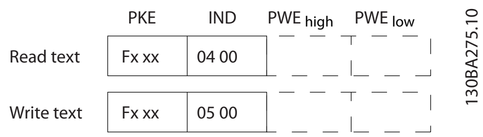


Figure 11.10

11.6.11 Data Types Supported by FC 300

Unsigned means that there is no operational sign in the telegram.

Data types	Description
3	Integer 16
4	Integer 32
5	Unsigned 8
6	Unsigned 16
7	Unsigned 32
9	Text string
10	Byte string
13	Time difference
33	Reserved
35	Bit sequence

Table 11.6

11.6.12 Conversion

The various attributes of each parameter are displayed in the section Factory Settings. Parameter values are transferred as whole numbers only. Conversion factors are therefore used to transfer decimals.

4-12 Motor Speed Low Limit [Hz] has a conversion factor of 0.1.
To preset the minimum frequency to 10 Hz, transfer the value 100. A conversion factor of 0.1 means that the value transferred is multiplied by 0.1. The value 100 is thus perceived as 10.0.

Examples:
0s --> conversion index 0
0.00s --> conversion index -2
0ms --> conversion index -3
0.00ms --> conversion index -5

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

Table 11.7 Conversion table

11.6.13 Process Words (PCD)

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

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

Table 11.8

11.7 Examples

11.7.1 Writing a Parameter Value

Change *4-14 Motor Speed High Limit [Hz]* to 100 Hz.
Write the data in EEPROM.

PKE = E19E Hex - Write single word in *4-14 Motor Speed High Limit [Hz]*
IND = 0000 Hex
PWEHIGH = 0000 Hex
PWELOW = 03E8 Hex - Data value 1000, corresponding to 100 Hz, see Conversion.

11

The telegram will look like this:

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

130BA092.10

Figure 11.11

NOTE!

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

The response from the slave to the master will be:

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

130BA093.10

Figure 11.12

11.7.2 Reading a Parameter Value

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

PKE = 1155 Hex - Read parameter value in *3-41 Ramp 1 Ramp-up Time*
IND = 0000 Hex
PWEHIGH = 0000 Hex
PWELOW = 0000 Hex

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

130BA094.10

Figure 11.13

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

130BA267.10

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

Figure 11.14

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

11.8 Modbus RTU Overview

11.8.1 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.

11.8.2 What the User Should Already Know

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

11.8.3 Modbus RTU Overview

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

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

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

confirming the action taken, any data to be returned and an error-checking field. If an error occurs in receipt of the message, or if the slave is unable to perform the requested action, the slave will construct an error message, and send it in response, or a timeout occurs.

11.8.4 Adjustable Frequency Drive with Modbus RTU

The Adjustable frequency drive communicates in Modbus RTU format over the built-in RS485 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.

11.9 Network Configuration

11.9.1 Adjustable Frequency Drive with Modbus RTU

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 11.9

11.10 Modbus RTU Message Framing Structure

11.10.1 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 11.10*.

Start bit	Data byte								Stop/ parity	Stop

Table 11.10

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)

Table 11.11

11.10.2 Modbus RTU Message Structure

The transmitting device places a Modbus RTU message into a frame with a known beginning and ending point. This allows receiving devices to begin at the start of the message, read the address portion, determine which device is addressed (or all devices, if the message is broadcast), and to 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

11

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 below.

Typical Modbus RTU Message Structure

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 11.12

11.10.3 Start/Stop Field

Messages start with a silent period of at least 3.5 character intervals. This is implemented as a multiple of character intervals at the selected network baud rate (shown as Start T1-T2-T3-T4). The first field to be transmitted is the device address. Following the last transmitted character, a similar period of at least 3.5 character intervals marks the end of the message. A new message can begin after this period. The entire message frame must be transmitted as a continuous stream. If a silent period of more than 1.5 character intervals occurs before completion of the frame, the receiving device flushes the incomplete message and assumes that the next byte will be the address field of a new message. Similarly, if a new message begins prior to 3.5 character intervals after a previous message, the receiving device will consider it a continuation of the previous message. This will cause a timeout (no response from the slave), since the value in the final CRC field will not be valid for the combined messages.

11.10.4 Address Field

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

11.10.5 Function Field

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

11.10.6 Data Field

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

11.10.7 CRC Check Field

Messages include an error-checking field, operating on the basis of 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.

11.10.8 Coil Register Addressing

In Modbus, all data are organized in coils and holding registers. Coils hold a single bit, whereas holding registers hold a 2-byte word (i.e., 16 bits). All data addresses in Modbus messages are referenced to zero. The first occurrence of a data item is addressed as item number zero. For example: The coil known as 'coil 1' in a programmable controller is addressed as coil 0000 in the

data address field of a Modbus message. Coil 127 decimal is addressed as coil 007EHEX (126 decimal).
Holding register 40001 is addressed as register 0000 in the data address field of the message. The function code field already specifies a 'holding register' operation. Therefore, the '4XXXX' reference is implicit. Holding register 40108 is addressed as register 006BHEX (107 decimal).

<table>
<tr><th>Coil Number</th><th colspan="2">Description</th><th>Signal Direction</th></tr>
<tr><td>1-16</td><td colspan="2">Adjustable frequency drive control word (see table below)</td><td>Master to slave</td></tr>
<tr><td>17-32</td><td colspan="2">Adjustable frequency drive speed or setpoint reference Range 0x0 – 0xFFFF (-200% ... ~200%)</td><td>Master to slave</td></tr>
<tr><td>33-48</td><td colspan="2">Adjustable frequency drive status word (see table below)</td><td>Slave to master</td></tr>
<tr><td>49-64</td><td colspan="2">Open-loop mode: Adjustable frequency drive output frequency closed-loop mode: Adjustable frequency drive feedback signal</td><td>Slave to master</td></tr>
<tr><td rowspan="3">65</td><td colspan="2">Parameter write control (master to slave)</td><td rowspan="3">Master to slave</td></tr>
<tr><td>0 =</td><td>Parameter changes are written to the RAM of the Adjustable frequency drive</td></tr>
<tr><td>1 =</td><td>Parameter changes are written to the RAM and EEPROM of the Adjustable frequency drive.</td></tr>
<tr><td>66-65536</td><td colspan="2">Reserved</td><td></td></tr>
</table>

Table 11.13

Coil	0	1
01	Preset reference LSB	
02	Preset reference MSB	
03	DC brake	No DC brake
04	Coast stop	No coast stop
05	Quick stop	No quick stop
06	Freeze freq.	No freeze freq.
07	Ramp stop	Start
08	No reset	Reset
09	No jog	Jog
10	Ramp 1	Ramp 2
11	Data not valid	Data valid
12	Relay 1 off	Relay 1 on
13	Relay 2 off	Relay 2 on
14	Set up LSB	
15	Set up MSB	
16	No reversing	Reversing
Adjustable frequency drive control word (FC profile)		

Table 11.14

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
Adjustable frequency drive status word (FC profile)		

Table 11.15

Holding registers	
Register Number	Description
00001-00006	Reserved
00007	Last error code from an adjustable frequency drive 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 11.16

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

11.10.9 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.

11.10.10 Function Codes Supported by Modbus RTU

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

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

Table 11.17

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

Table 11.18

11.10.11 Modbus Exception Codes

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

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

Table 11.19

11.11 How to Access Parameters

11.11.1 Parameter Handling

The PNU (Parameter Number) is translated from the register address contained in the Modbus read or write message. The parameter number is translated to Modbus as (10 x parameter number) DECIMAL.

11.11.2 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).

11

11.11.3 IND

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

11.11.4 Text Blocks

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

11.11.5 Conversion Factor

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

11.11.6 Parameter Values

Standard Data Types
Standard data types are int16, int32, uint8, uint16 and uint32. They are stored as 4x registers (40001 – 4FFFF). The parameters are read using function 03HEX "Read Holding Registers." Parameters are written using the function 6HEX "Preset Single Register" for 1 register (16 bits), and the function 10HEX "Preset Multiple Registers" for 2 registers (32 bits). Readable sizes range from 1 register (16 bits) up to 10 registers (20 characters).

Non standard Data Types
Non standard data types are text strings stored as 4x registers (40001–4FFFF). The parameters are read using function 03HEX "Read Holding Registers" and written using function 10HEX "Preset Multiple Registers." Readable sizes range from 1 register (2 characters) up to 10 registers (20 characters).

11.12 Danfoss FC Control Profile

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

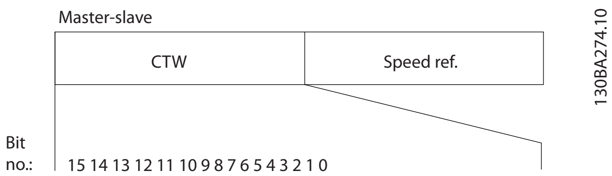


Figure 11.15

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

Table 11.20

Explanation of the Control Bits

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

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 11.21

NOTE!

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

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

NOTE!

If Freeze output is active, the 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 telegram always contains the control word, regardless of the telegram type. Thus, you can turn off the control word if you do not want to use it when updating or reading parameters.

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

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

Bit 13/14, Selection of set-up:
Use bits 13 and 14 to choose from the four menu set-ups according to the shown table: .

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

Table 11.22

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

Make a selection in *8-55 Set-up Select* to define how Bit 13/14 gates with the corresponding function on the digital inputs.

Bit 15 Reverse:
Bit 15 = '0': No reversing. Bit 15 = '1': Reversing. In the default setting, reversing is set to digital in *8-54 Reverse Select*. Bit 15 causes reversing only when Ser. communication, Logic or or Logic and is selected.

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

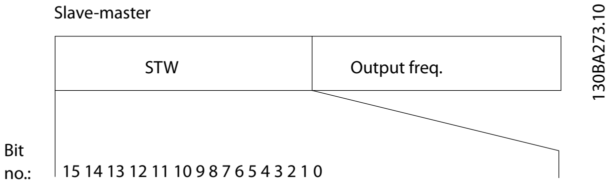


Figure 11.16

Bit	Bit = 0	Bit = 1
00	Control not ready	Control ready
01	Drive not ready	Drive ready
02	Coasting	Enable
03	No error	Trip
04	No error	Error (no trip)
05	Reserved	-
06	No error	Triplock
07	No warning	Warning
08	Speed ≠ reference	Speed = reference
09	Local operation	Bus control
10	Out of frequency limit	Frequency limit OK
11	No operation	In operation
12	Drive OK	Stopped, auto start
13	Voltage OK	Voltage exceeded
14	Torque OK	Torque exceeded
15	Timer OK	Timer exceeded

Table 11.23

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 24V 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, it 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. You cannot control the Adjustable frequency drive via serial communication. Bit 09 = '1' It is possible to control the Adjustable frequency drive via the serial communication bus / serial communication.

Bit 10, Out of frequency limit:
Bit 10 = '0': The output frequency has reached the value in *4-11 Motor Speed Low Limit [RPM]* or *4-13 Motor Speed High Limit [RPM]*. Bit 10 = "1": The output frequency is within the defined limits.

Bit 11, No operation/in operation:
Bit 11 = '0': The motor is not running. Bit 11 = '1': The 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 in the inverter. Bit 12 = '1': The inverter stops because of overtemperature, but the unit does not trip and will resume 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 intermediate circuit of the adjustable frequency drive 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 an internal communication problem has occurred.

11.12.3 Bus Speed Reference Value

Speed reference value is transmitted to the Adjustable frequency drive in a relative value in %. The value is transmitted in the form of a 16-bit word; in integers (0-32767) the value 16384 (4000 Hex) corresponds to 100%. Negative figures are formatted by means of 2's complement. The Actual Output frequency (MAV) is scaled in the same way as the bus reference.

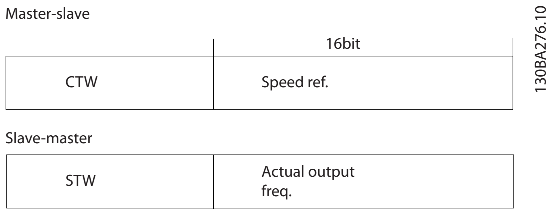


Figure 11.17

The reference and MAV are scaled as follows:

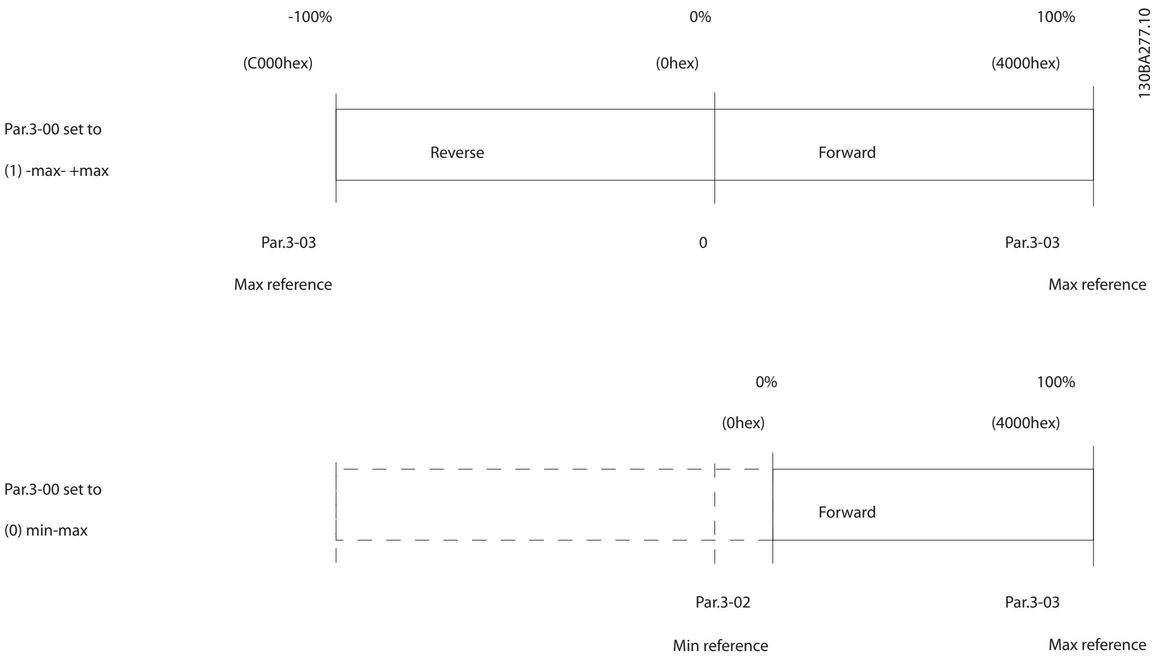


Figure 11.18

11.12.4 Status Word according to PROFIdrive Profile (STW)

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

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

Table 11.24

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 the unit present is not necessarily connected to a power supply (in the event of external 24 V supply of the control system).

Bit 01, VLT not ready/ready
Same significance as bit 00, however, there is a supply of the power unit. The 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 will be "1" after a switch-off acknowledgement, after activation of OFF2 or OFF3, and after switching on the AC line voltage. Start not possible will be reset, with bit 00 of the control word being set to "0" and bit 01, 02 and 10 being set to "1".

Bit 07, No warning/Warning
Bit 07 = “0” means that there are no warnings.
Bit 07 = “1” means that a warning has occurred.

Bit 08, Speed ≠ reference / Speed = reference
When bit 08 = "0", the current speed of the motor deviates from the set speed reference value. This may occur, for example, when the speed is being changed during start/stop through ramp-up/down.
When bit 08 = "1", the current speed of the motor corresponds to the set speed reference value.

Bit 09, Local operation/Bus control
Bit 09 = "0" indicates that the adjustable frequency drive has been stopped by means of the stop button on the LCP, or that [Linked to hand] or [Local] has been selected in *3-13 Reference Site*.
When bit 09 = "1", the 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.

11

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 will start 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 Drives
4401 N. Bell School Rd.
Loves Park IL 61111 USA
Phone: 1-800-432-6367
1-815-639-8600
Fax: 1-815-639-8000
www.danfossdrives.com

Danfoss Drives
8800 W. Bradley Rd.
Milwaukee, WI 53224 USA
Phone: 1-800-621-8806
1-414-355-8800
Fax: 1-414-355-6117
www.danfossdrives.com

130R0301 MG33BD22 *MG33BD22* Rev. 2012-07-12