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1 How to Read this Design Guide

1.1.1 How to Read this Design Guide

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

Available literature for AutomationDrive FC 300

- The VLT AutomationDrive Instruction Manual MG.33.AX.YY provides the neccessary 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 the 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.

1.1.2 Symbols

Symbols used in this guide.

NOTE!
Indicates something to be noted by the reader.

Indicates a general warning.

Indicates a high-voltage warning.

*	Indicates a default setting

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1.1.3 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
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	s
Synchronous Motor Speed	n_s
Torque limit	T_{LIM}
Volt	V
The maximum output current	$I_{VLT,MAX}$
The rated output current supplied by the adjustable frequency drive	$I_{VLT,N}$

1.1.4 Definitions

Adjustable frequency drive:

Coast

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

$I_{VLT,MAX}$

The maximum output current.

$I_{VLT,N}$

The rated output current supplied by the adjustable frequency drive.

$U_{VLT,\ MAX}$

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

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 parameters 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).

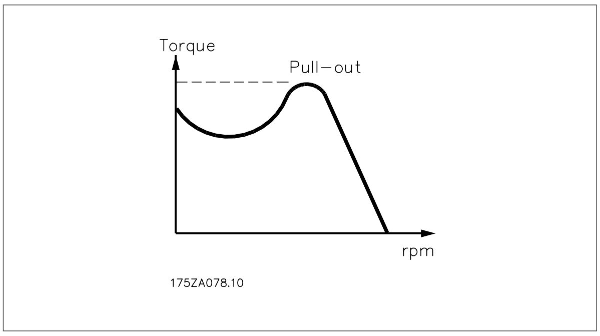
U_M

The instantaneous motor voltage.

$U_{M,N}$

The rated motor voltage (nameplate data).

Break-away torque



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η_{VLT}
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 0–10 V (FC 301 and FC 302) or -10–+10 V (FC 302) Current signal 0–20 mA or 4–20 mA

Binary Reference
A signal applied to the serial communication port (RS 485 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 10 V, 20 mA) and the resulting reference. The maximum reference value set in par. 3-03 *Maximum Reference*.

Ref_{MIN}
Determines the relationship between the reference input at 0% value (typically 0 V, 0 mA, 4 mA) and the resulting reference. The minimum reference value set in par. 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, 0–20 mA and 4–20 mA
Voltage input, 0–10 V DC (AutomationDrive FC 301)
Voltage input, -10–+10 V DC (AutomationDrive FC 302).

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

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

Brake Resistor
The brake resistor is a module capable of absorbing the 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 24 V DC (max. 40 mA) signal.

DSP
Digital Signal Processor.

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

Hiperface®

Hiperface® is a registered trademark by Stegmann.

Initializing

If initialization is carried out (par. 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 10 ft [3 m] 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 control and programming of 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 (par. 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. (Parameter group 13-xx Smart Logic Control (SLC).

STW

Status Word

FC Standard Bus

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

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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 harmonic contribution.

Trip

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

Trip Locked

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

VT Characteristics

Variable torque characteristics used for pumps and fans.

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 (par. 14-00 *Switching Pattern*).

Power Factor

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

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

The power factor for 3-phase control:

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

The power factor indicates to which extent the 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

2.1.1 Safety Precautions

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 damage to the equipment, serious personal injury or death. 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 driver 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 3.5 mA.
5. Protection against motor overload is not included in the factory setting. If this function is desired, set par. 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 24 V 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 *Safe Stop* section 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.

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 24 V 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.

Hoisting applications:
The adjustable frequency drive functions for controlling mechanical brakes cannot be considered as a primary safety circuit. There must always be a redundancy for controlling external brakes.

Protection Mode
Once a hardware limit on motor current or DC link voltage is exceeded, the 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 drive while re-establishing full control of the motor.
In hoist applications, “Protection mode” is not usable because the 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.
"Protection mode” can be disabled by setting par. 14-26 *Trip Delay at Inverter Fault* to zero, which means that the drive will trip immediately if one of the hardware limits is exceeded.

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

The DC link capacitors remain charged after power has been disconnected. 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
	125–275 hp [90–200 kW]	20 minutes
	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

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.

AutomationDrive FC 300

Design Guide

Software version: 5.5x

This Design Guide can be used for all AutomationDrive FC 300 adjustable frequency drives with software version 5.5x.

The software version number can be seen from par. 15-43 *Software Version*.

2.4.1 CE Conformity and Labeling

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 three EU directives:

The machinery directive (98/37/EEC)

All machines with critical moving parts are covered by the machinery directive of January 1, 1995. Since an adjustable frequency drive is largely electrical, it does not fall under the Machinery Directive. However, if an adjustable frequency drive is supplied for use in a machine, we provide information on its safety aspects in We do this by means of a manufacturer's declaration.

The low-voltage directive (73/23/EEC)

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 50–1000 V AC and the 75–1500 V DC voltage ranges. Danfoss CE-labels in accordance with the directive and issues a declaration of conformity upon request.

The EMC directive (89/336/EEC)

EMC is short for electromagnetic compatibility. The presence of electromagnetic compatibility means that the mutual interference between different components/appliances does not affect the way the appliances work.

The EMC directive came into effect on 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.

2.4.2 What Is Covered

The EU "*Guidelines on the Application of Council Directive 89/336/EEC*" outline three typical situations of using an adjustable frequency drive. See below for EMC coverage and CE labeling.

1. The adjustable frequency drive is sold directly to the end-consumer. For example, it may be 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 must 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.

2.4.3 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 an 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 issuesWe issue 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.

2.4.4 Compliance with EMC Directive 89/336/EEC

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-correct 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 122°F [50°C].

2.5.1 Aggressive Environments

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

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.

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 the presence of 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 reactions 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.

NOTE!
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

NOTE!
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 AutomationDrive FC 300

3.1 Product Overview

Frame size depends on enclosure type, power range and AC line voltage

Frame size		**A1**	**A2**	**A3**	**A5**
					
Enclosure	IP	20/21	20/21	20/21	55/66
protection	NEMA	Chassis/Type 1	Chassis/ Type 1	Chassis/ Type 1	Type 12
High overload rated power - 160% overload torque		0.22–2 hp [0.25–1.5 kW] (200–240 V) 0.5–2 hp [0.37–1.5 kW] (380–480 V)	0.34–4 hp [0.25–3 kW] (200–240 V) 0.5–5 hp [0.37–4.0 kW] (380–480/ 500 V) 1–5 hp [0.75–4 kW] (525–600 V)	5 hp [3.7 kW] (200–240 V) 7.5–10 hp [5.5–7.5 kW] (380–480/ 500 V) 7.5–10 hp [5.5–7.5 kW] (525–600 V)	0.33–5 hp [0.25–3.7 kW] (200–240 V) 0.5–10 hp [0.37–7.5 kW] (380–480/500 V) 1–10 hp [0.75–7.5 kW] (525–600 V)
Frame size		**B1**	**B2**	**B3**	**B4**
					
Enclosure	IP	21/55/66	21/55/66	20	20
protection	NEMA	Type 1/Type 12	Type 1/Type 12	Chassis	Chassis
High overload rated power - 160% overload torque		7.5–10 hp [5.5–7.5 kW] (200–240 V) 15–20 hp [11–15 kW] (380–480/ 500 V) 15–20 hp [11–15 kW] (525–600 V)	15 hp [11 kW] (200-250 V) 25–30 hp [18.5–22 kW] (380–480/ 500 V) 25–30 hp [18.5–22 kW] (525–600 V) 15–30 hp [11–22 kW] (525–690 V)	7.5–10 hp [5.5–7.5 kW] (200–240 V) 15–20 hp [11–15 kW] (380–480/500 V) 15–20 hp [11–15 kW] (525–600 V)	15–20 hp [11–15 kW] (200–240 V) 25–40 hp [18.5–30 kW] (380–480/ 500 V) 25–40 hp [18.5–30 kW] (525–600 V)

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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		25–30 hp [15–22 kW] (200–240 V) 40–60 hp [30–45 kW] (380–480/ 500 V) 40–60 hp [30–45 kW] (525–600 V)	40–50 hp [30–37 kW] (200–240 V) 75–100 hp [55–75 kW] (380–480/500 V) 75–125 hp [55–90 kW] (525–600 V) 40–100 hp [30–75 kW] (525–690 V)	25–30 hp [18.5–22 kW] (200–240 V) 50–60 hp [37–45 kW] (380–480/500 V) 50–60 hp [37–45 kW] (525–600 V)	40–50 hp [30–37 kW] (200–240 V) 75–100 hp [55–75 kW] (380–480/ 500 V) 75–125 hp [55–90 kW] (525–600 V)

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		125–150 hp [90–110 kW] at 400 V (380–500 V) 50–175 hp [37–132 kW] at 690 V (525–690 V)	175–300 hp [132–200 kW] at 400 V (380–500 V) 250–450 hp [160–315 kW] at 690 V (525–690 V)	125–150 hp [90–110 kW] at 400 V (380–500 V) 50–175 hp [37–132 kW] at 690 V (525–690 V)	175–300 hp [132–200 kW] at 400 V (380–500 V) 250–450 hp [160–315 kW] at 690 V (525–690 V)
Frame size		**E1**	**E2**	**F1/F3**	**F2/ F4**
					
Enclosure protection	IP	21/54	00	21/54	21/54
	NEMA	Type 1/ Type 12	Chassis	Type 1/ Type 12	Type 1/ Type 12
High overload rated power - 160% overload torque		350–550 hp [250–400 kW] at 400 V (380–500 V) 500–750 hp [355–560 kW] at 690 V (525–690 V)	350–550 hp [250–400 kW] at 400 V (380–500 V) 500–750 hp [355–560 kW] at 690 V (525–690 V)	600–850 hp [450–630 kW] at 400 V (380–500 V) 850–1075 hp [630–800 kW] at 690 V (525–690 V)	950–1075 hp [710–800] kW at 400 V (380–500 V) 1200–1350 hp [900–1000 kW] at 690 V (525–690 V)

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.

3.2.1 Control Principle

An adjustable frequency drive rectifies AC voltage from line into DC voltage, after which this 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 AutomationDrive FC 300 Controls

The adjustable frequency drive is capable of controlling either the speed or the torque on the motor shaft. Setting par. 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 par. 7-00 *Speed PID Feedback Source*.

Torque control (AutomationDrive 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 AutomationDrive FC 301 vs. AutomationDrive FC 302 Control Principle

AutomationDrive FC 301 is a general purpose adjustable frequency drive for variable speed applications. The control principle is based on Voltage Vector Control (VVC^{plus}).

AutomationDrive FC 301 can handle asynchronous motors only.

The current sensing principle in AutomationDrive 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 AutomationDrive 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.

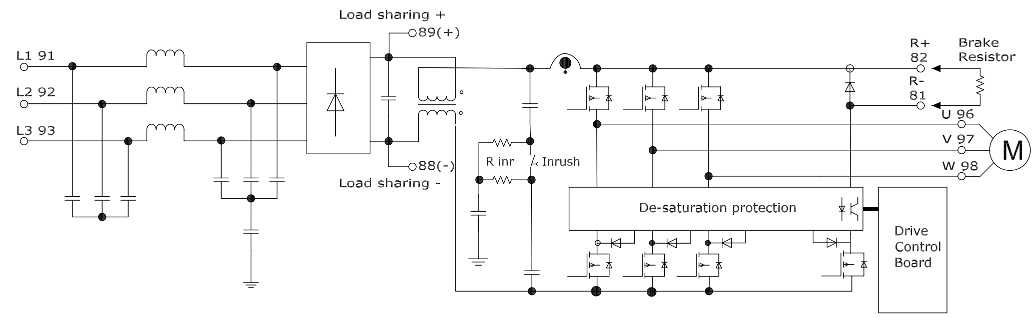


Figure 3.1: AutomationDrive FC 301

AutomationDrive 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.

AutomationDrive 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 AutomationDrive FC 302 depends on the 3 current transducers in the motor phases and the desaturation protection with feedback from the brake.

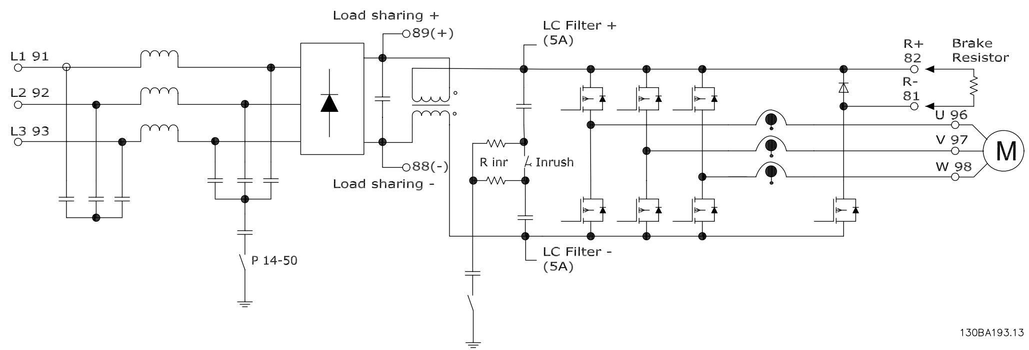
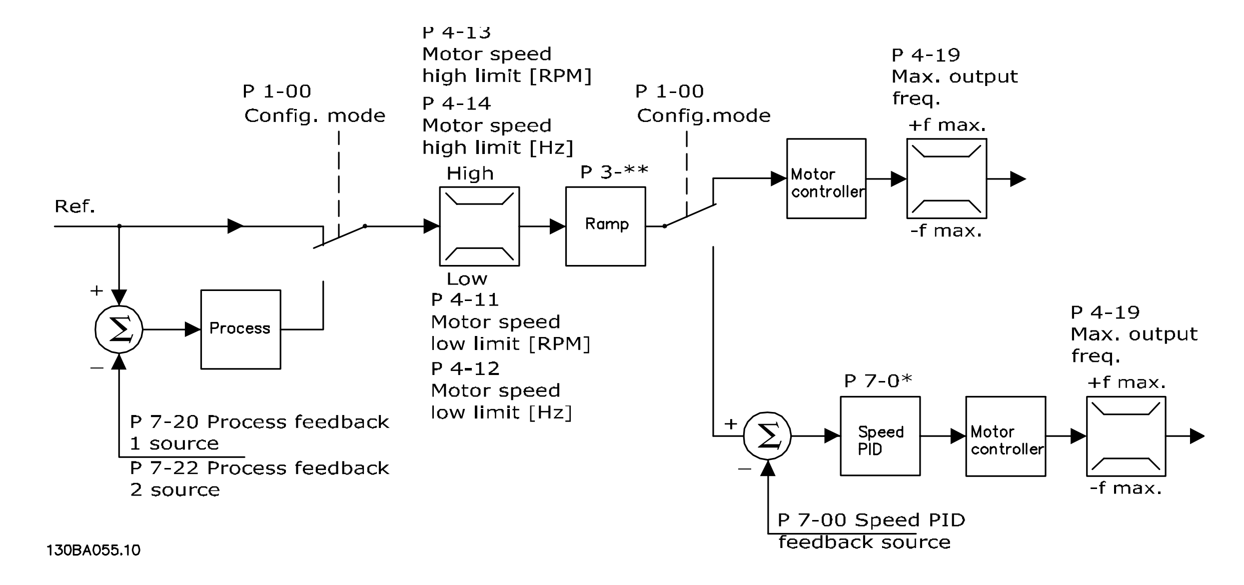


Figure 3.2: AutomationDrive FC 302

3.2.4 Control Structure in VVC^plus Advanced Vector Control

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



In the configuration shown in the figure above, par. 1-01 *Motor Control Principle* is set to "VVC^plus [1]" and par. 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.

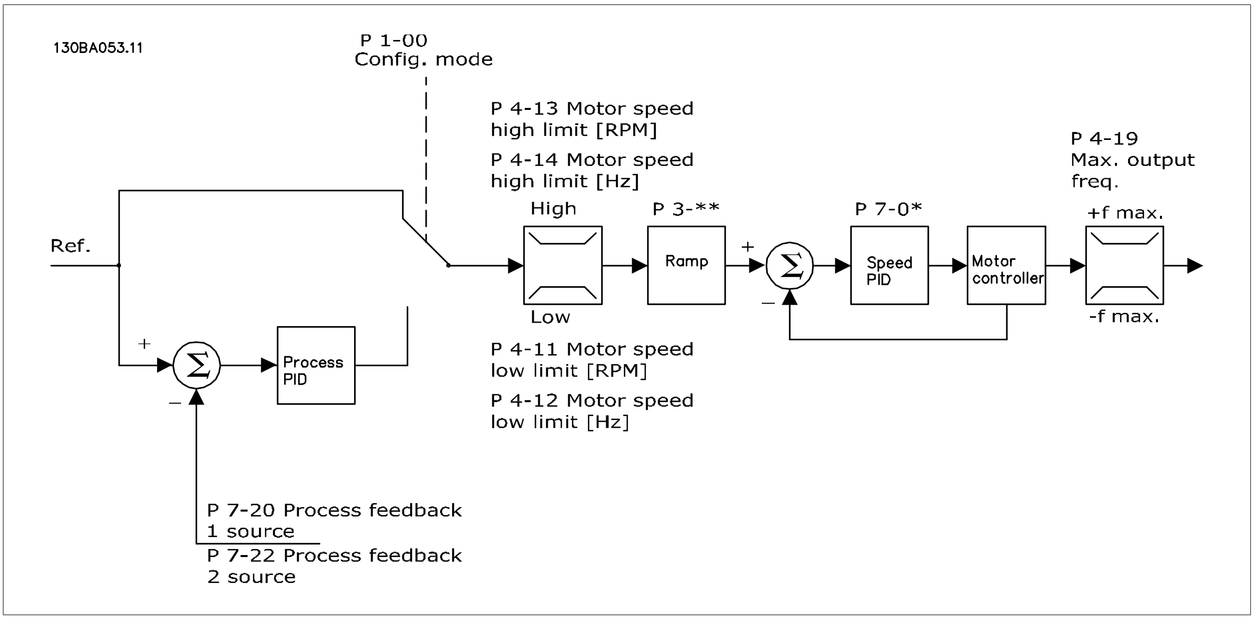
If par. 1-00 *Configuration Mode* is set to "Speed closed-loop [1]" the resulting reference will be passed from the ramp limitation and speed limitation into a speed PID control. The Speed PID control parameters are located in the par. group 7-0*. The resulting reference from the speed PID control is sent to the motor control limited by the frequency limit.

Select "Process [3]" in par. 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 par. group 7-2* and 7-3*.

3

3.2.5 Control Structure in Flux Sensorless (AutomationDrive FC 302 only)

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



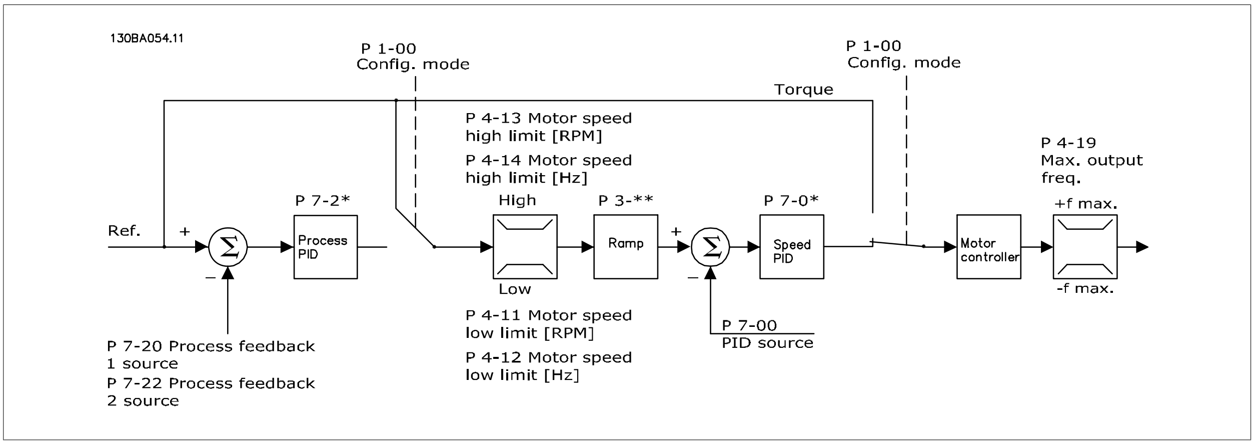
In the shown configuration, par. 1-01 *Motor Control Principle* is set to "Flux sensorless [2]" and par. 1-00 *Configuration Mode* is set to "Speed open-loop [0]". The resulting reference from the reference handling system is fed through the ramp and speed limitations as determined by the parameter settings 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 (par. group 7-0*).

Select "Process [3]" in par. 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 par. 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 AutomationDrive FC 302):



In the shown configuration, par. 1-01 *Motor Control Principle* is set to "Flux w motor feedb [3]" and par. 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 par. 1-02 *Flux Motor Feedback Source*).

Select "Speed closed-loop [1]" in par. 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 par. group 7-0*.

Select "Torque [2]" in par. 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* (par. 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 par. 1-00 *Configuration Mode* to use the process PID control for closed-loop control of, e.g., speed or a process variable in the controlled application.

3.2.7 Internal Current Control in VVC^{plus} Mode

The 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 par. 4-16 *Torque Limit Motor Mode*, par. 4-17 *Torque Limit Generator Mode* and par. 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 par. 0-40 *[Hand on] Key on LCP*, par. 0-41 *[Off] Key on LCP*, par. 0-42 *[Auto on] Key on LCP*, and par. 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 arrow key on the LCP.

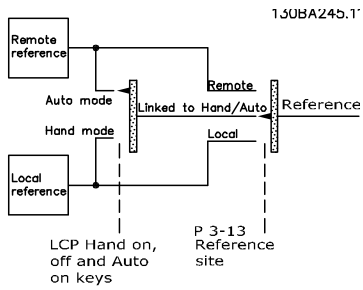
After pressing the [Auto On] key, the adjustable frequency drive goes into auto mode and follows (as default) the remote reference. In this mode, it is possible to control the adjustable frequency drive via the digital inputs and various serial interfaces (RS-485, USB, or an optional serial communication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

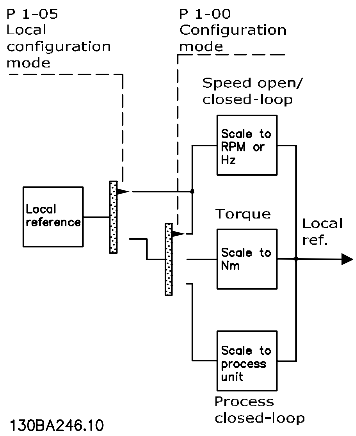
3

Active Reference and Configuration Mode

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

In par. 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).





Hand On Auto LCP Keys	par. 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

The table shows under which conditions either the local reference or the remote reference is active. One of them is always active, but both can not be active at the same time.

Par. 1-00 *Configuration Mode* determines what kind of application control principle (e.g., Speed, Torque or Process Control) is used when the remote reference is active (see table above for the conditions).

Par. 1-05 *Local Mode Configuration* determines the kind of application control principle that is used when the local reference is made active.

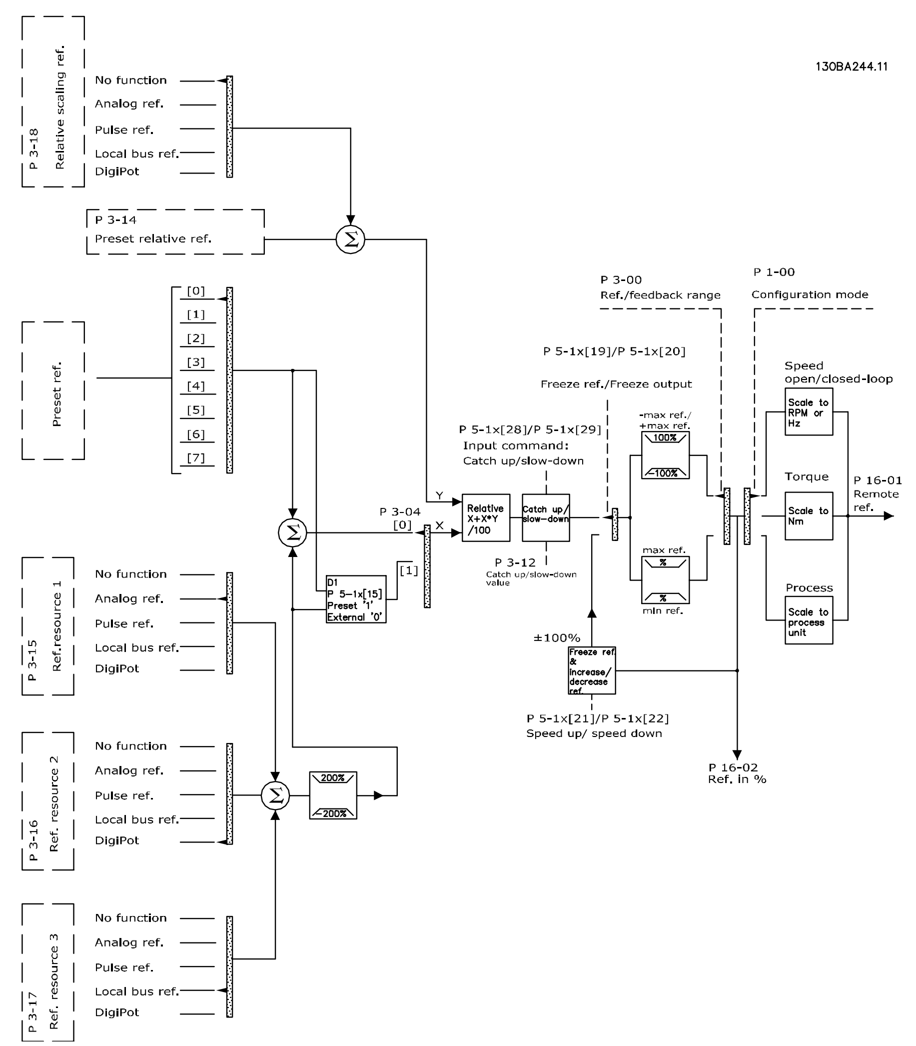
3.3 Reference Handling

Local Reference

The local reference is active when the drive is operated with 'Hand On' bottom 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 the figure below.



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

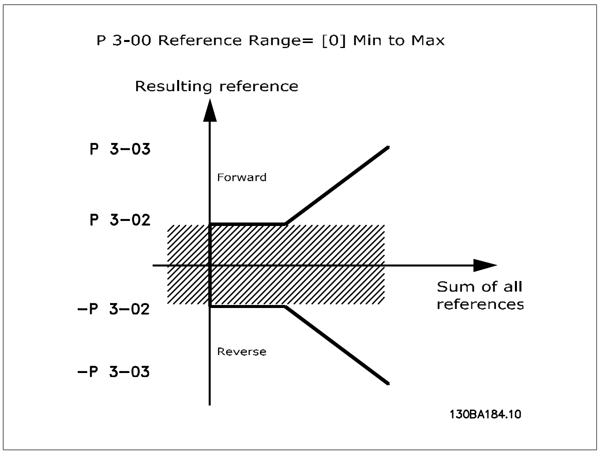
1. X (the external reference): A sum (see par. 3-04 *Reference Function*) of up to four externally selected references, comprising any combination (determined by the setting of par. 3-15 *Reference Resource 1*, par. 3-16 *Reference Resource 2* and par. 3-17 *Reference Resource 3*) of a fixed preset reference (par. 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.).

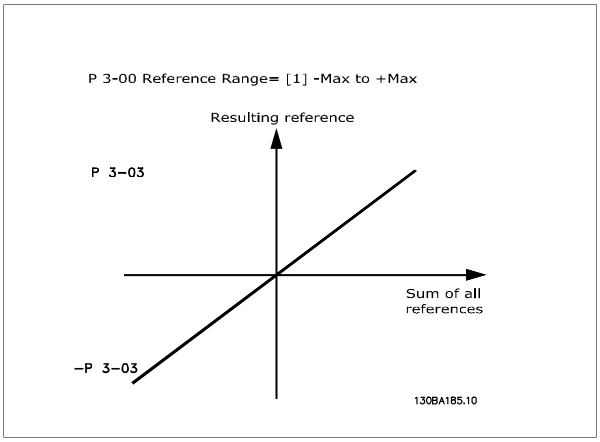
2. Y- (the relative reference): A sum of one fixed preset reference (par. 3-14 *Preset Relative Reference*) and one variable analog reference (par. 3-18 *Relative Scaling Reference Resource*) in [%].

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 par. groups 6-1* and 6-2*, and the scaling of digital pulse references are described in par. group 5-5*. Reference limits and ranges are set in par. group 3-0*.

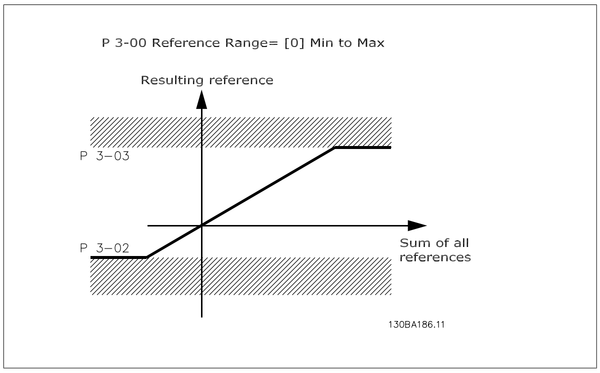
3.3.1 Reference Limits

Par. 3-00 *Reference Range* , par. 3-02 *Minimum Reference* and par. 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.





The value of par. 3-02 *Minimum Reference* cannot be set to less than 0, unless the par. 1-00 *Configuration Mode* is set to [3] Process. In this case, the subsequent relations between the resulting reference (after clamping) and the sum of all references are as shown to the right.



3.3.2 Scaling of Preset References and Bus References

Preset references are scaled according to the following rules:

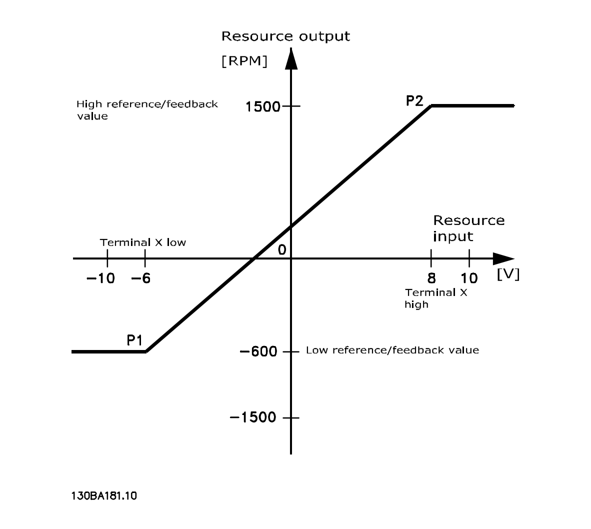
- When par. 3-00 *Reference Range* : [0] Min–Max 0% reference equals 0 [unit] where unit can be any unit, e.g., rpm, m/s, bar, etc. 100% reference equals the Max (abs (par. 3-03 *Maximum Reference*), abs (par. 3-02 *Minimum Reference*)).
- When par. 3-00 *Reference Range* : [1] -Max–+Max 0% reference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

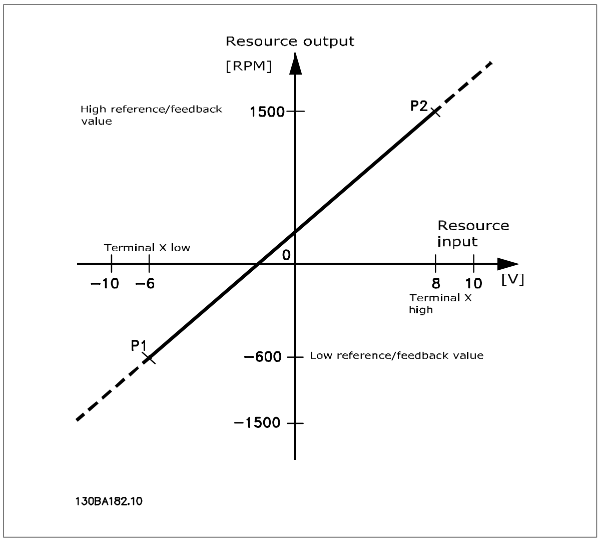
Bus references are scaled according to the following rules:

- When par. 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 par. 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 the graph below) are clamped, whereas a feedback above or below is not.





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

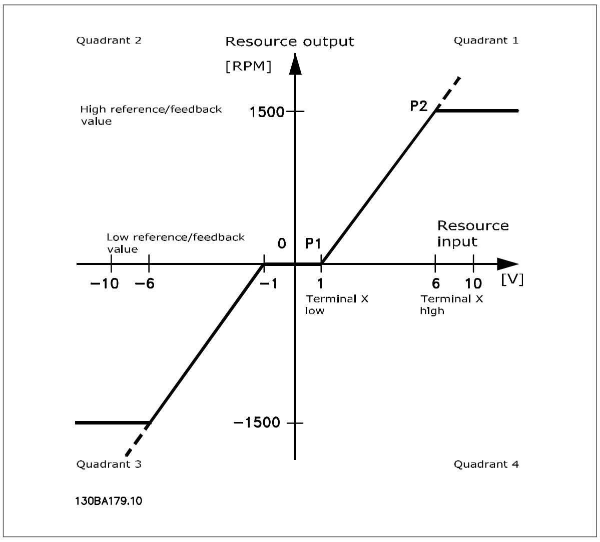
3.3.4 Dead Band Around Zero

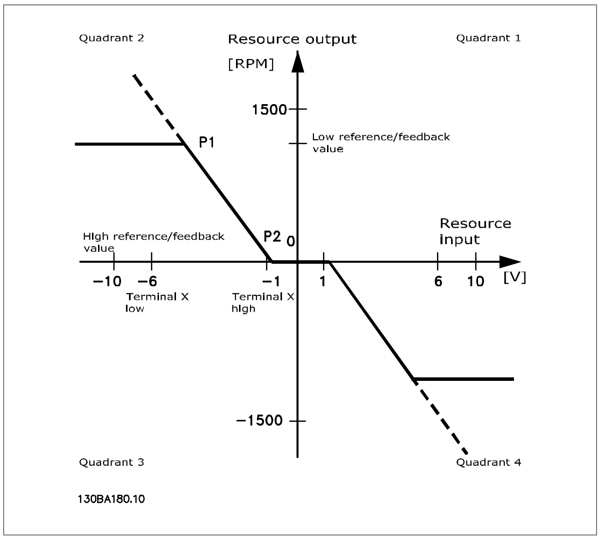
In some cases, the reference (in rare cases also the feedback) should have a Dead Band around zero (i.e., to make sure the machine is stopped when the reference is "near zero").

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 the graph below.

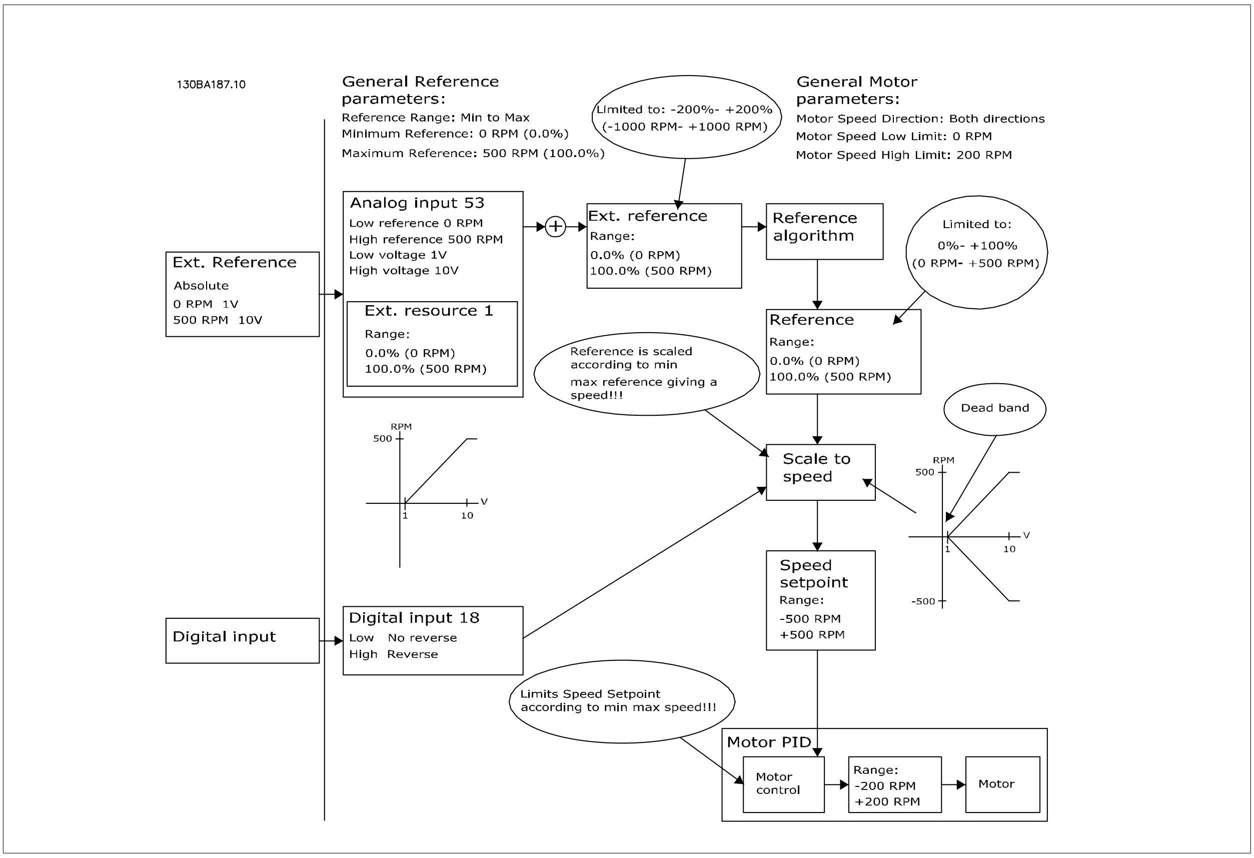




Thus, a reference endpoint of P1 = (0 V, 0 RPM) will not result in any dead band, but a reference endpoint of P1 = (1 V, 0 RPM), for example, will result in a -1 V to +1 V dead band in this case, provided that the end point P2 is placed in either quadrant 1 or quadrant 4.

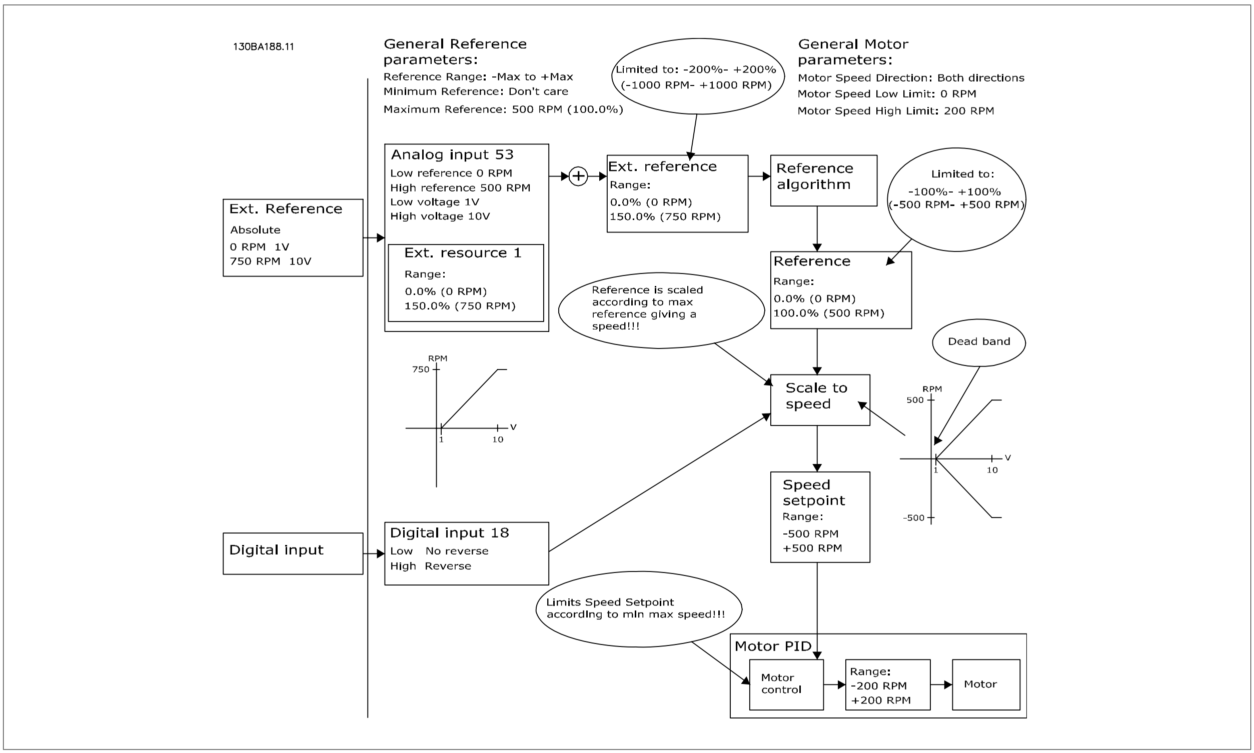
Case 1: Positive Reference with Dead band, Digital input to trigger reverse

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

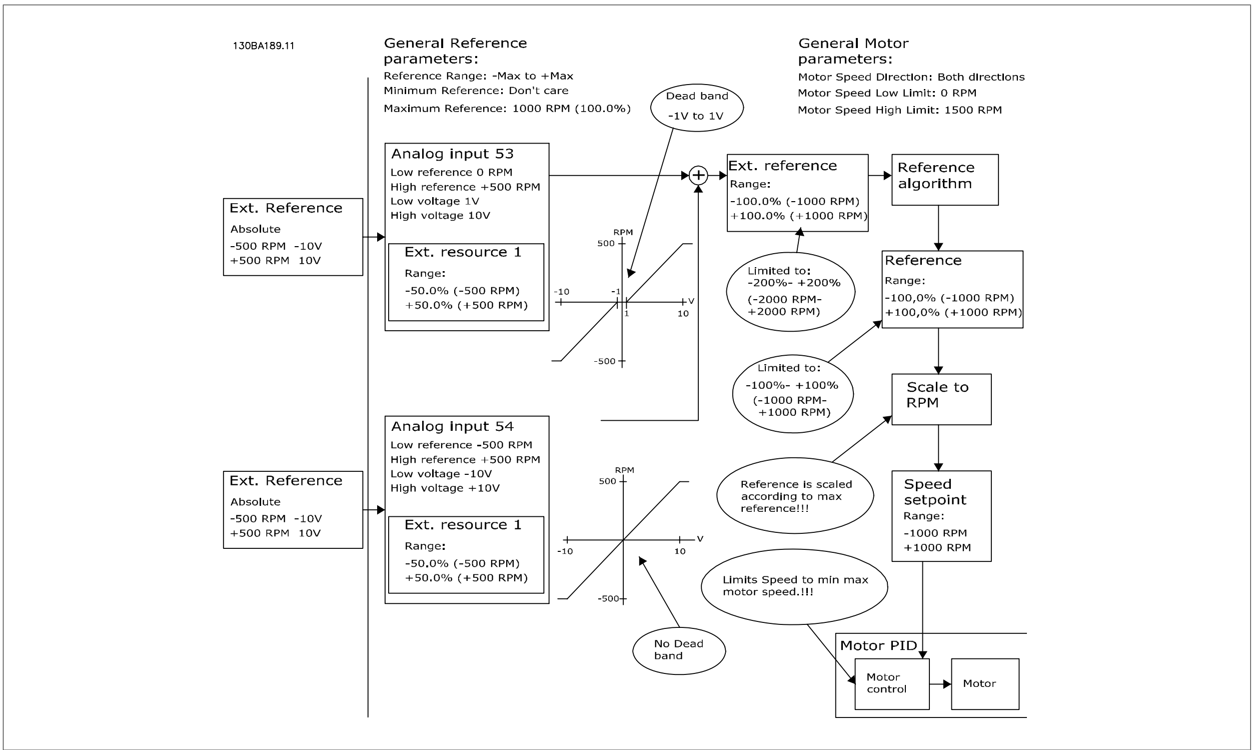


Case 2: Positive reference with dead band, digital input to trigger reverse. Clamping rules.

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.



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



3.4 PID Control

3.4.1 Speed PID Control

The table shows the control configurations where the Speed Control is active.

Par. 1-00 *Configuration Mode*	Par. 1-01 *Motor Control Principle* 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

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

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

The following parameters are relevant for the Speed Control:

Parameter	Description of function
Par. 7-00 *Speed PID Feedback Source*	Select from which input the speed PID should get its feedback.
Par. 7-02 *Speed PID Proportional Gain*	The higher the value, the quicker the control. However, too high value may lead to oscillations.
Par. 7-03 *Speed PID Integral Time*	Eliminates steady state speed error. Lower value means quick reaction. However, too high value may lead to oscillations.
Par. 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.
Par. 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.
Par. 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 7-06 taken from the number of pulses per revolution on from encoder (PPR):

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

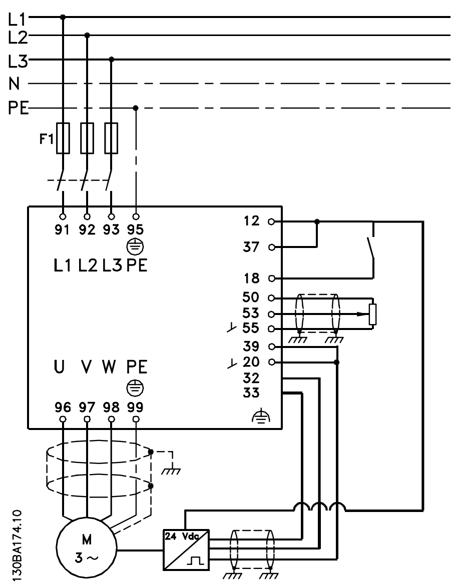
Below is an example of how to program the speed control:

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.



In the parameter list below, it is assumed that all other parameters and switches remain at their default setting.

The following must be programmed in the order shown - see an explanation of the settings in the Programming Guide.

Function	Par. 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	par. 1-29 *Automatic Motor Adaptation (AMA)*	[1] Enable complete AMA
2) Check that 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 par. 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 par. 16-20 *Motor Angle* is increasing or decreasing.	par. 16-20 *Motor Angle*	N.A. (read-only parameter) Note: An increasing value overflows at 65535 and starts again at 0.
If par. 16-20 *Motor Angle* is decreasing, then change the encoder direction in par. 5-71 *Term 32/33 Encoder Direction*.	par. 5-71 *Term 32/33 Encoder Direction*	[1] Counter clockwise (if par. 16-20 *Motor Angle* is decreasing)
3) Make sure the drive limits are set to safe values		
Set acceptable limits for the references.	par. 3-02 *Minimum Reference* par. 3-03 *Maximum Reference*	0 RPM (default) 1500 RPM (default)
Check that the ramp settings are within drive capabilities and allowed application operating specifications.	par. 3-41 *Ramp 1 Ramp-up Time* par. 3-42 *Ramp 1 Ramp-down Time*	default setting default setting
Set acceptable limits for the motor speed and frequency.	par. 4-11 *Motor Speed Low Limit [RPM]* par. 4-13 *Motor Speed High Limit [RPM]* par. 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	par. 1-00 *Configuration Mode*	[1] Speed closed-loop
Selection of Motor Control Principle	par. 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	par. 3-15 *Reference Resource 1*	Not necessary (default)
Scale Analog Input 53 0 RPM (0 V) 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	par. 5-14 *Terminal 32 Digital Input* par. 5-15 *Terminal 33 Digital Input*	[0] No operation (default)
Choose terminal 32/33 as motor feedback	par. 1-02 *Flux Motor Feedback Source*	Not necessary (default)
Choose terminal 32/33 as Speed PID feedback	par. 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	par. 0-50 *LCP Copy*	[1] All to LCP

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 par. 7-02 *Speed PID Proportional Gain* is dependent on the combined inertia of the motor and load, and the selected bandwidth can be calculated using the following formula:

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

Note: Par. 1-20 *Motor Power [kW]* is the motor power in [kW] (e.g., 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 par. 7-02 *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):

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

A good start value for par. 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 par. 5-70 *Term 32/33 Pulses per Revolution* (24V HTL on standard drive) or par. 17-11 *Resolution (PPR)* (5 V TTL on MCB102 Option).

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

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

Par. 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.

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

Note: The 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.

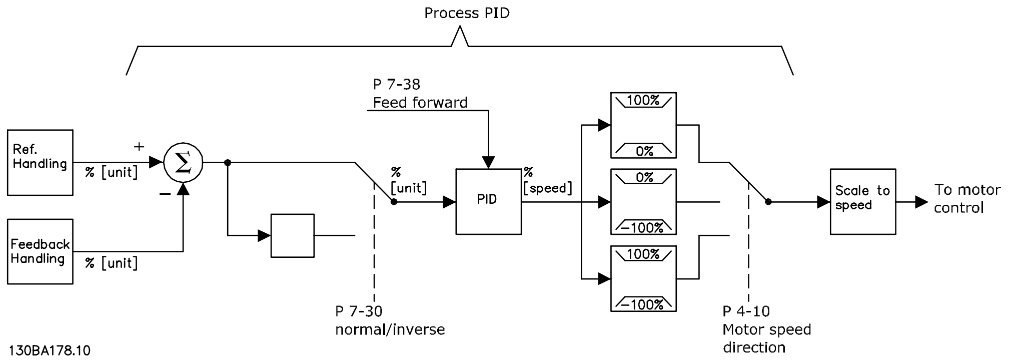


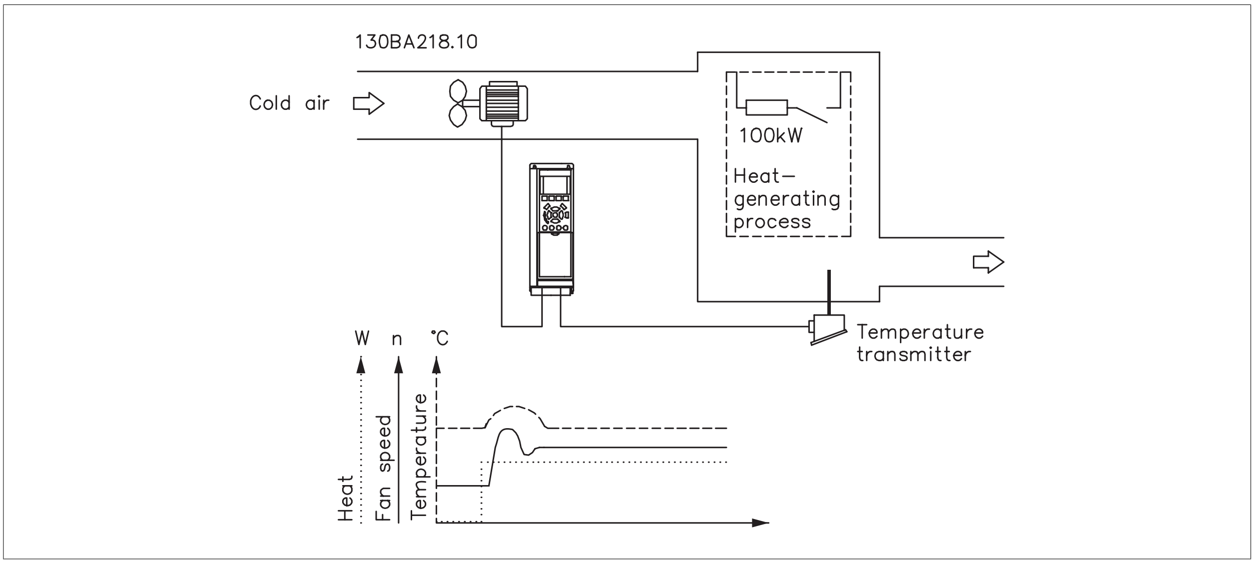
Figure 3.3: Process PID Control diagram

The following parameters are relevant for process control.

Parameter	Description of function
Par. 7-20 *Process CL Feedback 1 Resource*	Select from which source (i.e., analog or pulse input) the process PID should receive its feedback
Par. 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.
Par. 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.
Par. 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".
Par. 7-32 *Process PID Controller Start Value*	In some applications, reaching the required speed/setpoint 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 par. 7-32 *Process PID Controller Start Value*.
Par. 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.
Par. 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.
Par. 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.
Par. 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.
Par. 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.
Par. 5-54 *Pulse Filter Time Constant #29* (Pulse term. 29), par. 5-59 *Pulse Filter Time Constant #33* (Pulse term. 33), par. 6-16 *Terminal 53 Filter Time Constant* (Analog term 53), par. 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.

3.4.4 Example of Process PID Control

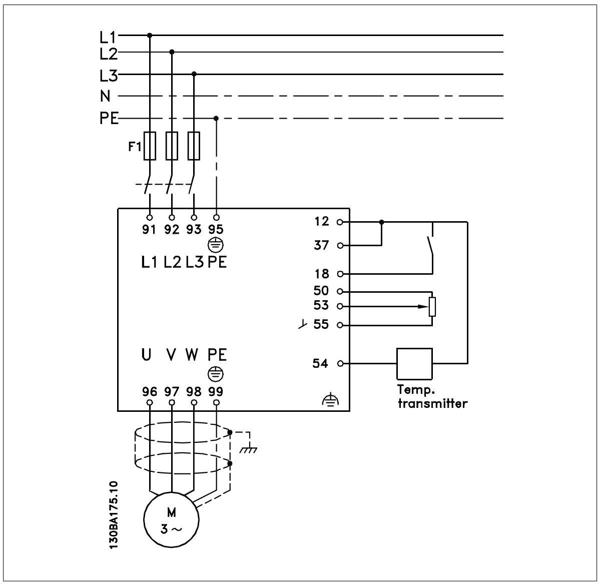
The following is an example of process PID control used in a ventilation system:



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 Volt. 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.

NOTE!
The example shows a 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).

Example of Process PID Control set-up

Function	Par. no.	Setting
Initialize the adjustable frequency drive	14-22	[2] Initialization - perform 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 **A**utomation **M**otor **A**daptation	1-29	[1] Enable complete AMA
2) Make sure that motor is running in the right direction. When motor is connected to 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 par. 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]°F [[60]°C] unit shown on display 23°F [-5°C] 95°F [35°C] [0] 35% $Ref = \frac{Par.\ 3-10_{(0)}}{100} \times ((Par.\ 3-03) - (par.\ 3-02)) = 24,5^{\circ}\ C$ par. 3-14 *Preset Relative Reference* to par. 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		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	0 V 10 V 23°F [-5°C] 95°F [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

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 (par. 7-33 *Process PID Proportional Gain*, par. 7-34 *Process PID Integral Time*, par. 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 par. 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 par. 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 par. 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.

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

3

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.

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

The criteria for adjusting the parameters are based on evaluating the system at the limit of stability rather than on taking a step response. We increase the proportional gain until we observe continuous oscillations (as measured on the feedback), that is, until the system becomes marginally stable. The corresponding gain *(K_u)* is called the ultimate gain. The period of the oscillation *(P_u)* (called the ultimate period) is determined as shown in Figure 1.

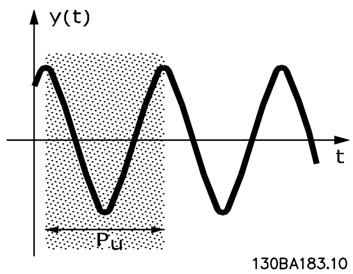


Figure 3.4: Figure 1: Marginally stable system

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 1: 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.

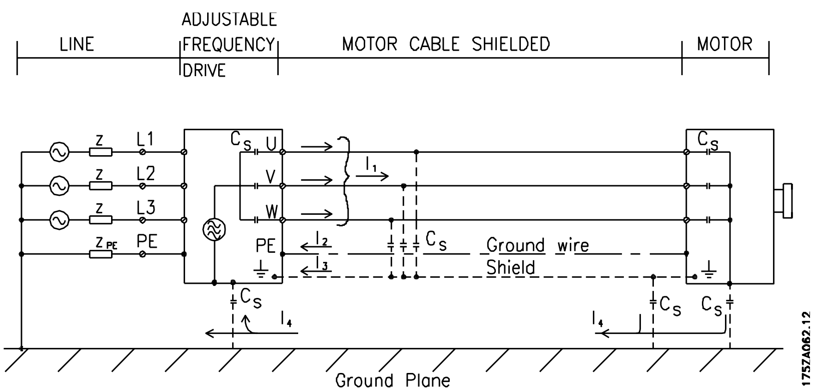
Step 4: Use the table above to calculate the necessary PID control parameters.

3.5 General Aspects of EMC

3.5.1 General Aspects of EMC Emissions

Electrical interference is usually conducted at frequencies in the range of 150 kHz to 30 MHz. Airborne interference from the drive system in the range 30 MHz to 1 GHz 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 dV/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 5 MHz. 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 the serial communication busserial 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.



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 driver chassis.

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

3

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

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						
AutomationDrive FC 301:	0–50 hp [0–37 kW] 200–240 V	32.8 ft [10 m]	164 ft [50 m]	246 ft [75 m]	No	Yes
	0–100 hp [0–75 kW] 380–480 V	32.8 ft [10 m]	164 ft [50 m]	246 ft [75 m]	No	Yes
AutomationDrive 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 [0–75 kW] 380–480 V	164 ft [50 m]	492 ft [150 m]	492 ft [150 m]	No	Yes
H2						
AutomationDrive FC 301/ AutomationDrive FC 302:	0–5 hp (0–3.7 kW) 200–240 V	No	No	5 m	No	No
	7.5–50 hp [5.5–37 kW] 200–240 V	No	No	82 in [25 m]	No	No
	0–10 hp (0–7.5 kW) 380–480 V	No	No	5 m	No	No
	15–100 hp [11–75 kW] 380–480 V	No	No	82 in [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] 525–690 V 1)	No	No	82 in [25 m]	No	No
	40–100 hp [30–75 kW] 525–690 V 2)	No	No	82 in [25 m]	No	No
	50 –1350 hp [37–1000 kW] 525–690 V3)	No	No	492 ft [150 m]	No	No
H3						
AutomationDrive FC 301:	0–2 hp [0–1.5 kW] 200–240 V	8.2 ft [2.5 m]	82 in [25 m]	164 ft [50 m]	No	Yes
	0–2 hp [0–1.5 kW] 380–480 V	8.2 ft [2.5 m]	82 in [25 m]	164 ft [50 m]	No	Yes
H4						
AutomationDrive 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] 525–690 V 1)	No	328 ft [100 m]	328 ft [100 m]	No	Yes
	40–100 hp [30–75 kW] 525–690 V 2)	No	492 ft [150 m]	492 ft [150 m]	No	Yes
	50– 450 hp [37–315 kW] 525–690 V3)	No	30 m	492 ft [150 m]	No	No
Hx						
AutomationDrive FC 302	1–100 hp [0.75–75 kW] 525–600 V	-	-	-	-	-

Table 3.1: 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 (600 V units only)

H1 - Integrated EMC filter. Fulfil EN 55011 Class A1/B and EN/IEC 61800-3 Category 1/2
H2 - No additional EMC filter. Fulfil EN 55011 Class A2 and EN/IEC 61800-3 Category 3
H3 - Integrated EMC filter. Fulfil EN 55011 class A1/B and EN/IEC 61800-3 Category 1/2 (Frame size A1 only)
H4 - Integrated EMC filter. Fulfil EN 55011 class A1 and EN/IEC 61800-3 Category 2

3.5.3 Emission Requirements

According to the EMC product standard for adjustable speed adjustable frequency drives EN/IEC61800-3:2004, 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 the table below:

Category	**Definition**	**Conducted emission requirement according to the limits given in EN55011**
C1	adjustable frequency drives installed in the first environment (home and office) with a supply voltage less than 1,000 V.	Class B
C2	adjustable frequency drives installed in the first environment (home and office) with a supply voltage of less than 1000 V, which are neither plug-in nor movable and are intended to be installed and commissioned by a professional.	Class A Group 1
C3	adjustable frequency drives installed in the second environment (industrial) with a supply voltage lower than 1,000 V.	Class A Group 2
C4	Adjustable frequency drives installed in the second environment with a supply voltage equal to or above 1000 V or rated current equal to or above 400 A or intended for use in complex systems.	No limit line. An EMC plan should be made.

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 EN55011**
First environment (home and office)	EN/IEC61000-6-3 Emission standard for residential, commercial and light industrial environments.	Class B
Second environment (industrial environment)	EN/IEC61000-6-4 Emission standard for industrial environments.	Class A Group 1

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 an 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.

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- 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 following EMC immunity form.

Voltage range: 200–240 V, 380–480 V

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

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

Table 3.2: Immunity

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 400 V).

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

The components that make up the electrical isolation, 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):

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.

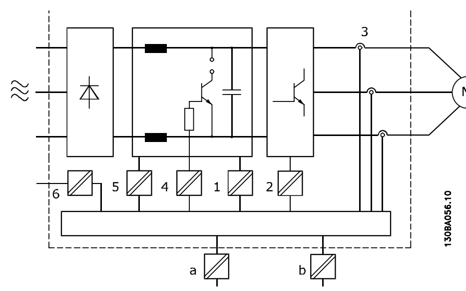


Figure 3.5: Galvanic isolation

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

Installation at high altitude:
380–500 V, enclosure A, B and C: At altitudes above 6,500 ft [2 km], please contact Danfoss regarding PELV.
380–500 V, enclosure D, E and F: At altitudes above 10,000 ft [3 km], please contact Danfoss regarding PELV.
525–690 V: At altitudes above 6,500 ft [2 km], please contact Danfoss regarding PELV.

Warning:
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 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.

Leakage Current
The ground leakage current from the adjustable frequency drive exceeds 3.5 mA. To ensure that the ground cable has a good mechanical connection to the ground connection (terminal 95), the cable cross-section must be at least 3.9 in^2 [10 mm^2] or two rated ground wires terminated separately.
Residual Current Device
This product can cause DC current in the protective conductor. Where a residual current device (RCD) is used for protection in case of direct or indirect contact, only an RCD of Type B is allowed on the supply side of this product. Otherwise, another protective measure shall be applied, such as separation from the environment by double or reinforced insulation, or isolation from the supply system by a transformer. See also RCD Application Note MN.90.GX.02.
Protective grounding of the adjustable frequency drive and the use of RCDs must always follow national and local regulations.

3.8 Brake Functions in AutomationDrive 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).

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

3.8.3 Selection of Brake Resistor

To handle higher demands by generatoric braking, a brake resistor is necessary. Using a brake resistor ensures that the energy is absorbed in the brake resistor and not in the adjustable frequency drive.

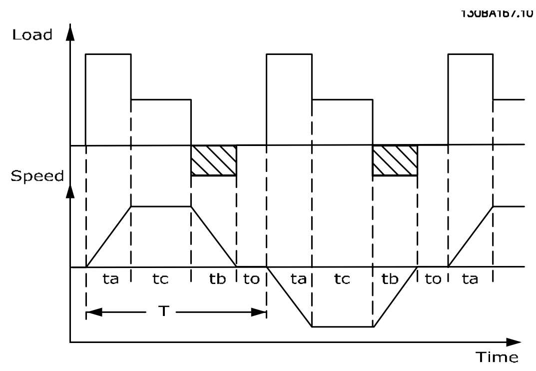
If the amount of kinetic energy transferred to the resistor in each braking period is not known, the average power can be calculated on the basis of the cycle time and braking time, also known as the intermitted duty cycle. The resistor intermittent duty cycle is an indication of the duty cycle at which the resistor is active. The below figure shows a typical braking cycle.

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

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

$Duty\ cycle = t_b/T$

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



	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 3.3: Braking at High overload torque level

1) 675 hp [500 kW] at 86% braking torque
750 hp [560 kW] at 76% braking torque
2) 675 hp [500 kW] at 130% braking torque
750 hp [560 kW] at 115% braking torque

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

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

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

The brake resistance is calculated as shown:

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

where

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

3

As can be seen, the brake resistance depends on the intermediate circuit voltage (U_{dc}).
The AutomationDrive FC 301 and AutomationDrive FC 302 brake function is settled in 4 areas of line power:

Size	Brake active	Warning before cut out	Cut out (trip)
AutomationDrive FC 301 / AutomationDrive FC 302 3 x 200–240 V	390 V (UDC)	405 V	410 V
AutomationDrive FC 301 3 x 380–480 V	778 V	810 V	820 V
AutomationDrive FC 302 3 x 380–500 V*	810 V/ 795 V	840 V/ 828 V	850 V/ 855 V
AutomationDrive FC 302 3 x 525–600 V	943 V	965 V	975 V
AutomationDrive FC 302 3 x 525–690 V	1084 V	1109 V	1130 V

* Power size dependent

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

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

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

η_{motor} is typically at 0.90

η_{VLT} is typically at 0.98

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

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

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

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

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

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

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

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

2) For adjustable frequency drives with 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.

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 par. 2-12 *Brake Power Limit (kW)*. In par. 2-13 *Brake Power Monitoring*, select the function to carry out when the power transmitted to the brake resistor exceeds the limit set in par. 2-12 *Brake Power Limit (kW)*.

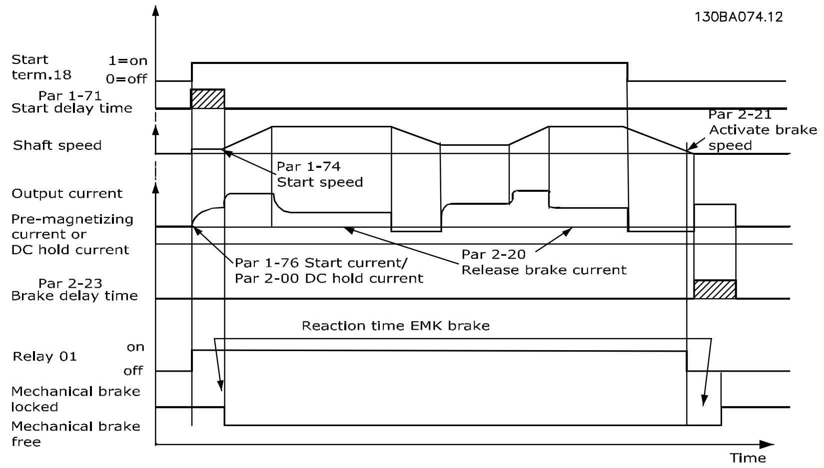
NOTE!
Monitoring the braking energy is not a safety function; a thermal switch is required for that purpose. The brake resistor circuit is not protected against ground leakage.

Overvoltage control (OVC) (exclusive brake resistor) can be selected as an alternative brake function in par. 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 par. 5-40 *Function Relay* (Array parameter), par. 5-30 *Terminal 27 Digital Output*, or par. 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 par. 2-20 *Release Brake Current*. During stop, the mechanical brake will close when the speed is below the level selected in par. 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.



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 par. 5-4* (or in par. 5-3*) before connecting the mechanical brake.
- The brake is released when the motor current exceeds the preset value in par. 2-20 *Release Brake Current*.
- The brake is engaged when the output frequency is less than the frequency set in par. 2-21 *Activate Brake Speed [RPM]* or par. 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 par. 4-16 *Torque Limit Motor Mode* and par. 4-17 *Torque Limit Generator Mode* are set lower than the current limit in par. 4-18 *Current Limit*. Also it is recommendable to set par. 14-25 *Trip Delay at Torque Limit* to "0", par. 14-26 *Trip Delay at Inverter Fault* to "0" and par. 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 par. 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 par. 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

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 par. 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 par. 2-26 *Torque Ref*, the brake is released. The value set in par. 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.

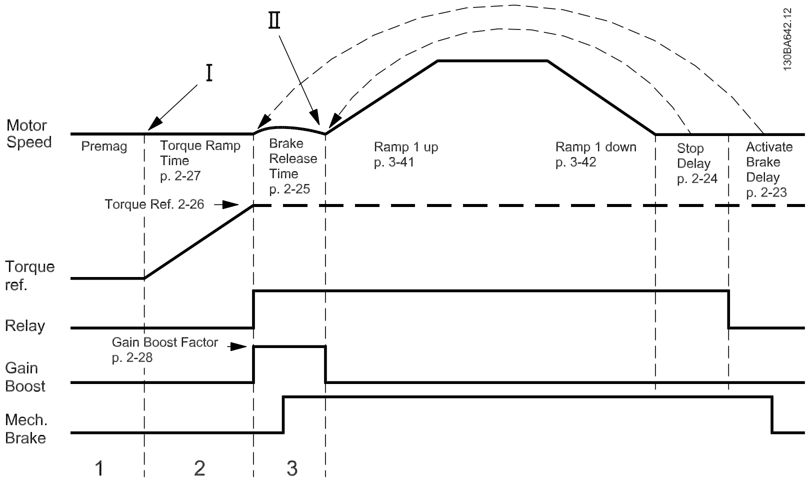


Figure 3.6: Brake release sequence for hoist mechanical brake control

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 par. 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.

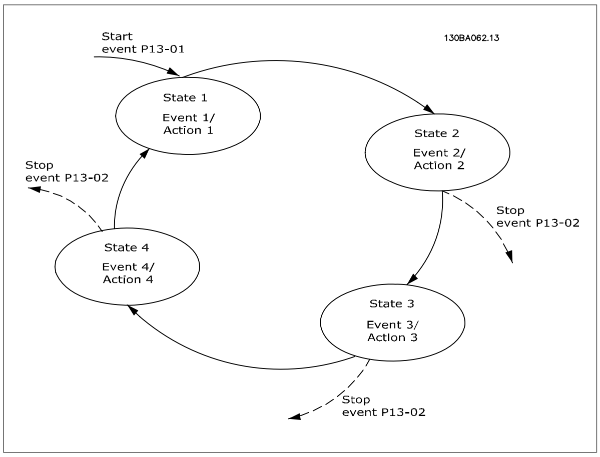
For enhanced EMC performance, a metal shield can be used.

3.10 Smart Logic Controller - AutomationDrive FC 300

The Smart Logic Control (SLC) is essentially a sequence of user defined actions (see par. 13-52 *SL Controller Action*) executed by the SLC when the associated user defined *event* (see par. 13-51 *SL Controller Event*) is evaluated as TRUE by the SLC.
Events and *actions* are each numbered and are linked in pairs called states. This means that when *event [1]* is fulfilled (attains the value TRUE), *action [1]* is executed. After this, the conditions of *event [2]* will be evaluated and if evaluated TRUE, *action [2]* will be executed and so on. Events and actions are placed in array parameters.

Only one *event* will be evaluated at any time. If an *event* is evaluated as FALSE, nothing happens (in the SLC) during the present scan interval and no other *events* will be evaluated. This means that when the SLC starts, it evaluates *event [1]* (and only *event [1]*) each scan interval. Only when *event [1]* is evaluated TRUE, the SLC executes *action [1]* and starts evaluating *event [2]*.

It is possible to program from 0 to 20 *events* and *actions*. When the last *event / action* has been executed, the sequence starts over again from *event [1] / action [1]*. The figure shows an example with three *events / actions*.



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.

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.

The control unit may attempt to correct the ramp if possible (par. 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 par. 2-10 *Brake Function* and par. 2-17 *Over-voltage Control* to select the method used for controlling the intermediate circuit voltage level.

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 par. 4-16 *Torque Limit Motor Mode*/par. 4-17 *Torque Limit Generator Mode* is reached), the controls reduces the output frequency to reduce the load.
If the overload is excessive, a current may occur that makes the adjustable frequency drive cut out after approximately 5-10 s.

Operation within the torque limit is limited in time (0–60 s) in par. 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 par. 4-16 *Torque Limit Motor Mode* and or par. 4-17 *Torque Limit Generator Mode* and the time before the torque limit warning shall trip is controlled in par. 14-25 *Trip Delay at Torque Limit*.

Current Limit: The current limit is controlled in par. 4-18 *Current Limit* and the time before the current limit warning shall trip is controlled in par. 14-24 *Trip Delay at Current Limit*.

Min Speed Limit: (par. 4-11 *Motor Speed Low Limit [RPM]* or par. 4-12 *Motor Speed Low Limit [Hz]*) limit the operating speed range to for instance between 30 and 50/60 Hz. Max Speed Limit: (par. 4-13 *Motor Speed High Limit [RPM]* or par. 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:

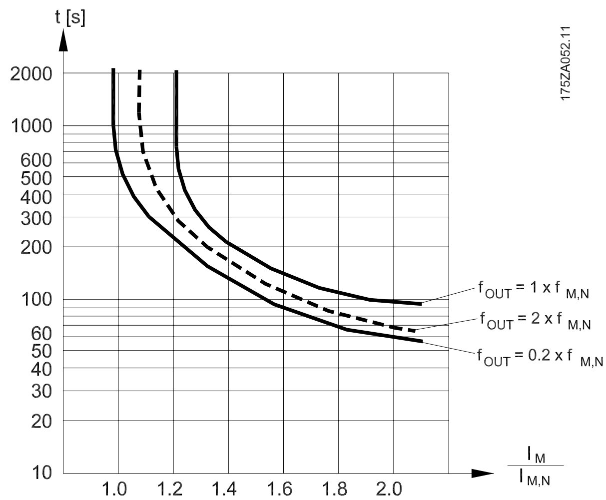


Figure 3.7: Figure ETR: The X-axis shows the ratio between I_{motor} and I_{motor} nominal. The Y-axis shows the time in seconds before the ETR cuts off and trips the drive. The curves show the characteristic nominal speed, at twice the nominal speed and at 0.2 x the nominal speed. At lower speed the 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 par. 16-18 *Motor Thermal* in the AutomationDrive FC 300.

3

3.12 Safe Stop of AutomationDrive FC 300

The AutomationDrive FC 302, and also the AutomationDrive FC 301 in A1 enclosure, can perform the safety function *Safe Torque Off* (As defined by IEC 61800-5-2) or *Stop Category 0* (as defined in EN 60204-1).

AutomationDrive FC 301 A1 enclosure: When safe stop is included in the drive, position 18 of Type Code must be either T or U. If the position 18 is B or X, the Safe Stop Terminal 37 is not included!
Example:
Type Code for FC 301 A1 with safe stop: FC-301PK75T4**Z20**H4**T**GCXXXSXXXXA0BXCXXXXD0

It is designed and approved as suitable for the requirements of:

- Safety Category 3 in EN 954-1 (and ISO EN 13849-1)
- Performance Level "d" in ISO EN 13849-1
- SIL 2 Capability in IEC 61508 and EN 61800-5-2
- SILCL 2 in EN 61062

This functionality is called 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.

After installing safe stop, a commissioning test as specified in section *Safe Stop Commissioning Test* of the Design Guide must be performed. A passed commissioning test is mandatory for fulfilling Safety Cat. 3 (EN 954-1) / PL "d" (ISO 13849-1)

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

Performance Level "d":

- MTTFD (Mean Time To Dangerous Failure): 24816 years
- DC (Diagnostic Coverage): 99.99%
- Category 3

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 (1oo1D architecture)

Abbreviations related to Functional Safety

Abbreviation	Reference	Description
Cat.	EN 954-1	Safety category, levels 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 dangerous Failure: (The total number of life units) / (the number of dangerous, undetected failures), during particular measurement interval under stated conditions
PFHd	IEC 61508	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 or greater than twice the frequency of testing. 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 or greater than twice the frequency of testing.
PL	EN ISO 13849-1	Performance Level: Corresponds SIL, 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

Prüf- und Zertifizierungsstelle
im BG-PRÜFZERT

BGIA
Berufsgenossenschaftliches Institut für Arbeitsschutz

Hauptverband der gewerblichen Berufsgenossenschaften

Translation
In any case, the German original shall prevail.

Type Test Certificate

05 06004
No. of certificate

Name and address of the holder of the certificate: (customer)	Danfoss Drives A/S, Ulnaes 1 DK-6300 Graasten, Dänemark
Name and address of the manufacturer:	Danfoss Drives A/S, Ulnaes 1 DK-6300 Graasten, Dänemark

Ref. of customer:	Ref. of Test and Certification Body: Apf/Köh VE-Nr. 2003 23220	Date of Issue: 13.04.2005

Product designation:	Frequency converter with integrated safety functions
Type:	VLT® Automation Drive FC 302
Intended purpose:	Implementation of safety function „Safe Stop“
Testing based on:	EN 954-1, 1997-03, DKE AK 226.03, 1998-06, EN ISO 13849-2; 2003-12, EN 61800-3, 2001-02, EN 61800-5-1, 2003-09,
Test certificate:	No.: 2003 23220 from 13.04.2005
Remarks:	The presented types of the frequency converter FC 302 meet the requirements laid down in the test bases. With correct wiring a category 3 according to DIN EN 954-1 is reached for the safety function.

The type tested complies with the provisions laid down in the directive 98/37/EC (Machinery).

Further conditions are laid down in the Rules of Procedure for Testing and Certification of April 2004.

130BA373.11

Head of certification body
(Prof. Dr. rer. nat. Dietmar Reinert)

Certification officer
(Dipl.-Ing. R. Apfeld)

PZB10E
01.05

Postal adress:
53754 Sankt Augustin

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53757 Sankt Augustin

Phone: 0 22 41/2 31-02
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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:

TÜV NORD Certification
Safety Approved

FC 102
FC 202
FC 301 A1
FC 302
with STO function

EN ISO 13849-1:2006
PL „d"
IEC 61508-1:1998 and
Corrrigendum 1999;
IEC 61508-2:2000;
SIL2 capability
IEC 62061:2005
SILCL2 capability
EN 954-1:1996
Category 3;

SAS1724/07
Voluntary Certification

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

08

130BB178.10

3.12.1 Safe Stop Installation - AutomationDrive FC 302 only (and AutomationDrive FC 301 in Frame Size A1)

To carry out an installation of a Category 0 Stop (EN60204) in conformance with Safety Cat. 3 (EN 954-1) / PL "d" (ISO 13849-1), follow these instructions:

1. The bridge (jumper) between Terminal 37 and 24 V DC must be removed. Cutting or breaking the jumper is not sufficient. Remove it entirely to avoid short-circuiting. See jumper on figure.
2. Connect terminal 37 to 24 V DC by a short circuit-protected cable. The 24 V DC voltage supply must be interruptible by a Cat. 3 (EN 954-1) / PL "d" (ISO 13849-1) circuit interrupt device. If the interrupt device and the adjustable frequency drive are placed in the same installation panel, you can use a regular cable instead of a protected one.
3. The safe stop function only fulfills Cat. 3 (EN 954-1) / PL "d" (ISO 13849-1) if particular protection against, or avoidance of, conductive contamination is provided. Such a protection is achieved by using AutomationDrive FC 302 with protection class IP54 or higher. If AutomationDrive FC 302 with lower protection (or AutomationDrive FC 301 A1, which is only delivered with an IP21 enclosure) are used, then an operating environment corresponding to the inside of an IP54 encapsulation must be ensured. If there is a risk of conductive contamination in the operating environment, an obvious solution,would be to mount the devices in a cabinet that provides IP54 protection.

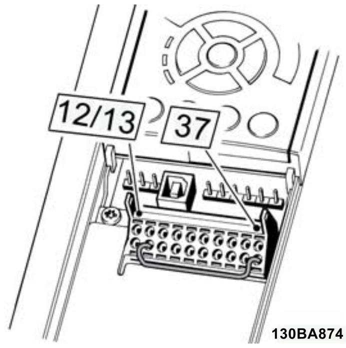


Figure 3.8: Bridge jumper between terminal 37 and 24 VDC

The figure below shows a Stopping Category 0 (EN 60204-1) with Safety Cat. 3 (EN 954-1) / PL "d" (ISO 13849-1). The circuit interrupt is caused by an opening door contact. The figure also shows how to connect a non-safety related hardware coast.

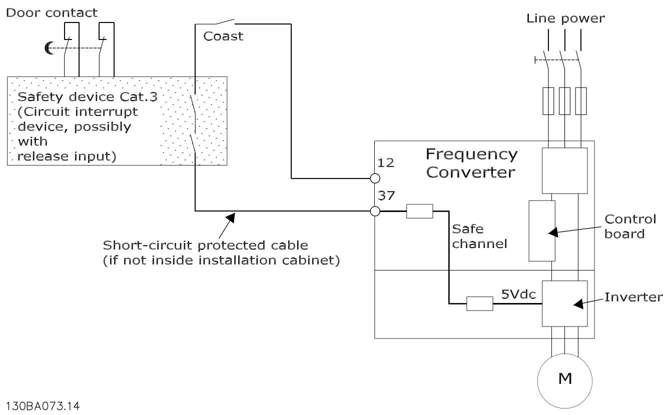


Figure 3.9: Figure of the essential aspects of an installation to achieve a Stopping Category 0 (EN 60204-1) with Safety Cat. 3 (EN 954-1) / PL "d" (ISO 13849-1).

Activation and Termination of Safe Stop

The safe stop 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 relay, an installation for a safe Stop Category 1 can be obtained. The Safe Stop function of AutomationDrive FC 302 can be used for asynchronous and synchronous motors.

Safe stop activation (i.e., removal of 24 V DC voltage supply to terminal 37) does not provide electrical safety.

1. Activate the Safe Stop function by removing the 24 V 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 shorter than 10 ms for the complete performance range of AutomationDrive FC 302. For AutomationDrive FC 302 up to 10 hp [7.5 kW], it is even shorter than 5 ms.

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). After activation of Safe Stop, the AutomationDrive 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 24 V DC supply to terminal 37 is kept removed or low by a safety device which itself fulfills Cat. 3 (EN 954-1) / PL “d” (ISO 13849-1).

In order to resume operation after Safe Stop is activated, 24 V DC voltage must first 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 the inverter).

By default, the safe stop function is set to unintended restart prevention behavior. This means that in order to terminate the safe stop and resume normal operation, the 24 V DC must first 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 par. 5-19 *Terminal 37 Safe Stop* from default value [1] to value [3]. If an MCB112 option is connected to the drive, 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 24 V DC are applied to Terminal 37, no reset signal is required.

IMPORTANT! 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, the following paragraphs of standards under the EU Machinery Directive must be observed: 5.2.1, 5.2.2, and 5.2.3. of EN954-1:1996 (or ISO 13849-1:2006), 4.11.3 and 4.11.4 of EN292-2 (ISO 12100-2:2003).

3.12.2 Installation of External Safety Device in Combination with MCB112

If the ex-certified thermistor module MCB112 which uses Terminal 37 as its safety-related switch-off channel, is connected, then the output X44/12 of MCB112 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 MCB112 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 EN 954-1, Safety Category 3. 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 below:

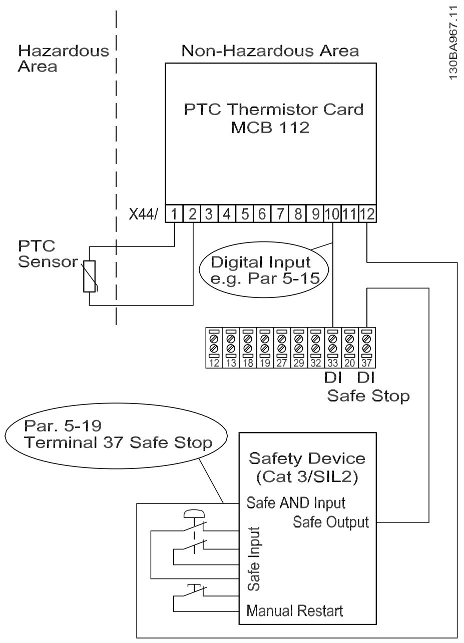


Figure 3.10: Figure of the essential aspects for installing a combination of a safe stop application and a MCB112 application. The diagram shows a Restart input for the external Safety Device. This means that in this installation, par. 5-19 *Terminal 37 Safe Stop* might be set to value [7] or [8].

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, the following paragraphs of standards under the EU Machinery Directive must be observed: 5.2.1, 5.2.2, and 5.2.3. of EN954-1:1996 (or ISO 13849-1:2006), 4.11.3 and 4.11.4 of EN292-2 (ISO 12100-2:2003).

See section Application Examples 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 AutomationDrive FC 300 Safe Stop.
Moreover, perform the test after each modification of the installation or application, of which the AutomationDrive FC 300 Safe Stop is a part.

NOTE!
Passing a commissioning test is mandatory for fulfilling Safety Category 3 by this type of installation or application.

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 par. 5-19 *Terminal 37 Safe Stop* is set to default value [1], or combined Safe Stop and MCB112 where par. 5-19 *Terminal 37 Safe Stop* is set to [6] or [9]):

1. Remove the 24 V DC voltage supply to terminal 37 by the interrupt device while the motor is driven by the AutomationDrive FC 302 (i.e., 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.
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.
3. Reapply 24 V DC to terminal 37. The test step is passed if the motor remains in the coasted state, and the mechanical brake (if connected) remains activated. Step 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 par. 5-19 *Terminal 37 Safe Stop* is set to [3], or combined Safe Stop and MCB112 where par. 5-19 *Terminal 37 Safe Stop* is set to [7] or [8]):

1. Remove the 24 V DC voltage supply to terminal 37 by the interrupt device while the motor is driven by the AutomationDrive FC 302 (i.e., 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. 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.
3. Reapply 24 V DC to terminal 37.

The test step is passed if the motor becomes operational again. The commissioning test is passed if all three test steps 2.1, 2.2, and 2.3 are passed.

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

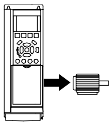
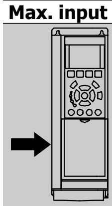
NOTE!
In order to use the safe stop functionality in conformance with the requirements of EN-954-1 Category 3, a number of conditions must be fulfilled by the installation of safe stop. Please see the section *Safe Stop Installation* for further information.

NOTE!
The adjustable frequency drive does not provide safety-related protection against unintended or malicious voltage supply to terminal 37 and subsequent reset. Provide this protection via the interrupt device, at the application level, or organizational level.
For more information, see section *Safe Stop Installation*.

4 AutomationDrive FC 300 Selection

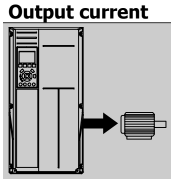
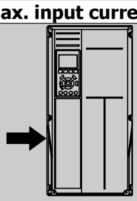
4.1 Electrical Data - 200–240 V

Line Power Supply 3 x 200–240 V AC

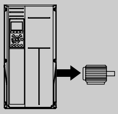
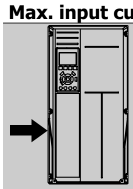
AutomationDrive FC 301/AutomationDrive FC 302		PK25	PK37	PK55	PK75	P1K1	P1K5	P2K2	P3K0	P3K7
	Typical Shaft Output [kW]	0.25	0.37	0.55	0.75	1.1	1.5	2.2	3	3.7
	Enclosure IP 20/IP 21	A2	A2	A2	A2	A2	A2	A2	A3	A3
	Enclosure IP 20 (AutomationDrive FC 301 only)	A1	A1	A1	A1	A1	A1	-	-	-
	Enclosure IP 55, 66	A5	A5	A5	A5	A5	A5	A5	A5	A5
Output current										
	Continuous (3 x 200–240 V) [A]	1.8	2.4	3.5	4.6	6.6	7.5	10.6	12.5	16.7
	Intermittent (3 x 200–240 V) [A]	2.9	3.8	5.6	7.4	10.6	12.0	17.0	20.0	26.7
	Continuous KVA (208 V AC) [KVA]	0.65	0.86	1.26	1.66	2.38	2.70	3.82	4.50	6.00
	Max. cable size (line power, motor, brake) [mm^2 (AWG[2)])]	0.2–4 (24–10)								
Max. input current										
	Continuous (3 x 200–240 V) [A]	1.6	2.2	3.2	4.1	5.9	6.8	9.5	11.3	15.0
	Intermittent (3 x 200–240 V) [A]	2.6	3.5	5.1	6.6	9.4	10.9	15.2	18.1	24.0
	Max. electrical fuses[1)] [A]	10	10	10	10	20	20	20	32	32
	Environment									
	Estimated power loss at rated max. load [W] [4)]	21	29	42	54	63	82	116	155	185
	Weight, enclosure IP20 [kg]	4.7	4.7	4.8	4.8	4.9	4.9	4.9	6.6	6.6
	A1 (IP20)	2.7	2.7	2.7	2.7	2.7	2.7	-	-	-
	A5 (IP55, 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

0.34–5 hp [0.25–3.7 kW] only available as 160% high overload.

Line Power Supply 3 x 200–240 V AC

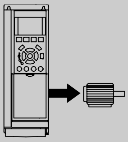
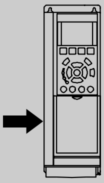
AutomationDrive FC 301/ AutomationDrive FC 302		P5K5		P7K5		P11K	
High/ Normal Load*		HO	NO	HO	NO	HO	NO
	Typical Shaft Output [kW]	5.5	7.5	7.5	11	11	15
	Enclosure IP20	B3		B3		B4	
	Enclosure IP21	B1		B1		B2	
	Enclosure IP55, 66	B1		B1		B2	
Output current							
	Continuous (3 x 200–240 V) [A]	24.2	30.8	30.8	46.2	46.2	59.4
	Intermittent (60 sec overload) (3 x 200–240 V) [A]	38.7	33.9	49.3	50.8	73.9	65.3
	Continuous KVA (208 V AC) [KVA]	8.7	11.1	11.1	16.6	16.6	21.4
Max. input current							
	Continuous (3 x 200–240 V) [A]	22	28	28	42	42	54
	Intermittent (60 sec overload) (3 x 200–240 V) [A]	35.2	30.8	44.8	46.2	67.2	59.4
	Max. cable size [mm^2 (AWG)] [2)]	16 (6)		16 (6)		35 (2)	
	Max cable size with line power disconnect	16 (6)					
	Max. electrical fuses [A] [1]	63		63		80	
	Estimated power loss at rated max. load [W] [4)]	239	310	371	514	463	602
	Weight, enclosure IP21, IP 55, 66 [kg]	23		23		27	
	Efficiency[4)]	0.964		0.959		0.964	

* High overload = 160% torque during 60 s, Normal overload = 110% torque during 60 s

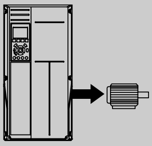
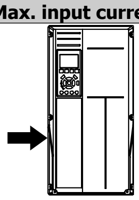
Line Power Supply 3 x 200–240 V AC										
AutomationDrive FC 301/ AutomationDrive FC 302	P15K		P18K5		P22K		P30K		P37K	
High/ Normal Load*	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft Output [kW]	15	18.5	18.5	22	22	30	30	37	37	45
Enclosure IP20	B4		C3		C3		C4		C4	
Enclosure IP21	C1		C1		C1		C2		C2	
Enclosure IP55, 66	C1		C1		C1		C2		C2	
Output current										
 Continuous (3 x 200–240 V) [A]	59.4	74.8	74.8	88	88	115	115	143	143	170
Intermittent (60 sec overload) (3 x 200–240 V) [A]	89.1	82.3	112	96.8	132	127	173	157	215	187
Continuous KVA (208 V AC) [KVA]	21.4	26.9	26.9	31.7	31.7	41.4	41.4	51.5	51.5	61.2
Max. input current										
 Continuous (3 x 200–240 V) [A]	54	68	68	80	80	104	104	130	130	154
Intermittent (60 sec overload) (3 x 200–240 V) [A]	81	74.8	102	88	120	114	156	143	195	169
Max. cable size, IP20 [mm^2 (AWG)] 2)	35 (2)		90 (3/0)		90 (3/0)		120 (4/0)		120 (4/0)	
Max. cable size, IP 21/55/66 [mm^2 (AWG)] 2)	90 (3/0)		90 (3/0)		90 (3/0)		120 (4/0)		120 (4/0)	
Max cable size with line power disconnect	35 (2)						70 (3/0)		150 (MCM 300)	
Max. electrical fuses [A] 1	125		125		160		200		250	
Estimated power loss at rated max. load [W] 4)	624	737	740	845	874	1140	1143	1353	1400	1636
Weight, enclosure IP21, IP 55, 66 [kg]	45		45		45		65		65	
Efficiency 4)	0.96		0.97		0.97		0.97		0.97	

* High overload = 160% torque during 60 s, Normal overload = 110% torque during 60 s

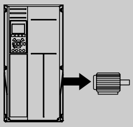
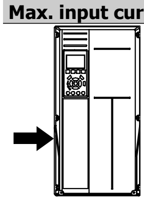
4.2 Electrical Data - 380–500 V

Line Power Supply 3 x 380–500 V AC (AutomationDrive FC 302), 3 x 380–480 V AC (AutomationDrive FC 301)	PK 37	PK 55	PK75	P1K1	P1K5	P2K2	P3K0	P4K0	P5K5	P7K5
AutomationDrive FC 301/AutomationDrive 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 (AutomationDrive FC 301 only)	A1	A1	A1	A1	A1					
Enclosure IP55, 66	A5	A5	A5	A5	A5	A5	A5	A5	A5	A5
Output current High overload 160% for 1 minute										
Shaft output [kW]	0.37	0.55	0.75	1.1	1.5	2.2	3	4	5.5	7.5
 Continuous (3 x 380–440 V) [A]	1.3	1.8	2.4	3	4.1	5.6	7.2	10	13	16
Intermittent (3 x 380–440 V) [A]	2.1	2.9	3.8	4.8	6.6	9.0	11.5	16	20.8	25.6
Continuous (3 x 441–500 V) [A]	1.2	1.6	2.1	2.7	3.4	4.8	6.3	8.2	11	14.5
Intermittent (3 x 441–500 V) [A]	1.9	2.6	3.4	4.3	5.4	7.7	10.1	13.1	17.6	23.2
Continuous kVA (400 V AC) [kVA]	0.9	1.3	1.7	2.1	2.8	3.9	5.0	6.9	9.0	11.0
Continuous kVA (460 V AC) [kVA]	0.9	1.3	1.7	2.4	2.7	3.8	5.0	6.5	8.8	11.6
Max. cable size (line power, motor, brake) [AWG] 2) [mm^2]	24 - 10 AWG 0.00031–0.0062 in^2 [0.2–4 mm^2]								24 - 10 AWG 0.00031–0.0062 in^2 [0.2–4 mm^2]	
Max. input current										
 Continuous (3 x 380–440 V) [A]	1.2	1.6	2.2	2.7	3.7	5.0	6.5	9.0	11.7	14.4
Intermittent (3 x 380–440 V) [A]	1.9	2.6	3.5	4.3	5.9	8.0	10.4	14.4	18.7	23.0
Continuous (3 x 441–500 V) [A]	1.0	1.4	1.9	2.7	3.1	4.3	5.7	7.4	9.9	13.0
Intermittent (3 x 441–500 V) [A]	1.6	2.2	3.0	4.3	5.0	6.9	9.1	11.8	15.8	20.8
Max. electrical fuses 1) [A]	10	10	10	10	10	20	20	20	32	32
Environment										
Estimated power loss at rated max. load [W] 4)	35	42	46	58	62	88	116	124	187	255
Weight, enclosure IP20	4.7	4.7	4.8	4.8	4.9	4.9	4.9	4.9	6.6	6.6
Enclosure IP55, 66	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	14.2	14.2
Efficiency 4)	0.93	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.97
0.5–10 hp [0.37–7.5 kW] only available as 160% high overload.										

4

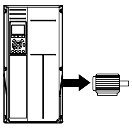
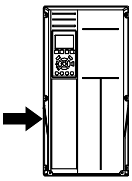
Line Power Supply 3 x 380–500 V AC (AutomationDrive FC 302), 3 x 380–480 V AC (AutomationDrive FC 301)									
AutomationDrive FC 301/ AutomationDrive FC 302		P11K		P15K		P18K		P22K	
High/ Normal Load*		HO	NO	HO	NO	HO	NO	HO	NO
	Typical Shaft output [kW]	11	15	15	18.5	18.5	22.0	22.0	30.0
	Enclosure IP20	B3		B3		B4		B4	
	Enclosure IP21	B1		B1		B2		B2	
	Enclosure IP55, 66	B1		B1		B2		B2	
Output current									
	Continuous (3 x 380-440 V) [A]	24	32	32	37.5	37.5	44	44	61
	Intermittent (60 sec overload) (3 x 380–440 V) [A]	38.4	35.2	51.2	41.3	60	48.4	70.4	67.1
	Continuous (3 x 441–500 V) [A]	21	27	27	34	34	40	40	52
	Intermittent (60 sec overload) (3 x 441–500 V) [A]	33.6	29.7	43.2	37.4	54.4	44	64	57.2
	Continuous kVA (400 V AC) [kVA]	16.6	22.2	22.2	26	26	30.5	30.5	42.3
	Continuous kVA (460 V AC) [kVA]		21.5		27.1		31.9		41.4
Max. input current									
	Continuous (3 x 380–440 V) [A]	22	29	29	34	34	40	40	55
	Intermittent (60 sec overload) (3 x 380–440 V) [A]	35.2	31.9	46.4	37.4	54.4	44	64	60.5
	Continuous (3 x 441–500 V) [A]	19	25	25	31	31	36	36	47
	Intermittent (60 sec overload) (3 x 441–500 V) [A]	30.4	27.5	40	34.1	49.6	39.6	57.6	51.7
	Max. cable size [mm^2 / AWG] 2)	16/6		16/6		35/2		35/2	
	Max cable size with line power disconnect	16/6							
	Max. electrical fuses [A] 1	63		63		63		80	
	Estimated power loss at rated max. load [W] 4)	291	392	379	465	444	525	547	739
	Weight, enclosure IP20	12		12		23.5		23.5	
	Weight, enclosure IP21, IP 55, 66 [kg]	23		23		27		27	
	Efficiency4)	0.98		0.98		0.98		0.98	
* High overload = 160% torque during 60 s, Normal overload = 110% torque during 60 s									

Line Power Supply 3 x 380–500 V AC (AutomationDrive FC 302), 3 x 380–480 V AC (AutomationDrive FC 301)

AutomationDrive FC 301/AutomationDrive FC 302		P30K		P37K		P45K		P55K		P75K	
High/ Normal Load*		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 380-440 V) [A]	61	73	73	90	90	106	106	147	147	177
	Intermittent (60 sec overload) (3 x 380–440 V) [A]	91.5	80.3	110	99	135	117	159	162	221	195
	Continuous (3 x 441–500 V) [A]	52	65	65	80	80	105	105	130	130	160
	Intermittent (60 sec overload) (3 x 441–500 V) [A]	78	71.5	97.5	88	120	116	158	143	195	176
	Continuous kVA (400 V AC) [kVA]	42.3	50.6	50.6	62.4	62.4	73.4	73.4	102	102	123
	Continuous kVA (460 V AC) [kVA]		51.8		63.7		83.7		104		128
Max. input current											
	Continuous (3 x 380–440 V) [A]	55	66	66	82	82	96	96	133	133	161
	Intermittent (60 sec overload) (3 x 380–440 V) [A]	82.5	72.6	99	90.2	123	106	144	146	200	177
	Continuous (3 x 441–500 V) [A]	47	59	59	73	73	95	95	118	118	145
	Intermittent (60 sec overload) (3 x 441–500 V) [A]	70.5	64.9	88.5	80.3	110	105	143	130	177	160
	Max. cable size IP20, line power and motor [mm^2 (AWG[2)])]	35 (2)		50 (1)		50 (1)		95 (4/0)		150 (300 mcm)	
	Max. cable size IP20, load share and brake [mm^2 (AWG[2)])]	35 (2)		50 (1)		50 (1)		95 (4/0)		95 (4/0)	
	Max. cable size, IP21/55/66 [mm^2 (AWG[2)])]	90 (3/0)		90 (3/0)		90 (3/0)		120 (4/0)		120 (4/0)	
	Max cable size with line power disconnect	35 (2)						70 (3/0)		150 (300 mcm)	
	Max. electrical fuses [A] [1]	100		125		160		250		250	
	Estimated power loss at rated max. load [W] [4)]	570	698	697	843	891	1083	1022	1384	1232	1474
	Weight, enclosure IP21, IP 55, 66 [kg]	45		45		45		65		65	
	Efficiency[4)]	0.98		0.98		0.98		0.98		0.99	

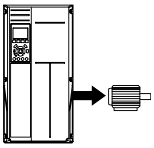
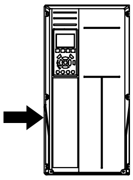
* High overload = 160% torque during 60 s, Normal overload = 110% torque during 60 s

4

Line Power Supply 3 x 380–500 V AC											
AutomationDrive FC 302		P90K		P110		P132		P160		P200	
High/ Normal Load*		HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
	Typical Shaft output at 400 V [kW]	90	110	110	132	132	160	160	200	200	250
	Typical Shaft output at 460 V [HP]	125	150	150	200	200	250	250	300	300	350
	Typical shaft output at 500 V [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 400 V) [A]	177	212	212	260	260	315	315	395	395	480
	Intermittent (60 sec overload) (at 400 V) [A]	266	233	318	286	390	347	473	435	593	528
	Continuous (at 460/500 V) [A]	160	190	190	240	240	302	302	361	361	443
	Intermittent (60 sec overload) (at 460/ 500 V) [A]	240	209	285	264	360	332	453	397	542	487
	Continuous KVA (at 400 V) [KVA]	123	147	147	180	180	218	218	274	274	333
	Continuous KVA (at 460 V) [KVA]	127	151	151	191	191	241	241	288	288	353
	Continuous KVA (at 500 V) [KVA]	139	165	165	208	208	262	262	313	313	384
Max. input current											
	Continuous (at 400 V) [A]	171	204	204	251	251	304	304	381	381	463
	Continuous (at 460/500 V) [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 400 V [W] [4)]	2641	3234	2995	3782	3425	4213	3910	5119	4625	5893
	Estimated power loss at 460 V [W]	2453	2947	2734	3665	3249	4063	3816	4652	4472	5634
	Weight, enclosure IP21, IP 54 [kg]	96		104		125		136		151	
	Weight, enclosure IP00 [kg]	82		91		112		123		138	
	Efficiency[4)]	0.98									
	Output frequency	0–800 Hz									
	Heatsink overtemp. trip	185°F [85°C]		194°F [90°C]		221°F [105°C]		221°F [105°C]		239°F [115°C]	
	Power card ambient trip	140°F [60°C]									

* High overload = 160% torque during 60 s, Normal overload = 110% torque during 60 s

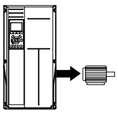
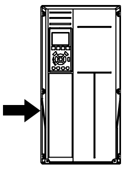
Line Power Supply 3 x 380–500 V AC

AutomationDrive FC 302		P250		P315		P355		P400	
High/ Normal Load*		HO	NO	HO	NO	HO	NO	HO	NO
	Typical Shaft output at 400 V [kW]	250	315	315	355	355	400	400	450
	Typical Shaft output at 460 V [HP]	350	450	450	500	500	600	550	600
	Typical shaft output at 500 V [kW]	315	355	355	400	400	500	500	530
	Enclosure IP21	E1		E1		E1		E1	
	Enclosure IP54	E1		E1		E1		E1	
	Enclosure IP00	E2		E2		E2		E2	
	Output current								
	Continuous (at 400 V) [A]	480	600	600	658	658	745	695	800
	Intermittent (60 sec over-load) (at 400 V) [A]	720	660	900	724	987	820	1043	880
	Continuous (at 460/500 V) [A]	443	540	540	590	590	678	678	730
	Intermittent (60 sec over-load) (at 460/ 500 V) [A]	665	594	810	649	885	746	1017	803
	Continuous KVA (at 400 V) [KVA]	333	416	416	456	456	516	482	554
	Continuous KVA (at 460 V) [KVA]	353	430	430	470	470	540	540	582
	Continuous KVA (at 500 V) [KVA]	384	468	468	511	511	587	587	632
Max. input current									
	Continuous (at 400 V) [A]	472	590	590	647	647	733	684	787
	Continuous (at 460/500 V) [A]	436	531	531	580	580	667	667	718
	Max. cable size, line power, motor and load share [mm² (AWG[2]))]	4x240 (4x500 mcm)		4x240 (4x500 mcm)		4x240 (4x500 mcm)		4x240 (4x500 mcm)	
	Max. cable size, brake [mm² (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 400 V [W] [4)]	5164	6790	6960	7701	7691	8879	8178	9670
	Estimated power loss at 460 V [W]	4822	6082	6345	6953	6944	8089	8085	8803
	Weight, enclosure IP21, IP 54 [kg]	263		270		272		313	
	Weight, enclosure IP00 [kg]	221		234		236		277	
	Efficiency[4)]	0.98							
	Output frequency	0–600 Hz							
	Heatsink overtemp. trip	203°F [95°C]							
	Power card ambient trip	154°F [68°C]							

* High overload = 160% torque during 60 s, Normal overload = 110% torque during 60 s

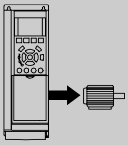
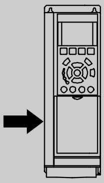
4

Line Power Supply 3 x 380–500 V AC

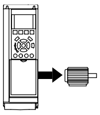
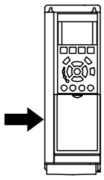
AutomationDrive FC 302	P450		P500		P560		P630		P710		P800	
High/ Normal Load*	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft output at 400 V [kW]	450	500	500	560	560	630	630	710	710	800	800	1000
Typical Shaft output at 460 V [HP]	600	650	650	750	750	900	900	1000	1000	1200	1200	1350
Typical shaft output at 500 V [kW]	530	560	560	630	630	710	710	800	800	1000	1000	1100
EnclosureIP21, 54 without/ with options cabinet	F1/ F3		F1/ F3		F1/ F3		F1/ F3		F2/ F4		F2/ F4	
Output current												
 Continuous (at 400 V) [A]	800	880	880	990	990	1120	1120	1260	1260	1460	1460	1720
Intermittent (60 sec overload) (at 400 V) [A]	1200	968	1320	1089	1485	1232	1680	1386	1890	1606	2190	1892
Continuous (at 460/500 V) [A]	730	780	780	890	890	1050	1050	1160	1160	1380	1380	1530
Intermittent (60 sec overload) (at 460/ 500 V) [A]	1095	858	1170	979	1335	1155	1575	1276	1740	1518	2070	1683
Continuous KVA (at 400 V) [KVA]	554	610	610	686	686	776	776	873	873	1012	1012	1192
Continuous KVA (at 460 V) [KVA]	582	621	621	709	709	837	837	924	924	1100	1100	1219
Continuous KVA (at 500 V) [KVA]	632	675	675	771	771	909	909	1005	1005	1195	1195	1325
Max. input current												
 Continuous (at 400 V) [A]	779	857	857	964	964	1090	1090	1227	1227	1422	1422	1675
Continuous (at 460/500 V) [A]	711	759	759	867	867	1022	1022	1129	1129	1344	1344	1490
Max. cable size,motor [mm^2 (AWG[2)])]	8x150 (8x300 mcm)								12x150 (12x300 mcm)			
Max. cable size, 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, loadsharing [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 400 V [W] [4)]	9492	10647	10631	12338	11263	13201	13172	15436	14967	18084	16392	20358
Estimated power loss at 460 V [W]	8730	9414	9398	11006	10063	12353	12332	14041	13819	17137	15577	17752
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 [kg]	1004/ 1299		1004/ 1299		1004/ 1299		1004/ 1299		1246/ 1541		1246/ 1541	
Weight Rectifier Module [kg]	102		102		102		102		136		136	
Weight Inverter Module [kg]	102		102		102		136		102		102	
Efficiency[4)]	0.98											
Output frequency	0–600 Hz											
Heatsink overtemp. trip	203°F [95°C]											
Power card ambient trip	154°F [68°C]											

* High overload = 160% torque during 60 s, Normal overload = 110% torque during 60 s

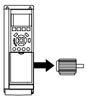
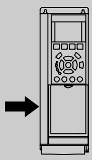
4.3 Electrical Data - 525–600 V

Line Power Supply 3 x 525–600 V AC (AutomationDrive FC 302 only)									
AutomationDrive 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	A2	A2	A2	A2	A2	A2	A3	A3
	Enclosure IP55	A5	A5	A5	A5	A5	A5	A5	A5
Output current									
	Continuous (3 x 525–550 V) [A]	1.8	2.6	2.9	4.1	5.2	6.4	9.5	11.5
	Intermittent (3 x 525–550 V) [A]	2.9	4.2	4.6	6.6	8.3	10.2	15.2	18.4
	Continuous (3 x 551–600 V) [A]	1.7	2.4	2.7	3.9	4.9	6.1	9.0	11.0
	Intermittent (3 x 551–600 V) [A]	2.7	3.8	4.3	6.2	7.8	9.8	14.4	17.6
	Continuous kVA (525 V AC) [kVA]	1.7	2.5	2.8	3.9	5.0	6.1	9.0	11.0
	Continuous kVA (575 V AC) [kVA]	1.7	2.4	2.7	3.9	4.9	6.1	9.0	11.0
	Max. cable size (line power, motor, brake) [AWG] 2) [mm²]	24 - 10 AWG 0.00031–0.0062 in² [0.2–4 mm²]					24 - 10 AWG 0.00031–0.0062 in² [0.2–4 mm²]		
Max. input current									
	Continuous (3 x 525–600 V) [A]	1.7	2.4	2.7	4.1	5.2	5.8	8.6	10.4
	Intermittent (3 x 525–600 V) [A]	2.7	3.8	4.3	6.6	8.3	9.3	13.8	16.6
	Max. electrical fuses1) [A]	10	10	10	20	20	20	32	32
	Environment								
	Estimated power loss at rated max. load [W] 4)	35	50	65	92	122	145	195	261
	Weight, Enclosure IP20 [kg]	6.5	6.5	6.5	6.5	6.5	6.5	6.6	6.6
	Weight, enclosure IP55 [kg]	13.5	13.5	13.5	13.5	13.5	13.5	14.2	14.2
	Efficiency 4)	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97

Line Power Supply 3 x 525–600 VAC

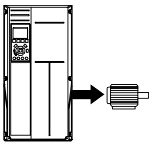
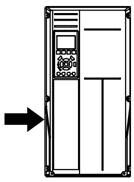
AutomationDrive FC 302	P11K		P15K		P18K5		P22K		P30K	
High/ Normal Load*	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft Output [kW]	11	15	15	18.5	18.5	22	22	30	30	37
Enclosure IP 21, 55, 66	B1		B1		B2		B2		C1	
Enclosure IP20	B3		B3		B4		B4		B4	
Output current										
Continuous (3 x 525–550 V) [A]	19	23	23	28	28	36	36	43	43	54
Intermittent (3 x 525–550 V) [A]	30	25	37	31	45	40	58	47	65	59
Continuous (3 x 525–600 V) [A]	18	22	22	27	27	34	34	41	41	52
Intermittent (3 x 525–600 V) [A]	29	24	35	30	43	37	54	45	62	57
 Continuous kVA (550 V AC) [kVA]	18.1	21.9	21.9	26.7	26.7	34.3	34.3	41.0	41.0	51.4
Continuous kVA (575 V AC) [kVA]	17.9	21.9	21.9	26.9	26.9	33.9	33.9	40.8	40.8	51.8
Max. cable size IP20 (line power, motor, load share and brake) [AWG] 2) [mm^2]	16(6)				35(2)					
Max. cable size IP21, 55, 66 (line power, motor, load share and brake) [AWG] 2) [mm^2]	16(6)				35(2)				90 (3/0)	
Max cable size with line power disconnect	16(6)								35(2)	
Max. input current										
Continuous at 550 V [A]	17.2	20.9	20.9	25.4	25.4	32.7	32.7	39	39	49
Intermittent at 550 V [A]	28	23	33	28	41	36	52	43	59	54
 Continuous at 575 V [A]	16	20	20	24	24	31	31	37	37	47
Intermittent at 575 V [A]	26	22	32	27	39	34	50	41	56	52
Max. electrical fuses1) [A]	63		63		63		80		100	
Environment										
Estimated power loss at rated max. load [W] 4)		225		285		329		700		700
Weight, enclosure IP21, 55 [kg]	23		23		27		27		27	
Weight, enclosure IP20 [kg]	12		12		23.5		23.5		23.5	
Efficiency 4)	0.98		0.98		0.98		0.98		0.98	

Line Power Supply 3 x 525–600 VAC

AutomationDrive 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 525–550 V) [A]	54	65	65	87	87	105	105	137
Intermittent (3 x 525–550 V) [A]	81	72	98	96	131	116	158	151
Continuous (3 x 525–600 V) [A]	52	62	62	83	83	100	100	131
 Intermittent (3 x 525–600 V) [A]	78	68	93	91	125	110	150	144
Continuous kVA (550 V AC) [kVA]	51.4	61.9	61.9	82.9	82.9	100.0	100.0	130.5
Continuous kVA (575 V AC) [kVA]	51.8	61.7	61.7	82.7	82.7	99.6	99.6	130.5
Max. cable size IP20 (line power, motor) [AWG] 2) [mm²]	50 (1)				95 (4/0)		150 (300 mcm)	
Max. cable size IP20 (load share, brake) [AWG] 2) [mm²]	50 (1)				95 (4/0)			
Max. cable size IP21, 55, 66 (line power, motor, load share and brake) [AWG] 2) [mm²]	90 (3/0)				120 (4/0)			
Max cable size with line power disconnect	35 (2)				70 (3/0)		150 (300 mcm)	
Max. input current								
Continuous at 550 V [A]	49	59	59	78.9	78.9	95.3	95.3	124.3
Intermittent at 550 V [A]	74	65	89	87	118	105	143	137
Continuous at 575 V [A]	47	56	56	75	75	91	91	119
Intermittent at 575 V [A]	70	62	85	83	113	100	137	131
 Max. electrical fuses 1) [A]	125		160		250		250	
Environment								
Estimated power loss at rated max. load [W] 4)		850		1100		1400		1500
Weight, enclosure IP20 [kg]	35		35		50		50	
Weight, enclosure IP21, 55 [kg]	45		45		65		65	
Efficiency 4)	0.98		0.98		0.98		0.98	

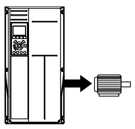
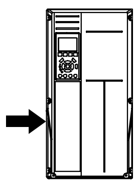
4.4 Electrical Data - 525–690 V

Line Power Supply 3 x 525–690 V AC

AutomationDrive FC 302		P11K		P15K		P18K		P22K	
High/ Normal Load*		HO	NO	HO	NO	HO	NO	HO	NO
	Typical Shaft output at 550 V [kW]	7.5	11	11	15	15	18.5	18.5	22
	Typical Shaft output at 575 V [HP]	11	15	15	20	20	25	25	30
	Typical Shaft output at 690 V [kW]	11	15	15	18.5	18.5	22	22	30
	Enclosure IP21, 55	B2		B2		B2		B2	
Output current									
	Continuous (3 x 525–550 V) [A]	14	19	19	23	23	28	28	36
	Intermittent (60 sec over-load) (3 x 525–550 V) [A]	22.4	20.9	30.4	25.3	36.8	30.8	44.8	39.6
	Continuous (3 x 551–690 V) [A]	13	18	18	22	22	27	27	34
	Intermittent (60 sec over-load) (3 x 551–690 V) [A]	20.8	19.8	28.8	24.2	35.2	29.7	43.2	37.4
	Continuous KVA (at 550 V) [KVA]	13.3	18.1	18.1	21.9	21.9	26.7	26.7	34.3
	Continuous KVA (at 575 V) [KVA]	12.9	17.9	17.9	21.9	21.9	26.9	26.9	33.9
	Continuous KVA (at 690 V) [KVA]	15.5	21.5	21.5	26.3	26.3	32.3	32.3	40.6
Max. input current									
	Continuous (3 x 525–690 V) [A]	15	19.5	19.5	24	24	29	29	36
	Intermittent (60 sec over-load) (3 x 525–690 V) [A]	23.2	21.5	31.2	26.4	38.4	31.9	46.4	39.6
	Max. cable size, line power, motor, load share and brake [mm² (AWG)]	35 (1/0)							
	Max. external electrical fuses [A] 1	63		63		63		63	
	Estimated power loss at rated max. load [W] 4)	228		285		335		375	
	Weight, enclosure IP21, IP 55 [kg]	27							
	Efficiency4)	0.98		0.98		0.98		0.98	

* High overload = 160% torque during 60 s, Normal overload = 110% torque during 60 s

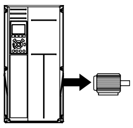
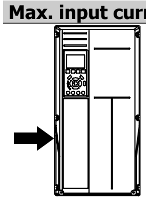
Line Power Supply 3 x 525–690 V AC

AutomationDrive FC 302		P30K		P37K		P45K		P55K		P75K	
High/ Normal Load*		HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
	Typical Shaft output at 550 V [kW]	22	30	30	37	37	45	45	55	55	75
	Typical Shaft output at 575 V [HP]	30	40	40	50	50	60	60	75	75	100
	Typical Shaft output at 690 V [kW]	30	37	37	45	45	55	55	75	75	90
	Enclosure IP21, 55	C2		C2		C2		C2		C2	
Output current											
	Continuous (3 x 525–550 V) [A]	36	43	43	54	54	65	65	87	87	105
	Intermittent (60 sec overload) (3 x 525–550 V) [A]	54	47.3	64.5	59.4	81	71.5	97.5	95.7	130.5	115.5
	Continuous (3 x 551–690 V) [A]	34	41	41	52	52	62	62	83	83	100
	Intermittent (60 sec overload) (3 x 551–690 V) [A]	51	45.1	61.5	57.2	78	68.2	93	91.3	124.5	110
	Continuous KVA (at 550 V) [KVA]	34.3	41.0	41.0	51.4	51.4	61.9	61.9	82.9	82.9	100.0
	Continuous KVA (at 575 V) [KVA]	33.9	40.8	40.8	51.8	51.8	61.7	61.7	82.7	82.7	99.6
	Continuous KVA (at 690 V) [KVA]	40.6	49.0	49.0	62.1	62.1	74.1	74.1	99.2	99.2	119.5
Max. input current											
	Continuous (at 550 V) [A]	36	49	49	59	59	71	71	87	87	99
	Continuous (at 575 V) [A]	54	53.9	72	64.9	87	78.1	105	95.7	129	108.9
	Max. cable size, line power, motor, load share and brake [mm^2 (AWG)]	35 (1/0)									
	Max. external electrical fuses [A] [1]	80		100		125		160		160	
	Estimated power loss at rated max. load [W] [4)]	480		592		720		880		1200	
	Weight, enclosure IP21, IP 55 [kg]	65									
	Efficiency[4)]	0.98		0.98		0.98		0.98		0.98	

* High overload = 150% torque during 60 s, Normal overload = 110% torque during 60 s

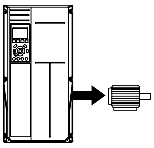
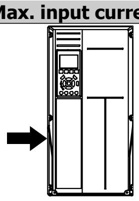
4

Line Power Supply 3 x 525–690 V AC

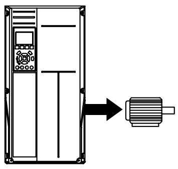
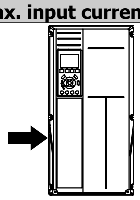
AutomationDrive FC 302		P37K		P45K		P55K		P75K		P90K	
High/ Normal Load*		HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
	Typical Shaft output at 550 V [kW]	30	37	37	45	45	55	55	75	75	90
	Typical Shaft output at 575 V [HP]	40	50	50	60	60	75	75	100	100	125
	Typical Shaft output at 690 V [kW]	37	45	45	55	55	75	75	90	90	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 550 V) [A]	48	56	56	76	76	90	90	113	113	137
	Intermittent (60 sec overload) (at 550 V) [A]	77	62	90	84	122	99	135	124	170	151
	Continuous (at 575/690 V) [A]	46	54	54	73	73	86	86	108	108	131
	Intermittent (60 sec overload) (at 575/690 V) [A]	74	59	86	80	117	95	129	119	162	144
	Continuous KVA (at 550 V) [KVA]	46	53	53	72	72	86	86	108	108	131
	Continuous KVA (at 575 V) [KVA]	46	54	54	73	73	86	86	108	108	130
	Continuous KVA (at 690 V) [KVA]	55	65	65	87	87	103	103	129	129	157
Max. input current											
	Continuous (at 550 V) [A]	53	60	60	77	77	89	89	110	110	130
	Continuous (at 575 V) [A]	51	58	58	74	74	85	85	106	106	124
	Continuous (at 690 V) [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 600 V [W] [4)]	1299	1398	1459	1645	1643	1827	1827	2156	2158	2532
	Estimated power loss at 690 V [W] [4)]	1355	1458	1459	1717	1721	1913	1913	2262	2264	2662
	Weight, enclosure IP21, IP 54 [kg]	96									
	Weight, enclosure IP00 [kg]	82									
	Efficiency[4)]	0.97		0.97		0.98		0.98		0.98	
	Output frequency	0–600 Hz									
	Heatsink overtemp. trip	185°F [85°C]									
	Power card ambient trip	140°F [60°C]									

* High overload = 160% torque during 60 s, Normal overload = 110% torque during 60 s

Line Power Supply 3 x 525–690 V AC

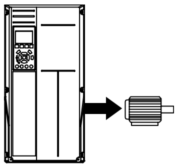
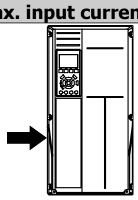
AutomationDrive FC 302		P110		P132		P160		P200	
High/ Normal Load*		HO	NO	HO	NO	HO	NO	HO	NO
	Typical Shaft output at 550 V [kW]	90	110	110	132	132	160	160	200
	Typical Shaft output at 575 V [HP]	125	150	150	200	200	250	250	300
	Typical Shaft output at 690 V [kW]	110	132	132	160	160	200	200	250
	Enclosure IP21	D1		D1		D2		D2	
	Enclosure IP54	D1		D1		D2		D2	
	Enclosure IP00	D3		D3		D4		D4	
	Output current								
	Continuous (at 550 V) [A]	137	162	162	201	201	253	253	303
	Intermittent (60 sec overload) (at 550 V) [A]	206	178	243	221	302	278	380	333
	Continuous (at 575/690 V) [A]	131	155	155	192	192	242	242	290
	Intermittent (60 sec overload) (at 575/690 V) [A]	197	171	233	211	288	266	363	319
	Continuous KVA (at 550 V) [KVA]	131	154	154	191	191	241	241	289
	Continuous KVA (at 575 V) [KVA]	130	154	154	191	191	241	241	289
	Continuous KVA (at 690 V) [KVA]	157	185	185	229	229	289	289	347
Max. input current									
	Continuous (at 550 V) [A]	130	158	158	198	198	245	245	299
	Continuous (at 575 V) [A]	124	151	151	189	189	234	234	286
	Continuous (at 690 V) [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 600 V [W] [4)]	2536	2963	2806	3430	3261	4051	4037	4867
	Estimated power loss at 690 V [W] [4)]	2664	3114	2953	3612	3451	4292	4275	5156
	Weight, Enclosure IP21, IP 54 [kg]	96		104		125		136	
	Weight, Enclosure IP00 [kg]	82		91		112		123	
	Efficiency[4)]	0.98							
	Output frequency	0–600 Hz							
	Heatsink overtemp. trip	185°F [85°C]		194°F [90°C]		230°F [110°C]		230°F [110°C]	
	Power card ambient trip	140°F [60°C]							

* High overload = 160% torque during 60 s, Normal overload = 110% torque during 60 s

Line Power Supply 3 x 525–690 V AC							
AutomationDrive FC 302		P250		P315		P355	
High/ Normal Load*		HO	NO	HO	NO	HO	NO
	Typical Shaft output at 550 V [kW]	200	250	250	315	315	355
	Typical Shaft output at 575 V [HP]	300	350	350	400	400	450
	Typical Shaft output at 690 V [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 550 V) [A]	303	360	360	418	395	470
	Intermittent (60 sec overload) (at 550 V) [A]	455	396	540	460	593	517
	Continuous (at 575/690 V) [A]	290	344	344	400	380	450
	Intermittent (60 sec overload) (at 575/690 V) [A]	435	378	516	440	570	495
	Continuous KVA (at 550 V) [KVA]	289	343	343	398	376	448
	Continuous KVA (at 575 V) [KVA]	289	343	343	398	378	448
	Continuous KVA (at 690 V) [KVA]	347	411	411	478	454	538
Max. input current							
	Continuous (at 550 V) [A]	299	355	355	408	381	453
	Continuous (at 575 V) [A]	286	339	339	390	366	434
	Continuous (at 690 V) [A]	296	352	352	400	366	434
	Max. cable size, line power, motor and load share [mm² (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 [mm² (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 600 V [W] 4)	4601	5493	4938	5852	5107	6132
	Estimated power loss at 690 V [W] 4)	4875	5821	5185	6149	5383	6449
	Weight, enclosure IP21, IP 54 [kg]	151		165		263	
	Weight, enclosure IP00 [kg]	138		151		221	
	Efficiency 4)	0.98					
	Output frequency	0–600 Hz		0–500 Hz		0–500 Hz	
	Heatsink overtemp. trip	230°F [110°C]		230°F [110°C]		185°F [85°C]	
	Power card ambient trip	140°F [60°C]		140°F [60°C]		154°F [68°C]	

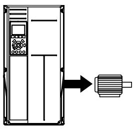
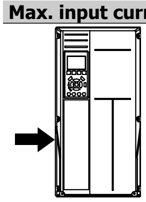
* High overload = 160% torque during 60 s, Normal overload = 110% torque during 60 s

Line Power Supply 3 x 525–690 V AC

AutomationDrive FC 302		P400		P500		P560	
High/ Normal Load*		HO	NO	HO	NO	HO	NO
	Typical Shaft output at 550 V [kW]	315	400	400	450	450	500
	Typical Shaft output at 575 V [HP]	400	500	500	600	600	650
	Typical Shaft output at 690 V [kW]	400	500	500	560	560	630
	Enclosure IP21	E1		E1		E1	
	Enclosure IP54	E1		E1		E1	
	Enclosure IP00	E2		E2		E2	
	Output current						
	Continuous (at 550 V) [A]	429	523	523	596	596	630
	Intermittent (60 sec overload) (at 550 V) [A]	644	575	785	656	894	693
	Continuous (at 575/690 V) [A]	410	500	500	570	570	630
	Intermittent (60 sec overload) (at 575/690 V) [A]	615	550	750	627	855	693
	Continuous KVA (at 550 V) [KVA]	409	498	498	568	568	600
	Continuous KVA (at 575 V) [KVA]	408	498	498	568	568	627
	Continuous KVA (at 690 V) [KVA]	490	598	598	681	681	753
Max. input current							
	Continuous (at 550 V) [A]	413	504	504	574	574	607
	Continuous (at 575 V) [A]	395	482	482	549	549	607
	Continuous (at 690 V) [A]	395	482	482	549	549	607
	Max. cable size, 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 600 V [W] [4)]	5538	6903	7336	8343	8331	9244
	Estimated power loss at 690 V [W] [4)]	5818	7249	7671	8727	8715	9673
	Weight, enclosure IP21, IP 54 [kg]	263		272		313	
	Weight, enclosure IP00 [kg]	221		236		277	
	Efficiency[4)]	0.98					
	Output frequency	0–500 Hz					
	Heatsink overtemp. trip	185°F [85°C]					
	Power card ambient trip	154°F [68°C]					

* High overload = 160% torque during 60 s, Normal overload = 110% torque during 60 s

Line Power Supply 3 x 525–690 V AC

AutomationDrive FC 302		P630		P710		P800		P900		P1M0	
High/ Normal Load*		HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
	Typical Shaft output at 550 V [kW]	500	560	560	670	670	750	750	850	850	1000
	Typical Shaft output at 575 V [HP]	650	750	750	950	950	1050	1050	1150	1150	1350
	Typical Shaft output at 690 V [kW]	630	710	710	800	800	900	900	1000	1000	1200
	Enclosure IP21, 54 without/with options cabinet	F1/ F3		F1/ F3		F1/ F3		F2/ F4		F2/ F4	
	Output current										
	Continuous (at 550 V) [A]	659	763	763	889	889	988	988	1108	1108	1317
	Intermittent (60 sec overload) (at 550 V) [A]	989	839	1145	978	1334	1087	1482	1219	1662	1449
	Continuous (at 575/690 V) [A]	630	730	730	850	850	945	945	1060	1060	1260
	Intermittent (60 sec overload) (at 575/690 V) [A]	945	803	1095	935	1275	1040	1418	1166	1590	1386
	Continuous KVA (at 550 V) [KVA]	628	727	727	847	847	941	941	1056	1056	1255
	Continuous KVA (at 575 V) [KVA]	627	727	727	847	847	941	941	1056	1056	1255
	Continuous KVA (at 690 V) [KVA]	753	872	872	1016	1016	1129	1129	1267	1267	1506
Max. input current											
	Continuous (at 550 V) [A]	642	743	743	866	866	962	962	1079	1079	1282
	Continuous (at 575 V) [A]	613	711	711	828	828	920	920	1032	1032	1227
	Continuous (at 690 V) [A]	613	711	711	828	828	920	920	1032	1032	1227
	Max. cable size, motor [mm² (AWG²⁾)]	8x150 (8x300 mcm)						12x150 (12x300 mcm)			
	Max. cable size, line power F1/F2 [mm² (AWG²⁾)]	8x240 (8x500 mcm)									
	Max. cable size, line power F3/F4 [mm² (AWG²⁾)]	8x456 (8x900 mcm)									
	Max. cable size, load-sharing [mm² (AWG²⁾)]	4x120 (4x250 mcm)									
	Max. cable size, brake [mm² (AWG²⁾)	4x185 (4x350 mcm)						6x185 (6x350 mcm)			
	Max. external electrical fuses [A] ¹	1600								2000	
	Estimated power loss at 600 V [W] ⁴⁾	9201	10771	10416	12272	12260	13835	13755	15592	15107	18281
	Estimated power loss at 690V [W] ⁴⁾	9674	11315	10965	12903	12890	14533	14457	16375	15899	19207
	F3/F4 Max added losses CB or Disconnect & Contactor	342	427	419	532	519	615	556	665	634	863
	Max panel options losses	400									
	Weight, enclosure IP21, IP 54 [kg]	1004/ 1299		1004/ 1299		1004/ 1299		1246/ 1541		1246/ 1541	
	Weight, Rectifier Module [kg]	102		102		102		136		136	
	Weight, Inverter Module [kg]	102		102		136		102		102	
	Efficiency⁴⁾	0.98									
	Output frequency	0–500 Hz									
	Heatsink overtemp. trip	185°F [85°C]									
	Power card ambient trip	154°F [68°C]									

* High overload = 160% torque during 60 s, Normal overload = 110% torque during 60 s

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

4

4.5 General Specifications

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

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

Supply frequency	50/60 Hz ±5%
Max. 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 [7.5 kW]	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 [90 kW]	maximum 1 time/2 min.
Environment according to EN60664-1	overvoltage category III/pollution degree 2

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

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

** Voltage and power dependent*

Torque characteristics:	
Starting torque (Constant torque)	maximum 160% for 60 sec.*
Starting torque	maximum 180% up to 0.5 sec.*
Overload torque (Constant torque)	maximum 160% for 60 sec.*
Starting torque (Variable torque)	maximum 110% for 60 sec.*
Overload torque (Variable torque)	maximum 110% for 60 sec.

**Percentage relates to the nominal torque.*

Cable lengths and cross-sections for control cables*:	
Max. motor cable length, shielded	AutomationDrive FC 301: 164 ft [50 m]/ AutomationDrive FC 301 (A1): 82 ft [25 m]/ AutomationDrive FC 302: 492 ft [150 m]
Max. motor cable length, unshielded	AutomationDrive FC 301: 246 ft [75 m] / AutomationDrive FC 301 (A1): 164 ft [50 m]/ AutomationDrive FC 302: 984 ft [300 m]
Maximum cross-section to control terminals, flexible/rigid wire without cable end sleeves	0.0023 in^2 [1.5 mm^2]/16 AWG
Maximum cross-section to control terminals, flexible wire with cable end sleeves	0.0016 in^2 [1 mm^2]/18 AWG
Maximum cross-section to control terminals, flexible wire with cable end sleeves with collar	0.0008 in^2 [0.5 mm^2]/20 AWG
Minimum cross-section to control terminals	0.0039 in^2 [0.25 mm^2]/24 AWG

** Power cables, see tables in section "Electrical Data" of the Design Guide*

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, 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 drive.

Digital inputs:

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

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

Voltage level	0–24 V DC
Voltage level, logic'0' PNP	< 4 V DC
Voltage level, logic'1' PNP	>20 V DC
Nominal input current at 24 V	50 mA rms
Nominal input current at 20 V	60 mA rms
Input capacitance	400 nF

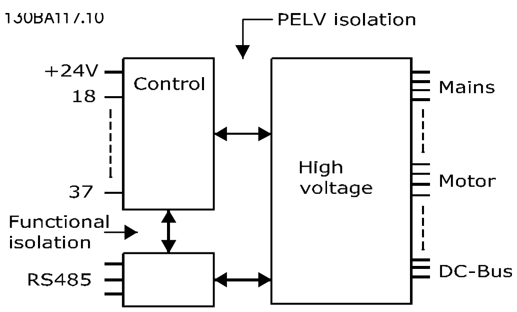
All digital inputs are galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.
1) Terminals 27 and 29 can also be programmed as output.

2) Except safe stop input Terminal 37.
3) Terminal 37 is only available in AutomationDrive FC 302 and AutomationDrive FC 301 A1 with Safe Stop. It can only be used as safe stop input. Terminal 37 is suitable for category 3 installations in accordance with EN 954-1 (safe stop according to category 0 EN 60204-1), and as required by the EU Machinery Directive 98/37/EC. Terminal 37 and the safe stop function are designed in accordance with EN 60204-1, EN 50178, EN 61800-2, EN 61800-3 and EN 954-1. For correct and safe use of the safe stop function follow the related information and instructions in the Design Guide.
4) AutomationDrive FC 302 only.

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	AutomationDrive FC 301: 0 to + 10/ AutomationDrive FC 302: -10 to +10 V (scaleable)
Input resistance, R_i	approx. 10 kΩ
Max. voltage	± 20 V
Current mode	Switch S201/switch S202 = ON (I)
Current level	0/4 to 20 mA (scaleable)
Input resistance, R_i	approx. 200 Ω
Max. current	30 mA
Resolution for analog inputs	10 bit (+ sign)
Accuracy of analog inputs	Max. error 0.5% of full scale
Bandwidth	AutomationDrive FC 301: 20 Hz/ AutomationDrive FC 302: 100 Hz

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



Pulse/encoder inputs:

Programmable pulse/encoder inputs	2/1
Terminal number pulse/encoder	29[1)], 33[2)] / 32[3)], 33[3)]
Max. frequency at terminal 29, 32, 33	110 kHz (push-pull driven)
Max. frequency at terminal 29, 32, 33	5 kHz (open collector)
Min. frequency at terminal 29, 32, 33	4 Hz
Voltage level	see section on Digital input
Maximum voltage on input	28 V DC
Input resistance, R_i	approx. 4 kΩ
Pulse input accuracy (0.1–1 kHz)	Max. error: 0.1% of full scale
Encoder input accuracy (1–110 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) AutomationDrive 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	0/4–20 mA
Max. load GND - analog output	500 Ω
Accuracy on analog output	Max. error: 0.5% of full scale
Resolution on analog output	12 bit

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	0–24 V
Max. output current (sink or source)	40 mA
Max. load at frequency output	1 kΩ
Max. capacitive load at frequency output	10 nF
Minimum output frequency at frequency output	0 Hz
Maximum output frequency at frequency output	32 kHz
Accuracy of frequency output	Max. error: 0.1% of full scale
Resolution of frequency outputs	12 bit

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

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

Control card, 24 V DC output:

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

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

Relay outputs:

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

1) IEC 60947 part 4 and 5

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

2) Overvoltage Category II

3) UL applications 300 V AC 2A

Control card, 10 V DC output:

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

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

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

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

Control card performance:	
Scan interval	AutomationDrive FC 301: 5 ms / AutomationDrive FC 302: 1 ms

Surroundings:	
Frame size A1, A2, 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	0.035 oz [1.0 g] RMS
Vibration test, frame size D, E and F	0.7 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] (24-hour average maximum 113°F [45°C])
Ambient temperature, frame size D, E and F	Max. 113°F [45°C] (24-hour average maximum 122°F [40°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.

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 the 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 98.43 ft [30 m].

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 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. The efficiency of motors from 15 hp [11 kW] and up improves by 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}):

η_{SYSTEM}) = $\eta_{VLT} \times \eta_{MOTOR}$

Example showing typical trends in the range 0–125 hp [0–90 kW]

Calculate the efficiency of the system at different loads based on the graph below. The factor in this graph must be multiplied with the specific efficiency factor listed in the specification tables:

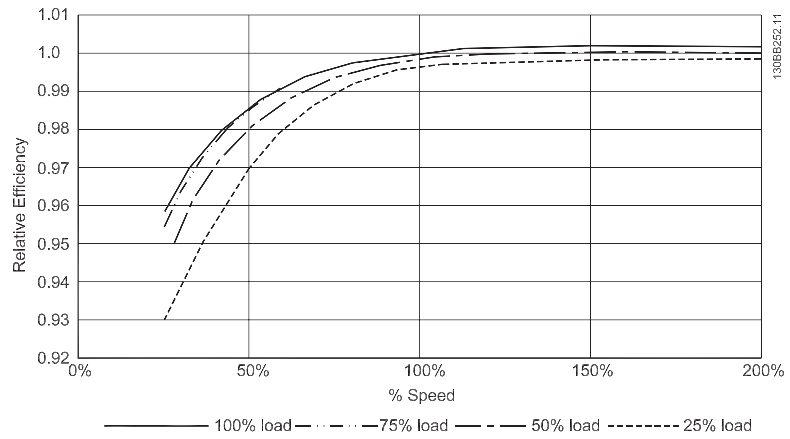


Figure 4.1: The above example shows the efficiency of a 75 hp [55 kW], 380–480 V AC adjustable frequency drive at 25% load at 25 Hz. The graph is showing 0.97 - rated efficiency for a 75 hp [55 kW] adjustable frequency drive is 0.98. The actual efficiency is then: 0.97x0.98=0.95.

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
D1+D3	74	76
D2+D4	73	74
E1/E2 *	73	74
E1/E2 **	82	83
F1/F2/F3/F4	78	80
* 350–675 hp [250 kW], 380–500 V AC and hp 500–550 hp [355–400 kW], 525–690 V AC only ** Remaining E1+E2 power sizes. *** For D and E sizes, reduced fan speed is at 87%.		

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 recommends fitting 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 - MG90NYXX.

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 AutomationDrive FC 300 complies with the demands of IEC 60034-25 regarding motors designed to be controlled by adjustable frequency drives. The AutomationDrive FC 300 also complies with IEC 60034-17 regarding norm motors controlled by adjustable frequency drives.
Measured values from lab tests:

AutomationDrive 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

AutomationDrive 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

AutomationDrive 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

AutomationDrive 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

AutomationDrive 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

AutomationDrive 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

AutomationDrive 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

AutomationDrive 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

AutomationDrive 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

AutomationDrive 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

AutomationDrive 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

AutomationDrive 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

AutomationDrive 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

AutomationDrive 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

AutomationDrive 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

AutomationDrive 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

AutomationDrive 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

AutomationDrive 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

AutomationDrive 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

AutomationDrive 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

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.

125–300 hp [90–200 kW] / 380–500 V

Cable length	AC line voltage	Rise time	Peak voltage	du/dt
115 ft [30 m]	400 V	0.34 µsec.	1040 V	2447 V/µsec.

350–1075 hp [250–800 kW] / 380–500 V

Cable length	AC line voltage	Rise time	Peak voltage	du/dt
115 ft [30 m]	500 V	0.71 µsec.	1165 V	1389 V/µsec.
115 ft [30 m]	500 V [1)]	0.80 µsec.	906 V	904 V/µsec.
115 ft [30 m]	400 V	0.61 µsec.	942 V	1233 V/µsec.
115 ft [30 m]	400 V [1)]	0.82 µsec.	760 V	743 V/µsec.

1) With Danfoss du/dt filter

125–450 hp [90–315 kW] / 525–690 V				
Cable length	AC line voltage	Rise time	Peak voltage	du/dt
115 ft [30 m]	690 V	0.38µsec.	1573	3309 V/µsec.
115 ft [30 m]	690 V 1)	1.72 µsec.	1329	640 V/µsec.
115 ft [30 m]	575 V	0.23 µsec.	1314	2750 V/µsec.
115 ft [30 m]	575 V 2)	0.72 µsec.	1061	857 V/µsec.

1) With Danfoss du/dt filter
2) With du/dt filter

500–1350 hp [355–1000 kW] / 525–690 V				
Cable length	AC line voltage	Rise time	Peak voltage	du/dt
115 ft [30 m]	690 V	0.57 µsec.	1611	2261 V/µsec.
115 ft [30 m]	575 V	0.25 µsec.		2510 V/µsec.
115 ft [30 m]	690 V 1)	1.13 µsec.	1629	1150 V/µsec.

1) With Danfoss du/dt filter.

4.9 Special Conditions

4.9.1 Purpose of Derating

Derating must be taken into account when using the adjustable frequency drive at low air pressure (high elevations), at low speeds, with long motor cables, cables with a large cross-section or at high ambient temperature. The required action is described in this section.

4.9.2 Derating for Ambient Temperature and IGBT Switching Frequency

The average temperature ($T_{AMB, AVG}$) measured over 24 hours must be at least 9°F [5°C] lower than the maximum allowed ambient temperature ($T_{AMB,MAX}$).

If the adjustable frequency drive is operated at high ambient temperatures, the continuous output current should be decreased.

The derating depends on the switching pattern, which can be set to 60° AVM or SFAVM in par. 14-00 *Switching Pattern*.

Frame size A

60° AVM - Pulse Width Modulation

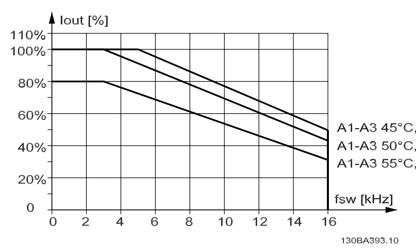


Figure 4.2: Derating of I_{out} for different $T_{AMB, MAX}$ for frame size A, using 60° AVM

SFAVM - Stator Frequency Asyncron Vector Modulation

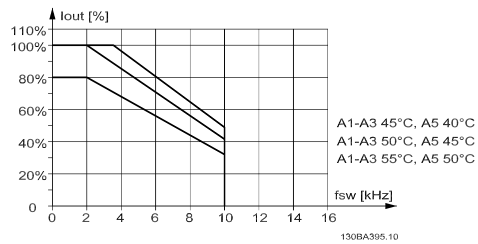


Figure 4.3: Derating of I_{out} for different $T_{AMB, MAX}$ for frame size A, using SFAVM

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

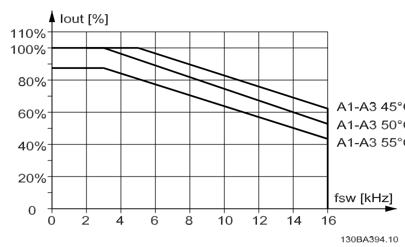


Figure 4.4: Derating of I_{out} for different $T_{AMB, MAX}$ for frame size A, using 60° AVM and maximum 33 ft [10 m] motor cable

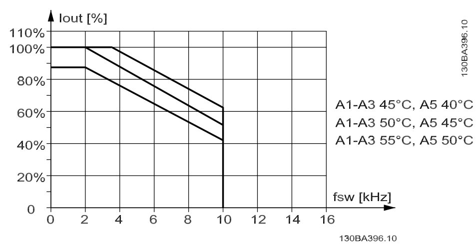


Figure 4.5: Derating of I_{out} for different $T_{AMB, MAX}$ for frame size A, using SFAVM and maximum 33 ft [10 m] motor cable

Frame Size B (except B2 525–690 V)

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

60° AVM - Pulse Width Modulation

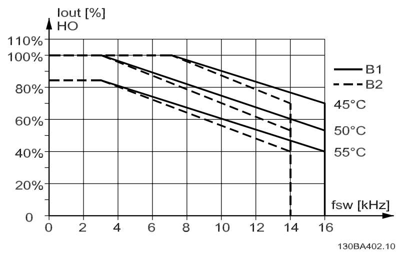


Figure 4.6: Derating of I_{out} for different $T_{AMB, MAX}$ for frame size B, using 60° AVM in High torque mode (160% over torque)

SFAVM - Stator Frequency Asyncron Vector Modulation

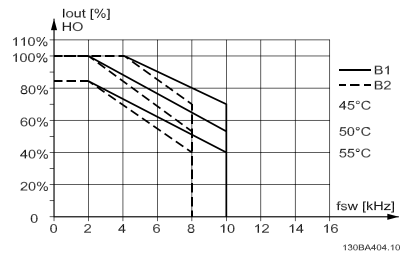


Figure 4.7: Derating of I_{out} for different $T_{AMB, MAX}$ for frame size B, using SFAVM in High torque mode (160% over torque)

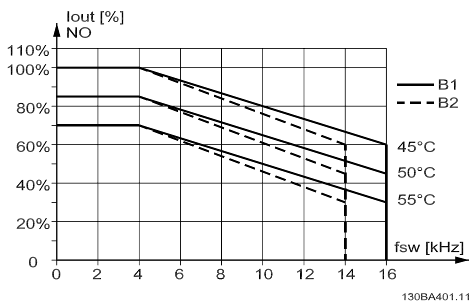


Figure 4.8: Derating of I_{out} for different $T_{AMB, MAX}$ for frame size B, using 60° AVM in Normal torque mode (110% over torque)

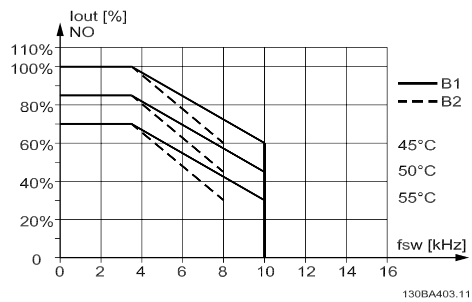


Figure 4.9: Derating of I_{out} for different $T_{AMB, MAX}$ for frame size B, using SFAVM in Normal torque mode (110% over torque)

Frame Size B2, 525–690 V

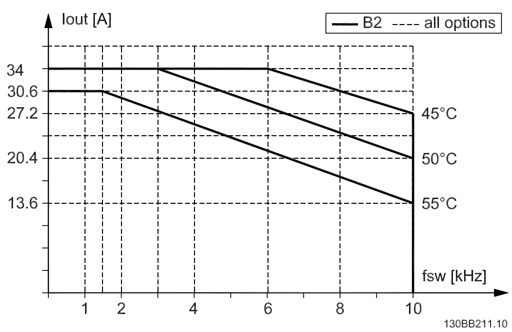


Figure 4.10: Output current derating with switching frequency and ambient temperature for frame size B2, 60° AVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.

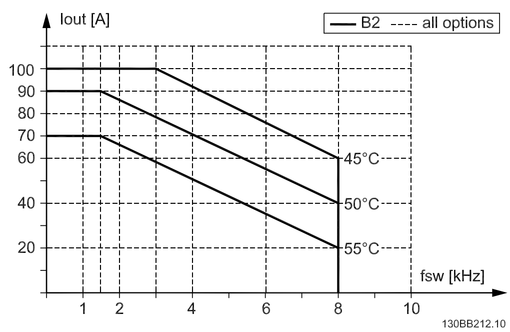


Figure 4.11: Output current derating with switching frequency and ambient temperature for frame size B2, SFAVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.

Frame size C (except C2 525–690 V)

60° AVM - Pulse Width Modulation

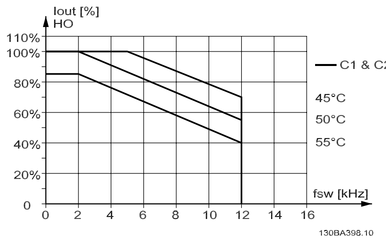


Figure 4.12: Derating of I_{out} for different $T_{AMB, MAX}$ for frame size C, using 60° AVM in High torque mode (160% over torque)

SFAVM - Stator Frequency Asyncron Vector Modulation

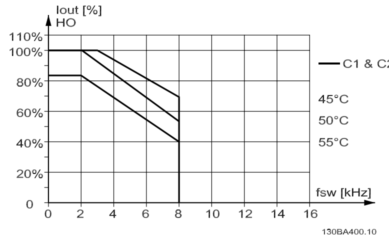


Figure 4.13: Derating of I_{out} for different $T_{AMB, MAX}$ for frame size C, using SFAVM in High torque mode (160% over torque)

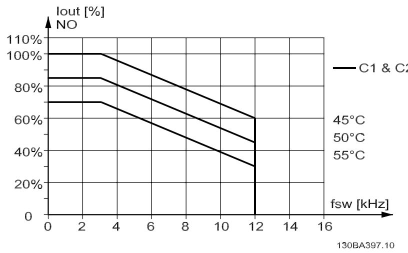


Figure 4.14: Derating of I_{out} for different $T_{AMB, MAX}$ for frame size C, using 60° AVM in Normal torque mode (110% over torque)

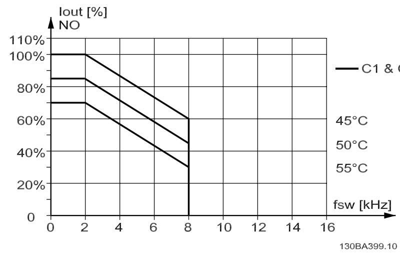


Figure 4.15: Derating of I_{out} for different $T_{AMB, MAX}$ for frame size C, using SFAVM in Normal torque mode (110% over torque)

Frame size C2, 525–690 V

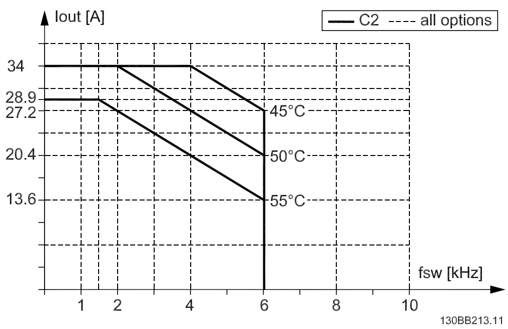


Figure 4.16: Output current derating with switching frequency and ambient temperature for frame size C2, 60° AVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.

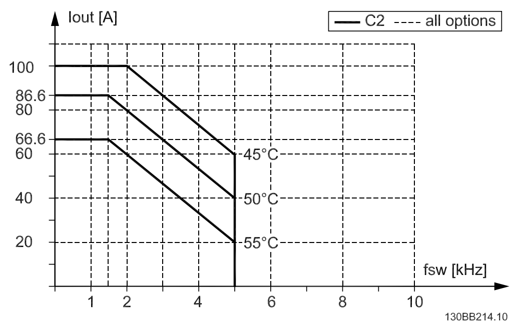


Figure 4.17: Output current derating with switching frequency and ambient temperature for frame size C2, SFAVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.

4

Frame size D

60° AVM - Pulse Width Modulation, 380–500 V

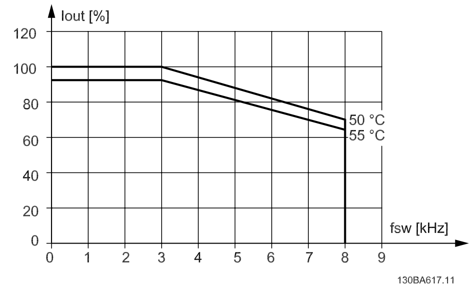


Figure 4.18: Derating of I_{out} for different $T_{AMB, MAX}$ for frame size D at 500 V, using 60° AVM in High torque mode (160% over torque)

SFAVM - Stator Frequency Asyncron Vector Modulation, 380–500 V

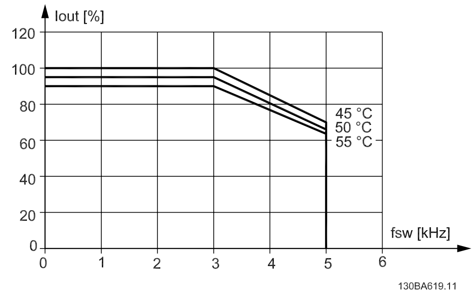


Figure 4.19: Derating of I_{out} for different $T_{AMB, MAX}$ for frame size D at 500 V, using SFAVM in High torque mode (160% over torque)

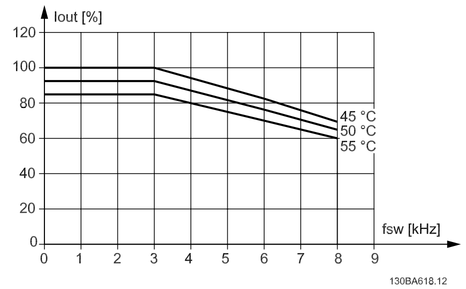


Figure 4.20: Derating of I_{out} for different $T_{AMB, MAX}$ for frame size D at 500 V, using 60° AVM in Normal torque mode (110% over torque)

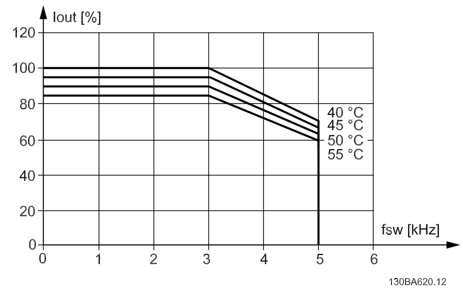


Figure 4.21: Derating of I_{out} for different $T_{AMB, MAX}$ for frame size D at 500 V, using SFAVM in Normal torque mode (110% over torque)

60° AVM - Pulse Width Modulation, 525–690 V (except P315)

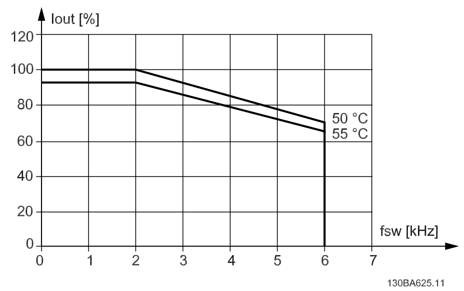


Figure 4.22: Derating of I_{out} for different $T_{AMB, MAX}$ for frame size D at 690 V, using 60° AVM in High torque mode (160% over torque). Note: *not* valid for P315.

SFAVM - Stator Frequency Asyncron Vector Modulation, 525–690 V (except P315)

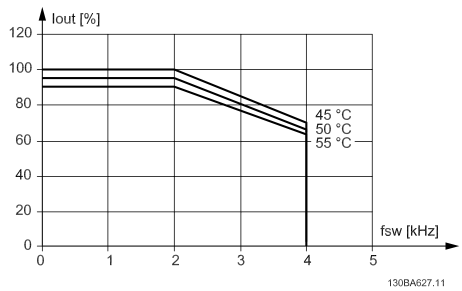


Figure 4.23: Derating of I_{out} for different $T_{AMB, MAX}$ for frame size D at 690 V, using SFAVM in High torque mode (160% over torque). Note: *not* valid for P315.

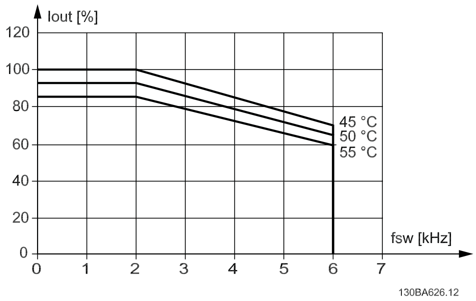


Figure 4.24: Derating of I_{out} for different $T_{AMB,\ MAX}$ for frame size D at 690 V, using 60° AVM in Normal torque mode (110% over torque). Note: *not* valid for P315.

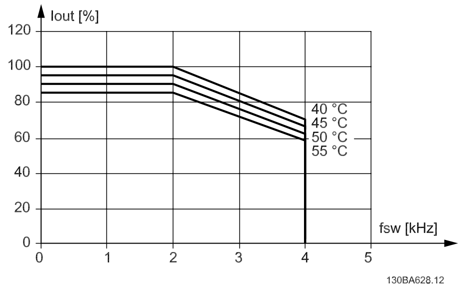


Figure 4.25: Derating of I_{out} for different $T_{AMB,\ MAX}$ for frame size D at 690 V, using SFAVM in Normal torque mode (110% over torque). Note: *not* valid for P315.

60° AVM - Pulse Width Modulation, 525–690 V, P315

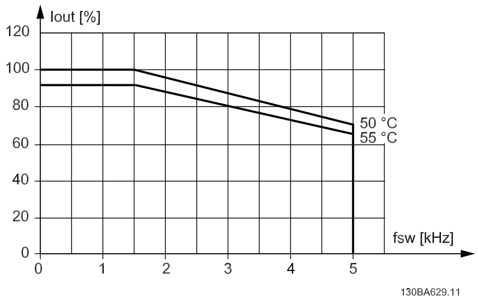


Figure 4.26: Derating of I_{out} for different $T_{AMB,\ MAX}$ for frame size D at 690 V, using 60° AVM in High torque mode (160% over torque). Note: P315 *only*.

SFAVM - Stator Frequency Asyncron Vector Modulation, 525–690 V, P315

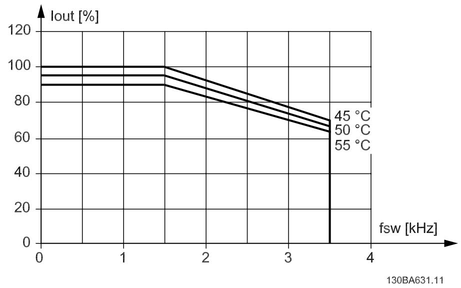


Figure 4.27: Derating of I_{out} for different $T_{AMB,\ MAX}$ for frame size D at 690 V, using SFAVM in High torque mode (160% over torque). Note: P315 *only*.

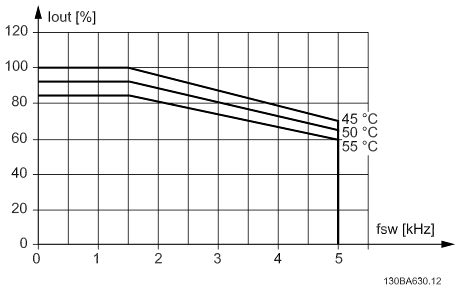


Figure 4.28: Derating of I_{out} for different $T_{AMB,\ MAX}$ for frame size D at 690 V, using 60° AVM in Normal torque mode (110% over torque). Note: P315 *only*.

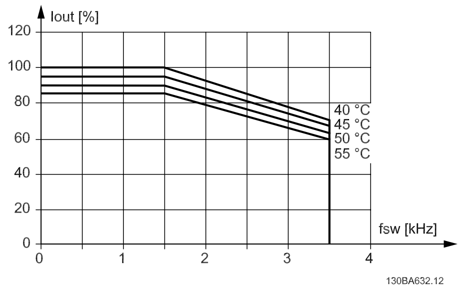


Figure 4.29: Derating of I_{out} for different $T_{AMB,\ MAX}$ for frame size D at 690 V, using SFAVM in Normal torque mode (110% over torque). Note: P315 *only*.

Frame sizes E and F

60° AVM - Pulse Width Modulation, 380–500 V

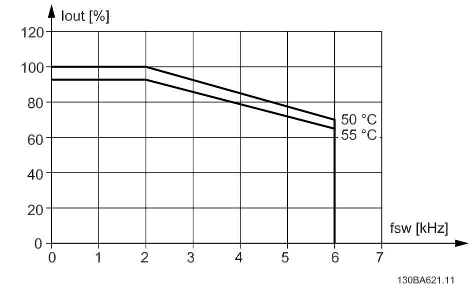


Figure 4.30: Derating of I_{out} for different $T_{AMB, MAX}$ for frame sizes E and F at 500 V, using 60° AVM in High torque mode (160% over torque)

SFAVM - Stator Frequency Asyncron Vector Modulation, 380–500 V

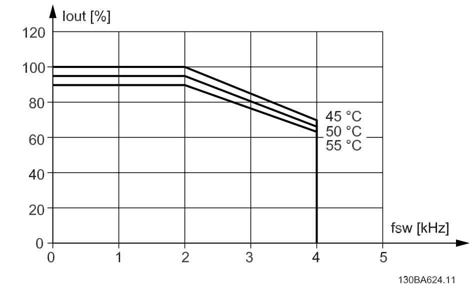


Figure 4.31: Derating of I_{out} for different $T_{AMB, MAX}$ for frame sizes E and F at 500 V, using SFAVM in High torque mode (160% over torque).

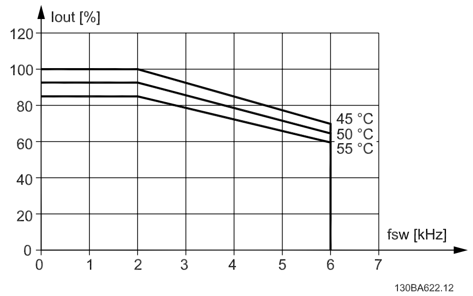


Figure 4.32: Derating of I_{out} for different $T_{AMB, MAX}$ for frame sizes E and F at 500 V, using 60° AVM in Normal torque mode (110% over torque)

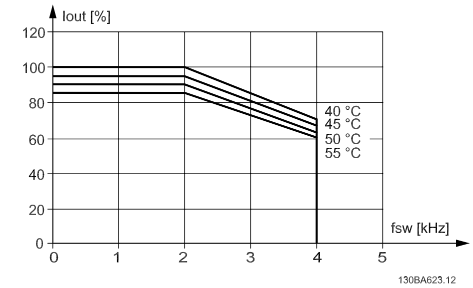


Figure 4.33: Derating of I_{out} for different $T_{AMB, MAX}$ for frame sizes E and F at 500 V, using SFAVM in Normal torque mode (110% over torque)

60° AVM - Pulse Width Modulation, 525–690 V

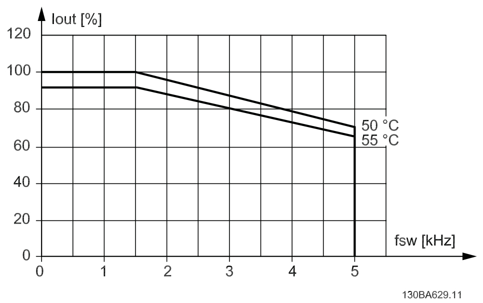


Figure 4.34: Derating of I_{out} for different $T_{AMB, MAX}$ for frame sizes E and F at 690 V, using 60° AVM in High torque mode (160% over torque).

SFAVM - Stator Frequency Asyncron Vector Modulation, 525–690 V

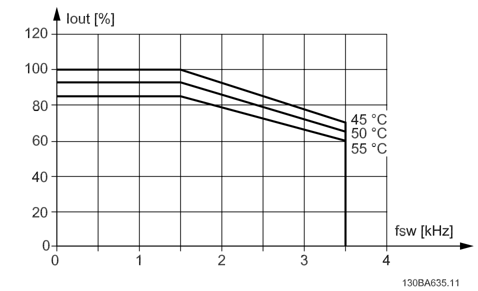


Figure 4.35: Derating of I_{out} for different $T_{AMB, MAX}$ for frame sizes E and F at 690 V, using SFAVM in High torque mode (160% over torque).

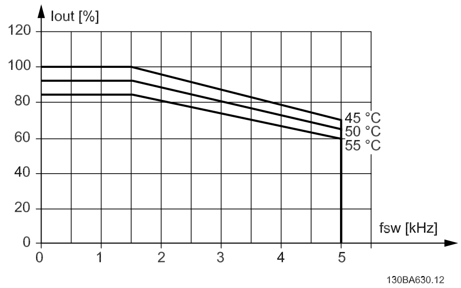


Figure 4.36: Derating of I_{out} for different $T_{AMB, MAX}$ for frame sizes E and F at 690 V, using 60° AVM in Normal torque mode (110% over torque).

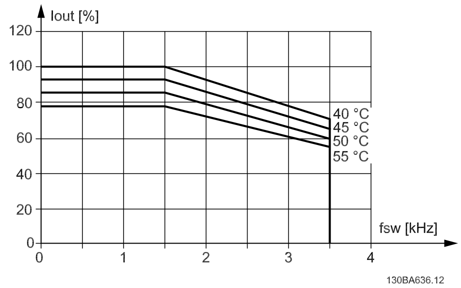


Figure 4.37: Derating of I_{out} for different $T_{AMB, MAX}$ for frame sizes E and F at 690 V, using SFAVM in Normal torque mode (110% over torque).

4

4

4.9.3 Derating for low air pressure

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

At an altitude lower than 3,280 ft [1,000 m], no derating is necessary, but above 3,280 ft [1,000 m], the ambient temperature (T_{AMB}) or max. output current (I_{out}) should be derated in accordance with the diagram shown.

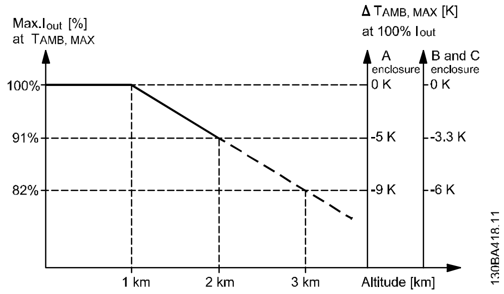
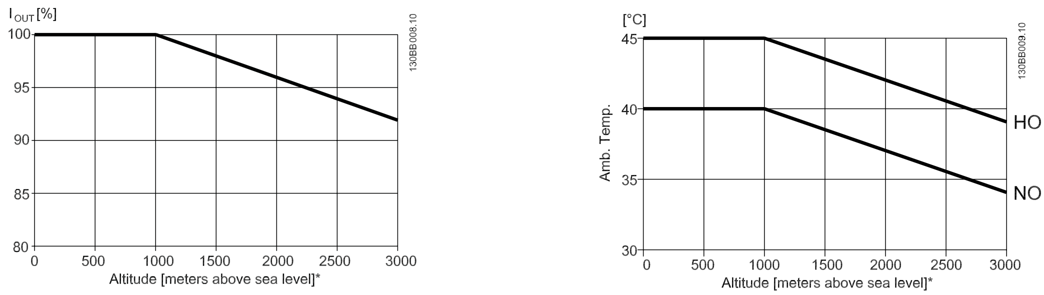


Figure 4.38: Derating of output current versus altitude at $T_{AMB, MAX}$ for frame sizes A, B and C. At altitudes above 6,600 feet [2 km], please contact Danfoss regarding PELV.

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



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

4.9.4 Derating for running at low speed

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

Constant torque applications (CT mode)

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

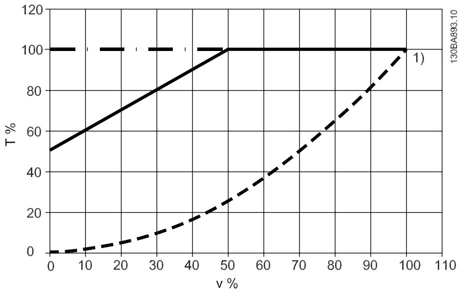
An alternative is to reduce the load level of the motor by choosing a larger motor. However, the design of the adjustable frequency drive limits the motor size.

Variable (quadratic) torque applications (VT)

In VT applications such as centrifugal pumps and fans, where the torque is proportional to the square of the speed and the power is proportional to the cube of the speed, there is no need for additional cooling or 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 an adjustable frequency drive type VLT FCxxx



Legend: – – – –Typical torque at VT load –•–•–Max torque with forced cooling ———Max torque
Note 1) Oversyncronous 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.

4.9.5 Automatic Adaptations to Ensure Performance

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 drive.

4

5 How to Order

5.1.1 Drive Configurator

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

For the AutomationDrive 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 the chapter *How to Select Your VLT*. In the example above, a Profibus DP V1 and a 24 V backup option is included in the drive.

Ordering numbers for AutomationDrive FC 300 standard variants can also be located in the chapter AutomationDrive FC 300 *Selection*.

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 global Internet site: 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.
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.

5

5.1.2 Ordering Form 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

FC- 0 P T H XSXXXXA B C D

130BA052.15

Product groups	1-3	
Adjustable frequency drive series	4-6	
Power rating	8-10	
Phases	11	
AC Line Voltage	12	
Enclosure	13-15	
Enclosure type		
Enclosure class		
Control supply voltage		
Hardware configuration		
RFI filter	16-17	
Brake	18	
Display (LCP)	19	
Coating PCB	20	
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**	

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

Ordering type codemodel number frame sizes A, B and C

Description	Pos	Possible choice
Product group	1-3	FC 30x
Drive series	4-6	AutomationDrive FC 301 AutomationDrive 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: 200–240 V AC T 4: 380–480 V AC T 5: 380–500 V AC T 6: 525–600 V AC T 7: 525–690 V AC
Enclosure	13-15	E20: IP20 E55: IP 55/NEMA Type 12 P20: IP20 (with backplate) P21: IP21/ NEMA Type 1 (with back-plate) P55: IP55/ NEMA Type 12 (with back-plate) Z20: IP 20 1) E66: IP 66
RFI filter	16-17	H1: RFI filter class A1/B1 H2: No RFI filter, observes class A2 H3: RFI filter class A1/B1 1) H6: RFI filter, maritime use1) HX: No filter (600 V 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 power option 1: Line power disconnect 3: Line power disconnect and fuse2) 5: Line power disconnect, fuse and load sharing 2, 3) 7: Fuse 2) 8: Line power disconnect and load sharing3) A: Fuse and load sharing 2, 3) D: Load sharing 3)
Adaptation	22	Reserved
Adaptation	23	Reserved
Software release	24-27	Current software
Software language	28	

1): AutomationDrive FC 301/ frame sizeA1 only
2) US market only
3): Power sizes ≥ 15 hp [11 kW] only

Ordering type codemodel number frame sizes D and E

Description	Pos	Possible choice
Product group	1-3	AutomationDrive FC 302
Drive series	4-6	AutomationDrive FC 302
Power rating	8-10	50–750 hp [37-560 kW]
Phases	11	Three phases (T)
AC line voltage	11-12	T 5: 380–500 V AC T 7: 525–690 V 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 use2)
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 380–480/500 V only)
Line power option	21	X: No AC 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	Reserved
Adaptation	23	Reserved
Software release	24-27	Current software
Software language	28	

1): Available for all D frames. E frames 380–480/500 V only
2) Consult factory for applications requiring maritime certification

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Ordering type codemodel number frame size F

Description	Pos	Possible choice
Product group	1-3	AutomationDrive FC 302
Drive series	4-6	AutomationDrive FC 302
Power rating	8-10	600–1600 hp [450–1200 kW]
Phases	11	Three phases (T)
AC line voltage	11-12	T 5: 380–500 V AC T 7: 525–690 V AC
Enclosure	13-15	E21: IP 21/ NEMA Type 1 E54: IP 54/ NEMA Type 12 L2X: IP21/NEMA 1 with cabinet light & IEC 230 V power outlet L5X: IP54/NEMA 12 with cabinet light & IEC 230 V power outlet L2A: IP21/NEMA 1 with cabinet light & NAM 115 V power outlet L5A: IP54/NEMA 12 with cabinet light & NAM 115 V power outlet H21: IP21 with space heater and thermostat H54: IP54 with space heater and thermostat R2X: IP21/NEMA1 with space heater, thermostat, light & IEC 230 V outlet R5X: IP54/NEMA12 with space heater, thermostat, light & IEC 230 V outlet R2A: IP21/NEMA1 with space heater, thermostat, light, & NAM 115 V outlet R5A: IP54/NEMA12 with space heater, thermostat, light, & NAM 115 V outlet
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]
Brake	18	B: Brake IGBT mounted X: No brake IGBT R: Regeneration terminals M: IEC Emergency stop pushbutton (with Pilz safety relay)[4] N: IEC Emergency stop pushbutton with brake IGBT and brake terminals [4] P: IEC Emergency stop pushbutton with regeneration terminals[4]
Display	19	G: Graphical Local Control Panel LCP
Coating PCB	20	C: Coated PCB

Description	Pos	Possible choice
Line power option	21	X: No AC line power 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)
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, 24 V power supply (customer use) J: External temperature monitoring G: 5A, 24 V power supply (customer use) & external temperature monitoring
Software release	24-27	Current software
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) 380–480/500 V only
4) Requires contactor

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) A1: MCA 101 Profibus DP V1 (with top entry) A4: MCA 104 DeviceNet (standard) A4: MCA 104 DeviceNet (with top entry) A6: MCA 105 CANOpen (standard) A6: MCA 105 CANOpen (with top entry) AN: MCA 121 Ethernet IP AT: MCA 113 Profibus drive VLT3000 AY: MCA 123 Ethernet PowerLink
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
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: DC backup D0: MCB 107 Ext. 24 V backup

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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: IP21/IP 4X Top/TYPE 1	130B1121	
IP 21/4X top/TYPE 1 kit	Enclosure, frame size A2: IP21/IP 4X Top/TYPE 1	130B1122	
IP 21/4X top/TYPE 1 kit	Enclosure, frame sizeA3: IP21/IP 4X Top/TYPE 1	130B1123	
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	C1 IP21/ IP55/ NEMA 12	130B3910	
MCF 108 Backplate	C2 IP21/ IP55/ NEMA 12	130B3911	
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	
Footmount frame for flat pack resistors, frame size A2		175U0085	
Footmount frame for flat pack resistors, frame size A3		175U0088	
Footmount frame for 2 flat pack resistors, frame size A2		175U0087	
Footmount frame for 2 flat pack resistors, frame size A3		175U0086	
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
Options for C0			
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 C1			
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

Type	Description	Ordering no.	
Option for Slot D			
MCB 107	24 V DC back-up	130B1108	130B1208
External Options			
Ethernet IP	Ethernet master	175N2584	
PC Software			
MCT 10	MCT 10 Set-up software - 1 user	130B1000	
MCT 10	MCT 10 Set-up software - 5 users	130B1001	
MCT 10	MCT 10 Set-up software - 10 users	130B1002	
MCT 10	MCT 10 Set-up software - 25 users	130B1003	
MCT 10	MCT 10 Set-up software - 50 users	130B1004	
MCT 10	MCT 10 Set-up software - 100 users	130B1005	
MCT 10	MCT 10 Set-up software - unlimited users	130B1006	
Options can be ordered as factory built-in options, see ordering information. For information on serial communication bus and application option combatibility with older software versions, please contact your Danfoss supplier.			

Type	Description	Ordering no.	
Spare Parts			
Control board AutomationDrive FC 302	Coated version	-	130B1109
Control board AutomationDrive 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 AutomationDrive FC 300 Profibus	10 pieces Profibus connectors	130B1075	
Connectors AutomationDrive FC 300 DeviceNet	10 pieces DeviceNet connectors	130B1074	
Connectors AutomationDrive FC 302 10-pole	10 pieces 10-pole spring loaded connectors	130B1073	
Connectors AutomationDrive FC 301 8-pole	10 pieces 8-pole spring loaded connectors	130B1072	
Connectors AutomationDrive FC 300 6-pole	10 pieces 6-pole spring-loaded connectors	130B1071	
Connectors AutomationDrive FC 300 RS485	10 pieces 3-pole spring-loaded connectors for RS 485	130B1070	
Connectors AutomationDrive FC 300 3-pole	10 pieces 3-pole connectors for relay 01	130B1069	
Connectors AutomationDrive FC 302 3-pole	10 pieces 3-pole connectors for relay 02	130B1068	
Connectors AutomationDrive FC 300 Line Power	10 pieces line connectors IP20/21	130B1067	
Connectors AutomationDrive FC 300 Line Power	10 pieces line connectors IP 55	130B1066	
Connectors AutomationDrive FC 300 Motor	10 pieces motor connectors	130B1065	
Accessory bag MCO 305		130B7535	

5.2.2 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

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5.2.3 Ordering Numbers: High Power Option 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
Backchannel 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	
Backchannel 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	175R0076
(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
Loadshare	D1/D3 Frame	176F8456	175R5637
	D2/D4 Frame	176F8455	
Top Entry Sub D or Shield Termination	D3/D4/E2 Frames	176F1742	175R5964

5.2.4 Ordering Numbers: Brake Resistors 10%

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

AutomationDrive 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)

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

AutomationDrive 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 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)

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

AutomationDrive FC 301/302	$P_{m\ (HO)}$	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]	[%]
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)

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

AutomationDrive 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)

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

Automation Drive 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)
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)

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

Automation Drive 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	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							

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

AutomationDrive 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)

5.2.5 Ordering Numbers: Brake Resistors 40%

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

AutomationDrive 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)

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

AutomationDrive 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]	[%]
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)

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

AutomationDrive FC 301/302	$P_{m\ (HO)}$	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)

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

AutomationDrive FC 301	$P_{m\ (HO)}$	R_{min}	$R_{br,\ nom}$	R_{rec}	$P_{br\ avg}$	Order no.	Period	Cable cross-section²*	Therm. relay	Max. brake torque with R_{rec}*
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)

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

AutomationDrive 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)

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

AutomationDrive 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							

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

AutomationDrive 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)

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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

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5.2.6 Flat Packs

AutomationDrive FC 301 - Line power: 200–240 V (T2)

AutomationDrive FC 301				Flatpack IP65 for horizontal conveyors		
	$P_{m\ (HO)}$	R_{min}	$R_{br,\ nom}$	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

AutomationDrive FC 302 Line power: 200–240 V (T2)

AutomationDrive FC 302				Flatpack IP65 for horizontal conveyors		
	$P_{m\ (HO)}$	R_{min}	$R_{br.\ nom}$	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

AutomationDrive FC 301 Line power: 380–480 V (T4)

AutomationDrive FC 301				Flatpack IP65 for horizontal conveyors		
	$P_{m\ (HO)}$	R_{min}	$R_{br.\ nom}$	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

AutomationDrive FC 302 Line power: 380–500 V (T5)

AutomationDrive FC 302				Flatpack IP65 for horizontal conveyors		
	$P_{m\ (HO)}$	R_{min}	$R_{br.\ nom}$	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

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5.2.7 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 5.1: **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 5.2: **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 5.3: **440–480 V, 60Hz**

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 5.4: 500 V, 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

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

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.

5.2.8 Ordering Numbers: Sine Wave Filter Modules, 200–500 V AC

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

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 par. 14-01 *Switching Frequency*.

5.2.9 Ordering Numbers: Sine-wave Filter Modules, 525–690 V AC

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	525–600 V	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	130B2370	130B2341		P315 - P400
530	1.5	100	130B2371	130B2342		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

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 par. 14-01 *Switching Frequency*.

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

Line power supply 3x380–500 V

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

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

Line power supply 3x525–690 V

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

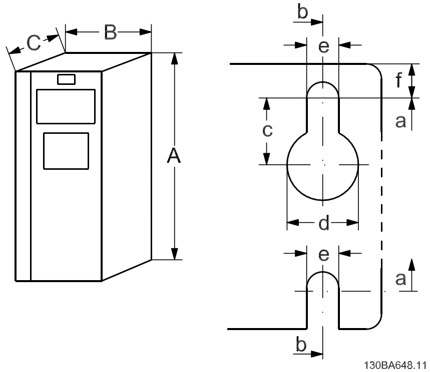
6 Mechanical Installation - Frame Size A, B and C

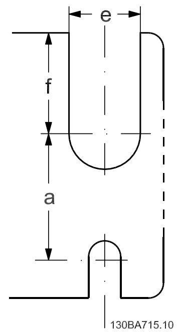
6.1.1 Safety Requirements of Mechanical Installation

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

The adjustable frequency drive is cooled by air circulation.
To protect the unit from overheating, it must be ensured that the ambient temperature *does not exceed the maximum temperature stated for the adjustable frequency drive*, and that the 24-hour average temperature *is not exceeded*. Locate the maximum temperature and 24-hour average in the paragraph *Derating for Ambient Temperature*.
If the ambient temperature is in the range of 113°–131°F [45°–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	A5	B1	B2	B3	B4	C1	C2	C3	C4
IP20	IP20/21	IP20/21	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

Frame Size		A1	A2		A3		A5	B1	B2	B3	B4	C1	C2	C3	C4
Rated Power [kW]	**200–240 V**	**0.25–1.5**	**0.25–2.2**		**3–3.7**		**0.25–3.7**	**5.5–7.5**	**11**	**5.5–7.5**	**11-15**	**15-22**	**30-37**	**18.5–22**	**30-37**
	380–480/500 V	**0.37–1.5**	**0.37–4.0**		**5.5–7.5**		**0.37–7.5**	**11-15**	**18.5–22**	**11-15**	**18.5–30**	**30-45**	**55-75**	**37-45**	**55-75**
	525–600 V				**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**
	525–690 V								**11-22**				**30-75**		
IP NEMA		20 Chassis	20 Chassis	21 Type 1	20 Chassis	21 Type 1	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]	16.53 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	A	12.44 in [316 mm]	14.72 in [374 mm]		14.72 in [374 mm]	-	-	-	-	16.53 in [420 mm]	23.43 in [595 mm]			24.80 [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 [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]	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]	8.47 in [215 mm]	8.28 in [210 mm]	8.28 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]

6

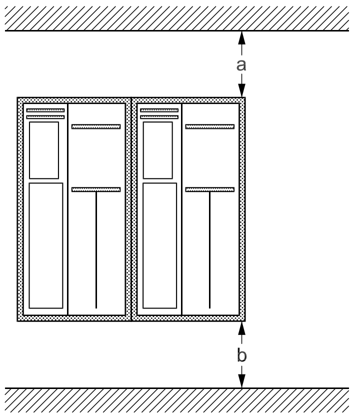
Frame Size		A1	A2		A3		A5	B1	B2	B3	B4	C1	C2	C3	C4
Rated Power [kW]	200–240 V	0.25–1.5	0.25–2.2		3–3.7		0.25–3.7	5.5–7.5	11	5.5–7.5	11-15	15-22	30-37	18.5–22	30-37
	380–480/500 V	0.37–1.5	0.37–4.0		5.5–7.5		0.37–7.5	11-15	18.5–22	11-15	18.5–30	30-45	55-75	37-45	55-75
	525–600 V				0.75–7.5		0.75–7.5	11-15	18.5–22	11-15	18.5–30	30-45	55-90	37-45	55-90
	525–690 V								11-22				30-75		
IP NEMA		20 Chassis	20 Chassis	21 Type 1	20 Chassis	21 Type 1	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
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]	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]	13.20 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]	7.68 in [195 mm]	10.24 in [260 mm]	10.24 in [260 mm]	10.35 in [262 mm]	9.53 in [242 mm]	12.21 in [310 mm]	13.20 in [335 mm]	13.11 in [333 mm]	13.11 in [333 mm]
Screw holes															
	c	0.24 in [6.0 mm]	0.32 in [8.0 mm]	0.32 in [8.0 mm]	0.32 in [8.0 mm]	0.32 in [8.0 mm]	0.33 in [8.25 mm]	0.47 in [12 mm]	0.47 in [12 mm]	0.32 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]	ø0.75 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)	ø0.35 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]	0.35 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 lb [2.7 kg]	10.8 lb [4.9 kg]	11.69 lb [5.3 kg]	14.55 lb [6.6 kg]	15.43 lb [7.0 kg]	29.76/31.31 lb [13.5/14.2 kg]	50.7 lb [23 kg]	59.53 lb [27 kg]	26.46 lb [12 kg]	51.81 lb [23.5 kg]	99.21 lb [45 kg]	143.3 [65 kg]	77.16 [35 kg]	110.23 lb [50 kg]

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:	A1*	A2	A3	A5	B1	B2	B3	B4	C1	C2	C3	C4
a (mm):	100	100	100	100	100	200	100	200	200	225	200	225
b (mm):	100	100	100	100	100	200	100	200	200	225	200	225

Table 6.1: * AutomationDrive 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.

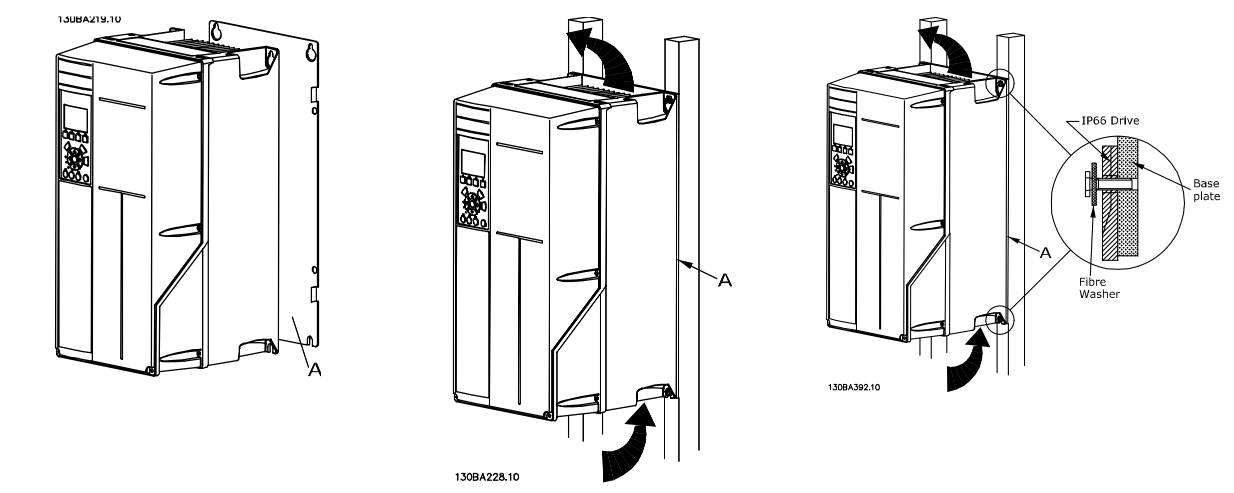


Table 6.2: Mounting frame sizes A5, B1, B2, B3, B4, C1, C2, C3 and C4 on a non-solid back wall, the drive must be provided with a backplate A due to insufficient cooling air over the heatsink.

6.1.3 Field Mounting

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

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7 Mechanical Installation - Frame size D, E and F

7.1 Pre-installation

7.1.1 Planning the Installation Site

NOTE!
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.

NOTE!
The card box cover contains a drilling master for the mounting holes in the D frames. For the E size, please refer to section *Mechanical Dimensions* later in this chapter.

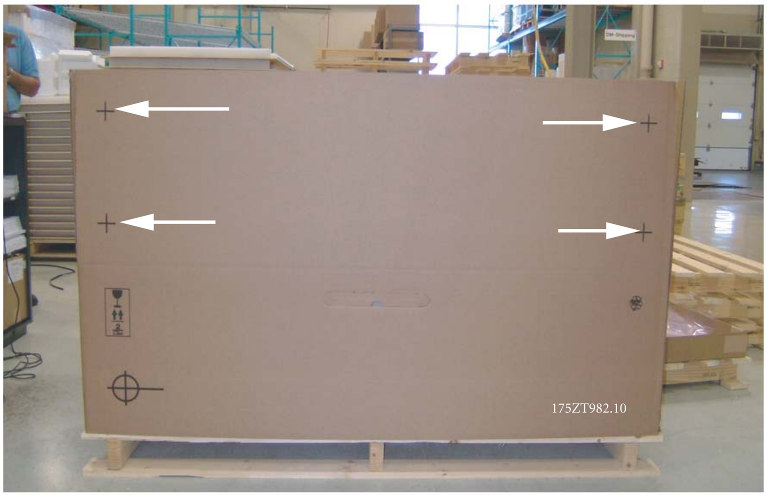


Figure 7.1: Mounting Template

7.1.4 Lifting

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

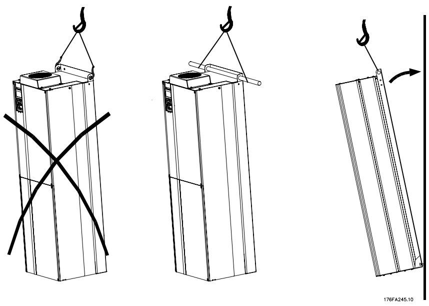


Figure 7.2: Recommended lifting method, frame sizes D and E .

NOTE!

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 degrees or greater.

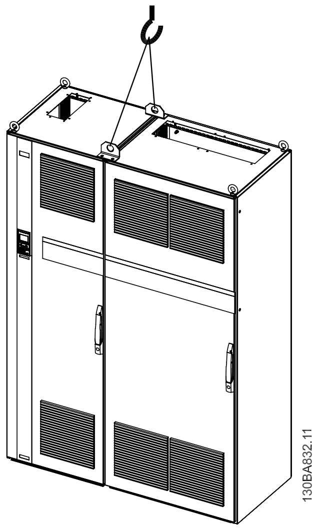


Figure 7.3: Recommended lifting method, frame size F1.

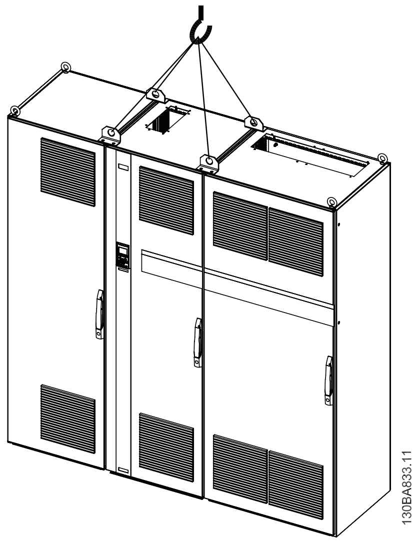


Figure 7.5: Recommended lifting method, frame size F3.

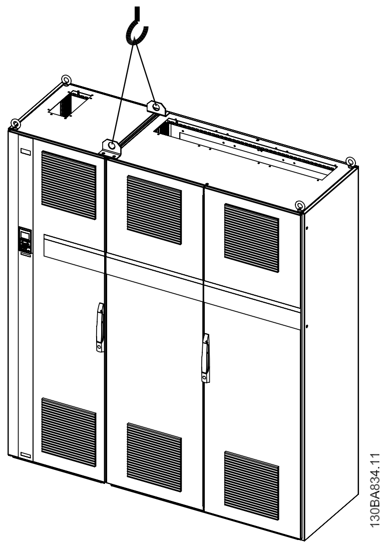


Figure 7.4: Recommended lifting method, frame size F2.

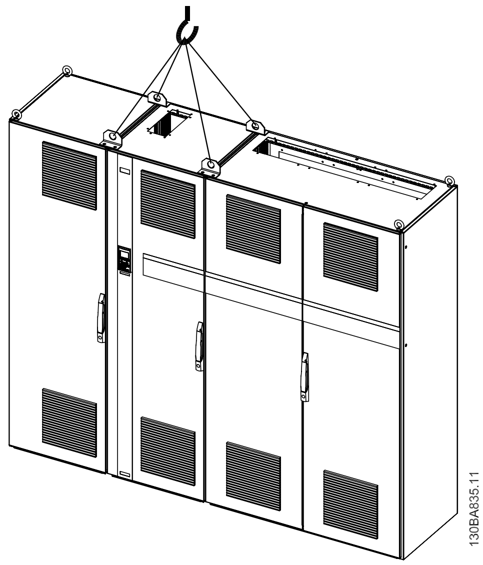
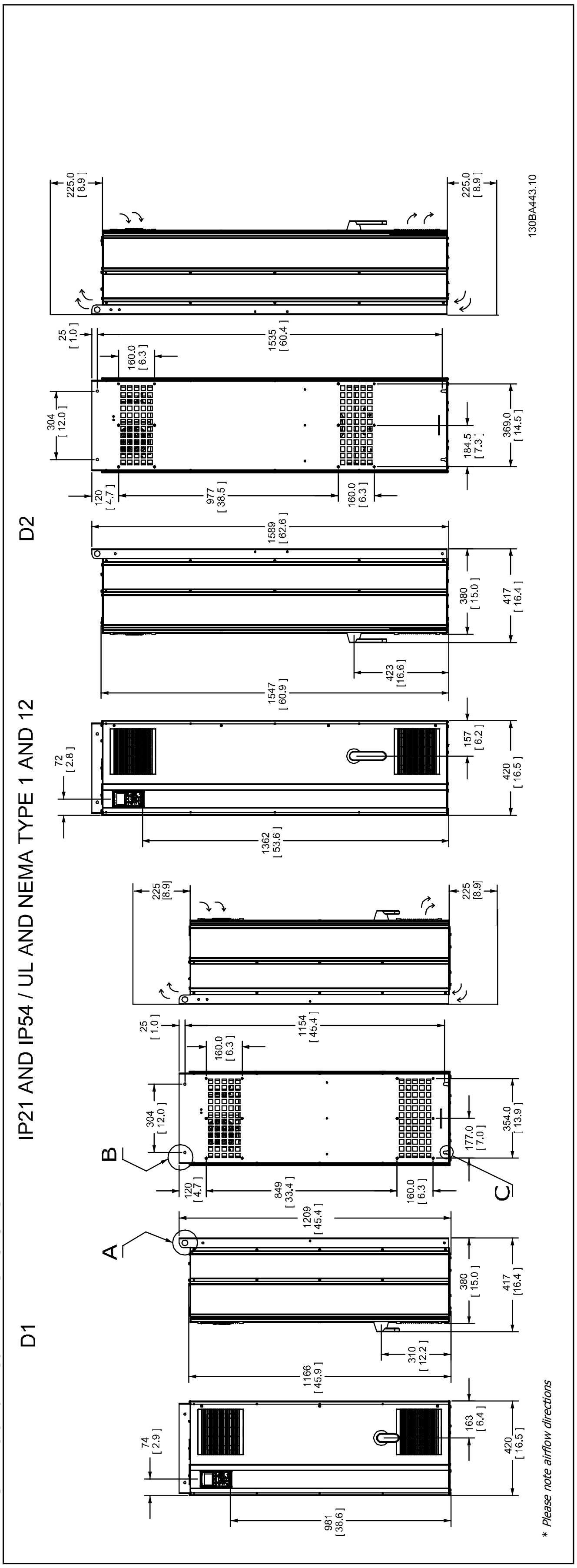


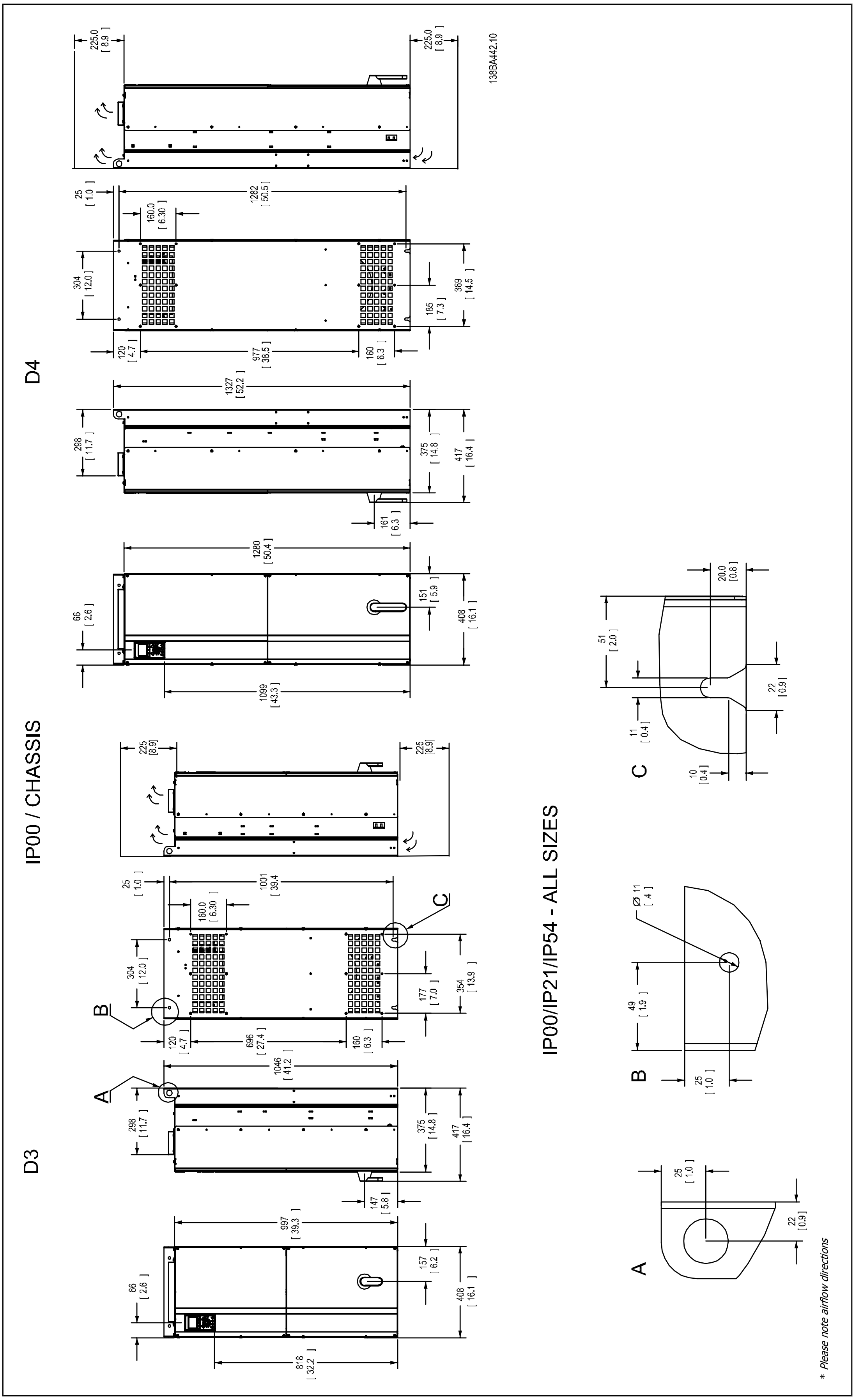
Figure 7.6: Recommended lifting method, frame size F4.

NOTE!
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 degrees or greater.

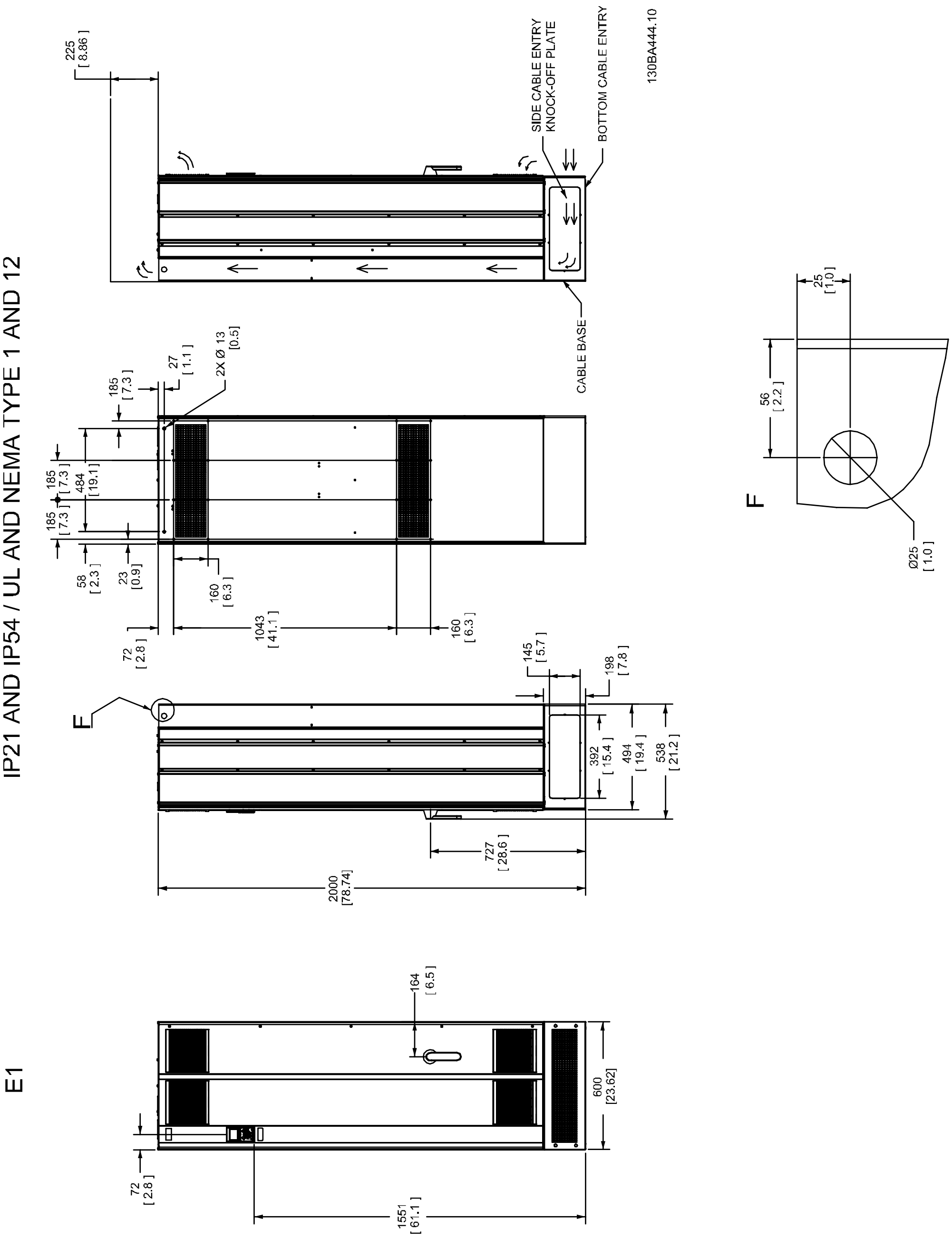
7

7.1.5 Mechanical Dimensions

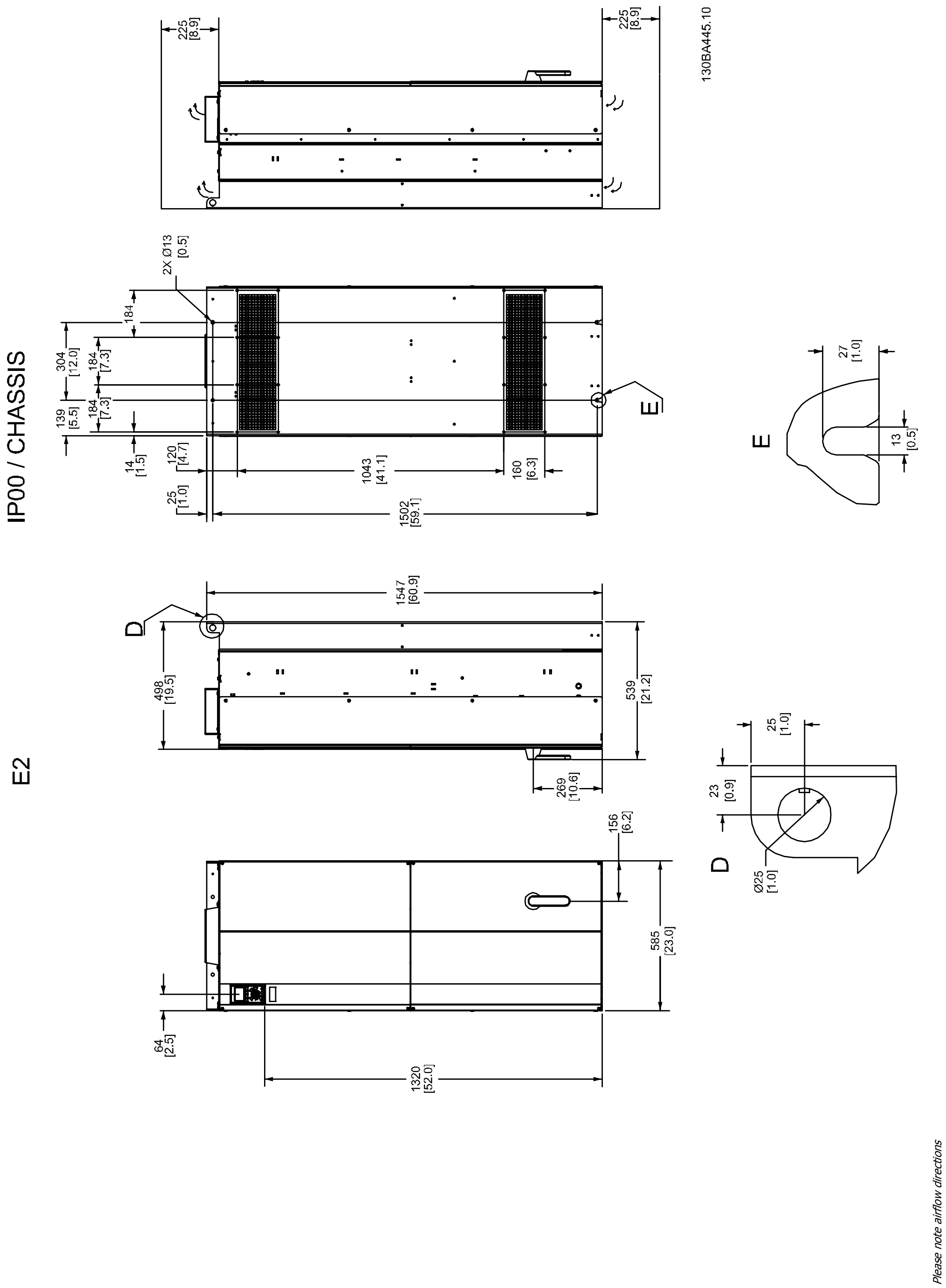


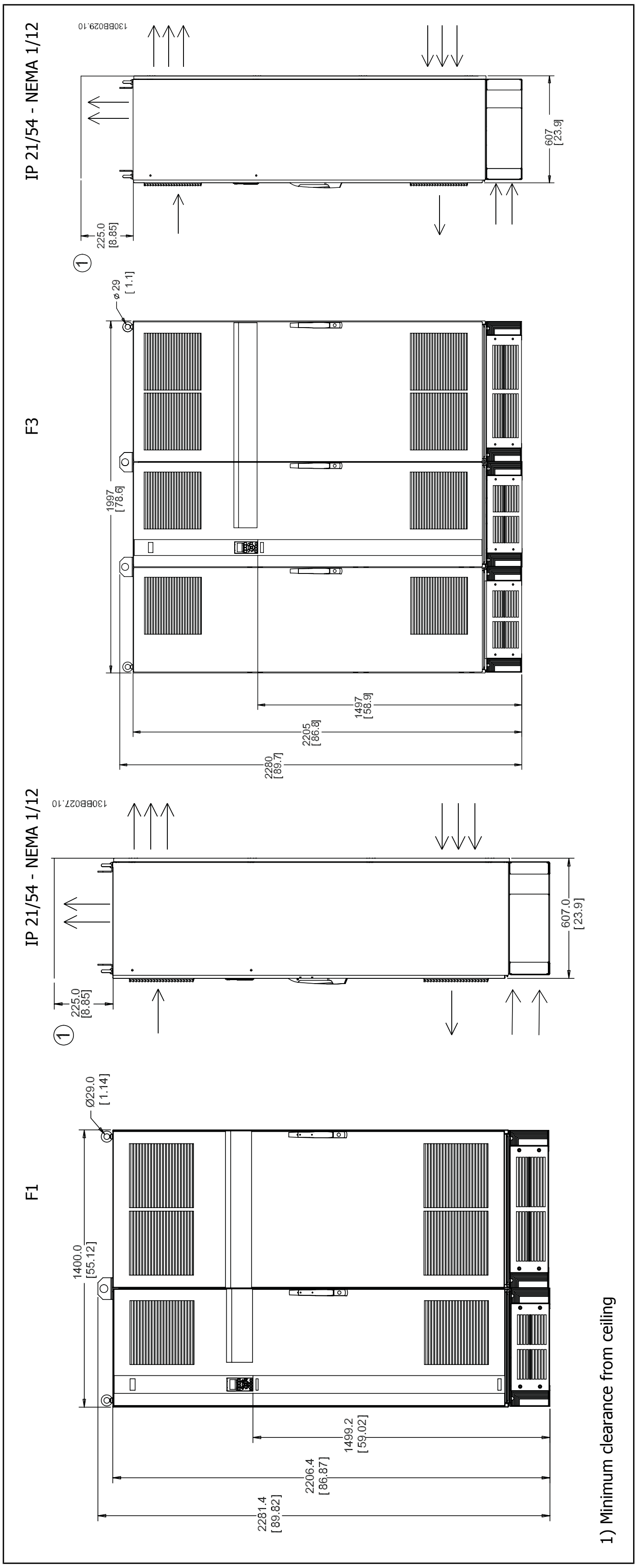

IP00 / CHASSIS
D3
D4
IP00/IP21/IP54 - ALL SIZES
A
B
C
130BA442.10
* Please note airflow directions

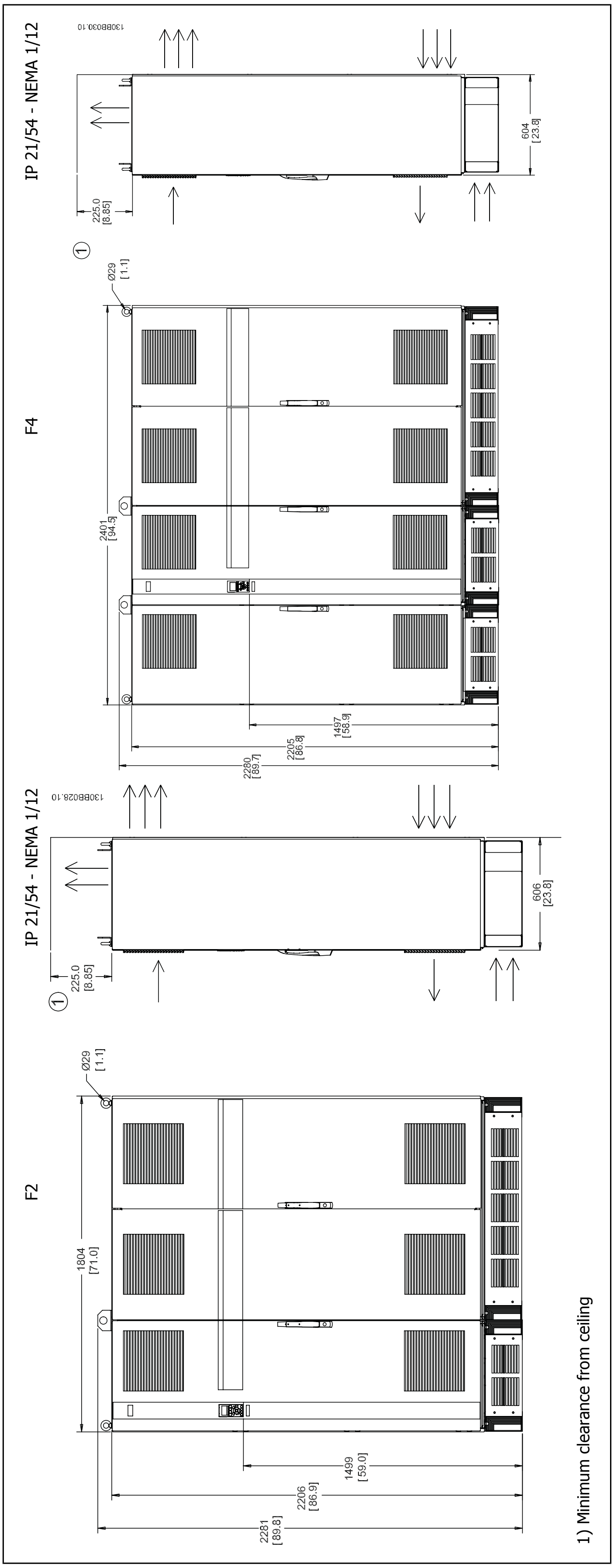
7



* *Please note airflow directions*


IP00 / CHASSIS
E2
130BA445.10
D
E
225 [8.9]
2X Ø13 [0.5]
184
304 [12.0]
184 [7.3]
139 [5.5]
184 [7.3]
14 [1.5]
120 [4.7]
25 [1.0]
1043 [41.1]
160 [6.3]
1502 [59.1]
1547 [60.9]
498 [19.5]
539 [21.2]
269 [10.6]
156 [6.2]
585 [23.0]
64 [2.5]
1320 [52.0]
27 [1.0]
13 [0.5]
25 [1.0]
23 [0.9]
Ø25 [1.0]
* Please note airflow directions


F3
IP 21/54 - NEMA 1/12
130BB029.10
225.0
[8.85]
607
[23.9]
ø 29
[1.1]
1997
[78.6]
1497
[58.9]
2205
[86.8]
2280
[89.7]
F1
IP 21/54 - NEMA 1/12
130BB027.10
225.0
[8.85]
607.0
[23.9]
Ø29.0
[1.14]
1400.0
[55.12]
1499.2
[59.02]
2206.4
[86.87]
2281.4
[89.82]
1) Minimum clearance from ceiling


IP 21/54 - NEMA 1/12
F4
130BB030.10
225.0
[8.85]
604
[23.8]
Ø29
[1.1]
2401
[94.5]
1497
[58.9]
2205
[86.8]
2280
[89.7]
IP 21/54 - NEMA 1/12
F2
130BB028.10
225.0
[8.85]
606
[23.8]
Ø29
[1.1]
1804
[71.0]
1499
[59.0]
2206
[86.9]
2281
[89.8]
1) Minimum clearance from ceiling

7

7

Mechanical dimensions, frame size D

Frame size		**D1**		**D2**		**D3**	**D4**
		125–150 hp [90–110 kW] (380–500 V) 50–175 hp [37–132 kW] (525–690 V)		**175–300 hp [132–200 kW] (380–500 V) 250–450 hp [160–315 kW] (525–690 V)**		**125–150 hp [90–110 kW] (380–500 V) 50–175 hp [37–132 kW] (525–690 V)**	**175–300 hp [132–200 kW] (380–500 V) 250–450 hp [160–315 kW] (525–690 V)**
IP NEMA		21 Type 1	54 Type 12	21 Type 1	54 Type 12	00 Chassis	00 Chassis
Shipping dimensions	Height	25.6 in [650 mm]	25.6 in [650 mm]	25.6 in [650 mm]	25.6 in [650 mm]	25.6 in [650 mm]	25.6 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]	58.7 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	47.59 in [1209 mm]	47.59 in [1209 mm]	62.56 in [1589 mm]	62.56 in [1589 mm]	41.18 in [1046 mm]	52.24 in [1327 mm]
	Width	16.53 in [420 mm]	16.53 in [420 mm]	16.53 in [420 mm]	16.53 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	229.28 lb [104 kg]	229.28 lb [104 kg]	332.89 lb [151 kg]	332.89 lb [151 kg]	200.62 lb [91 kg]	304.23 lb [138 kg]

Mechanical dimensions, frame sizes E and F

Frame size		**E1**	**E2**	**F1**	**F2**	**F3**	**F4**
		350–550 hp [250–400 kW] (380–500 V) 500–750 hp [355–560 kW] (525–690 V)	**350–550 hp [250–400 kW] (380–500 V) 500–750 hp [355–560 kW] (525–690 V)**	**600–850 hp [450–630 kW] (380–500 V) 850–1075 hp [630–800 kW] (525–690 V)**	**[950–1075 hp [710–800 kW] (380–500 V) 1200–1350 hp [900–1000 kW] (525–690 V)**	**600–850 hp [450–630 kW] (380–500 V) 850–1075 hp [630–800 kW] (525–690 V)**	**[950–1075 hp [710–800 kW] (380–500 V) 1200–1350 hp [900–1000 kW] (525–690 V)**
IP NEMA		21, 54 Type 12	00 Chassis	21, 54 Type 12	21, 54 Type 12	21, 54 Type 12	21, 54 Type 12
Shipping dimensions	Height	33.07 in [840 mm]	3272 in [831 mm]	91.50 in [2324 mm]	91.50 in [2324 mm]	91.50 in [2324 mm]	91.50 in [2324 mm]
	Width	86.50 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]	36.50 in [927 mm]	36.50 in [927 mm]	36.50 in [927 mm]	36.50 in [927 mm]
Drive dimensions	Height	78.7 in [2000 mm]	60.91 in [1547 mm]	2204	2204	2204	2204
	Width	23.62 in [600 mm]	23.03 in [585 mm]	1400	1800	2000	2400
	Depth	19.45 in [494 mm]	19.61 in [498 mm]	606	606	606	606
	Max weight	690.05 lb [313 kg]	610.68 lb [277 kg]	1004	1246	1299	1541

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 (0.28-0.67 in (7-17 mm))
- 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

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.

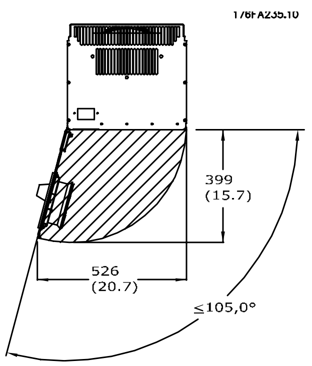


Figure 7.7: Space in front of IP21/IP54 enclosure type, frame size D1 and D2.

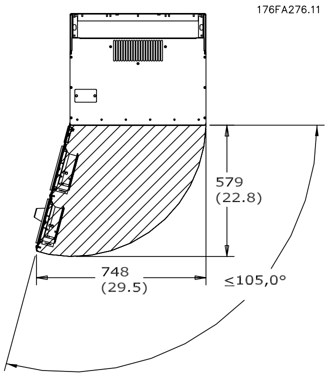


Figure 7.8: Space in front of IP21/IP54 enclosure type, frame size E1.

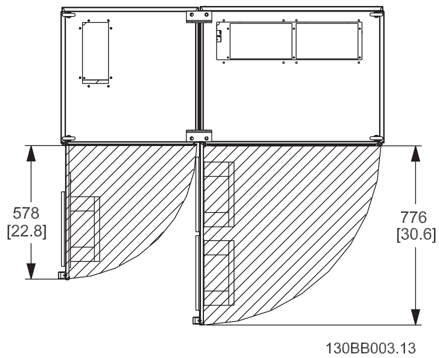


Figure 7.9: Space in front of IP21/IP54 enclosure type, frame size F1

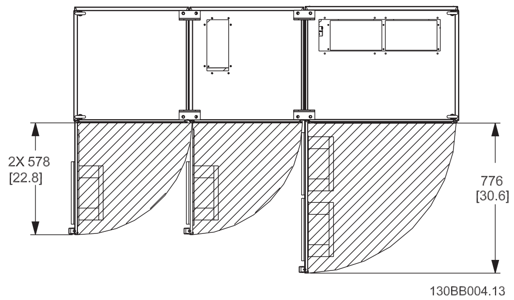


Figure 7.10: Space in front of IP21/IP54 enclosure type, frame size F3

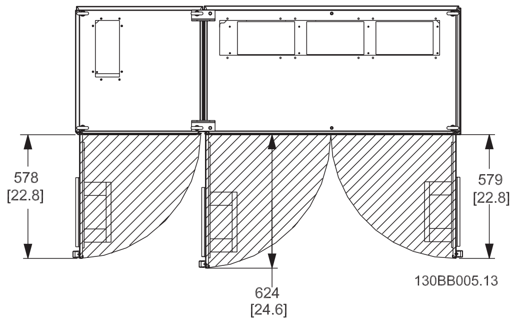


Figure 7.11: Space in front of IP21/IP54 enclosure type, frame size F2

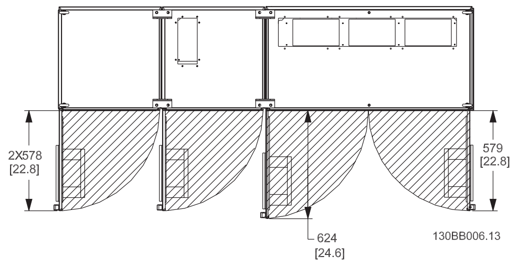


Figure 7.12: Space in front of IP21/IP54 enclosure type, frame size F4

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.

NOTE!

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

7.2.3 Terminal Locations - Frame size D

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

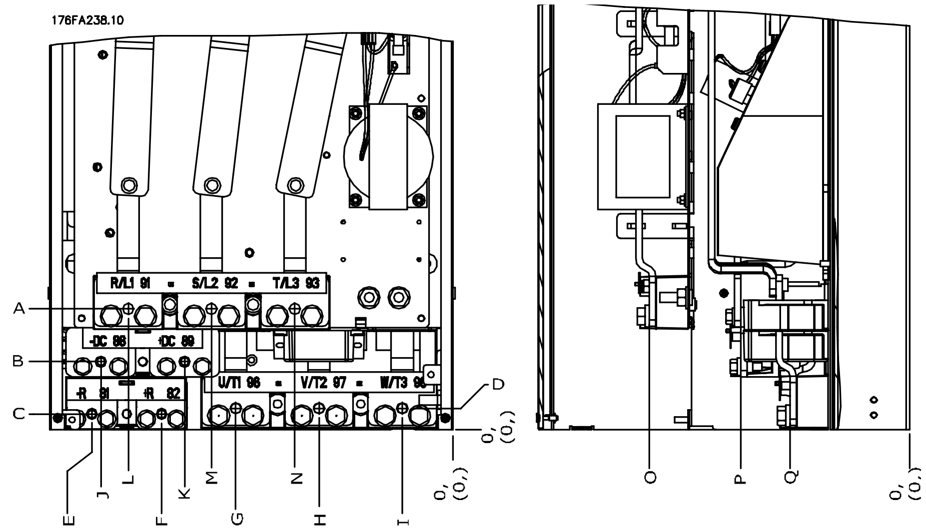


Figure 7.13: Position of power connections, frame size D3 and D4

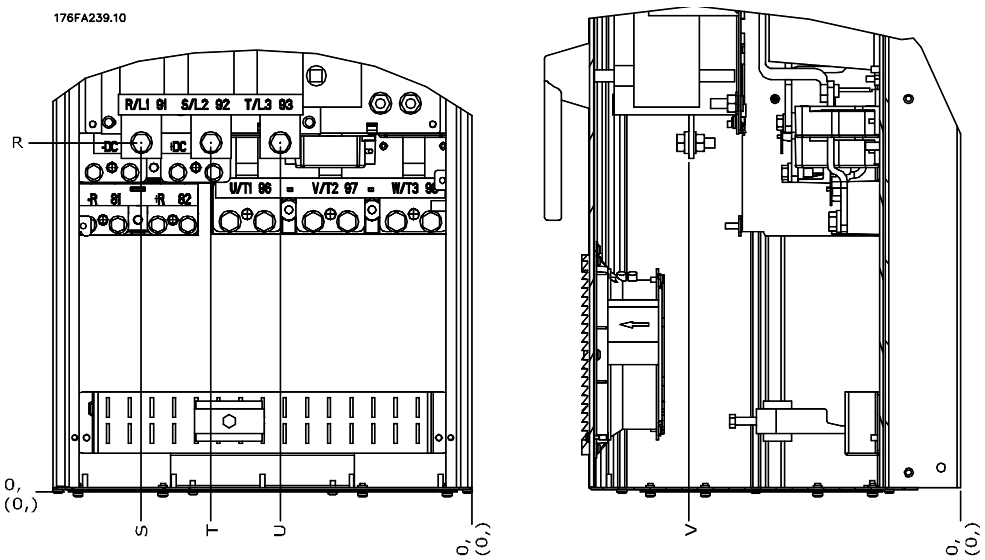


Figure 7.14: Position of power connections with disconnect switch, frame size D1 and D2

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 table on the next page.

	IP 21 (NEMA 1) / IP 54 (NEMA 12)		IP 00 / 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 7.1: 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.

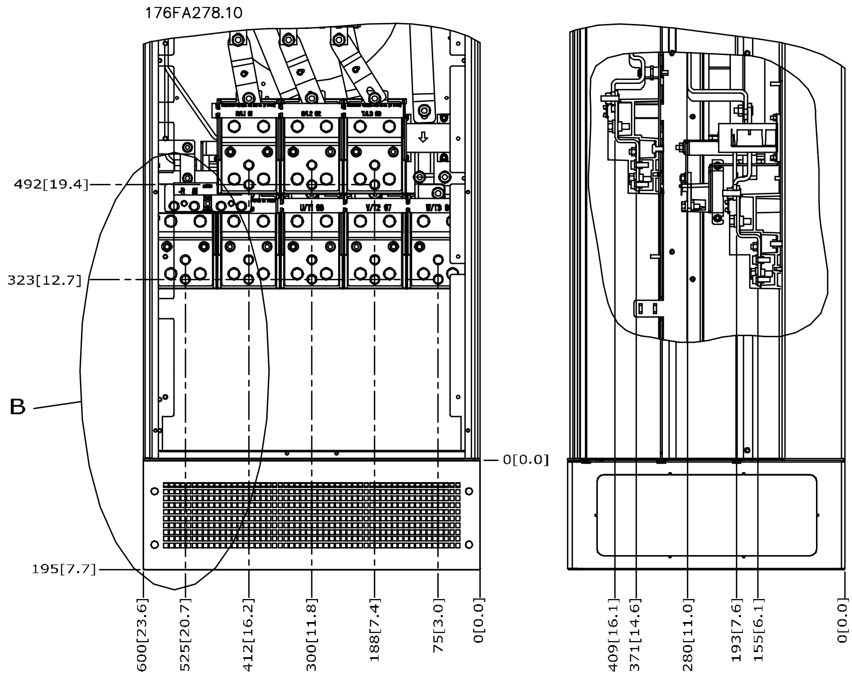


Figure 7.15: IP21 (NEMA Type 1) and IP54 (NEMA Type 12) enclosure power connection positions

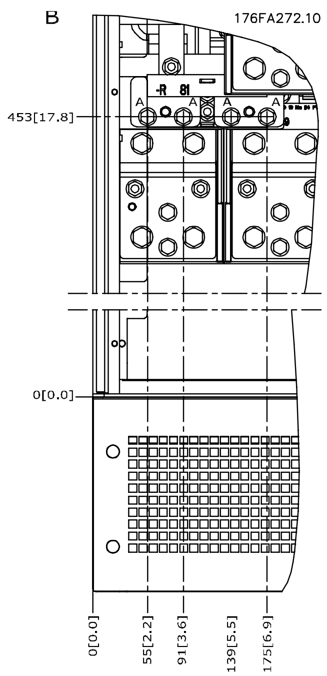


Figure 7.16: IP21 (NEMA type 1) and IP54 (NEMA type 12) enclosure power connection positions (detail B)

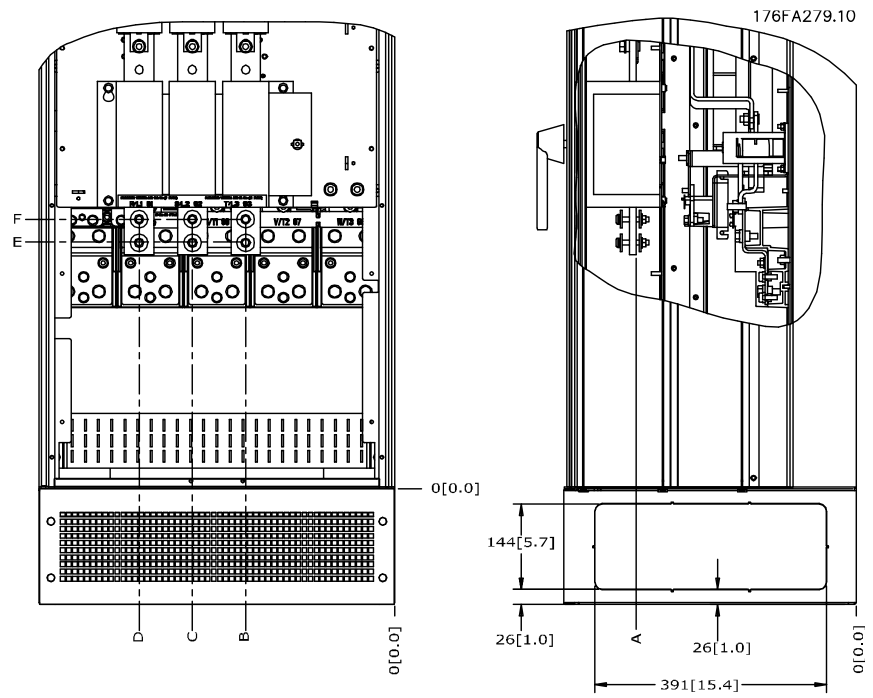


Figure 7.17: IP21 (NEMA type 1) and IP54 (NEMA type 12) enclosure power connection position of disconnect switch

Frame size	Unit type	Dimension for disconnect terminal					
	IP54/IP21 UL AND NEMA1/NEMA12						
E1	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)

Terminal locations - Frame size E2

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

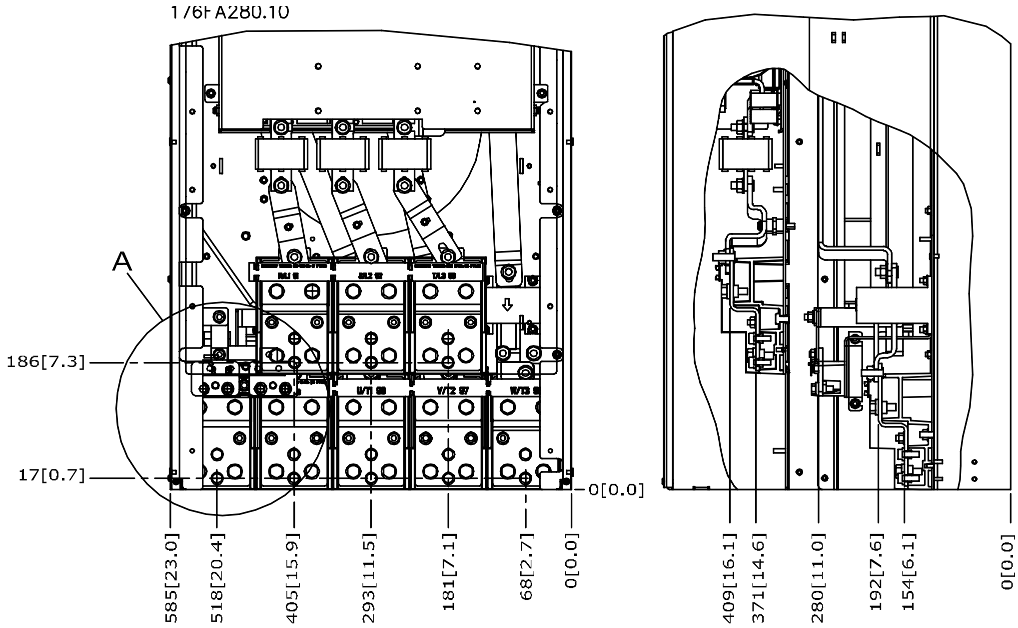


Figure 7.18: IP00 enclosure power connection positions

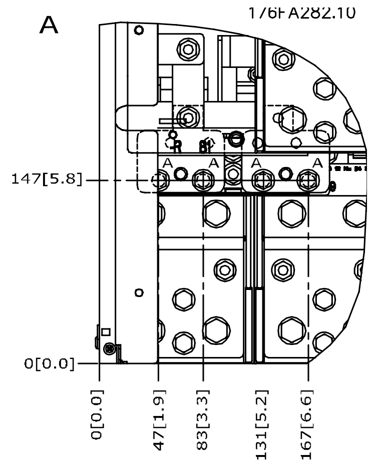


Figure 7.19: IP00 enclosure power connection positions

7

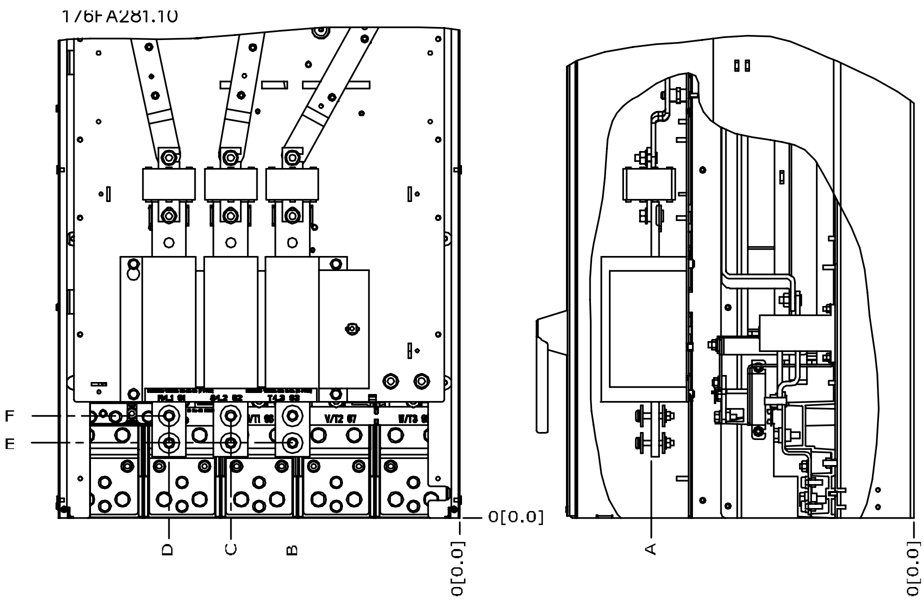


Figure 7.20: IP00 enclosure power connections positions of disconnect switch

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.

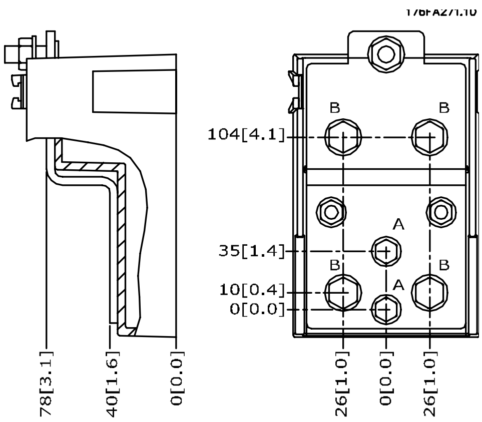


Figure 7.21: Terminal in details

NOTE!

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)

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

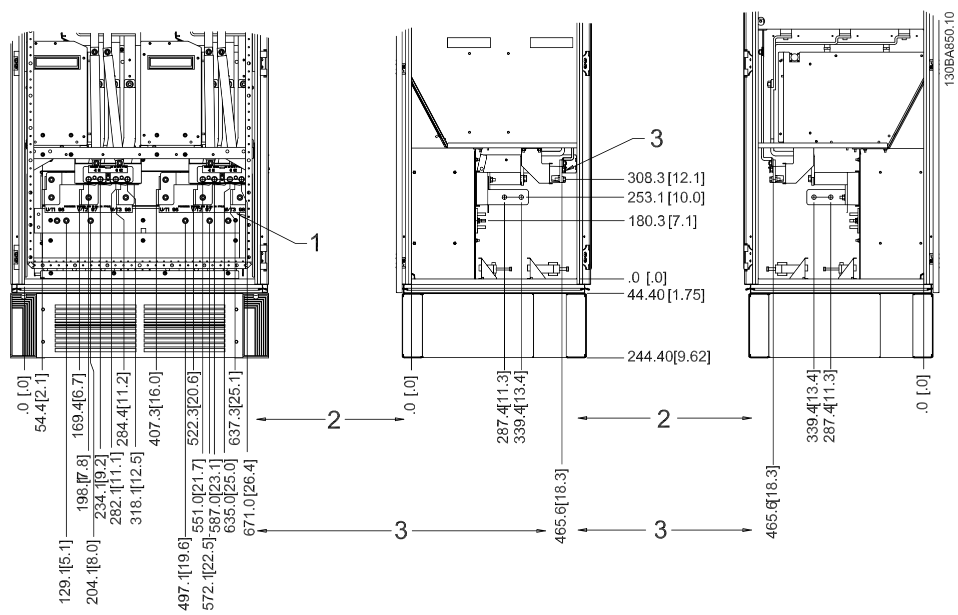


Figure 7.22: Terminal locations - Inverter Cabinet - F1 and F3 (front, left and right side view). The connector plate is 1.65 in [42 mm] below . 0 level.

1) Earth ground bar

2) Motor terminals

3) Brake terminals

Terminal locations - Frame size F2 and F4

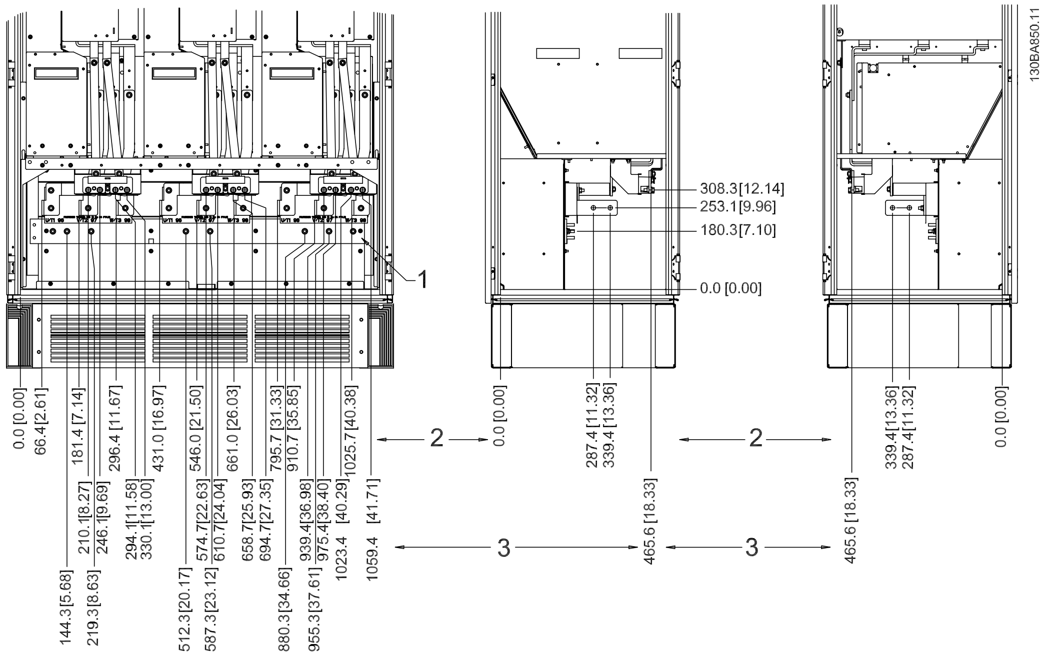
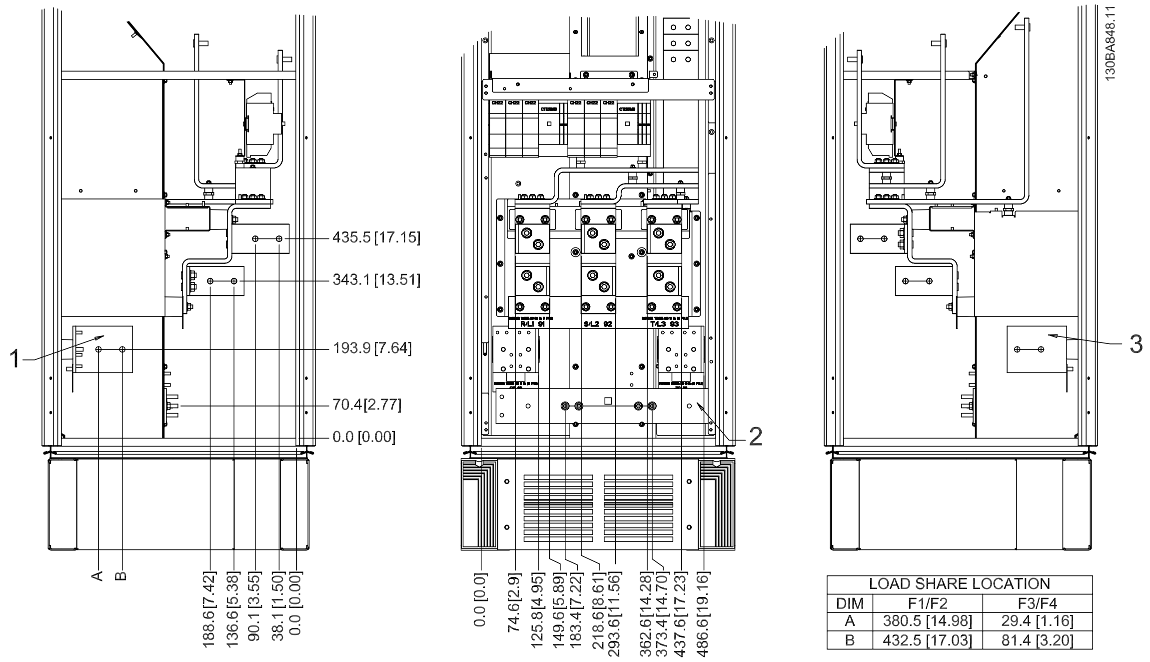


Figure 7.23: Terminal locations - Inverter cabinet - F2 and F4 (front, left and right side view). The connector plate is 1.65 in [42 mm] below . 0 level.

1) Earth ground bar

7

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 7.24: 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) Earth ground bar

3) Load Share Terminal (+)

Terminal locations - Options cabinet (F3 and F4)

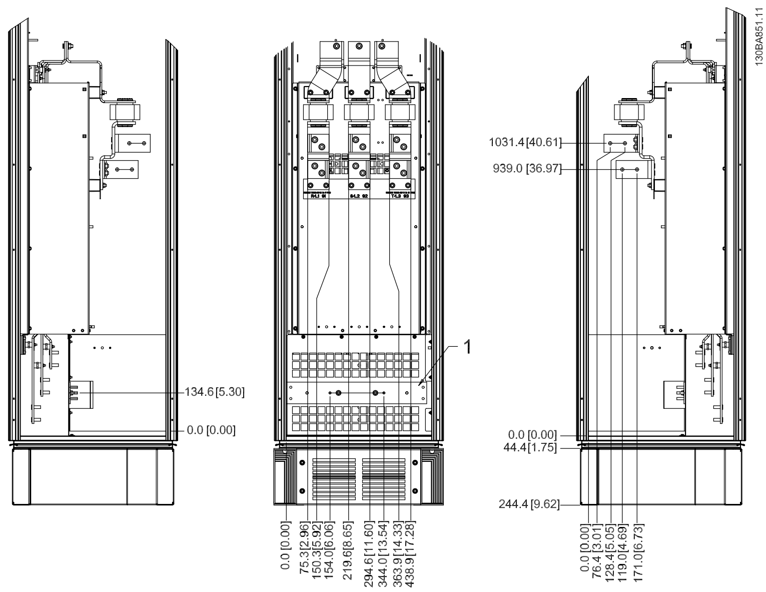


Figure 7.25: Terminal locations - Options cabinet (left side, front and right side view). The connector plate is 1.65 in [42 mm] below .0 level.

1) Earth ground bar

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

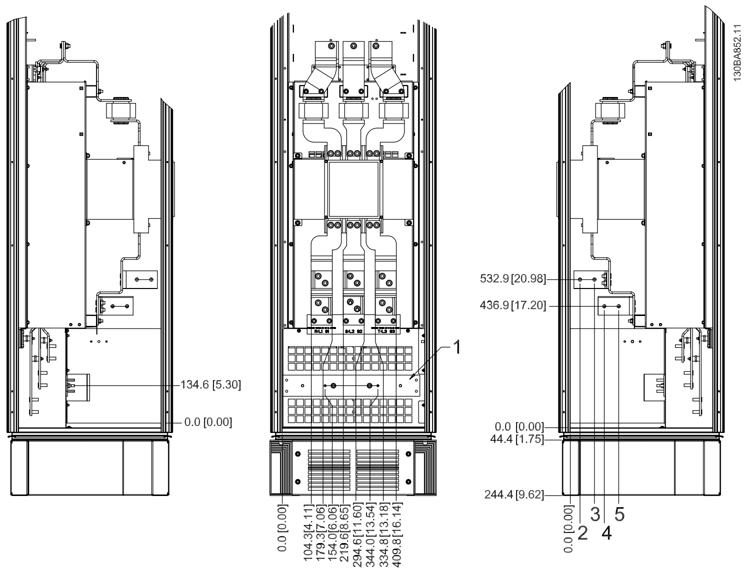


Figure 7.26: Terminal locations - Options cabinet with circuit breaker/ molded case switch (left side, front and right side view). The connector plate is 1.65 in [42 mm] below .0 level.

1) Earth ground bar

Power size	2	3	4	5
450 kW (480 V), 630–710 kW (690 V)	34.9	86.9	122.2	174.2
500–800 kW (480 V), 800–1000 kW (690 V)	46.3	98.3	119.0	171.0

Table 7.2: Dimension for terminal

7.2.6 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 losses 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/Top fan airflow	Airflow over heatsink
IP21 / NEMA 1	D1 and D2	170 m^3/h (100 cfm)	765 m^3/h (450 cfm)
IP54 / NEMA 12	E1 P250T5, P355T7, P400T7	340 m^3/h (200 cfm)	1105 m^3/h (650 cfm)
	E1 P315-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	340 m^3/h (200 cfm)	1105 m^3/h (650 cfm)
	E2 P315-P400T5, P500-P560T7	340 m^3/h (200 cfm)	1445 m^3/h (850 cfm)
* Airflow per fan. Frame size F contain multiple fans.			

Table 7.3: 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).

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.

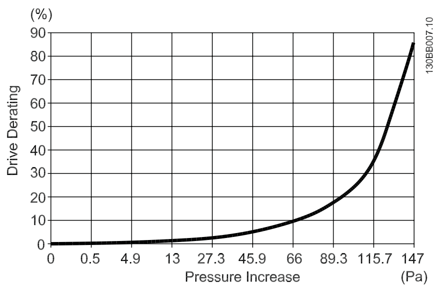


Figure 7.27: D frame Derating vs. Pressure Change

Drive air flow: 450 cfm (765 m3/h)

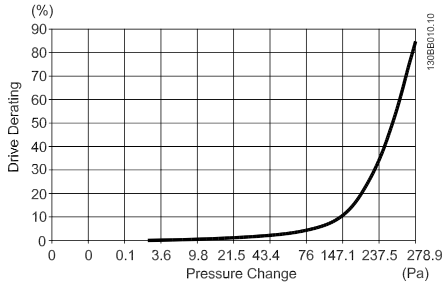


Figure 7.28: E frame Derating vs. Pressure Change (Small Fan), P250T5 and P355T7-P400T7

Drive air flow: 650 cfm (1105 m3/h)

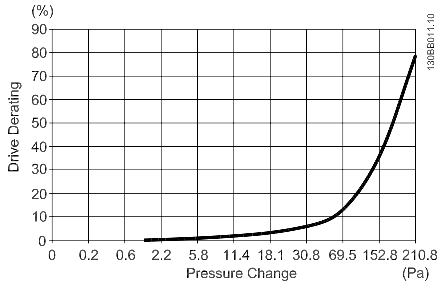


Figure 7.29: E frame Derating vs. Pressure Change (Large Fan), P315T5-P400T5 and P500T7-P560T7

Drive air flow: 850 cfm (1445 m3/h)

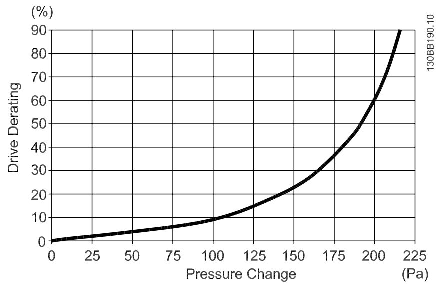


Figure 7.30: F1, F2, F3, F4 frame Derating vs. Pressure Change

Drive air flow: 580 cfm (985 m^3/h)

7.2.7 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.

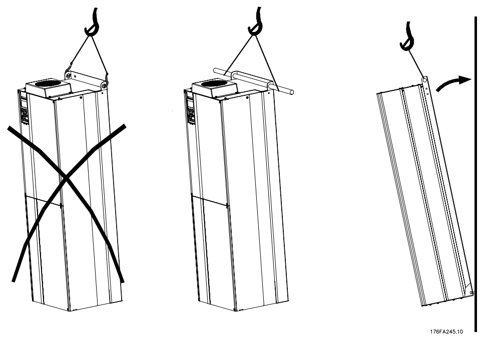


Figure 7.31: Lifting method for mounting drive on wall

7

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

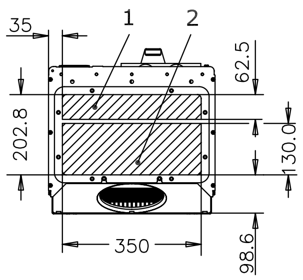
Cables are connected through the connector plate from the bottom. Remove the plate and plan where to place the entry for the connectors or conduits. Prepare holes in the marked area on the drawing.

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

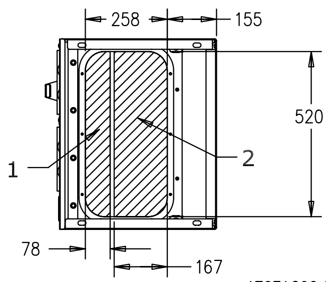
130BB073.10

Figure 7.32: Example of proper installation of the connector plate.

Frame size D1 + D2

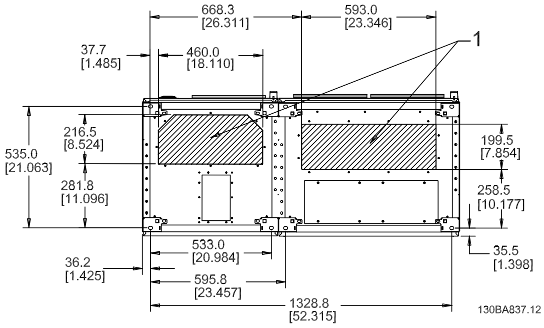


Frame size E1

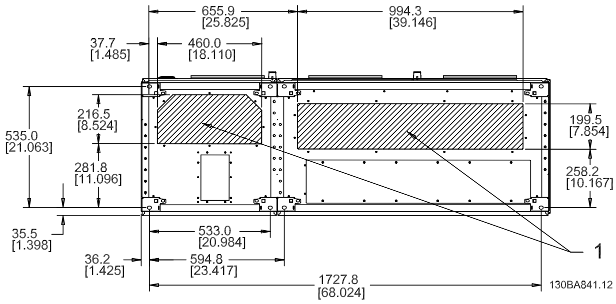


Cable entries viewed from the bottom of the adjustable frequency drive - 1) Line power side 2) Motor side

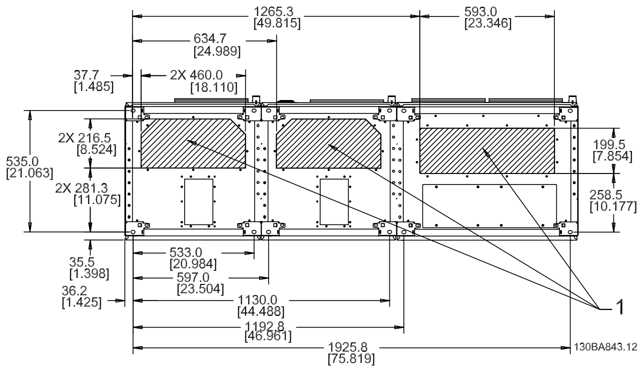
Frame size F1



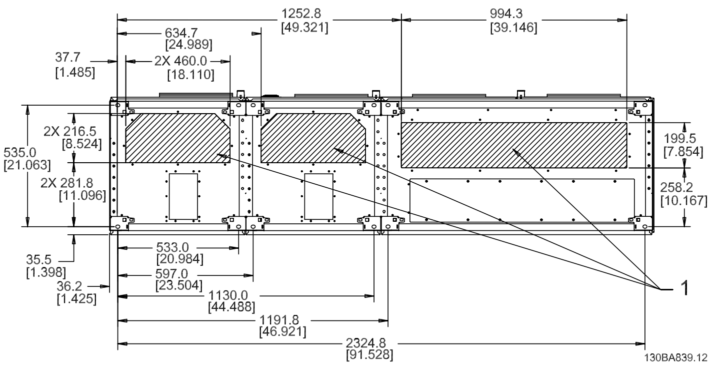
Frame size F2



Frame size F3



Frame size F4



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

7

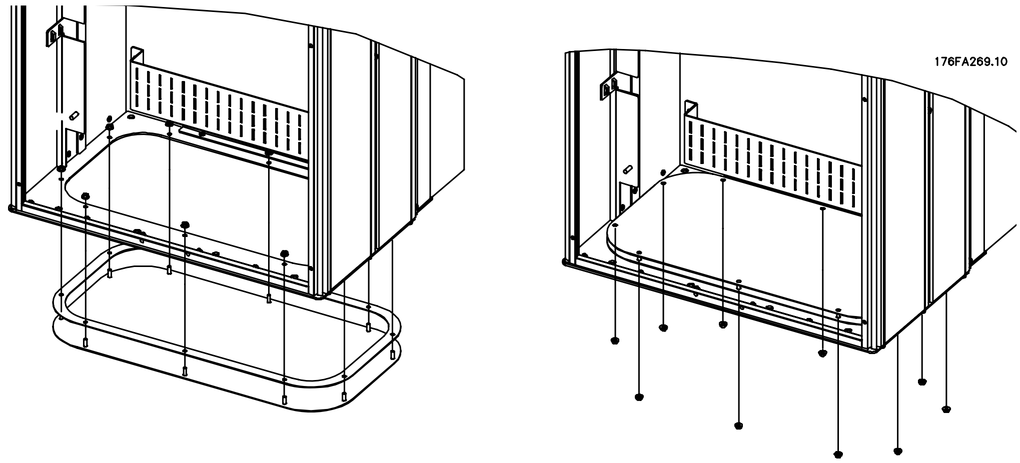


Figure 7.33: Mounting of bottom plate,frame size E1.

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

7.2.9 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).

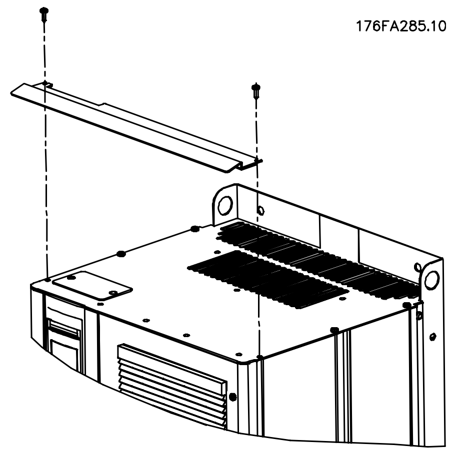


Figure 7.34: Install the drip shield.

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 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	0.34–3 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]	-		
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 0.15 in^2 [95 mm^2]) 24 Nm (over 0.15 in^2 [95 mm^2])
				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 0.15 in^2 [95 mm^2]) 24 Nm (over 0.15 in^2 [95 mm^2])
				Load sharing, brake cables	14 Nm
				Relay	0.5–0.6 Nm
				Ground	2–3 Nm

8

8.1.1 Removal of Knockouts for Extra Cables

1. Remove the cable entry from the adjustable frequency drive (this prevents foreign parts from falling into the adjustable frequency drive when removing knockouts)
2. 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 Power and Grounding

NOTE!
The plug connector for power is plugable on adjustable frequency drives up to 10 hp [7.5 kW].

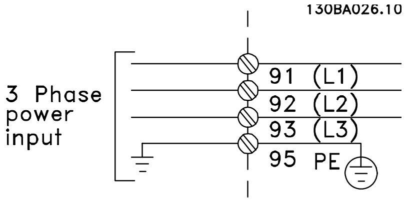
1. Insert the two screws into the de-coupling plate, slide it into place and tighten the screws.
2. Make sure the adjustable frequency drive is properly grounded. Connect to ground connection (terminal 95). Use screw from the accessory bag.
3. Place plug connector 91 (L1), 92 (L2), 93 (L3) from the accessory 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.

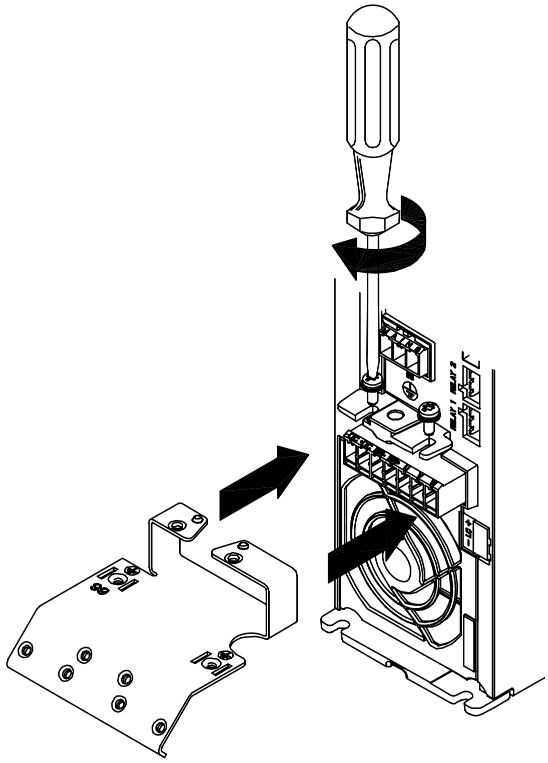
IT Line Power
Do not connect 400 V adjustable frequency drives with RFI filters to line power supplies with a voltage between phase and ground of more than 440 V.

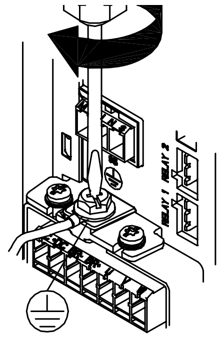
The ground connection cable cross-section must be at least 0.016 in^2 [10 mm^2] or 2 x rated line power wires terminated separately according to EN 50178.

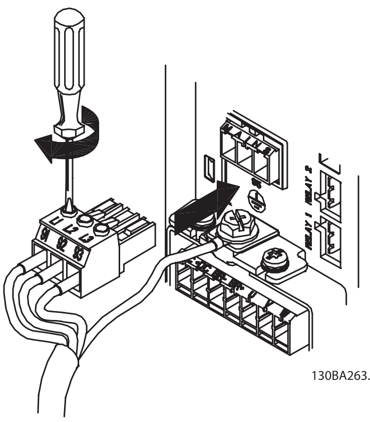
The AC line input connections are fitted to the line power switch if this is included.

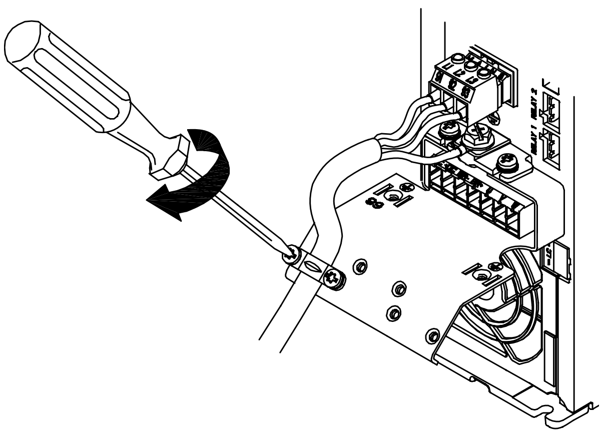


AC line input connections for Frame sizes A1, A2 and A3:

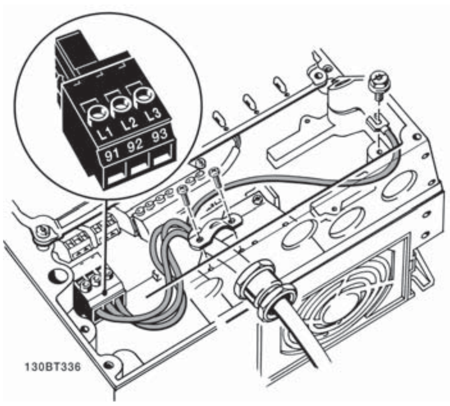


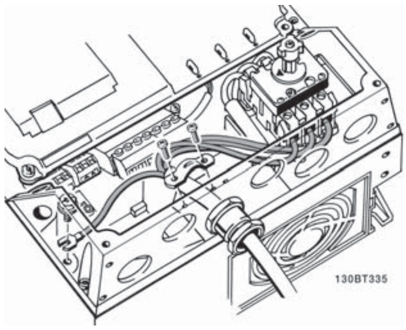






AC line power connector frame size A5 (IP 55/66)





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

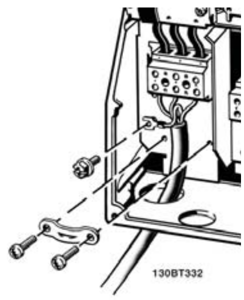


Figure 8.1: AC line input connections frame sizes B1 and B2 (IP 21/NEMA Type 1 and IP 55/66/ NEMA Type 12).

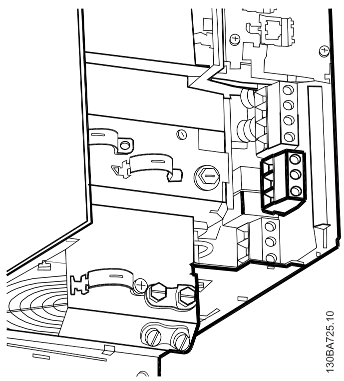


Figure 8.2: AC line input connections size B3 (IP20).

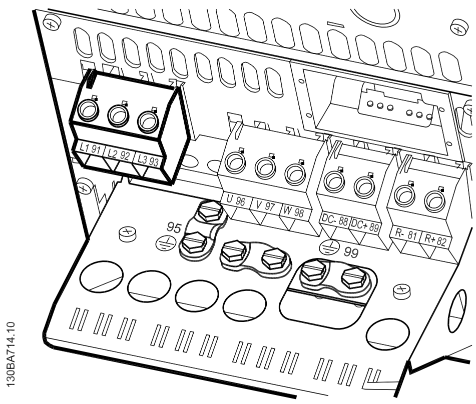


Figure 8.3: AC line input connections size B4 (IP20).

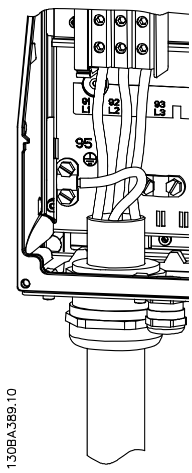


Figure 8.4: AC line input connections size C1 and C2 (IP 21/ NEMA Type 1 and IP 55/66/ NEMA Type 12).

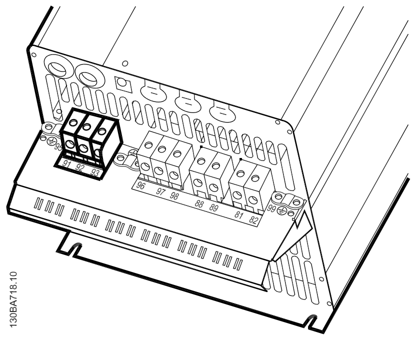


Figure 8.5: AC line input connections size C3 (IP20).

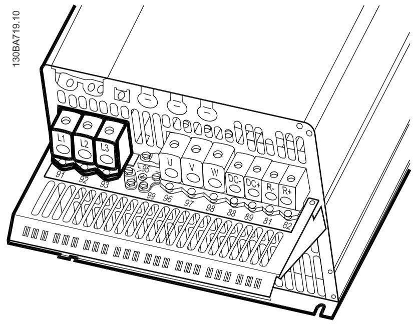


Figure 8.6: AC line input connections size C4 (IP20).

The power cables for line power are usually unshielded cables.

8.1.3 Motor Connection

NOTE!
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 Test Results*.

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

Shielding 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 shield to both of 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 instruction in par. 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.

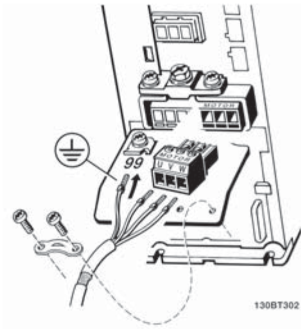


Figure 8.7: Motor connection for A1, A2 and A3

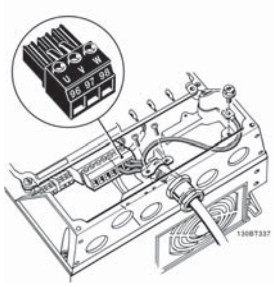


Figure 8.8: Motor connection for size A5 (IP 55/66/NEMA Type 12)

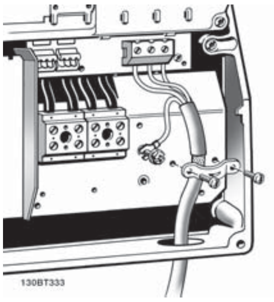


Figure 8.9: Motor connection for size B1 and B2 (IP 21/ NEMA Type 1, IP 55/ NEMA Type 12 and IP66/ NEMA Type 4X)

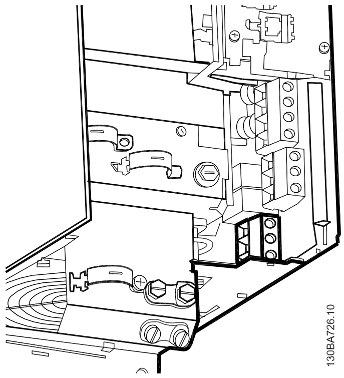


Figure 8.10: Motor connection for size B3.

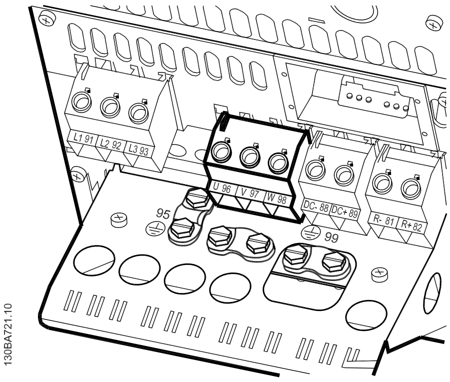


Figure 8.11: Motor connection for frame size B4 .

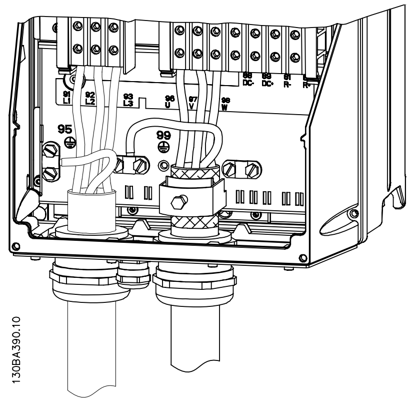


Figure 8.12: Motor connection frame size C1 and C2 (IP 21/ NEMA Type 1 and IP 55/66/ NEMA Type 12)

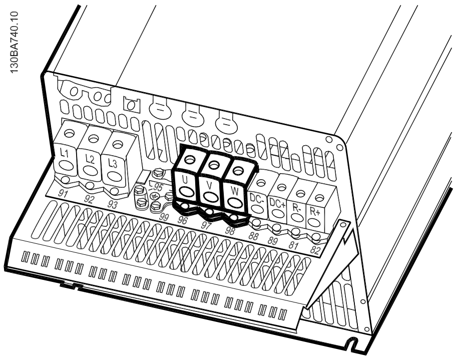


Figure 8.13: Motor connection for frame size C3 and C4.

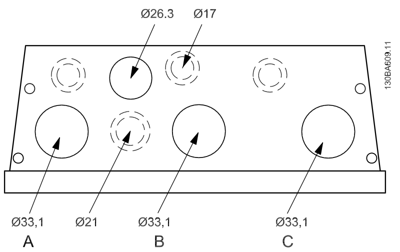


Figure 8.14: Cable entry holes for frame size B1. The suggested use of the holes are purely recommendations and other solutions are possible.

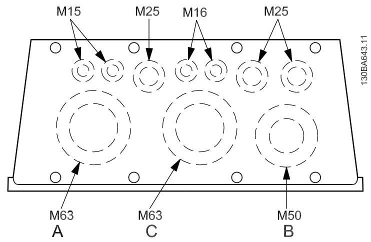


Figure 8.16: Cable entry holes for frame size C1. The suggested use of the holes are purely recommendations and other solutions are possible.

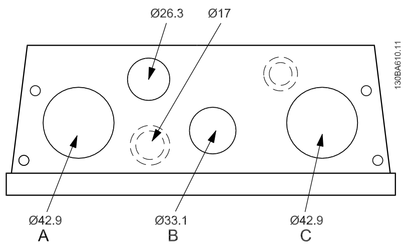


Figure 8.15: Cable entry holes for frame size B2. The suggested use of the holes are purely recommendations and other solutions are possible.

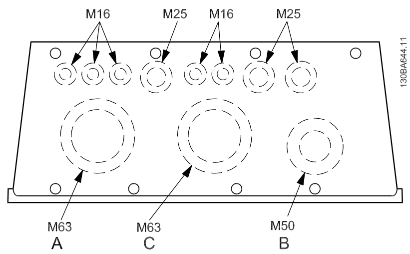
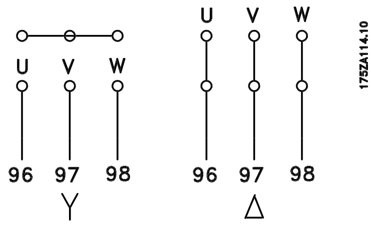


Figure 8.17: Cable entry holes for frame size C2. The suggested use of the holes are purely recommendations and other solutions are possible.

Term. no.	96	97	98	99	
	U	V	W	PE1)	Motor voltage 0–100% of AC line voltage. 3 wires out of motor
	U1	V1	W1	PE1)	Delta-connected
	W2	U2	V2		6 wires out of motor
	U1	V1	W1	PE1)	Star-connected U2, V2, W2 U2, V2 and W2 to be interconnected separately.

1)Protected Ground Connection

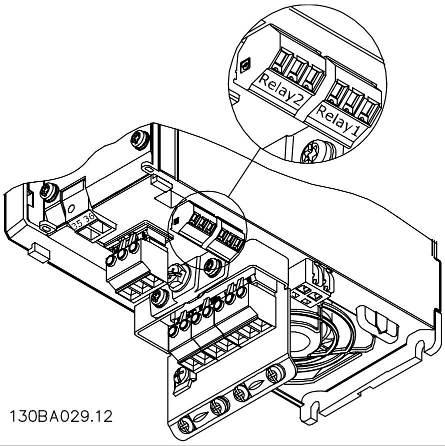


NOTE!
In motors without phase insulation paper or other insulation reinforcement suitable for operation with voltage supply (such as a adjustable frequency drive), fit a sine-wave filter on the output of the adjustable frequency drive.

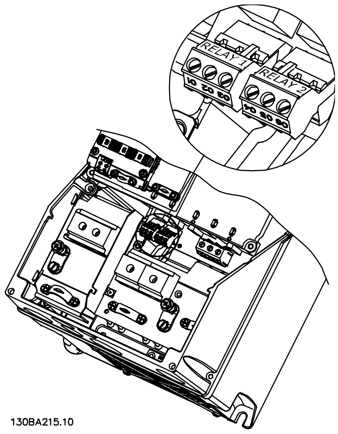
8.1.4 Relay Connection

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

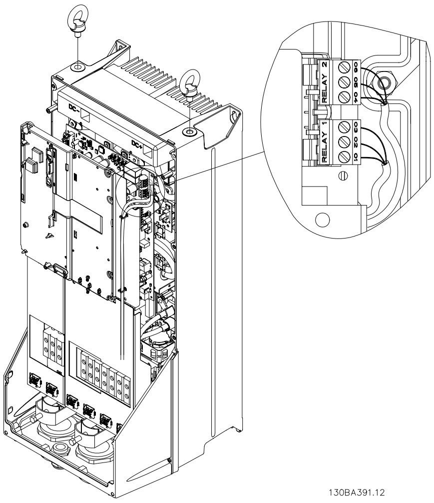
No.		
	01 - 02	make (normally open)
	01 - 03	break (normally closed)
	04 - 05	make (normally open)
	04 - 06	break (normally closed)



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).

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.

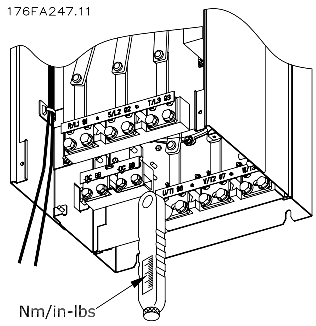


Figure 8.18: Always use a torque wrench to tighten the bolts.

Frame size	Terminal	Torque	Bolt size
D1, D2, D3 and D4	Line power Motor	19 Nm (168 in-lbs)	M10
	Load sharing Brake	9.5 Nm (84 in-lbs)	M8
E1 and E2	Line power Motor Load sharing	19 NM (168 in-lbs)	M10
	Brake	9.5 Nm (84 in-lbs)	M8
F1, F2, F3 and F4	Line power Motor	19 Nm (168 in-lbs)	M10
	Load sharing	19 Nm (168 in-lbs)	M10
	Brake	9.5 Nm (84 in-lbs)	M8
	Regen	19 Nm (168 in-lbs)	M10

Table 8.1: Torque for terminals

8.2.2 Power Connections

Cabling and Fusing

NOTE!

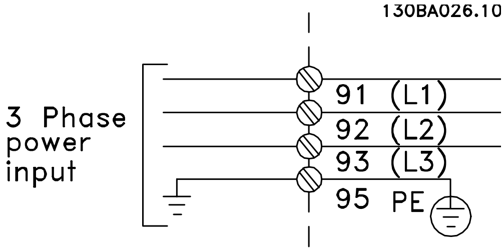
Cables General

All cabling must comply with national and local regulations on cable cross-sections and ambient temperature. UL applications require 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.



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 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 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:

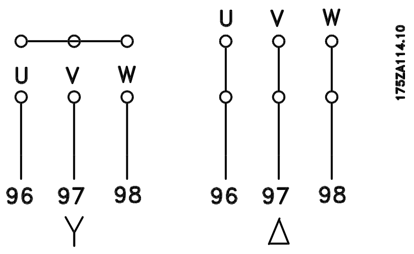
The adjustable frequency drive has been EMC tested with a given length of cable. Keep the motor cable as short as possible to reduce the noise level and leakage currents.

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 par. 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 W2	V1 U2	W1 V2	PE[1]	Delta-connected 6 wires out of motor
	U1	V1	W1	PE[1]	Star-connected U2, V2, W2 U2, V2 and W2 to be interconnected separately.

1)Protected Ground Connection



NOTE!

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.

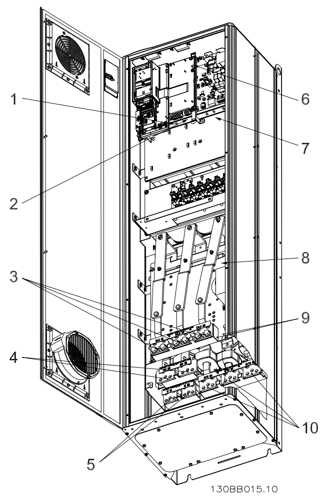


Figure 8.19: Compact IP 21 (NEMA 1) and IP 54 (NEMA 12), frame size D1

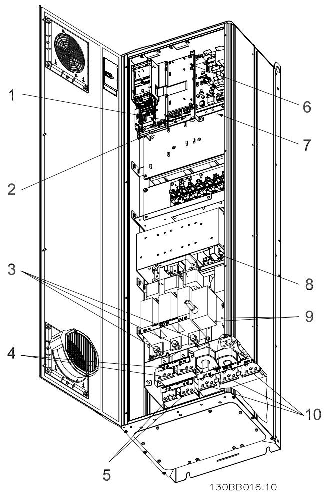


Figure 8.20: Compact IP 21 (NEMA 1) and IP 54 (NEMA 12) with disconnect, fuse and RFI filter, frame size D2

1) AUX Relay

01	02	03
04	05	06

2) Temp Switch

106	104	105

3) Line

R	S	T
91	92	93
L1	L2	L3

4) Load sharing

-DC	+DC
88	89

5) Brake

-R	+R
81	82

6) SMPS Fuse (see fuse tables for part number)

7) AUX Fan

100	101	102	103
L1	L2	L1	L2

8) Fan Fuse (see fuse tables for part number)

9) Line power ground

10) Motor

U	V	W
96	97	98
T1	T2	T3

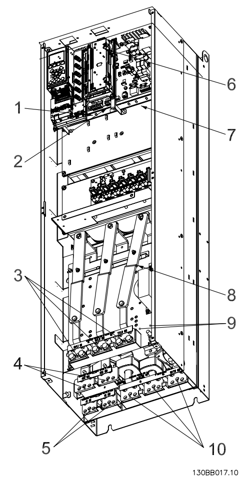


Figure 8.21: Compact IP 00 (Chassis), frame size D3

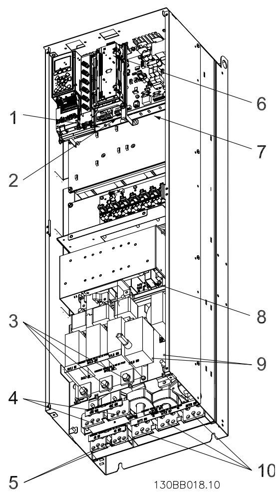


Figure 8.22: Compact IP 00 (Chassis) with disconnect, fuse and RFI filter, frame size D4

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

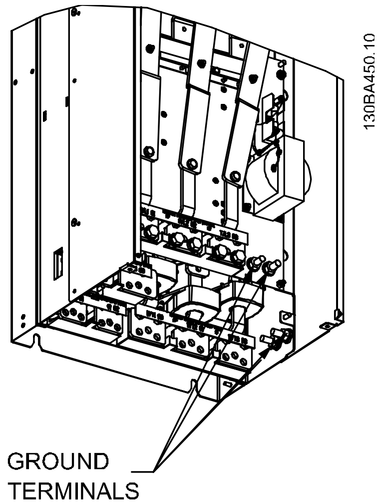


Figure 8.23: Position of ground terminals IP00, frame sizes D

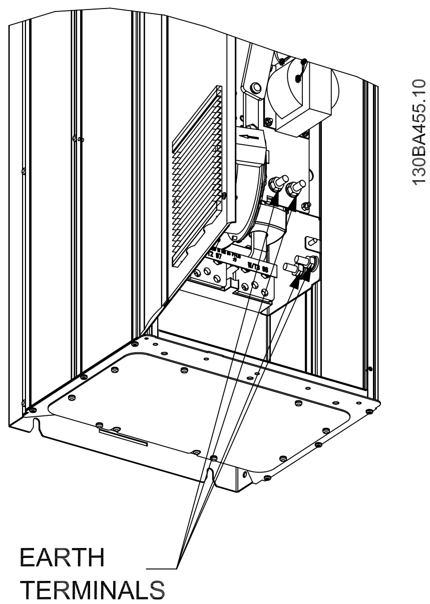


Figure 8.24: Position of ground terminals IP21 (NEMA type 1) and IP54 (NEMA type 12)

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

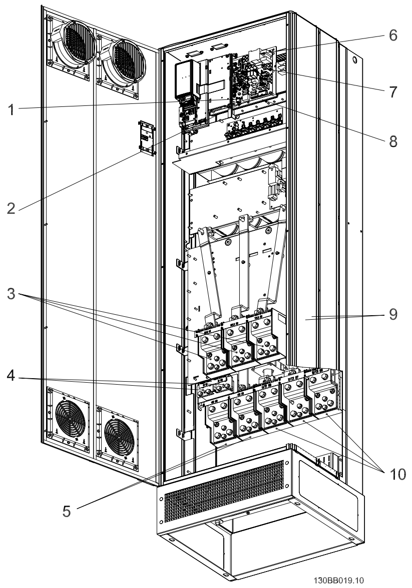


Figure 8.25: Compact IP 21 (NEMA 1) and IP 54 (NEMA 12) frame size E1

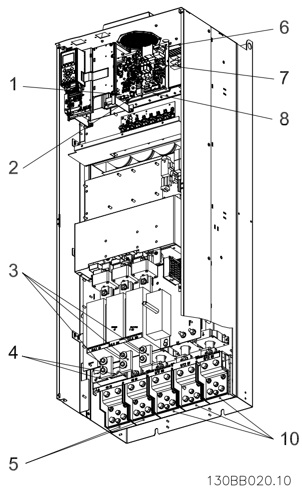


Figure 8.26: Compact IP 00 (Chassis) with disconnect, fuse and RFI filter, frame size E2

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	

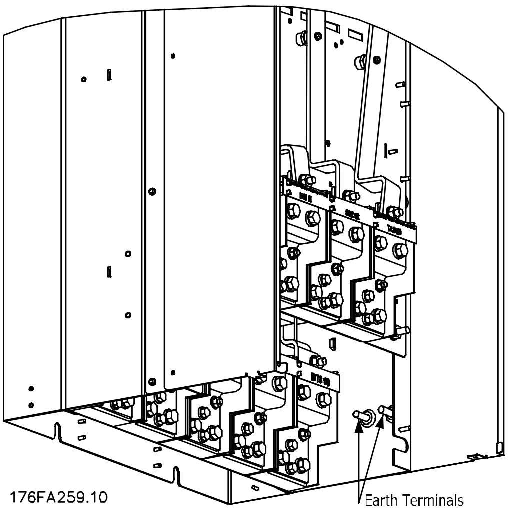


Figure 8.27: Position of ground terminals IP00, frame sizes E

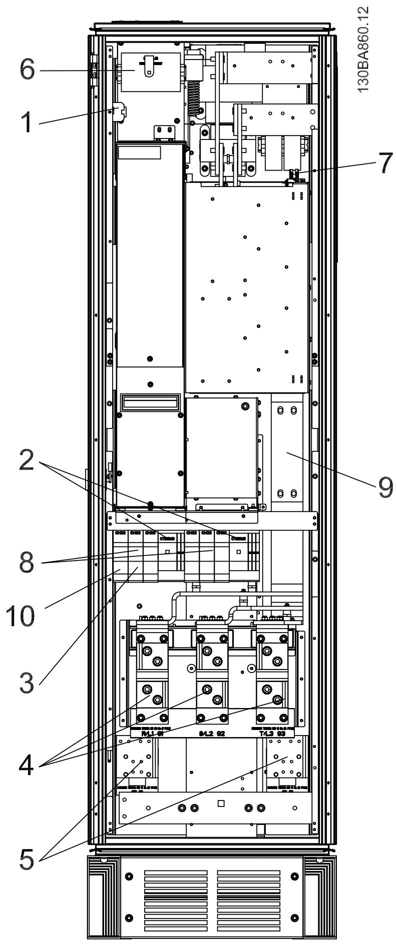


Figure 8.28: Rectifier Cabinet, frame size F1, F2, F3 and F4

1)	24 V DC, 5 A T1 Output Taps Temp Switch 106 104 105	5)	Load sharing -DC +DC 88 89
		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 R S T L1 L2 L3	9)	Line Fuses, F1 and F2 frame (3 pieces). See fuse tables for part numbers
		10)	30 Amp Fuse Protected Power fuses

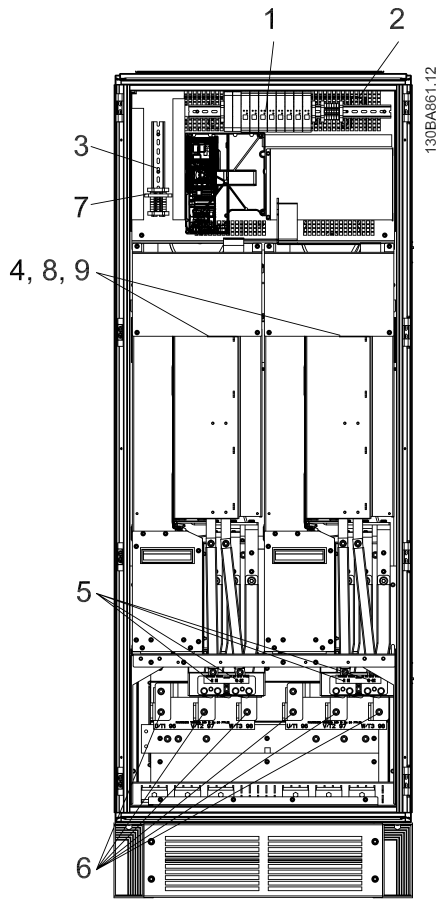


Figure 8.29: Inverter Cabinet, frame size F1 and F3

1) External Temperature Monitoring
2) AUX Relay

01	02	03
04	05	06

3) NAMUR
4) AUX Fan

100	101	102	103
L1	L2	L1	L2

5) Brake

-R	+R
81	82

6) Motor

U	V	W
96	97	98
T1	T2	T3

7) NAMUR Fuse. See fuse tables for part numbers
8) Fan Fuses. See fuse tables for part numbers
9) SMPS Fuses. See fuse tables for part numbers

8

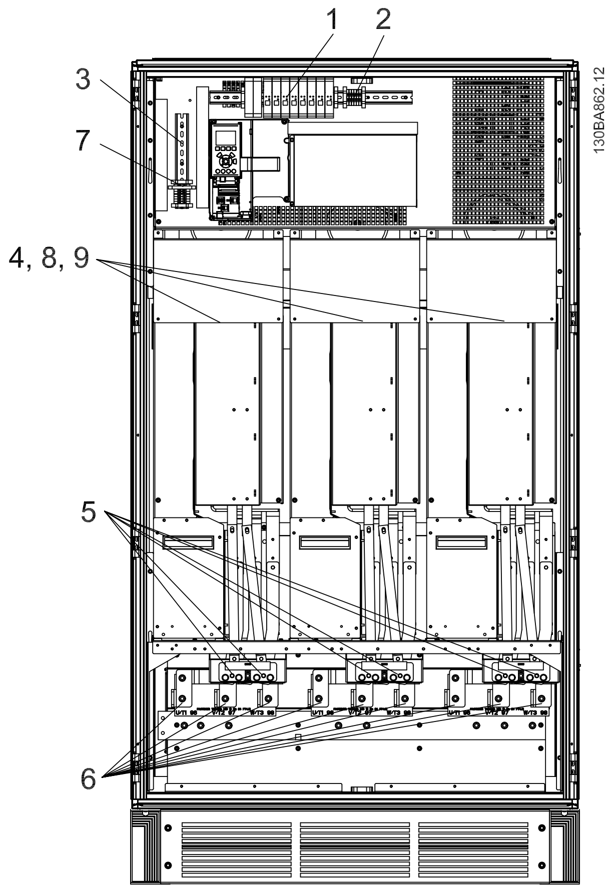


Figure 8.30: Inverter Cabinet, frame size F2 and F4

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

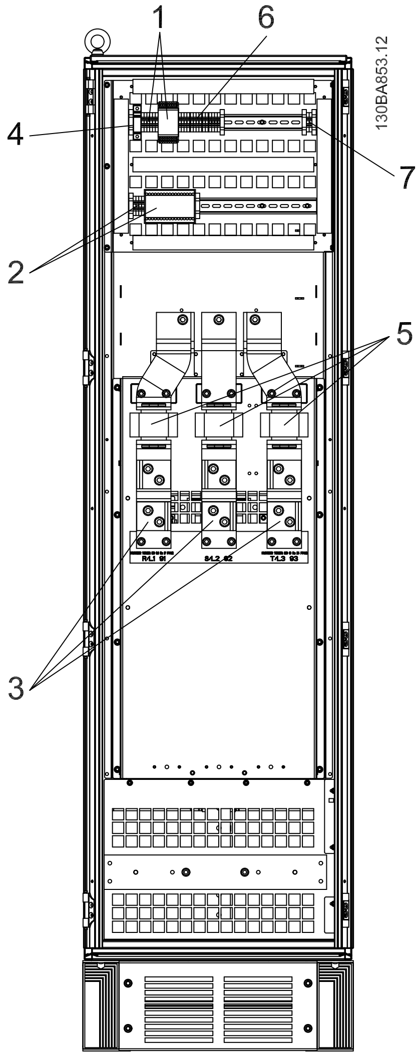


Figure 8.31: Options Cabinet, frame size F3 and F4

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

8.2.3 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 8.32: Mount the EMC shield.

8.2.4 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

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

Branch circuit protection:

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

Short-circuit protection:

The adjustable frequency drive must be protected against short-circuit to avoid electrical or fire hazard. Danfoss recommends using the fuses mentioned below to protect service personnel and equipment in case of an internal failure in the drive. The adjustable frequency drive provides full short-circuit protection in case of a short-circuit on the motor output.

Overcurrent protection:

Provide overload protection to avoid fire hazard due to overheating of the cables in the installation. The adjustable frequency drive is equipped with an internal overcurrent protection that can be used for upstream overload protection (UL applications excluded). See par. 4-18 *Current Limit*. Moreover, fuses or circuit breakers can be used to provide the overcurrent protection in the installation. Overcurrent protection must always be carried out according to national regulations.

Non-UL compliance

If UL/cUL is not to be complied with, we recommend using the following fuses, which will ensure compliance with EN50178:

In case of malfunction, not following the recommendation may result in unnecessary damage to the adjustable frequency drive.

	Max. fuse size[1)]	Min. rated voltage	Type
K25-K75	10A	200–240 V	type gG
1K1-2K2	20A	200–240 V	type gG
3K0-3K7	32A	200–240 V	type gG
5K5-7K5	63A	200–240 V	type gG
11K	80A	200–240 V	type gG
15K-18K5	125A	200–240 V	type gG
22K	160A	200–240 V	type aR
30K	200A	200–240 V	type aR
37K	250A	200–240 V	type aR

	Max. fuse size[1)]	Min. rated voltage	Type
K37-1K5	10A	380–500 V	type gG
2K2-4K0	20A	380–500 V	type gG
5K5-7K5	32A	380–500 V	type gG
11K-18K	63A	380–500 V	type gG
22K	80A	380–500 V	type gG
30K	100A	380–500 V	type gG
37K	125A	380–500 V	type gG
45K	160A	380–500 V	type gG*
55K-75K	250A	380–500 V	type gG*

* Type gG is not applicable to frame sizes C2 in IP21 enclosure and frame size C4. In this case, type aR is recommended.

	Max. fuse size[1)]	Voltage	Type
11-22K (B2)	63 A	525–690 V	type gG
30K (C2)	80 A	525–690 V	type gG
37K (C2)	100 A	525–690 V	type gG
45K (C2)	125 A	525–690 V	type gG
55K-75K (C2)	160 A	525–690 V	type gG

P90 - P200	380–500 V	type gG
P250 - P400	380–500 V	type gR

1) Max. fuses - refer to national/international regulations to select an appropriate fuse size.

UL Compliance - max. fuse size

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.

200–240 V

	Bussmann	Bussmann	Bussmann	Bussmann	Bussmann	Bussmann
kW	Type RK1	Type J	Type T	Type CC	Type CC	Type CC
K25-K37	KTN-R05	JKS-05	JJN-06	FNQ-R-5	KTK-R-5	LP-CC-5
K55-1K1	KTN-R10	JKS-10	JJN-10	FNQ-R-10	KTK-R-10	LP-CC-10
1K5	KTN-R15	JKS-15	JJN-15	FNQ-R-15	KTK-R-15	LP-CC-15
2K2	KTN-R20	JKS-20	JJN-20	FNQ-R-20	KTK-R-20	LP-CC-20
3K0	KTN-R25	JKS-25	JJN-25	FNQ-R-25	KTK-R-25	LP-CC-25
3K7	KTN-R30	JKS-30	JJN-30	FNQ-R-30	KTK-R-30	LP-CC-30
5K5	KTN-R50	KS-50	JJN-50	-	-	-
7K5	KTN-R60	JKS-60	JJN-60	-	-	-
11K	KTN-R80	JKS-80	JJN-80	-	-	-
15K-18K5	KTN-R125	JKS-150	JJN-125	-	-	-

	SIBA	Littel fuse	Ferraz-Shawmut	Ferraz-Shawmut
kW	Type RK1	Type RK1	Type CC	Type RK1
K25-K37	5017906-005	KLN-R05	ATM-R05	A2K-05R
K55-1K1	5017906-010	KLN-R10	ATM-R10	A2K-10R
1K5	5017906-016	KLN-R15	ATM-R15	A2K-15R
2K2	5017906-020	KLN-R20	ATM-R20	A2K-20R
3K0	5017906-025	KLN-R25	ATM-R25	A2K-25R
3K7	5012406-032	KLN-R30	ATM-R30	A2K-30R
5K5	5014006-050	KLN-R50	-	A2K-50R
7K5	5014006-063	KLN-R60	-	A2K-60R
11K	5014006-080	KLN-R80	-	A2K-80R
15K-18K5	2028220-125	KLN-R125	-	A2K-125R

	Bussmann	SIBA	Littel fuse	Ferraz-Shawmut
kW	Type JFHR2	Type RK1	JFHR2	JFHR2
22K	FWX-150	2028220-150	L25S-150	A25X-150
30K	FWX-200	2028220-200	L25S-200	A25X-200
37K	FWX-250	2028220-250	L25S-250	A25X-250

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

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

KLSR fuses from LITTEL FUSE may substitute for KLNR fuses for 240 V adjustable frequency drives.

L50S fuses from LITTEL FUSE may substitute for L50S fuses for 240 V adjustable frequency drives.

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

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

380–500 V, frame sizes A, B and C

	Bussmann	Bussmann	Bussmann	Bussmann	Bussmann	Bussmann
kW	Type RK1	Type J	Type T	Type CC	Type CC	Type CC
K37-1K1	KTS-R6	JKS-6	JJS-6	FNQ-R-6	KTK-R-6	LP-CC-6
1K5-2K2	KTS-R10	JKS-10	JJS-10	FNQ-R-10	KTK-R-10	LP-CC-10
3K0	KTS-R15	JKS-15	JJS-15	FNQ-R-15	KTK-R-15	LP-CC-15
4K0	KTS-R20	JKS-20	JJS-20	FNQ-R-20	KTK-R-20	LP-CC-20
5K5	KTS-R25	JKS-25	JJS-25	FNQ-R-25	KTK-R-25	LP-CC-25
7K5	KTS-R30	JKS-30	JJS-30	FNQ-R-30	KTK-R-30	LP-CC-30
11K	KTS-R40	JKS-40	JJS-40	-	-	-
15K	KTS-R50	JKS-50	JJS-50	-	-	-
18K	KTS-R60	JKS-60	JJS-60	-	-	-
22K	KTS-R80	JKS-80	JJS-80	-	-	-
30K	KTS-R100	JKS-100	JJS-100	-	-	-
37K	KTS-R125	JKS-150	JJS-150	-	-	-
45K	KTS-R150	JKS-150	JJS-150	-	-	-

kW	SIBA Type RK1	Littel fuse Type RK1	Ferraz-Shawmut Type CC	Ferraz-Shawmut Type RK1
K37-1K1	5017906-006	KLS-R6	ATM-R6	A6K-6R
1K5-2K2	5017906-010	KLS-R10	ATM-R10	A6K-10R
3K0	5017906-016	KLS-R15	ATM-R15	A6K-15R
4K0	5017906-020	KLS-R20	ATM-R20	A6K-20R
5K5	5017906-025	KLS-R25	ATM-R25	A6K-25R
7K5	5012406-032	KLS-R30	ATM-R30	A6K-30R
11K	5014006-040	KLS-R40	-	A6K-40R
15K	5014006-050	KLS-R50	-	A6K-50R
18K	5014006-063	KLS-R60	-	A6K-60R
22K	2028220-100	KLS-R80	-	A6K-80R
30K	2028220-125	KLS-R100	-	A6K-100R
37K	2028220-125	KLS-R125	-	A6K-125R
45K	2028220-160	KLS-R150	-	A6K-150R

kW	Bussmann JFHR2	Bussmann Type H	Bussmann Type T	Bussmann JFHR2
55K	FWH-200	-	-	-
75K	FWH-250	-	-	-

kW	SIBA Type RK1	Littel fuse JFHR2	Ferraz-Shawmut JFHR2	Ferraz-Shawmut JFHR2
55K	2028220-200	L50S-225	-	A50-P225
75K	2028220-250	L50S-250		A50-P250

Ferraz-Shawmut A50QS fuses may be substituted for A50P fuses.

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.

525–600 V, frame sizes A, B and C

kW	Bussmann Type RK1	Bussmann Type J	Bussmann Type T	Bussmann Type CC	Bussmann Type CC	Bussmann Type CC
K75-1K5	KTS-R-5	JKS-5	JJS-6	FNQ-R-5	KTK-R-5	LP-CC-5
2K2-4K0	KTS-R10	JKS-10	JJS-10	FNQ-R-10	KTK-R-10	LP-CC-10
5K5-7K5	KTS-R20	JKS-20	JJS-20	FNQ-R-20	KTK-R-20	LP-CC-20

kW	SIBA Type RK1	Littel fuse Type RK1	Ferraz-Shawmut Type RK1
K75-1K5	5017906-005	KLSR005	A6K-5R
2K2-4K0	5017906-010	KLSR010	A6K-10R
5K5-7K5	5017906-020	KLSR020	A6K-20R

kW	Bussmann JFHR2	SIBA Type RK1	Ferraz-Shawmut Type RK1
P37K	170M3013	2061032.125	6.6URD30D08A0125
P45K	170M3014	2061032.160	6.6URD30D08A0160
P55K	170M3015	2061032.200	6.6URD30D08A0200
P75K	170M3015	2061032.200	6.6URD30D08A0200
P90K	170M3016	2061032.250	6.6URD30D08A0250

525–690 V*, frame sizes B and C

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
11K	30 A	KTS-R-30	JKS-30	JKJS-30	5017906-030	KLSR030	A6K-30R	HST30
15K-18K5	45 A	KTS-R-45	JKS-45	JJS-45	5014006-050	KLSR045	A6K-45R	HST45
22K	60 A	KTS-R-60	JKS-60	JJS-60	5014006-063	KLSR060	A6K-60R	HST60
30K	80 A	KTS-R-80	JKS-80	JJS-80	5014006-080	KLSR075	A6K-80R	HST80
37K	90 A	KTS-R-90	JKS-90	JJS-90	5014006-100	KLSR090	A6K-90R	HST90
45K	100 A	KTS-R-100	JKS-100	JJS-100	5014006-100	KLSR100	A6K-100R	HST100
55K	125 A	KTS-R-125	JKS-125	JJS-125	2028220-125	KLS-125	A6K-125R	HST125
75K	150 A	KTS-R-150	JKS-150	JJS-150	2028220-150	KLS-150	A6K-150R	HST150
* UL compliance only 525–600 V								

380–500 V, frame sizes D, E and F

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.

Size/ Type	Bussmann E1958 JFHR2**	Bussmann E4273 T/JDDZ**	SIBA E180276 JFHR2	LittelFuse E71611 JFHR2**	Ferraz-Shawmut E76491 JFHR2	Bussmann E4274 H/JDDZ**	Bussmann E125085 JFHR2*	Internal Option Bussmann
P90K	FWH-300	JJS-300	2061032.315	L50S-300	6.6URD30D08A0315	NOS-300	170M3017	170M3018
P110	FWH-350	JJS-350	2061032.35	L50S-350	6.6URD30D08A0350	NOS-350	170M3018	170M3018
P132	FWH-400	JJS-400	2061032.4	L50S-400	6.6URD30D08A0400	NOS-400	170M4012	170M4016
P160	FWH-500	JJS-500	2061032.5	L50S-500	6.6URD30D08A0500	NOS-500	170M4014	170M4016
P200	FWH-600	JJS-600	2062032.63	L50S-600	6.6URD32D08A630	NOS-600	170M4016	170M4016

Table 8.2: Frame size D, Line fuses, 380–500 V

Size/Type	Bussmann PN*	Rating	Ferraz	Siba
P250	170M4017	700 A, 700 V	6.9URD31D08A0700	20 610 32.700
P315	170M6013	900 A, 700 V	6.9URD33D08A0900	20 630 32.900
P355	170M6013	900 A, 700 V	6.9URD33D08A0900	20 630 32.900
P400	170M6013	900 A, 700 V	6.9URD33D08A0900	20 630 32.900

Table 8.3: Frame size E, Line fuses, 380–500 V

Size/Type	Bussmann PN*	Rating	Siba	Internal Bussmann Option
P450	170M7081	1600 A, 700 V	20 695 32.1600	170M7082
P500	170M7081	1600 A, 700 V	20 695 32.1600	170M7082
P560	170M7082	2000 A, 700 V	20 695 32.2000	170M7082
P630	170M7082	2000 A, 700 V	20 695 32.2000	170M7082
P710	170M7083	2500 A, 700 V	20 695 32.2500	170M7083
P800	170M7083	2500 A, 700 V	20 695 32.2500	170M7083

Table 8.4: Frame size F, Line fuses, 380–500 V

Size/Type	Bussmann PN*	Rating	Siba
P450	170M8611	1100 A, 1000 V	20 781 32.1000
P500	170M8611	1100 A, 1000 V	20 781 32.1000
P560	170M6467	1400 A, 700 V	20 681 32.1400
P630	170M6467	1400 A, 700 V	20 681 32.1400
P710	170M8611	1100 A, 1000 V	20 781 32.1000
P800	170M6467	1400 A, 700 V	20 681 32.1400

Table 8.5: Frame size F, Inverter module DC Link Fuses, 380–500 V

*170M fuses from Bussmann shown use the -/80 visual indicator; -TN/80 Type T, -/110 or TN/110 Type T indicator fuses of the same size and amperage may be substituted for external use

**Any minimum 500 V UL listed fuse with associated current rating may be used to meet UL requirements.

525–690 V, frame sizes D, E and F

Size/Type	Bussmann E125085 JFHR2	Amps	SIBA E180276 JFHR2	Ferraz-Shawmut E76491 JFHR2	Internal Option Bussmann
P37K	170M3013	125	2061032.125	6.6URD30D08A0125	170M3015
P45K	170M3014	160	2061032.16	6.6URD30D08A0160	170M3015
P55K	170M3015	200	2061032.2	6.6URD30D08A0200	170M3015
P75K	170M3015	200	2061032.2	6.6URD30D08A0200	170M3015
P90K	170M3016	250	2061032.25	6.6URD30D08A0250	170M3018
P110	170M3017	315	2061032.315	6.6URD30D08A0315	170M3018
P132	170M3018	350	2061032.35	6.6URD30D08A0350	170M3018
P160	170M4011	350	2061032.35	6.6URD30D08A0350	170M5011
P200	170M4012	400	2061032.4	6.6URD30D08A0400	170M5011
P250	170M4014	500	2061032.5	6.6URD30D08A0500	170M5011
P315	170M5011	550	2062032.55	6.6URD32D08A550	170M5011

Table 8.6: Frame size D, 525–690 V

Size/Type	Bussmann PN*	Rating	Ferraz	Siba
P355	170M4017	700 A, 700 V	6.9URD31D08A0700	20 610 32.700
P400	170M4017	700 A, 700 V	6.9URD31D08A0700	20 610 32.700
P500	170M6013	900 A, 700 V	6.9URD33D08A0900	20 630 32.900
P560	170M6013	900 A, 700 V	6.9URD33D08A0900	20 630 32.900

Table 8.7: Frame size E, 525–690 V

Size/Type	Bussmann PN*	Rating	Siba	Internal Bussmann Option
P630	170M7081	1600 A, 700 V	20 695 32.1600	170M7082
P710	170M7081	1600 A, 700 V	20 695 32.1600	170M7082
P800	170M7081	1600 A, 700 V	20 695 32.1600	170M7082
P900	170M7081	1600 A, 700 V	20 695 32.1600	170M7082
P1M0	170M7082	2000 A, 700 V	20 695 32.2000	170M7082

Table 8.8: Frame size F, Line fuses, 525–690 V

Size/Type	Bussmann PN*	Rating	Siba
P630	170M8611	1100 A, 1000 V	20 781 32. 1000
P710	170M8611	1100 A, 1000 V	20 781 32. 1000
P800	170M8611	1100 A, 1000 V	20 781 32. 1000
P900	170M8611	1100 A, 1000 V	20 781 32. 1000
P1M0	170M8611	1100 A, 1000 V	20 781 32. 1000

Table 8.9: Frame size F, Inverter module DC Link Fuses, 525–690 V

*170M fuses from Bussmann shown use the -/80 visual indicator; -TN/80 Type T, -/110 or TN/110 Type T indicator fuses of the same size and amperage may be substituted for external use.
Suitable for use on a circuit capable of delivering not more than 100,000 rms symmetrical amperes, 500/600/690 Volts maximum when protected by the above fuses.

Supplementary fuses

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

Table 8.10: SMPS Fuse

8

Size/Type	Bussmann PN*	LittelFuse	Rating
P90K-P250, 380–500 V	KTK-4		4 A, 600 V
P37K-P400, 525–690 V	KTK-4		4 A, 600 V
P315-P800, 380–500 V		KLK-15	15A, 600 V
P500-P1M0, 525–690 V		KLK-15	15A, 600 V

Table 8.11: Fan Fuses

	Size/Type	Bussmann PN*	Rating	Alternative Fuses
2.5–4.0 A Fuse	P450-P800, 380–500 V	LPJ-6 SP or SPI	6 A, 600 V	Any listed Class J Dual Element, Time Delay, 6 A
	P630-P1M0, 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-P1M0, 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-P1M0, 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-P1M0, 525–690 V	LPJ-20 SP or SPI	20 A, 600 V	Any listed Class J Dual Element, Time Delay, 20 A

Table 8.12: Manual Motor Controller Fuses

8

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

Table 8.13: 30 A Fuse Protected Terminal Fuse

Frame size	Bussmann PN*	Rating	Alternative Fuses
F	LPJ-6 SP or SPI	6 A, 600 V	Any listed Class J Dual Element, Time Delay, 6 A

Table 8.14: Control Transformer Fuse

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

Table 8.15: NAMUR Fuse

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

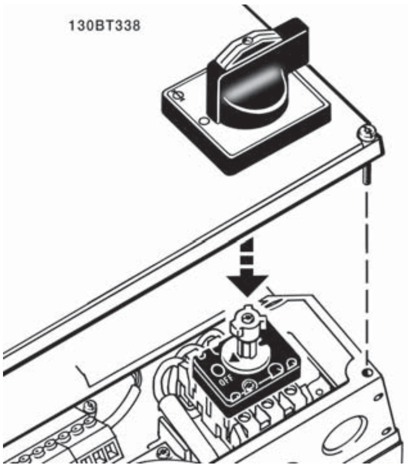
Table 8.16: Safety Relay Coil Fuse with PILS Relay

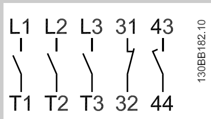
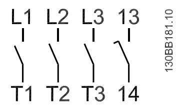
8.4 Disconnectors, Circuit Breakers and Contactors

8.4.1 Line Power Disconnectors

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

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



Frame size:	Type:	Terminal connections:
A5	Kraus&Naimer KG20A T303	
B1	Kraus&Naimer KG64 T303	
B2	Kraus&Naimer KG64 T303	
C1 50 hp [37 kW]	Kraus&Naimer KG100 T303	
C1 60–75 hp [45–55 kW]	Kraus&Naimer KG105 T303	
C2 100 hp [75 kW]	Kraus&Naimer KG160 T303	
C2 125 hp [90 kW]	Kraus&Naimer KG250 T303	

8.4.2 Line Power Disconnectors - Frame Size D, E and F

Frame size	Power & Voltage	Type
D1/D3	P90K-P110 380–500 V & P90K-P132 525–690 V	ABB OETL-NF200A or OT200U12-91
D2/D4	P132-P200 380–500 V & P160-P315 525–690 V	ABB OETL-NF400A or OT400U12-91
E1/E2	P250 380–500 V & P355-P560 525–690 V	ABB OETL-NF600A
E1/E2	P315-P400 380–500 V	ABB OETL-NF800A
F3	P450 380–500 V & P630-P710 525–690 V	Merlin Gerin NPJF36000S12AAYP
F3	P500-P630 380–500 V & P800 525–690 V	Merlin Gerin NRK36000S20AAYP
F4	P710-P800 380–500 V & P900-P1M0 525–690 V	Merlin Gerin NRK36000S20AAYP

8.4.3 F Frame Circuit Breakers

Frame size	Power & Voltage	Type
F3	P450 380–500 V & P630-P710 525–690 V	Merlin Gerin NPJF36120U31AABSCYP
F3	P500-P630 380–500 V & P800 525–690 V	Merlin Gerin NRJF36200U31AABSCYP
F4	P710 380–500 V & P900-P1M0 525–690 V	Merlin Gerin NRJF36200U31AABSCYP
F4	P800 380–500 V	Merlin Gerin NRJF36250U31AABSCYP

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	P630380–500 V	Eaton XTCEC14P22B
F4	P900 525–690 V	Eaton XTCE820N22A
F4	P710-P800 380–500 V & P1M0 525–690 V	Eaton XTCEC14P22B

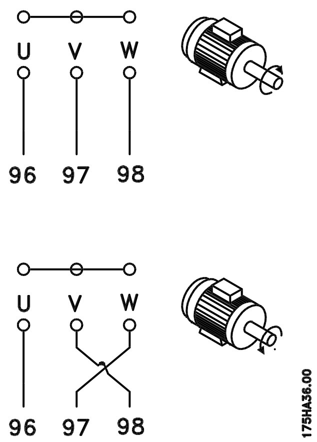
8.5 Additional Motor Information

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

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



The direction of rotation can be changed by switching two phases in the motor cable or by changing the setting of par. 4-10 *Motor Speed Direction*. Motor rotation check can be performed using par. 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, minimum 8.2 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 par. 1-90 *Motor Thermal Protection*is set for *ETR Trip* and par. 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.

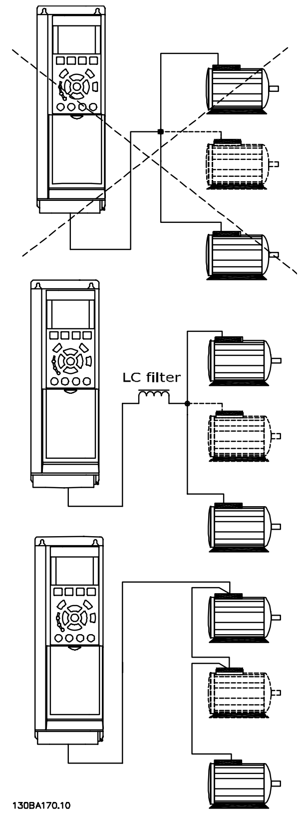
8.5.3 Parallel Connection of Motors

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).

NOTE!
Installations with cables connected using a common joint, as shown in the first example in the picture, are only recommended for short cable lengths.

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



Frame Size	Power Size	Voltage [V]	1 cable [m]	2 cables [m]	3 cables [m]	4 cables [m]
A1, A2, A5	0.5-1 hp [0.37–0.75 kW]	400	150	45	8	6
		500	150	7	4	3
A2, A5	1.5–2 hp [1.1–1.5 kW]	400	150	45	20	8
		500	150	45	5	4
A2, A5	3–5 hp [2.2–4 kW]	400	150	45	20	11
		500	150	45	20	6
A3, A5	7.5–10 hp [5.5–7.5 kW]	400	150	45	20	11
		500	150	45	20	11
B1, B2, B3, B4, C1, C2, C3, C4	11-75 kW	400	150	75	50	37
		500	150	75	50	37

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 ≤, 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} = 1300 V
420 V < $U_N \leq 500$ V	Reinforced U_{LL} = 1600 V
500 V < $U_N \leq 600$ V	Reinforced U_{LL} = 1800 V
600 V < $U_N \leq 690$ V	Reinforced U_{LL} = 2000 V

8.5.5 Motor Bearing Currents

All motors installed with AutomationDrive 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 means of a screwdriver (see figure).

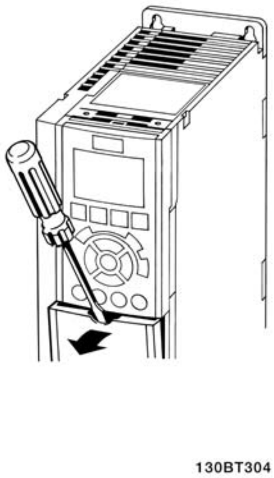


Figure 8.33: Frame sizes A1, A2, A3, B3, B4, C3 and C4

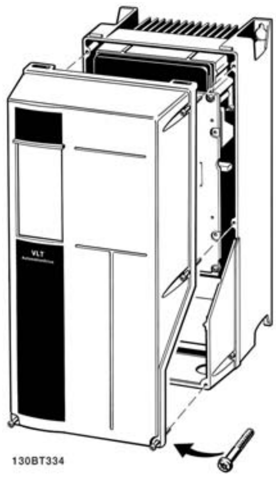


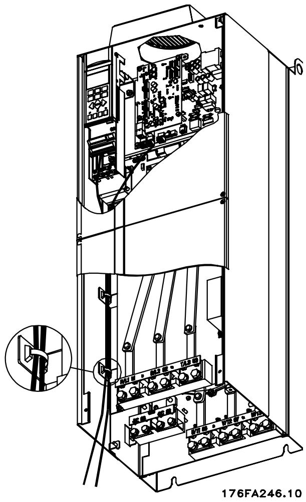
Figure 8.34: Frame sizes A5, B1, B2, C1 and C2

8.6.2 Control Cable Routing

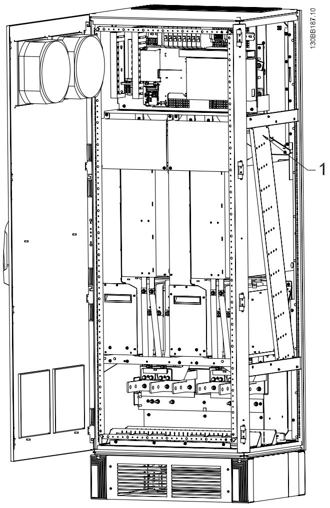
Tie down all control wires to the designated control cable routing as shown in the picture. Remember to connect the shields in a proper way to ensure optimum electrical immunity.

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 to the left inside the adjustable frequency drive and tied down together with other control wires (see picture).



Control card wiring path for the D3. Control card wiring for the D1, D2, D4, E1 and E2 use the same path.



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 on the picture to the right. On the NEMA 1 unit, a cover plate must be removed.
Kit number for serial communication bus top connection: 176F1742

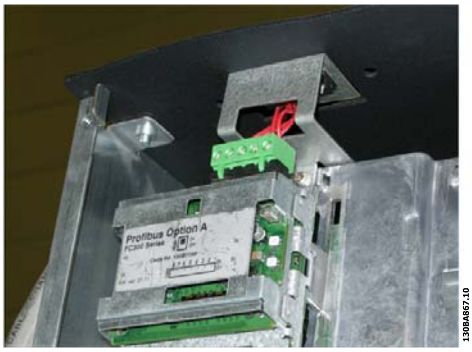
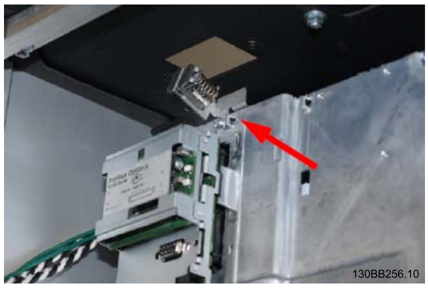


Figure 8.35: Top connection for serial communication bus.



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

24 VDC 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, AutomationDrive 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, AutomationDrive 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.

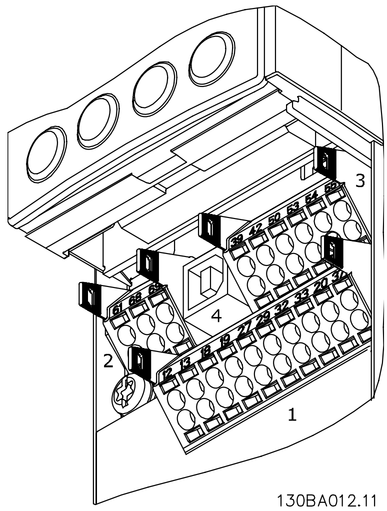


Figure 8.36: Control terminals (all frame sizes)

8.6.4 Switches S201, S202, and S801

Switches S201 (A53) and S202 (A54) are used to select a current (0-20 mA) or a voltage (-10 to 10 V) configuration for 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.*

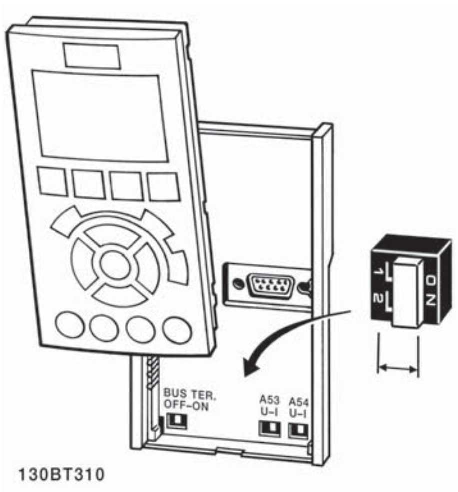
Default setting:

S201 (A53) = OFF (voltage input)

S202 (A54) = OFF (voltage input)

S801 (Bus termination) = OFF

> **!** 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.



8.6.5 Electrical Installation, Control Terminals

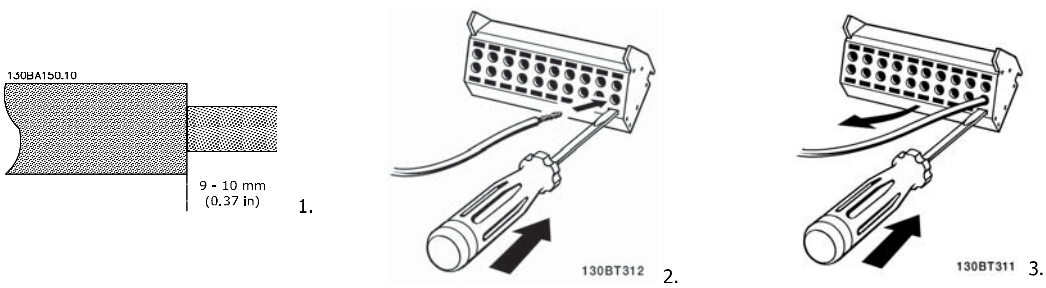
To mount the cable to the terminal:

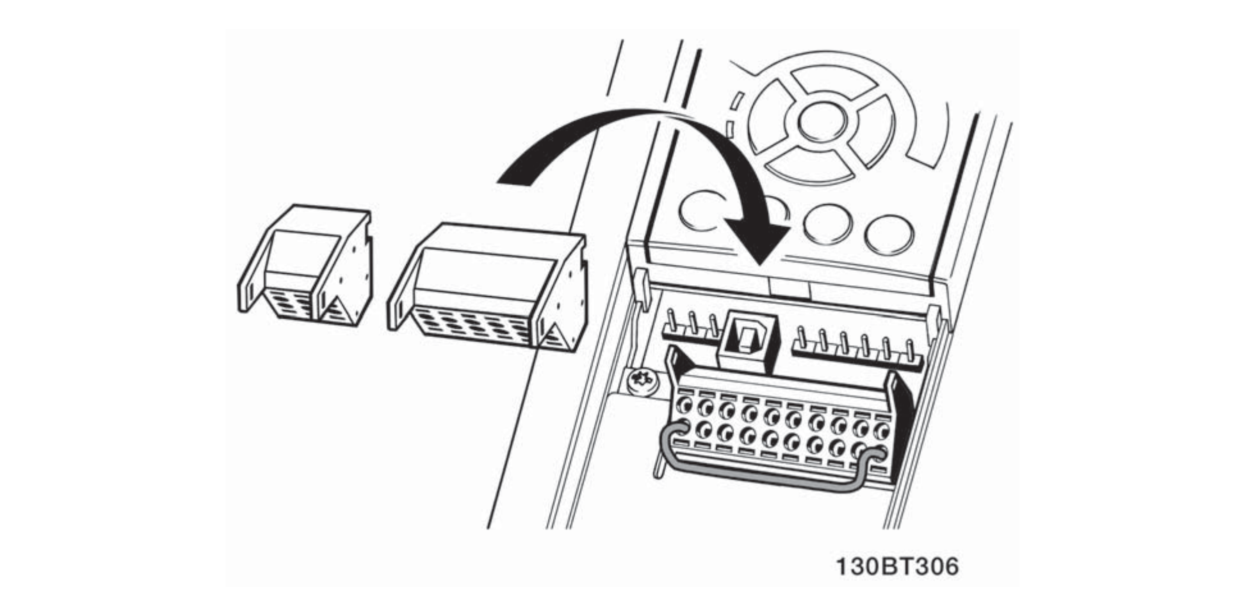
1. Strip insulation of 0.34–0.39 in [9–10 mm]
2. Insert a screwdriver[1)] in the square hole.
3. Insert the cable in the adjacent circular hole.
4. Remove the screwdriver. The cable is now mounted to the terminal.

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]





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8.6.6 Basic Wiring Example

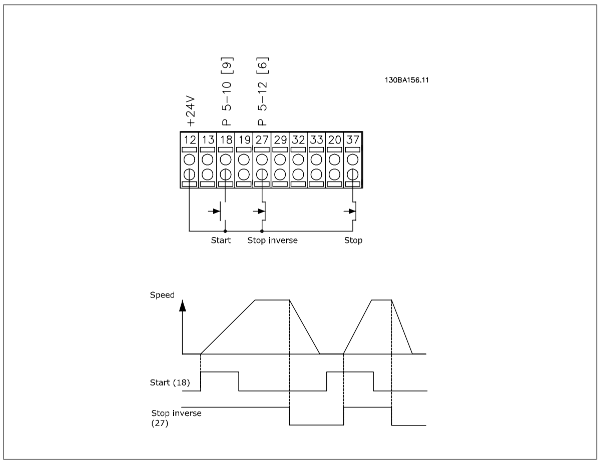
1. Mount terminals from the accessory bag to the front of the adjustable frequency drive.
2. Connect terminals 18, 27 and 37 (AutomationDrive FC 302 only) to +24 V (terminal 12/13)

Default settings:

18 = Start, par. 5-10 *Terminal 18 Digital Input* [9]

27 = Stop inverse, par. 5-12 *Terminal 27 Digital Input* [6]

37 = safe stop inverse



8.6.7 Electrical Installation, Control Cables

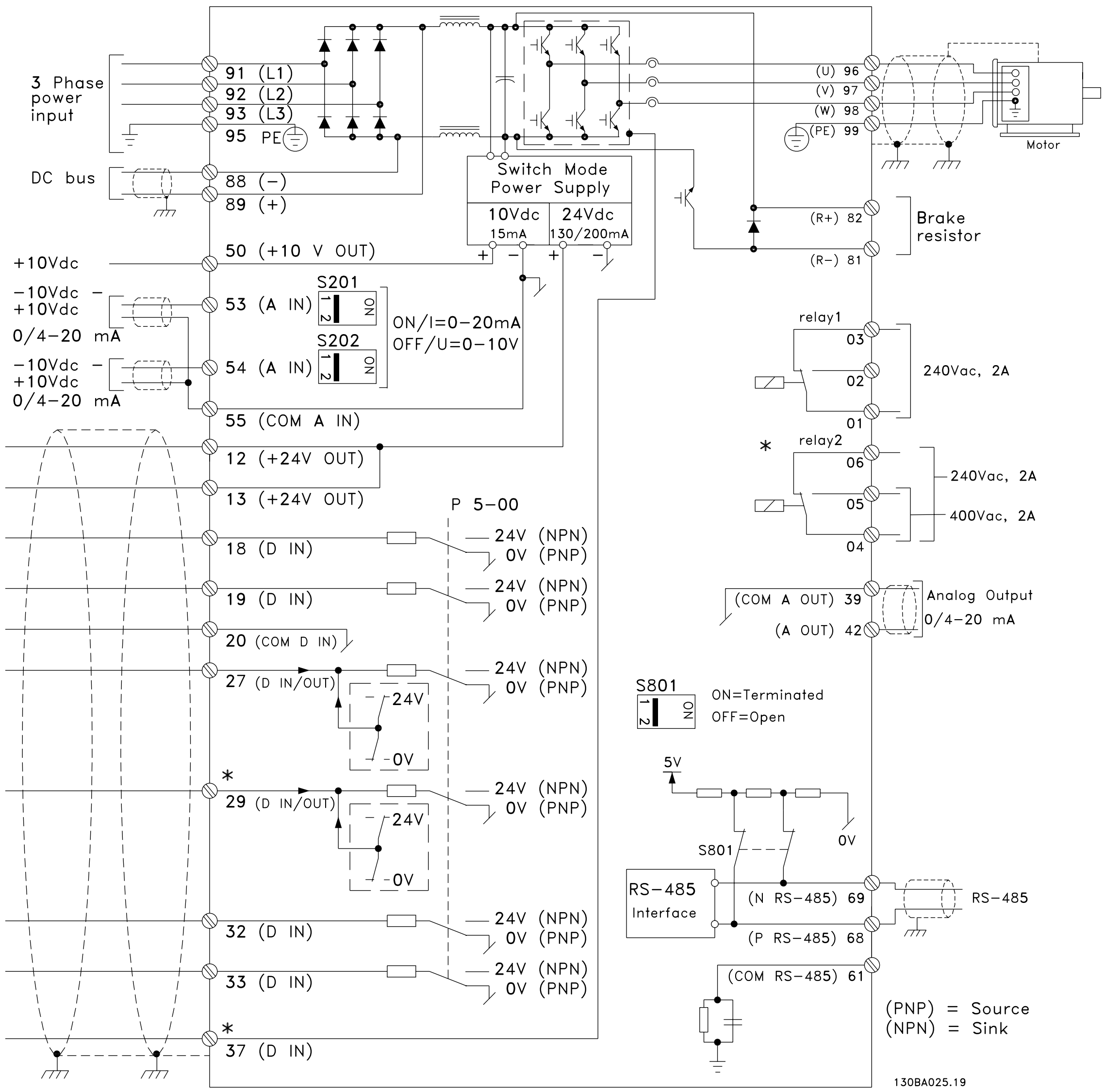


Figure 8.37: Diagram showing all electrical terminals without options.

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 AutomationDrive FC 301 (Except AutomationDrive FC 301 A1, which includes Safe Stop).

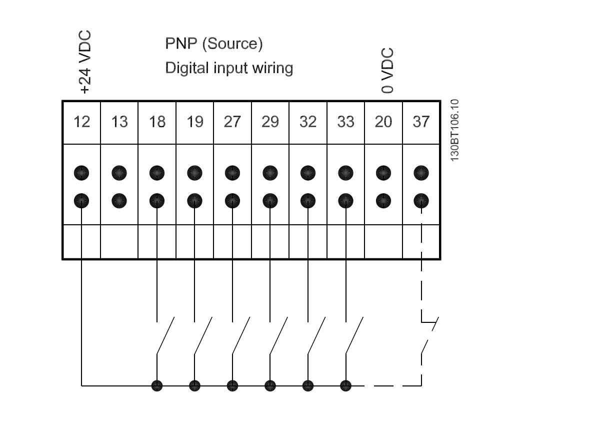
Relay 2 and Terminal 29, have no function in AutomationDrive FC 301.

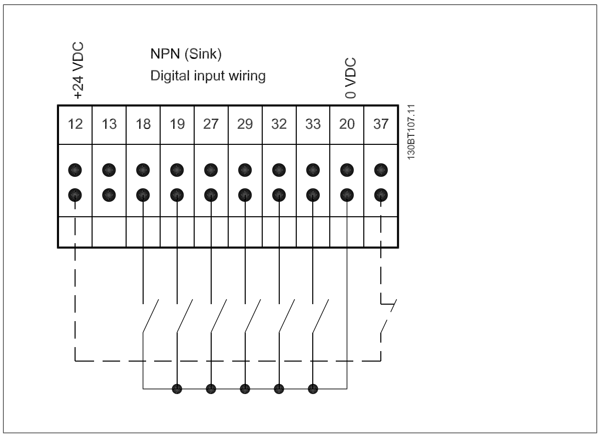
In rare cases, very long control cables and analog signals may, depending on installation, result in 50/60 Hz ground loops due to noise from line power supply cables.

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

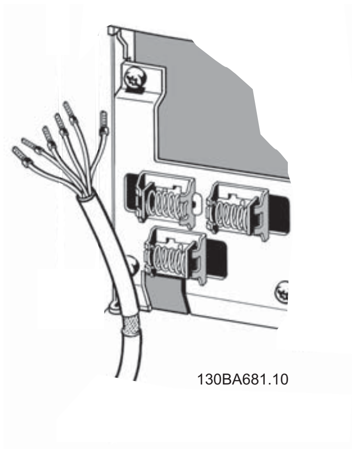




NOTE!

Control cables must be shielded/armored.

See section entitled *Grounding of Shielded/Armored Control Cables* for the correct termination of control cables.



8.6.8 Relay Output

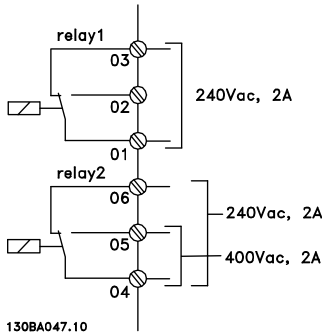
Relay 1

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

Relay 2 (Not AutomationDrive FC 301)

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

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



Additional relay outputs by using option module MCB 105.

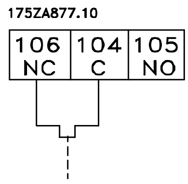
8.6.9 Brake Resistor Temperature Switch

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".
Normally closed: 104-106 (factory-installed jumper)
Normally open: 104-105

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

! 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.
A KLIXON switch must be installed that is 'normally closed'. If this function is not used, 106 and 104 must be short-circuited together.



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8.7 Additional Connections

8.7.1 DC Bus Connection

The DC bus terminal is used for DC back-up, with the intermediate circuit being supplied from an external source.

Terminal numbers used: 88, 89

Please contact Danfoss if you require further information.

8.7.2 Load Sharing

Terminal No.	Function
88, 89	Load sharing

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 back plate 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

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.

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

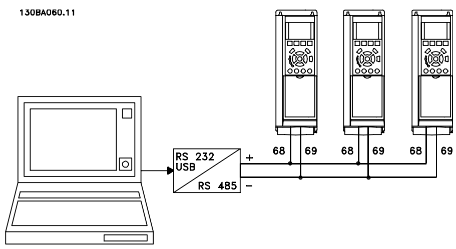
Frame size F Requirements

The brake resistor(s) must be connected to the brake terminals in each inverter module.

8.7.4 RS 485 Bus Connection

One or more adjustable frequency drives can be connected to a control (or master) using the RS-485 standardized interface. Terminal 68 is connected to the P signal (TX+, RX+), while terminal 69 is connected to the N signal (TX-, RX-).

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



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

Bus termination

The RS-485 bus must be terminated by a resistor network at both ends. For this purpose, set switch S801 on the control card to "ON".

For more information, see the paragraph *Switches S201, S202, and S801*.

NOTE!

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

8.7.5 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.

NOTE!

The USB connection is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals. The USB connection is connected to protection ground on the adjustable frequency drive. Use only isolated laptop for PC connection to the USB connector on the adjustable frequency drive.

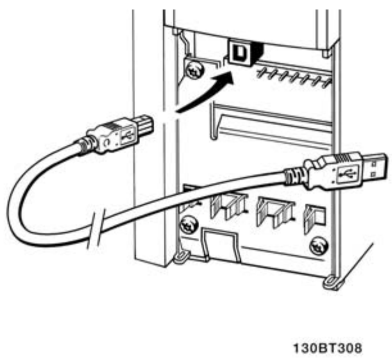


Figure 8.38: USB connection.

8.7.6 The AutomationDrive 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 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 380–500 V adjustable frequency drives and 2.525 kV DC for 525–690 V adjustable frequency drives for one second between this short-circuit and the chassis.

NOTE!
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.

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 0.39 in2 [10 mm2] or 2 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.

The illustration shows an example of an EMC-correct 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*.

8

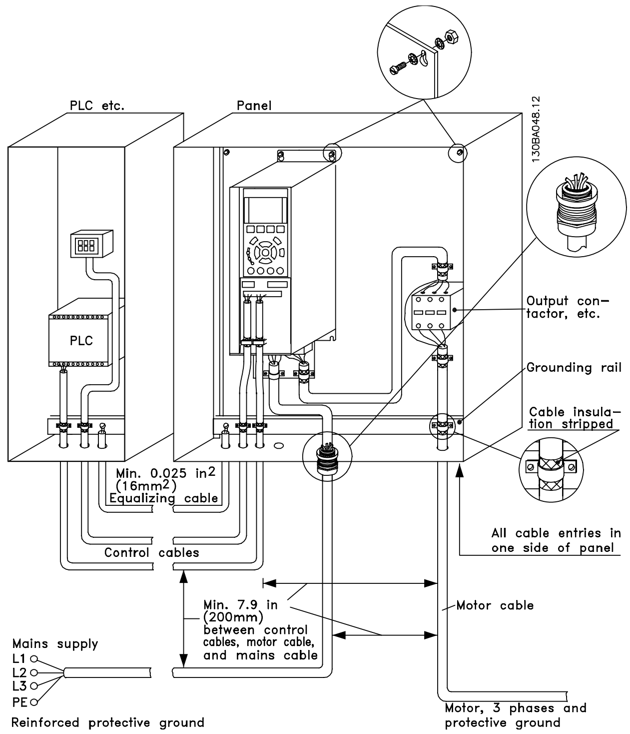


Figure 8.39: EMC-compliant electrical installation of an adjustable frequency drive in a cabinet.

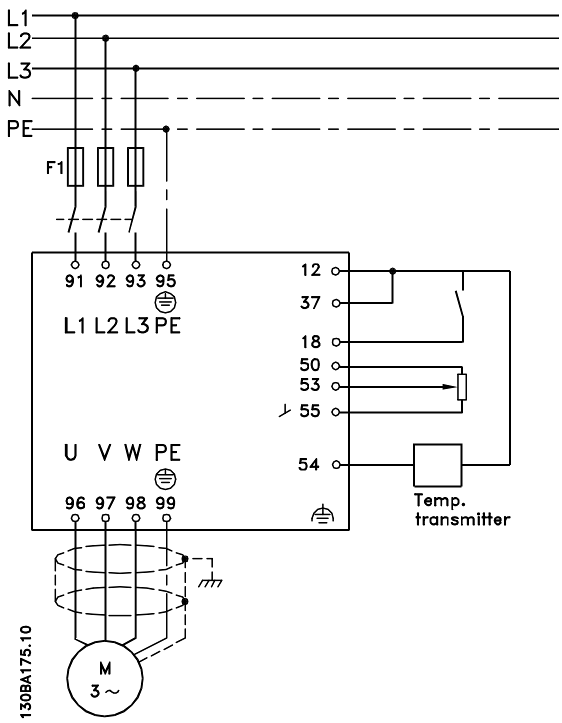


Figure 8.40: Electrical connection diagram.

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.

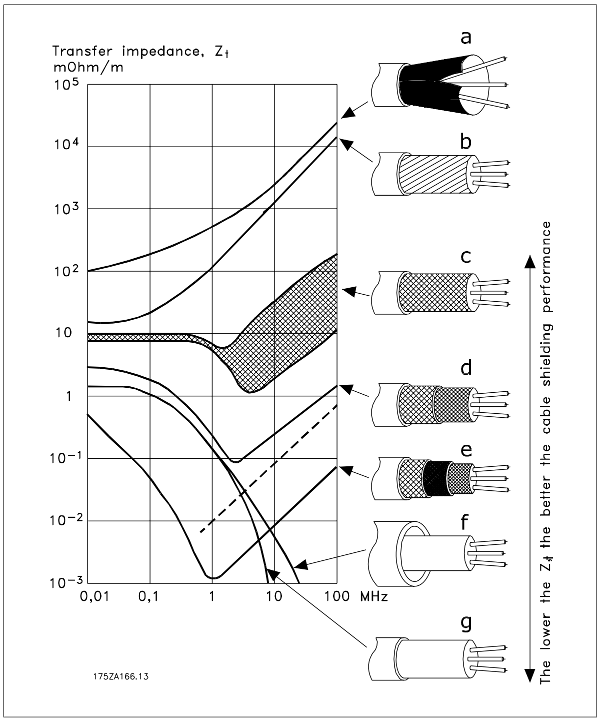
c. Single-layer braided copper wire with varying percentage shield coverage.
This is the typical Danfoss reference cable.

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 0.43 in [1.1 mm] wall thickness.



8.9.3 Grounding of Shielded/Armored Control Cables

Generally speaking, control cables must be braided and shielded/armored, and the shield must be connected by means of a cable clamp at both ends to the metal cabinet of the unit.

The drawing below indicates how correct grounding is carried out and what to do if in doubt.

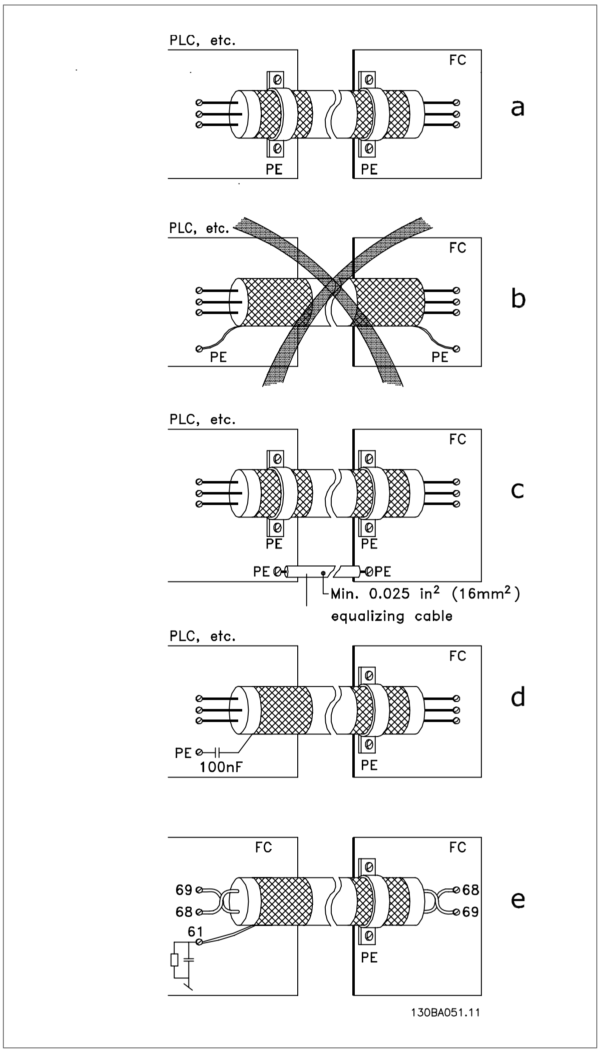
a. **Correct grounding**
Control cables and cables for serial communication must be fitted with cable clamps at both ends to ensure the best possible electrical contact.

b. **Wrong grounding**
Do not use twisted cable ends (pigtails). They increase the shield impedance at high frequencies.

c. **Protection with respect to ground potential between PLC and**
If the ground potential between the adjustable frequency drive and the PLC (etc.) 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: 0.025 in^2 [16 mm^2].

d. **For 50/60 Hz ground loops**
If very long control cables are used, 50/60 Hz ground loops may occur. Solve this problem by connecting one end of the shield to ground via a 100nF capacitor (keeping leads short).

e. **Cables for serial communication**
Eliminate low-frequency noise currents between two adjustable frequency drives by connecting one end of the shield to terminal 61. This terminal is grounded via an internal RC link. Use twisted-pair cables to reduce the differential mode interference between the conductors.



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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 par. 14-50 *RFI 1*. For further reference, see IEC 364-3. In case optimum EMC performance is needed, parallel motors are connected or the motor cable length is above 82 ft [25 m],, it is recommended to set par. 14-50 *RFI 1* to [ON].

[1)] Not available for 525–600/690 V 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).

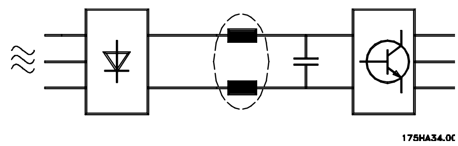
Please also refer to the application note *VLT on IT line power, MN.90.CX.02.* It is important to use isolation monitors that are capable for use together with power electronics (IEC 61557-8).

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

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.



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

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

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

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

(U_N% of U)

8.11.1 Residual Current Device

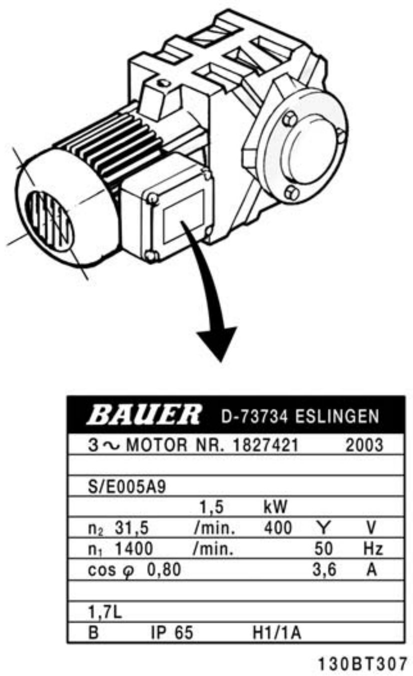
You can use RCD relays, multiple protective grounding or grounding as extra protection, provided that local safety regulations are complied with.
If a ground fault appears, a DC content may develop in the faulty current.
If RCD relays are used, you must observe local regulations. Relays must be suitable for protection of 3-phase equipment with a bridge rectifier and for a brief discharge on power-up see 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

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



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.	par. 1-20 *Motor Power [kW]* par. 1-21 *Motor Power [HP]*
2.	par. 1-22 *Motor Voltage*
3.	par. 1-23 *Motor Frequency*
4.	par. 1-24 *Motor Current*
5.	par. 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 par. 5-12 *Terminal 27 Digital Input* to 'No function'.
3. Activate the AMA par. 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 troubleshooting. If you contact Danfoss for service, make sure to mention the number and alarm description.

NOTE!
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

par. 3-02 *Minimum Reference*
par. 3-03 *Maximum Reference*

Table 8.17: Set up the desired limits for speed and ramp time.

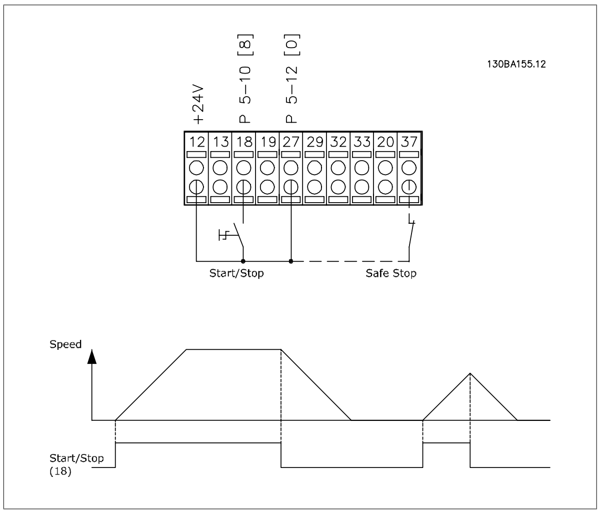
par. 4-11 *Motor Speed Low Limit [RPM]* or par. 4-12 *Motor Speed Low Limit [Hz]*
par. 4-13 *Motor Speed High Limit [RPM]* or par. 4-14 *Motor Speed High Limit [Hz]*

par. 3-41 *Ramp 1 Ramp-up Time*
par. 3-42 *Ramp 1 Ramp-down Time*

9 Application Examples

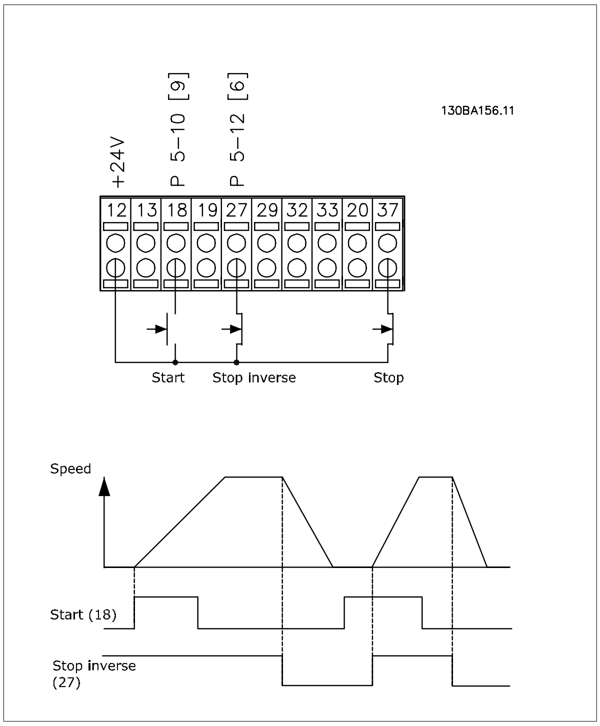
9.1.1 Start/Stop

Terminal 18 = par. 5-10 *Terminal 18 Digital Input* [8] *Start*
Terminal 27 = par. 5-12 *Terminal 27 Digital Input* [0] *No operation* (Default *coast inverse*)
Terminal 37 = Safe stop (where available!)



9.1.2 Pulse Start/Stop

Terminal 18 = par. 5-10 *Terminal 18 Digital Input*Latched start, [9]
Terminal 27= par. 5-12 *Terminal 27 Digital Input*Stop inverse, [6]
Terminal 37 = Safe stop (where available!)



9.1.3 Potentiometer Reference

Voltage reference via a potentiometer:

Reference Source 1 = [1] *Analog input 53* (default)

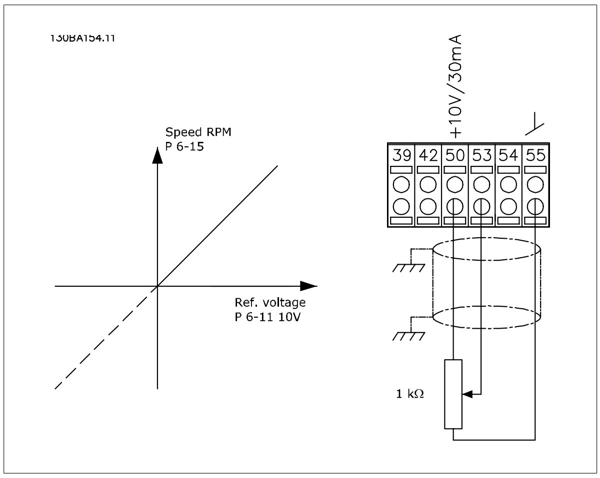
Terminal 53, Low Voltage = 0 Volt

Terminal 53, High Voltage = 10 Volt

Terminal 53, Low Ref./Feedback = 0 RPM

Terminal 53, High Ref./Feedback = 1,500 RPM

Switch S201 = OFF (U)



9.1.4 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.

Encoder connection to the adjustable frequency drive

24 V incremental encoder. Max. cable length 16 ft [5 m]

9.1.5 Encoder Direction

The direction of the encoder is determined by which order the pulses are entering the drive.
A 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.

9.1.6 Closed-loop Drive System

A drive system consist usually of more elements such as:

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

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

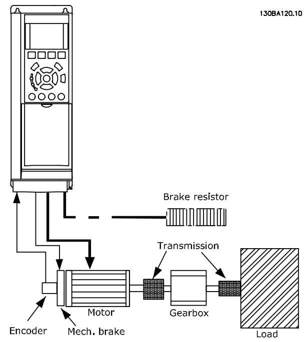


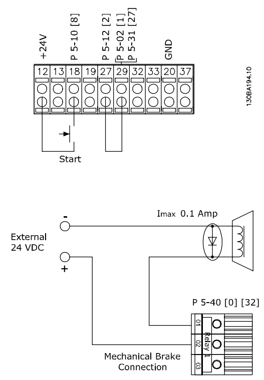
Figure 9.1: **Basic Set-up for AutomationDrive FC 302 Closed-loop Speed Control**

9.1.7 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
  par. 5-10 *Terminal 18 Digital Input* Start [8]
- Quickstop via terminal 27
  par. 5-12 *Terminal 27 Digital Input* Coasting Stop, Inverse [2]
- Terminal 29 Output
  par. 5-02 *Terminal 29 Mode* Terminal 29 Mode Output [1]
  par. 5-31 *Terminal 29 digital Output* Torque Limit & Stop [27]
- Relay output [0] (Relay 1)
  par. 5-40 *Function Relay* Mechanical Brake Control [32]

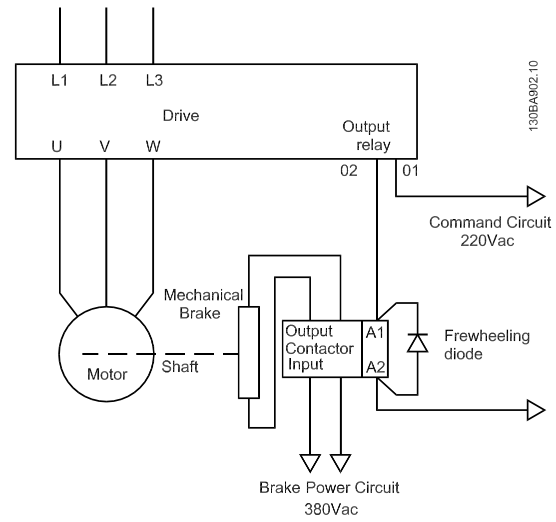


9.1.8 Advanced Mechanical Brake Control for Hoisting Applications

1. The vertical movement

In the vertical movement, the key point is that the load must be held, stopped, controlled (raised, lowered) in a perfectly safe mode during the entire operation.
Because the adjustable frequency drive is not a safety device, the crane/lift designer (OEM) must decide on the type and number of safety devices (e.g., speed switch, emergency brakes, etc.) to be used, in order to be able to stop the load in case of emergency or malfunction of the system, according to relevant national crane/lift regulations.

2. Connecting the mechanical brake to the adjustable frequency drive



- The electromagnetic disc brake works by the action of a set of springs and is released when applying voltage to the brake coil.
- This means the motor will brake automatically in case of voltage failure, as a significant safety feature.
- Whenever a mechanical brake is present, it is strongly recommended to use an external contactor to take over switching on/off the brake.
- Because of inverse voltage peaks during switch on/off, it is recommended to use a diode block mounted on the contactor's coil, for protection of the adjustable frequency drive.
- The contact 01-02 in the adjustable frequency drive stays normally open, so the output is not energized.
- When the START condition comes from the command circuit, the drive closes the 01-02 contact according to the programmed brake logic. The output is now energized until STOP condition occurs.
- If the adjustable frequency drive is in alarm or fault condition, the output relay immediately cuts in.

3. The control parameters

In open-loop structure, the relevant (active) parameters to controlling the mechanical brake output relay are:

- Par. 5-40 *Function Relay* or par. 5-41 *On Delay, Relay*. Mechanical brake control: activates the output brake relay function
- Par. 2-20 *Release Brake Current*. When the START condition is present, the motor current is increased to the set value (closed to the nominal motor current), in order to produce enough torque to hold the load during the brake release.
- Par. 2-21 *Activate Brake Speed [RPM]*. By setting this parameter the mechanical brake will be engaged over a rotating shaft. Recommended value is ½ of the slip. If the value is too high, the mechanical system will be exposed to shocks at every stop. If the value is too small, the

torque (current) might be insufficient to holding the load at zero speed. When the STOP condition is present, the motor is ramping down to zero speed (mechanical brake is still open), and at the set value (rpm) engages (closes down) the mechanical brake.

- Par. 2-22 *Activate Brake Speed [Hz]*. Linked to par. 2-21 *Activate Brake Speed [RPM]*. Automatically adjusted according to the par. 2-21 value.
- Par. 2-23 *Activate Brake Delay*. The shaft is held at zero speed with full holding torque. This function ensures that the mechanical brake has locked the load before the motor enters coast mode.
- Par. 2-24 *Stop Delay*. Allows successive starting without applying the mechanical brake (e.g., reversing).
- Par. 2-25 *Brake Release Time*. The time needed by the brake to be open/closed.

In closed-loop structure, the parameter dependency is:

- Par. 5-40 *Function Relay* or par. 5-41 *On Delay, Relay*
- Par. 1-72 *Start Function*: Hoist Mechanical Brake
- Par. 2-25 *Brake Release Time*
- Par. 2-26 *Torque Ref.* Sets the torque to be applied against the closed mechanical brake before release.
- Par. 2-27 *Torque Ramp Time*
- Par. 2-28 *Gain Boost Factor*. Compensates the "push back" when the speed controller takes over the torque controller.

9.1.9 Automatic Motor Adaptation (AMA)

AMA is an algorithm to measure the electrical motor parameters on a motor at standstill. This means thatAMA itself does not supply any torque.
AMA is useful when commissioning systems and optimizing the adjustment of the adjustable frequency drive to the applied motor. In particular, this feature is used where the default setting does not apply to the connected motor.
par. 1-29 *Automatic Motor Adaptation (AMA)* allows a choice of complete AMA with determination of all electrical motor parameters or reduced AMA with determination of the stator resistance Rs only.
The duration of a total AMA varies from a few minutes on small motors to more than 15 minutes on large motors.

9

Limitations and preconditions:

- For the AMA to determine the motor parameters optimally, enter the correct motor nameplate data in par. 1-20 *Motor Power [kW]* to par. 1-28 *Motor Rotation Check*.
- For the best adjustment of the adjustable frequency drive, carry out AMA on a cold motor. Repeated AMA runs may lead to a heating of the motor, which results in an increase of the stator resistance, Rs. Normally, this is not critical.
- AMA can only be carried out if the rated motor current is minimum 35% of the rated output current of the adjustable frequency drive. AMA can be carried out on up to one oversize motor.
- It is possible to carry out a reduced AMA test with a sine-wave filter installed. Avoid carrying out a complete AMA with a sine-wave filter. If an overall setting is required, remove the sine-wave filter while running a total AMA. After completion of the AMA, reinsert the sine-wave filter.
- If motors are coupled in parallel, use only reduced AMA if any.
- Avoid running a complete AMA when using synchronous motors. If synchronous motors are applied, run a reduced AMA and manually set the extended motor data. The AMA function does not apply to permanent magnet motors.
- The adjustable frequency drive does not produce motor torque during an AMA. During an AMA, it is imperative that the application does not force the motor shaft to run, which is known to happen with, e.g., wind milling in ventilation systems. This disturbs the AMA function.

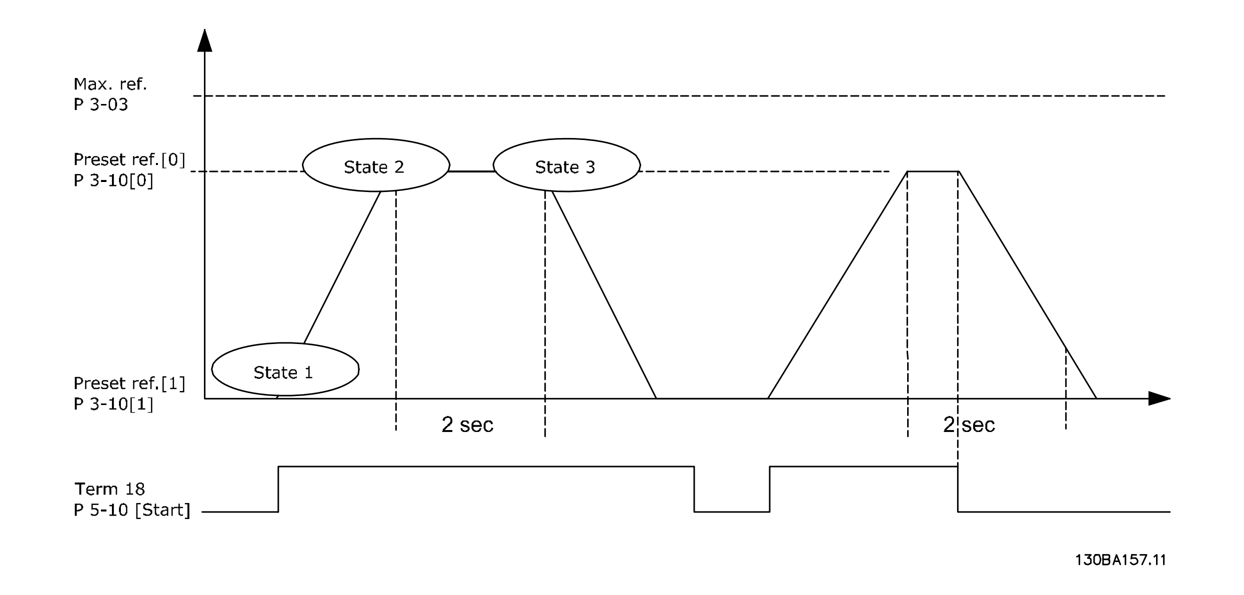
9.1.10 Smart Logic Control Programming

A new useful facility in AutomationDrive FC 300 is the Smart Logic Control (SLC).
In applications where a PLC is generating a simple sequence, the SLC may take over elementary tasks from the main control.
SLC is designed to act from event sent to or generated in the adjustable frequency drive. The adjustable frequency drive will then perform the pre-programmed action.

9.1.11 SLC Application Example

One sequence 1:

Start – ramp up – run at reference speed 2 sec – ramp down and hold shaft until stop.



Set the ramping times in par. 3-41 *Ramp 1 Ramp-up Time* and par. 3-42 *Ramp 1 Ramp-down Time* to the wanted times

$$t_{ramp} = \frac{t_{acc} \times n_{norm}(par.\ 1-25)}{ref[RPM]}$$

9

Set term 27 to *No Operation* (par. 5-12 *Terminal 27 Digital Input*)

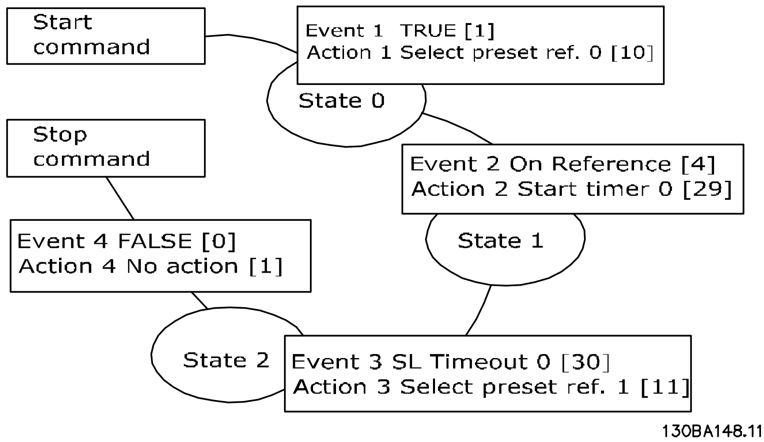
Set Preset reference 0 to first preset speed (par. 3-10 *Preset Reference* [0]) in percentage of Max reference speed (par. 3-03 *Maximum Reference*). Ex.: 60%

Set preset reference 1 to second preset speed (par. 3-10 *Preset Reference* [1] Ex.: 0% (zero).

Set the timer 0 for constant running speed in par. 13-20 *SL Controller Timer* [0]. Ex.: 2 sec.

Set Event 1 in par. 13-51 *SL Controller Event* [1] to *True* [1]
Set Event 2 in par. 13-51 *SL Controller Event* [2] to *On Reference* [4]
Set Event 3 in par. 13-51 *SL Controller Event* [3] to *Time Out 0* [30]
Set Event 4 in par. 13-51 *SL Controller Event* [1] to *False* [0]

Set Action 1 in par. 13-52 *SL Controller Action* [1] to *Select preset 0* [10]
Set Action 2 in par. 13-52 *SL Controller Action* [2] to *Start Timer 0* [29]
Set Action 3 in par. 13-52 *SL Controller Action* [3] to *Select preset 1* [11]
Set Action 4 in par. 13-52 *SL Controller Action* [4] to *No Action* [1]



Set the Smart Logic Control in par. 13-00 *SL Controller Mode* to ON.

Start / stop command is applied on terminal 18. If stop signal is applied the adjustable frequency drive will ramp down and go into free mode.

9.1.12 MCB 112 PTC Thermistor Card

The following two examples show the possibilities, when using the VLT PTC Thermistor Card MCB 112.

Connection of MCB 112

Terminals X44/ 1 and X44/ 2 (T1 and T2) are used to connect the PTCs from the motor with the option card. X44/ 12 is connected with Safe Stop terminal 37 on the FC 302.

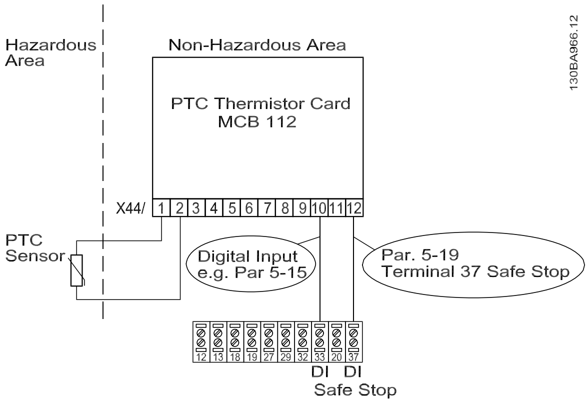
Terminal X44/ 10 is connected to a digital input of the FC 302. This digital input can be terminal 33, but this is only an example - any other digital input could be used instead. The use of this signal allows the drive to determine which source has activated the Safe Stop, as other components can be connected to the Safe Stop terminal 37 of the FC 302 at the same time.

9

NOTE!

Terminal X44/10 must be connected.

Standard use

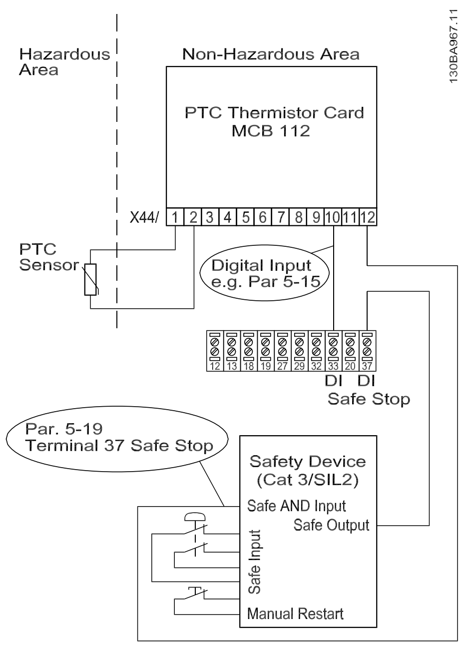


Programming example 1

Par. 5-19 Terminal 37 Safe Stop		
[4]	PTC 1 Alarm	In case the motor temperature is too high, or in the event of a PTC failure, the MCB 112 activates the Safe Stop of the FC 302 (Safe Stop terminal 37 goes LOW (active) and digital input 33 goes HIGH (active)). This parameter decides the consequence of the Safe Stop. With this option, the FC 302 coasts, and "PTC 1 SafeStop [A71]" is displayed in the LCP. The drive must be manually reset from LCP, digital input or serial communication bus when the conditions of the PTC are acceptable again (the temperature of the motor has dropped).
Par. 5-15 Terminal 33 Digital Input		
[80]	PTC Card 1	Connects the digital Input of terminal 33 in the FC 302 to the MCB 112, which makes it possible for the MCB 112 to indicate when Safe Stop has been activated from here.

Alternatively, par. 5-19 could be set to option [5] (PTC 1 Warning), which means an automatic restart when the conditions of the PTC circuit have returned to acceptable. The choice depends on the demands of the customer.

Combination with other component using Safe Stop



Programming example 2

Par. 5-19 Terminal 37 Safe Stop		
[6]	PTC 1 & Relay Alarm	In case the motor temperature is too high, or in the event of a PTC failure, the MCB 112 activates the Safe Stop of the FC 302 (Safe Stop terminal 37 goes LOW (active) and digital input 33 goes HIGH (active)). This parameter decides the consequence of the Safe Stop. With this option, the FC 302 coasts, and "PTC 1 SafeStop [A71]" is displayed in the LCP. The drive must be manually reset from LCP, digital input or serial communication bus when the conditions of the PTC are acceptable again (temperature of motor has dropped). An emergency stop can also activate the Safe Stop of the FC 302 (Safe Stop terminal 37 goes LOW (active) but digital input 33 is not triggered by MCB 112 X44/10 as the MCB 112 did not need to activate the Safe Stop; therefore, digital input 33 remains HIGH (inactive)).
Par. 5-15 Terminal 33 Digital Input		
[80]	PTC Card 1	Connects the digital Input of terminal 33 in the FC 302 to the MCB 112, which makes it possible for the MCB 112 to indicate when Safe Stop has been activated from here.

Alternatively, par. 5-19 could be set to [7] (PTC 1 & Relay Warning), which means an automatic restart when the conditions of the PTC circuit and/or emergency stop circuit have returned to normal. The choice depends on the demands of the customer. Also, the setting of parameter 5-19 could be [8] (PTC 1 & Relay A/W) or [9] (PTC 1 & Relay W/A), which are combinations of alarm and warning. The choice depends on the needs of the customer.

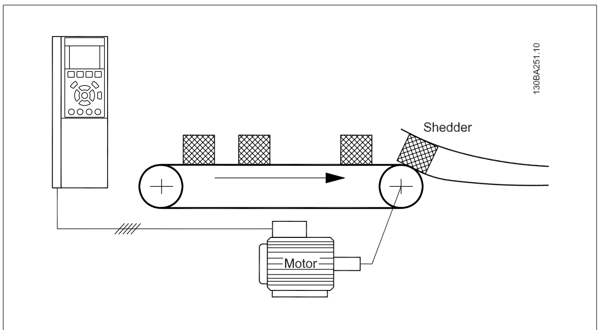
NOTE!
Selection [4] – [9] in par. 5-19 will only be visible in case the MCB 112 is plugged into the B-option slot.

Take care that the DI that is set to [80] is not also configured as Thermistor Resource (motor protection) in par. 1-93.

9

Please refer to *Parameter settings for external safety device in combination with MCB 112* in the *Introduction to FC 300* section for more information about the combination.

9.1.13 Torque Control Open-loop



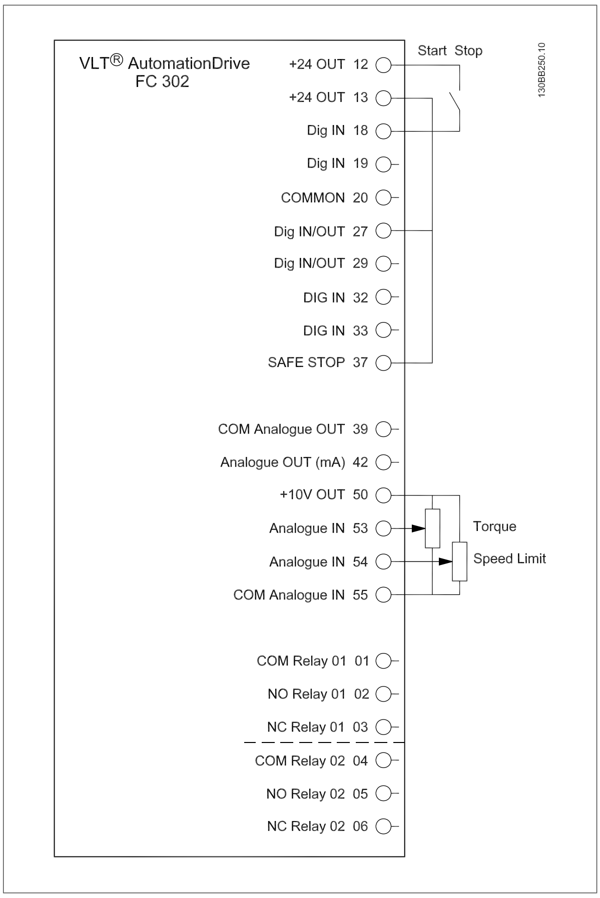
A conveyor belt feeds bales forward into a shredder at constant force, regardless of the conveyor speed. If there is a space between the bales, the conveyor belt must move the next bale to the shedder as fast as possible.

Optimization of the torque control. After setting the basic settings, the factory setting is optimized for most processes. It is rarely necessary to optimize the *torque proportional gain* in par. 7-12 and the torque integration time in par. 7-13.

Feedback
The feedback signal is an estimated torque, calculated by the adjustable frequency drive on the basis of the current values measured

Reference
The reference is in Nm. A minimum and a maximum reference can be set (par. 6-14 and 6-15) which limit the sum of all references. The reference range cannot go beyond the feedback range.

Speed limit function
Speed limit can be set in par. 6-20 to 6-25



Parameter set-up Torque open-loop in VVC+ mode

Function	Parameter	Setting	Data Value
Basic Settings			
Configuration Mode	1-00	Torque Open-loop	[4]
Motor Control Principle	1-01	VVC+	[1]
Torque PI control settings			
Torque PI Proportional Gain	7-12	Default 100%	
Torque PI Integration Time	7-13	Default 0.02 sec	
Reference Handling (Nm) Reference 53; Limit 54			
Reference range	3-00	Min - max	[0]
Terminal 53 Low Voltage	6-10	0 V (Default 0.07 V)	
Terminal 53 High Voltage	6-11	10V	
Terminal 53 Low Ref.	6-14	0 Nm	
Terminal 53 High Ref	6-15	Max torque on motor shaft	
Speed Limit Factor Adjustable on input 54			
Speed Limit Factor Source Operation	4-21	Analog Input 54	[6]
Terminal 54 Low Voltage	6-20	0 V (default 0.07 V)	
Terminal 54 High Voltage	6-21	10 V	
Terminal 54 Low Ref	6-24	0V	
Terminal 54 High Ref	6-25	1500 rpm (adjustable setting)	

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

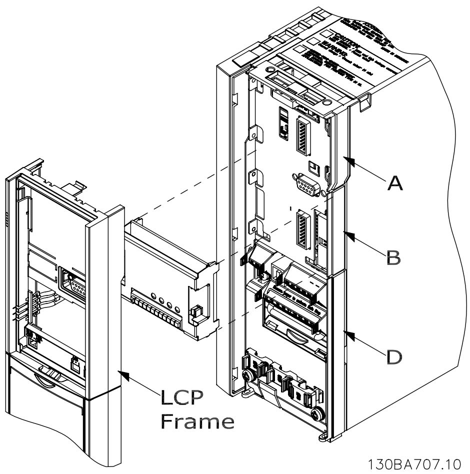
Slot A position is dedicated to serial communication bus options. For further information, see the Instruction Manual.

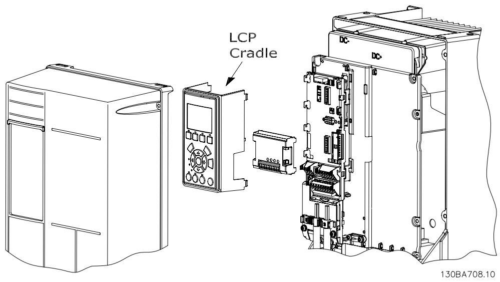
10.1.2 Mounting Option Modules in Slot B

The power to the adjustable frequency drive must be disconnected.

It is strongly recommended to make sure the parameter data is saved (e.g., by MCT10 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.
- Insert the MCB10x option card into slot B.
- Connect the control cables and relieve the cable by the enclosed cable strips.
  * Remove the knock-out in the extended LCP frame, so that the option will fit under the extended LCP frame.
- Fit the extended LCP frame and terminal cover.
- Fit the LCP or blind cover in the extended LCP frame.
- Connect power to the adjustable frequency drive.
- Set up the input/output functions in the corresponding parameters, as mentioned in the section *General Technical Data*.



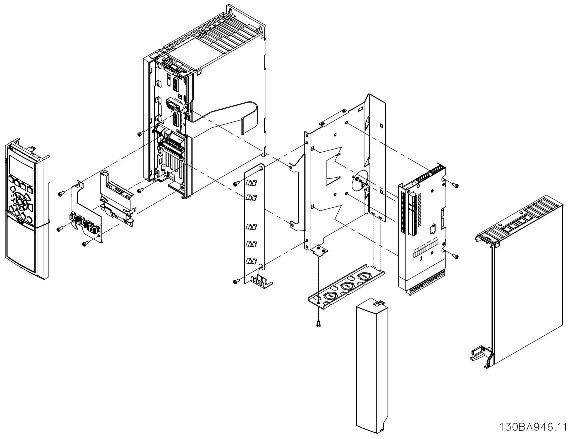


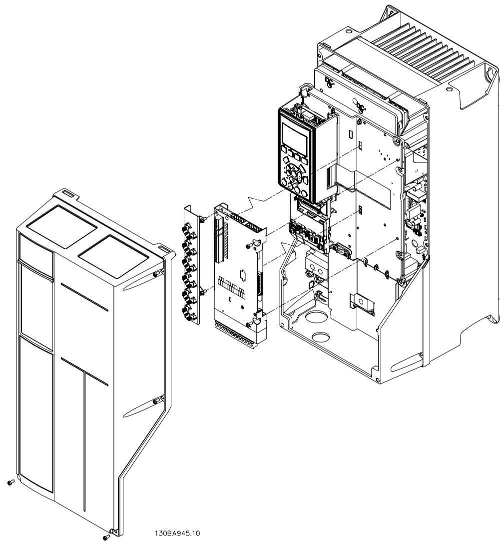
Frame sizes A2, A3 and B3	Frame sizes A5, B1, B2, B4, C1, C2, C3 and C4

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 (e.g., by MCT10 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 the MCO305, see the separate instruction manual.





Frame sizes A2, A3 and B3	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.

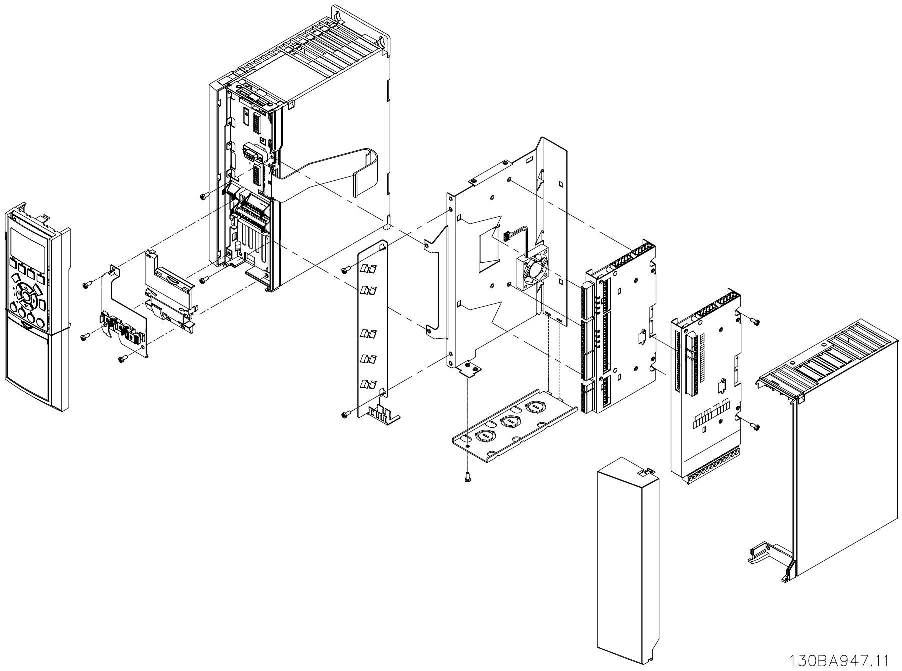


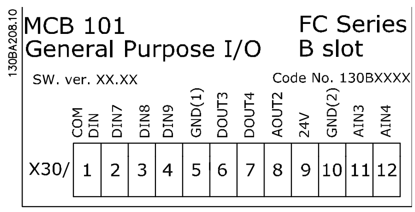
Figure 10.1: Frame sizes A2, A3 and B3

10.2 General Purpose Input Output Module MCB 101

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



10.2.1 Galvanic Isolation in the MCB101

Digital/analog inputs are galvanically isolated from other inputs/outputs on the MCB101 and in the control card of the adjustable frequency drive. Digital/analog outputs in the MCB101 are galvanically isolated from other inputs/outputs on the MCB101, but not from these on the control card of the drive.

If digital inputs 7, 8 or 9 are to be switched using the internal 24 V power supply (terminal 9), the connection between terminal 1 and 5 illustrated in the drawing has to be established.

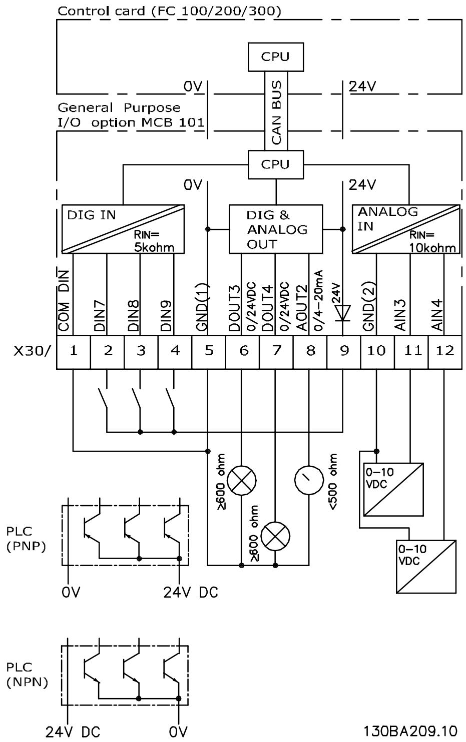


Figure 10.2: Principle Diagram

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	0–24 V DC
Voltage level, logic'0' PNP (GND = 0 V)	< 5 V DC
Voltage level, logic'1' PNP (GND = 0 V)	> 10 V DC
Voltage level, logic '0' NPN (GND = 24V)	< 14 V DC
Voltage level, logic '1' NPN (GND = 24 V)	> 19 V DC
Maximum voltage on input	28 V continuous
Pulse frequency ranges	0–110 kHz
Duty cycle, min. pulse width	4.5 ms
Input impedance	> 2 kΩ

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	0–10 V
Input impedance	> 10 kΩ
Max. voltage	20 V
Resolution for analog inputs	10 bit (+ sign)
Accuracy of analog inputs	Max. error 0.5% of full scale
Bandwidth	AutomationDrive FC 301: 20 Hz/ AutomationDrive FC 302: 100 Hz

10

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	0–24 V
Max. output current	40 mA
Max. load	≥ 600 Ω
Max. capacitive load	< 10 nF
Minimum output frequency	0 Hz
Maximum output frequency	≤ 32 kHz
Accuracy of frequency output	Max. error: 0.1% of full scale

10.2.5 Analog Output - Terminal X30/8:

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

10.3 Encoder Option MCB 102

The encoder module can be used as feedback source for closed-loop flux control (par. 1-02 *Flux Motor Feedback Source*) as well as closed-loop speed control (par. 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: 410 kHz
Incremental encoder: 1Vpp, sine-cosine
Hiperface® Encoder: Absolute and Sine-Cosine (Stegmann/SICK)
EnDat encoder: Absolute and Sine-Cosine (Heidenhain) Supports version 2.1
SSI encoder: Absolute
Encoder monitor:
The 4 encoder channels (A, B, Z, and D) are monitored, open and short circuit can be detected. There is a green LED for each channel which lights up when the channel is OK.

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

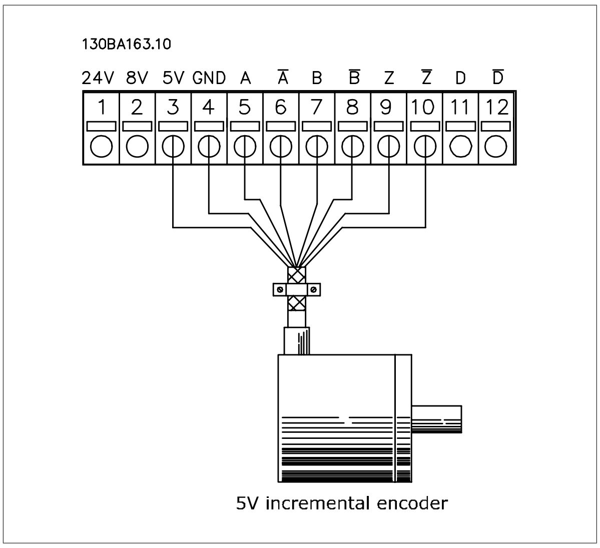
When the encoder option kit is ordered separately, it includes:

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

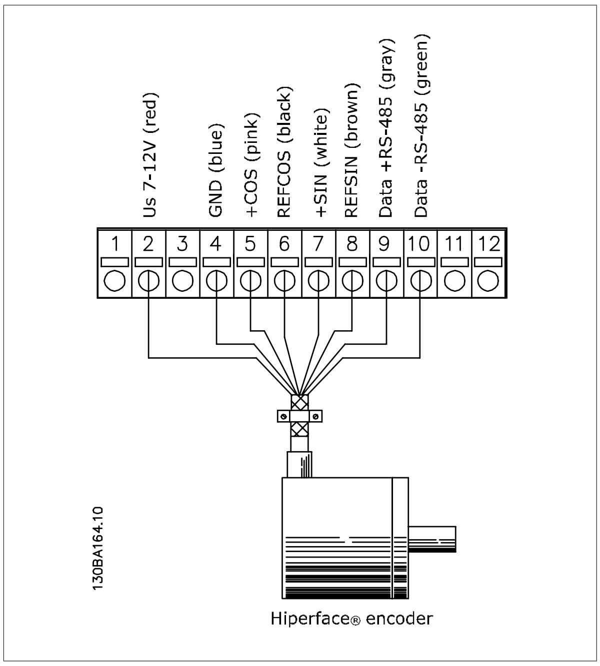
The encoder option does not support AutomationDrive FC 302 adjustable frequency drives manufactured before week 50/2004.
Min. software version: 2.03 (par. 15-43 *Software Version*)

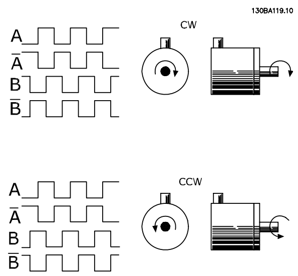
Connector Designa-tion X31	Incremental Encoder (please refer to Graphic A)	SinCos Encoder Hiperface® (please refer to Graphic B)	EnDat Encoder	SSI Encoder	Description
1	NC			24 V*	24 V output (21–25 V, I_{max}:125 mA)
2	NC	8 VCC			8 V output (7–12 V, I_{max}: 200 mA)
3	5 VCC		5 VCC	5 V*	5 V output (5 V ± 5%, I_{max}: 200 mA)
4	GND		GND	GND	GND
5	A input	+COS	+COS		A input
6	A inv input	REFCOS	REFCOS		A inv input
7	B input	+SIN	+SIN		B input
8	B inv input	REFSIN	REFSIN		B inv input
9	Z input	+Data RS485	Clock out	Clock out	Z input OR +Data RS485
10	Z inv input	-Data RS485	Clock out inv.	Clock out inv.	Z input OR -Data RS485
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



Max. cable length 492 ft [150 m].





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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.

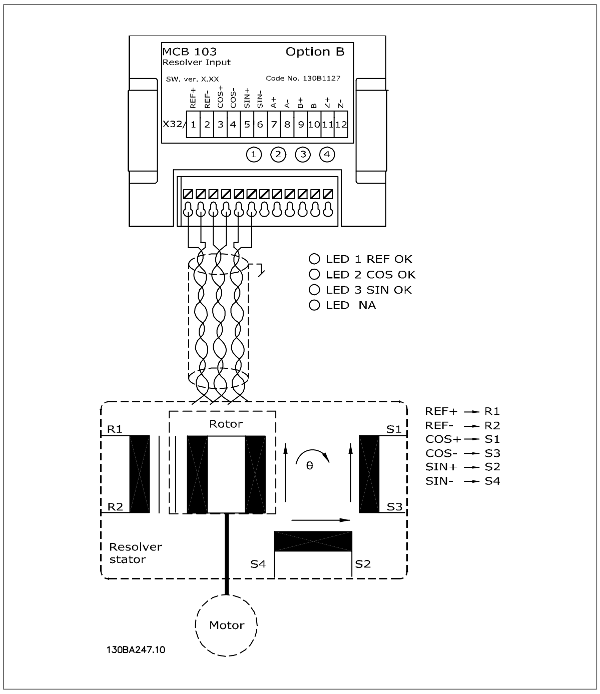
When the resolver option is ordered separately the kit includes:

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



NOTE!

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

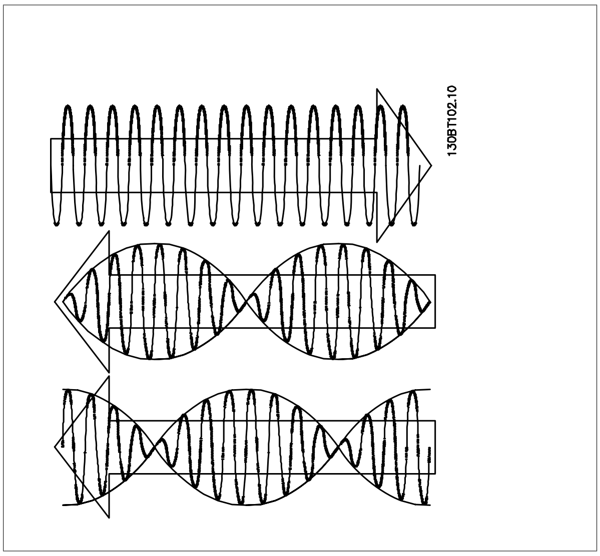
LED indicators

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 par. 17-61 *Feedback Signal Monitoring* is set to *Warning* or *Trip*.



Set-up example

In this example, a permanent magnet (PM) motor is used with resolver as speed feedback. A PM motor must usually operate in flux mode.

Wiring:

The max cable length is 490 ft [150 m] when a twisted-pair 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.

Adjust the following parameters:	
par. 1-00 *Configuration Mode*	Speed closed-loop [1]
par. 1-01 *Motor Control Principle*	Flux with feedback [3]
par. 1-10 *Motor Construction*	PM, non-salient SPM [1]
par. 1-24 *Motor Current*	Nameplate
par. 1-25 *Motor Nominal Speed*	Nameplate
par. 1-26 *Motor Cont. Rated Torque*	Nameplate
AMA is not possible on PM motors	
par. 1-30 *Stator Resistance (Rs)*	Motor data sheet
par. 1-37 *d-axis Inductance (Ld)*	Motor data sheet (mH)
par. 1-39 *Motor Poles*	Motor data sheet
par. 1-40 *Back EMF at 1000 RPM*	Motor data sheet
par. 1-41 *Motor Angle Offset*	Motor data sheet (Usually zero)
par. 17-50 *Poles*	Resolver data sheet
par. 17-51 *Input Voltage*	Resolver data sheet
par. 17-52 *Input Frequency*	Resolver data sheet
par. 17-53 *Transformation Ratio*	Resolver data sheet
par. 17-59 *Resolver Interface*	Enabled [1]

10.5 Relay Option MCB 105

The MCB 105 option includes 3 pieces of SPDT contacts and must be fitted into option slot B.

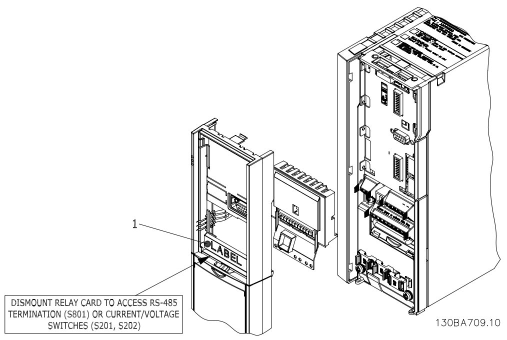
Electrical Data:	
Max terminal load (AC-1) [1] (Resistive load)	240 V AC 2A
Max terminal load (AC-15) [1] (Inductive load @ cosφ 0.4)	240 V AC 0.2 A
Max terminal load (DC-1)[1] (Resistive load)	24 V DC 1 A
Max terminal load (DC-13)[1] (Inductive load)	24 V DC 0.1 A
Min terminal load (DC)	5 V 10 mA
Max switching rate at rated load/min load	6 min^{-1}/20 sec^{-1}

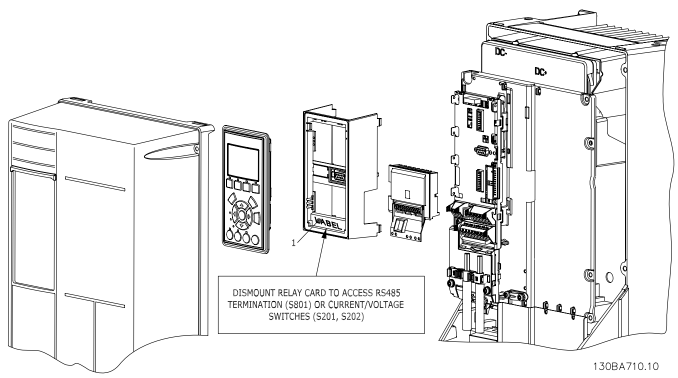
1) IEC 947 part 4 and 5

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 AutomationDrive FC 302 adjustable frequency drives manufactured before week 50/2004.
Min. software version: 2.03 (par. 15-43 *Software Version*).





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).

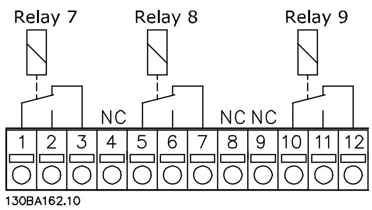
Warning Dual supply

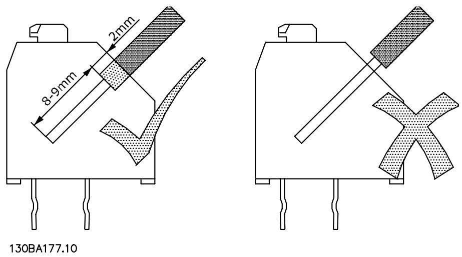
How to add the MCB 105 option:

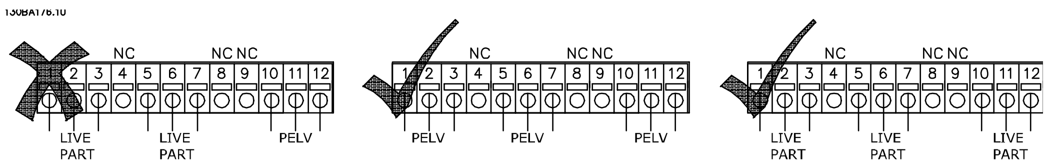
- The power to the adjustable frequency drive must be disconnected.
- The power to the live part connections on relay terminals must be disconnected.
- Remove the LCP, the terminal cover and the LCP fixture from the adjustable frequency drive.
- Fit the MCB 105 option in slot B.

- 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 par. 5-40 *Function Relay* [6-8], par. 5-41 *On Delay, Relay* [6-8] and par. 5-42 *Off Delay, Relay* [6-8].

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







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

10.6 24 V Backup Option MCB 107

External 24 V DC Supply

An external 24 V DC supply can be installed for low-voltage supply to the control card and any option card installed. This enables full operation of the LCP (including the parameter setting) without connection to line power.

External 24 V DC supply specification:

Input voltage range	24 V DC ±15 % (max. 37 V in 10 s)
Max. input current	2.2 A
Average input current for AutomationDrive FC 302	0.9 A
Max cable length	246 ft [75 m]
Input capacitance load	< 10 uF
Power-up delay	< 0.6 s

The inputs are protected.

Terminal numbers:

Terminal 35: - external 24 V DC supply.

Terminal 36: + external 24 V DC supply.

Follow these steps:

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

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

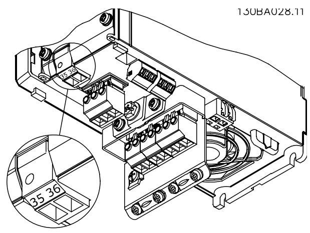


Figure 10.3: Connection to 24 V back-up supply on frame sizes A2 and A3.

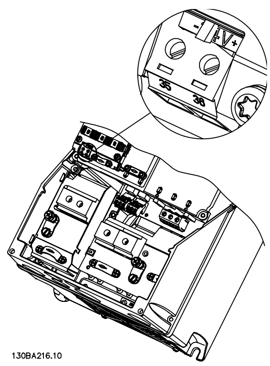


Figure 10.4: Connection to 24 V backup supply on frame sizes A5, B1, B2, C1 and C2.

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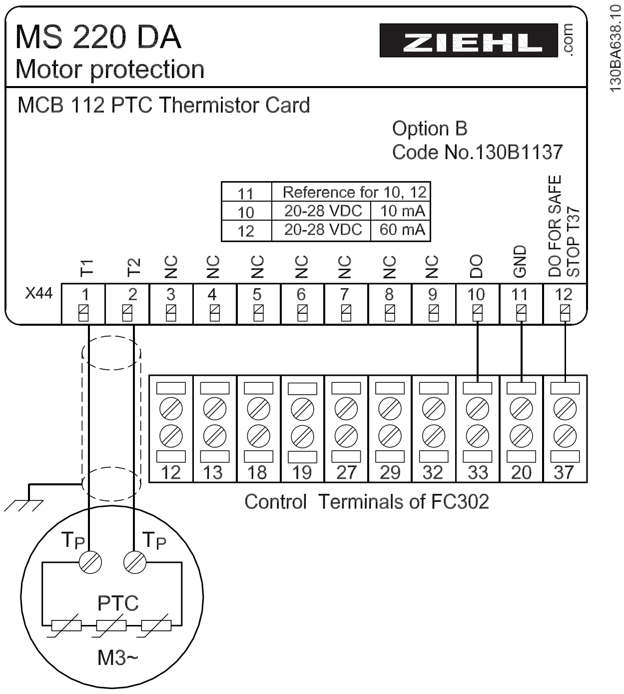
10.7 MCB 112 PTC Thermistor Card

The MCB 112 option makes it possible to monitor the temperature of an electrical motor through a PTC thermistor input. It is a B option for AutomationDrive FC 302 with safe stop.

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

X44/ 1 and X44/ 2 are the thermistor inputs, X44/ 12 will enable safe stop of the AutomationDrive FC 302 (T-37) if the thermistor values make it necessary and X44/ 10 will inform the AutomationDrive FC 302 that a request for safe stop came from the MCB 112 in order to ensure a suitable alarm handling. One of the digital Inputs of the AutomationDrive FC 302 (or a DI of a mounted option) must be set to PCT Card 1 [80] in order to use the information from X44/ 10. par. 5-19 *Terminal 37 Safe Stop* Terminal 37 Safe Stop must be configured to the desired safe stop functionality (default is Safe Stop Alarm).



ATEX Certification with AutomationDrive FC 302

The MCB 112 has been certified for ATEX which means that the AutomationDrive FC 302 together with the MCB 112 can now be used with motors in potentially explosive atmospheres. See the MCB 112 Instruction Manual for more information.

ATmosphère EXplosive (ATEX)

Electrical Data

Resistor connection:	
PTC compliant with DIN 44081 and DIN 44082.	
Number	1..6 resistors in series
Shut-off value	3.3 Ω.... 3.65 Ω ... 3.85 Ω
Reset value	1.7 Ω .... 1.8 Ω ... 1.95 Ω
Trigger tolerance	± 6°C
Collective resistance of the sensor loop	< 1.65 Ω
Terminal voltage	≤ 2.5 V for R ≤ 3.65 Ω, ≤ 9 V for R = ∞
Sensor current	≤ 1 mA
Short circuit	20 Ω ≤ R ≤ 40 Ω
Power consumption	60 mA

Testing conditions:	
EN 60 947-8	
Measurement voltage surge resistance	6000 V
Overvoltage category	III
Degree of pollution	2
Measurement isolation voltage Vbis	690 V
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 ... 1000 Hz 1.14g
Shock resistance	50 g

Safety system values:	
EN 61508, ISO 13849 for Tu = 167°F [75°C] ongoing	
Category	2
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	90%
$\lambda_S + \lambda_{DD}$	8515 FIT
λ_{DU}	932 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.

NOTE!
The MCB 113 can be used in all frame sizes. It can be installed at the same time as an MCO 305 (+ fan) in frame sizes A2, A3 and B3 (bookstyle), but not in the other frame sizes. Note that MCO305 cannot control the MCB 113.

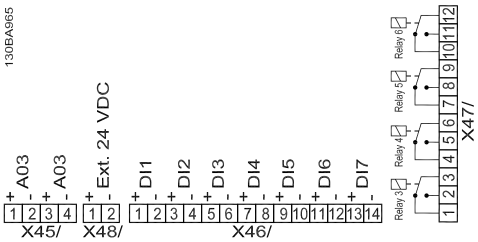


Figure 10.5: Electrical connections of MCB 113

The MCB 113 can be connected to an external 24 V on X58/ in order to ensure galvanic isolation between the VLT® AutomationDrive and the option card. If galvanic isolation is not needed, the option card can be supplied through internal 24 V from the drive.

NOTE!
It is OK to combine 24 V signals with high voltage signals in the relays as long as there is one unused relay in between.

To set up the MCB 113, use Par. 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 250 V AC/ 30 V DC	8 A
Load at 250 V AC/ 30 V DC with cosφ = 0.4	3.5 A
Overvoltage category (contact - ground)	III
Overvoltage category (contact - contact)	II
Combination of 250 V and 24 V signals	Possible with one unused relay in between
Maximum thru-put delay	10 ms
Isolated from ground/chassis for use on IT line power systems	

Digital Inputs:	
Numbers	7
Range	0/24V
Mode	PNP/NPN
Input impedance	5 hp [4 kW]
Low trigger level	6.4 V
High trigger level	17 V
Maximum thru-put delay	10 ms

Analog Outputs:	
Numbers	2
Range	0/4–20 mA
Resolution	11 bit
Linearity	<0.2%

Analog Outputs:	
Numbers	2
Range	0/4–20 mA
Resolution	11 bit
Linearity	<0.2%

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

10.9 MCF 106 A/ B in C Option Adaptor

The A/ B in C option adaptor is a C option that makes it possible to combine a number of different options.

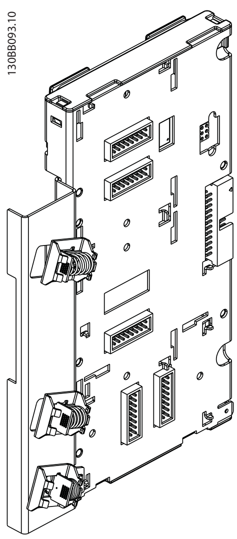


Figure 10.6: Drawing of MCF 106 A/B in C option adaptor. Two options can be installed in the MCF 106 at the same time. The upper slot is called E0 and the lower is called E1.

One A and one B option can be installed in the standard A and B slots of the control card – behind the LCP/ blind cover. With the addition of the MCF 106 the possibilities are increased.

- Up to three different B options – one in the standard B slot and two in the adaptor

- One serial communication bus (A option) at any time – in the standard A slot or in the E0 slot of the adaptor.
- The MCB 121 Ethernet takes up both slot A and slot B when installed in the standard slot A of the control card. The only way to install a B option at the same time: Use the standard B slot of the control card and move the MCA 121 in the E1 slot of the adapter.
- MCA 121 EthernetIP has bottom entry when installed in the adaptor
- Two identical options cannot be installed at the same time
- MCB 105 Relay Card and MCB 112 PTC Thermistor card are not supported by the adaptor and thus can only be installed in the standard slot B of the control card. That also means that these two options can not be combined.

10.9.1 Combinations

The following table shows which combinations can be realized.

Option	Mounting in the MCF 106	ID	Name	Possible combinations	
				with MCF 106	without MCF 106
A	Yes6)	MCA 101	Profibus DP V1	+ 3B + D	+ B + C + D
	Yes6)	MCA 104	DeviceNet	+ 3B + D	+ B + C + D
	Yes6)	MCA 105	CanOpen	+ 3B + D	+ B + C + D
	Yes7)	MCA 121	EtherNetIP	+ 2B + D	+ C + D
B	Yes	MCB 102	Encoder option	+ A + 2B1) + D	+ A2) + C + D
	No	MCB 105	Relay option 3)	+ A + 2B1) + D	+ A2) + C + D
	Yes	MCB 101	General Purpose I/O	+ A + 2B1) + D	+ A2) + C + D
	Yes	MCB 103	Resolver option	+ A + 2B1) + D	+ A2) + C + D
	Yes	MCB 108	PLC Safe Interface	+ A + 2B1) + D	+ A2) + C + D
	No	MCB 112	PTC Thermistor Card 3)	+ A + 2B1) + D	+ A2) + C + D
C0	No	MCO 305	Programmable Motion Control	None	+ A + B4) + C!5) + D
	No	MCO 350	Synchronizing Control	None	+ A + B4) + D
	No	MCO 351	Positioning Control	None	+ A + B4) + D
	No	MCO 352	Center Winder	None	+ A + B4) + D
C1	No	MCA 103	ProfiSafe-Safe Stop	None	+ A + B4) + D
	No	MCB 113	Stt. Relay Card	None	+ A + B4) + D
D	No	MCB 107	24V External Supply	+ A + 3B1)	+ A + B4) + C

Table 10.1: Overview of different possibilities for combinations. Look up one of the options in question and see which additional options this can be combined with, if MCF 106 is used and if only the standard drive is used. A list of limitations and exceptions can be found below.

1) One B less if MCA 121 EthernetIP is used
2) Does not incl. MCA 121 EthernetIP
3) MCB 105 and MCB 112 must always be installed in the standard B slot of the control card and thus can never be combined
4) Can only incl. B if A is not MCA 121 EtherNetIP
5) One C1 option can be added on top of the MCO 305 in the bookstyle enclosures (A2, A3 and B3)
6) Only in E0 slot
7) Only in E1 slot

NOTE!
Two identical options can not be installed at the same time

10.9.2 Ordering

The MCF 106 can be purchased factory-installed or as a separate option.

- Built-in: position 33-37 of the type code. These characters specify which options are desired in the upper and the lower position of the MCF 106.
- Separate option: Sales no.130B1130 for non-coated and 130B1230 for coated.

A/B Options in C Slot		Position: 33-37
Upper position in MCF 106		Position: 33-34
BB	No option in 1st A/B-in-C-slot	
A0	MCA-101 Profibus DP V1	
A1	MCA-101 Profibus DP V1	
A4	MCA-104 DeviceNet	
A5	MCA-104 DeviceNet	
A6	MCA-105 CanOpen	
A7	MCA-105 CanOpen	
BK	MCB-101 General purpose I/O	
BR	MCB-102 Encoder Option	
BU	MCB-103 Resolver Option	
BZ	MCB-108 Safety PLC Interface	
MCF 106 A/B in C Option Adaptor		Position: 35
E	MCF 106 A/B in C Option Adaptor	
Lower position in MCF 106		Position: 36-37
BB	No option in 2nd A/B-in-C-slot	
AN	MCA-121 Ethernet IP	
BK	MCB-101 General purpose I/O	
BR	MCB-102 Encoder Option	
BU	MCB-103 Resolver Option	
BZ	MCB-108 Safety PLC Interface	

The option adapter only supports options that have been prepared for this use. The various options will be prepared for this use in the near future. MCA 121 EthernetIP will be the first one to be available for MCF 106.
For installations in bookstyle enclosures (A2, A3 and B3), the 2.36 in [60 mm] mounting kit is used and must be ordered when buying the adaptor as a separate option.
Please see the MCF 106 Instruction Manual, MI38Fxyy, for installation instructions.

10.10 Brake Resistors

In applications where the motor is used as a brake, energy is generated in the motor and sent back into the adjustable frequency drive. If the energy cannot be transported back to the motor, it 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 shut down. Brake resistors are used to dissipate the excess energy resulting from the regenerative braking. The resistor is selected in respect to its ohmic value, its power dissipation rate and its physical size. Danfoss offers a wide variety of different resistors that are specially designed to our adjustable frequency drives. See the section *Control with brake function* for the dimensioning of brake resistors. Code numbers can be found in the section *How to order*.

10.11 Remote Mounting Kit for LCP

The LCP can be moved to the front of a cabinet by using the remote built-in kit. The enclosure is the IP65. The fastening screws must be tightened with a torque of max. 1 Nm.

Technical data	
Enclosure:	IP 65 front
Max. cable length between and unit:	9.8 ft [3 m]
Communication std:	RS 485

Ordering no. 130B1113

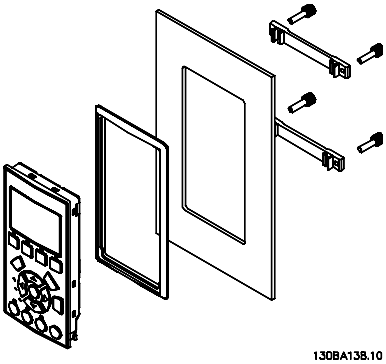


Figure 10.7: LCP kit with graphical LCP, fasteners, 9.8 ft [3 m] cable and gasket.

Ordering no. 130B1114

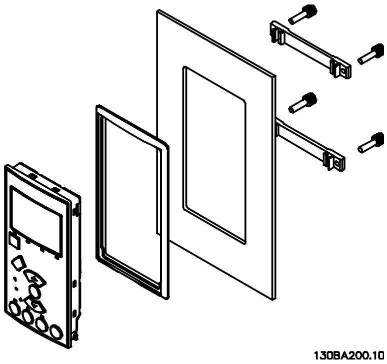
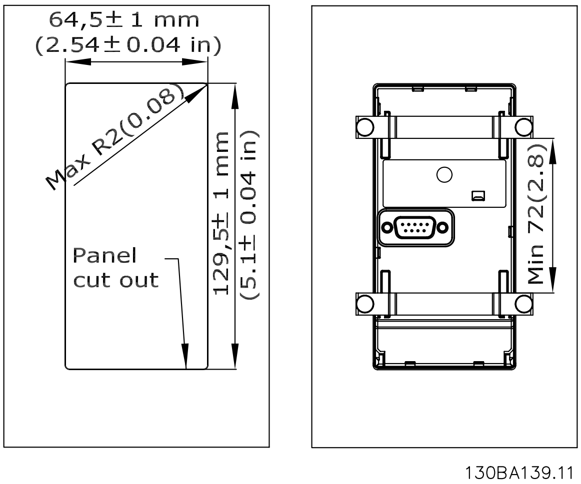


Figure 10.8: LCP kit with numerical LCP, fasteners and gasket.

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



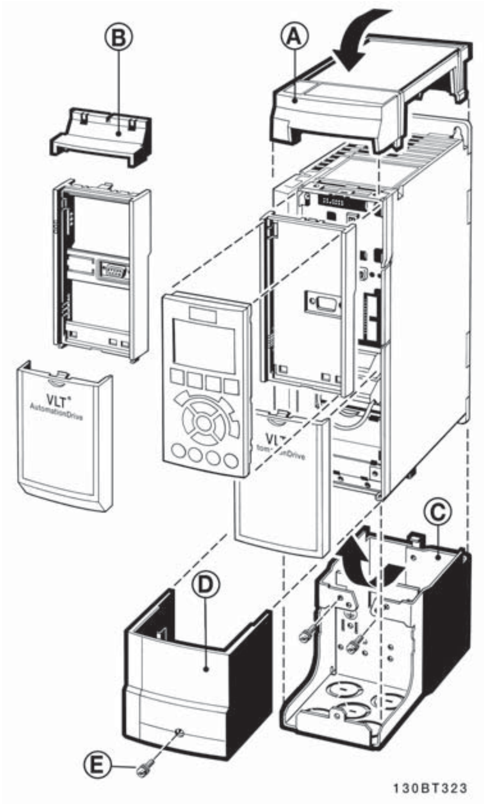
10.12 IP21/IP 4X/ TYPE 1 Enclosure Kit

IP 20/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.

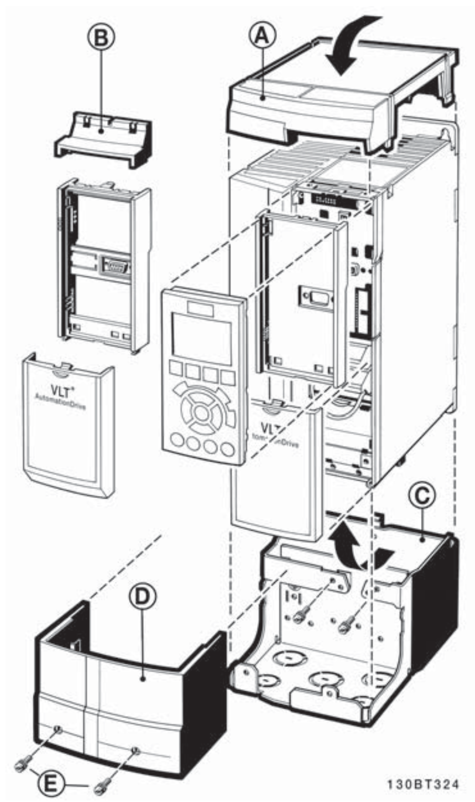
The IP 4X top can be applied to all standard IP 20 FC 30X variants.

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

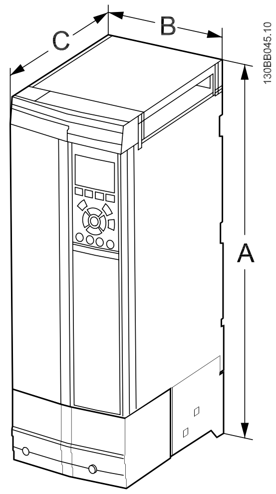


A3 Enclosure

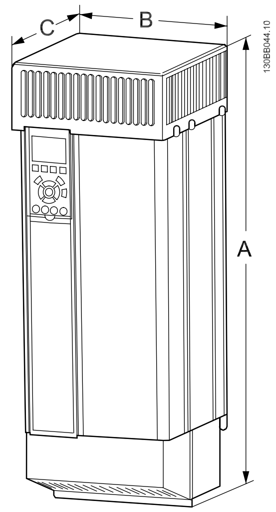
Dimensions

Enclosure type	Height (mm) A	Width (mm) B	Depth (mm) C*
A2	372	90	205
A3	372	130	205
B3	475	165	249
B4	670	255	246
C3	755	329	337
C4	950	391	337

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

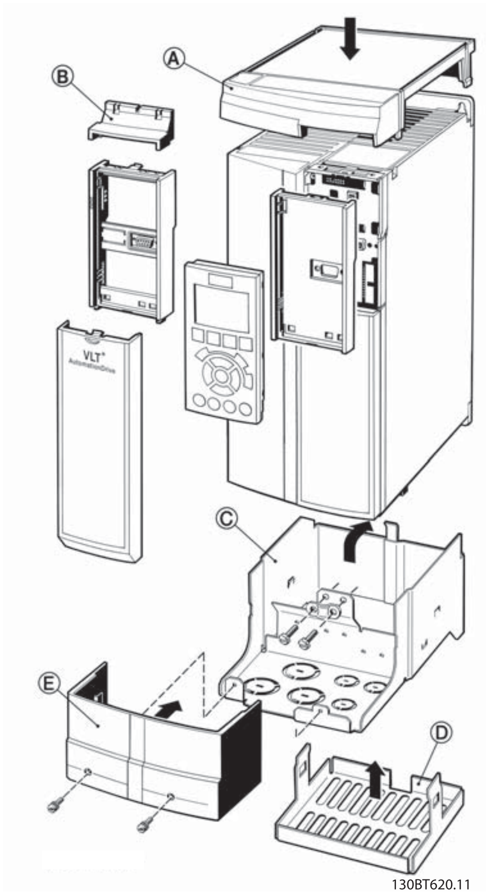


A2, A3, B3

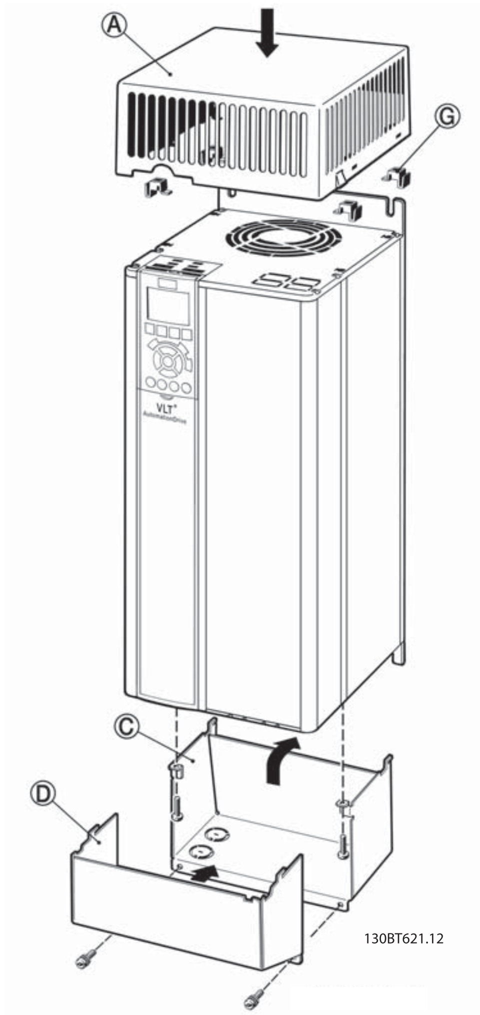


B4, C3, C4

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

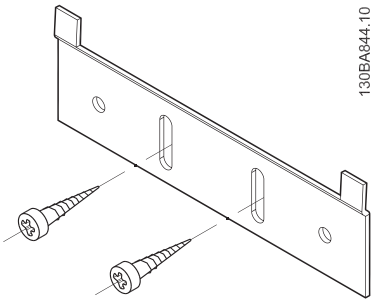


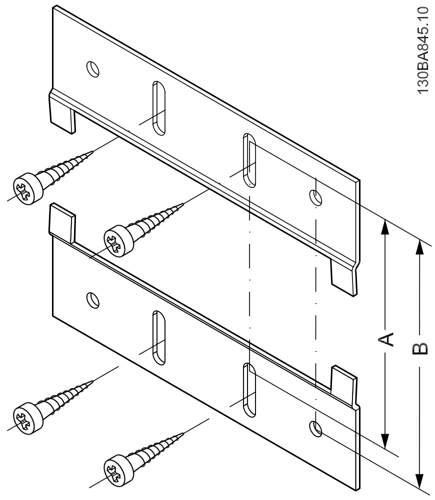
B4 - C3 - C4 Enclosure

NOTE!
Side-by-side installation is not possible when using the *IP 21/ IP 4X/ TYPE 1 Enclosure Kit*

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

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





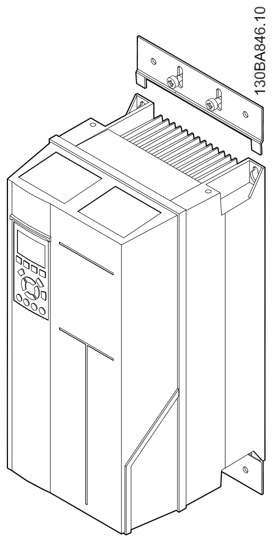
Step 1

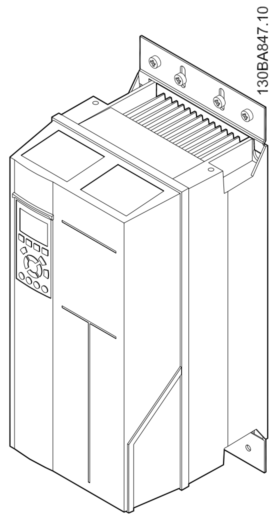
Position the lower bracket and mount it with screws. Do not tighten the screws completely since this will make it difficult to mount the adjustable frequency drive.

Step 2

Measure distance A or B, and position the upper bracket, but do not tighten it. See dimensions below

Frame size	A5	B1	B2	B3	B4
IP	55/66	21/55/66	21/55/66	21/55/66	21/55/66
A [mm]	480	535	705	730	820
B [mm]	495	550	720	745	835
Ordering number	130B1080	130B1081	130B1082	130B1083	130B1084





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.

10.14 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 AutomationDrive 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.

10.15 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, *MG33UXYY*.

10.15.1 Frame Size F Panel 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).

10

Cabinet Light with Power Outlet
A light mounted on the cabinet interior of frame size F adjustable frequency drives increase 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 380–480/500 V380–480 V drive will initially be set to the 525 V tap and a 525–690 V drive will be set to the 690 V 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 figure of rectifier in the *Power Connections* section.

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

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.

Manual Motor Starters

Provide 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, 120 W, 24 VDC
- 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 eight universal input modules plus two dedicated thermistor input modules. All ten 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).

Universal inputs (8)

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

Dedicated thermistor inputs (2)

Features:

- Each module is capable of monitoring up to six thermistors in a series
- Fault diagnostics for wire breakage or short-circuits of sensor leads
- ATEX/UL/CSA certification
- A third thermistor input can be provided by the PTC thermistor option card MCB 112, if necessary.

11 RS-485 Installation and Set-up

11.1 RS-485 Installation and Set-up

11.1.1 Overview

RS-485 is a two-wire bus interface compatible with multi-drop network topology, i.e., nodes can be connected as a bus, or via drop cables from a common trunk line. A total of 32 nodes can be connected to one network segment.
Network segments are divided up by repeaters. 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 very important, also at high frequencies. This can be achieved by connecting a large surface of the shield to ground, by means of a cable clamp or a conductive cable gland, for example. It may be necessary to apply potential-equalizing cables to maintain the same ground potential throughout the network, particularly in installations where there are long lengths of cable.
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: 120 Ohm
Cable length: Max. 3,396 ft [1,200 m] (including drop lines)
Max. 1,640 ft [500 m] station-to-station

11.1.2 Network Connection

Connect the adjustable frequency drive to the RS-485 network as follows (see also diagram):

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

NOTE!
Shielded, twisted-pair cables are recommended in order to reduce noise between conductors.

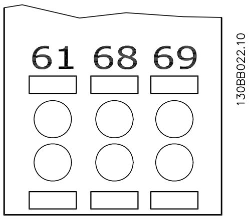


Figure 11.1: Network Terminal Connection

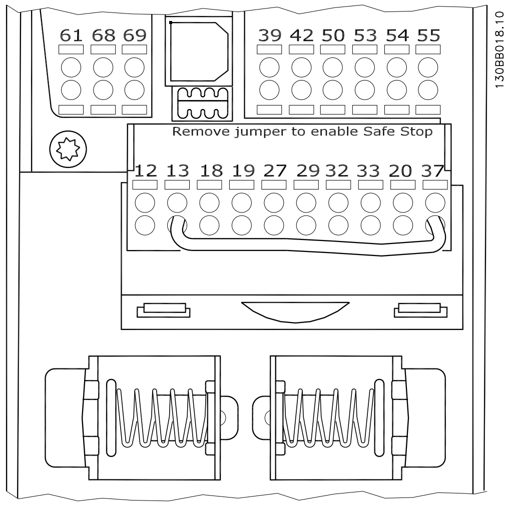
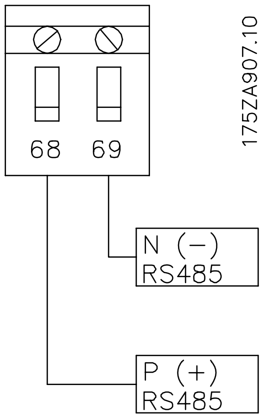


Figure 11.2: Control card terminals

11.1.3 RS-485 Bus Termination

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

NOTE!
The factory setting for the dip switch is OFF.

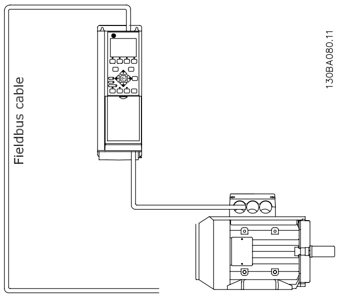


Terminator Switch Factory Setting

11.1.4 EMC Precautions

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

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



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 individual slaves are selected by the master 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 RS-485, thus utilizing the RS-485 port built into the adjustable frequency drive. The adjustable frequency protocol supports different message formats; a short format of 8 bytes for process data, and a long format of 16 bytes that also includes a parameter channel. A third message format is used for texts.

11.3 Network Configuration

11.3.1 AutomationDrive FC 300 Adjustable Frequency Drive Set-up

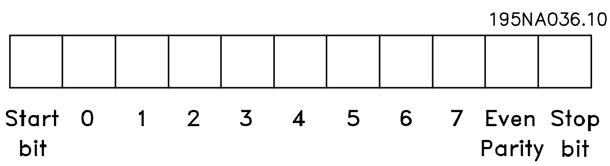
Set the following parameters to enable the Adjustable Frequency protocol for the adjustable frequency drive.

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

11.4 Adjustable frequency drive Protocol Message Framing Structure - AutomationDrive FC 300

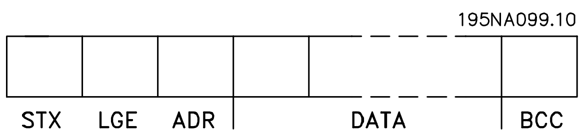
11.4.1 Content of a Character (byte)

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



11.4.2 Message Structure

Each message begins with a start character (STX)=02 Hex, followed by a byte denoting the message length (LGE) and a byte denoting the adjustable frequency drive address (ADR). A number of data bytes (variable, depending on the type of message) follows. The message is completed by a data control byte (BCC).



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11.4.3 Message Length (LGE)

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

The length of messages with 4 data bytes is	LGE = 4 + 1 + 1 = 6 bytes
The length of messages with 12 data bytes is	LGE = 12 + 1 + 1 = 14 bytes
The length of messages 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).

11.4.4 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.

11.4.5 Data Control Byte (BCC)

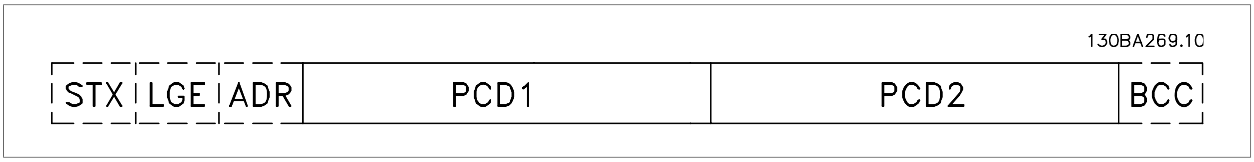
The checksum is calculated as an XOR-function. Before the first byte in the telegram is received, the calculated checksum is 0.

11.4.6 The Data Field

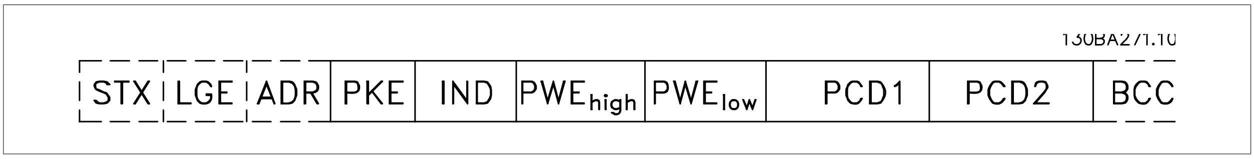
The structure of data blocks depends on the type of message. There are three message types, and the type applies for both control messages (master=>slave) and response messages (slave=>master).

The three types of message are:

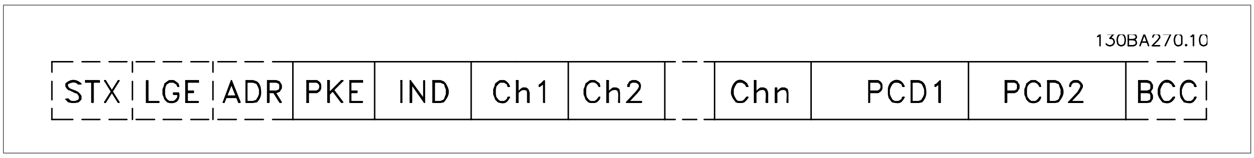
Process block (PCD):
The PCD is made up of a data block of four bytes (2 words) and contains:
- Control word and reference value (from master to slave)
- Status word and present output frequency (from slave to master).



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.

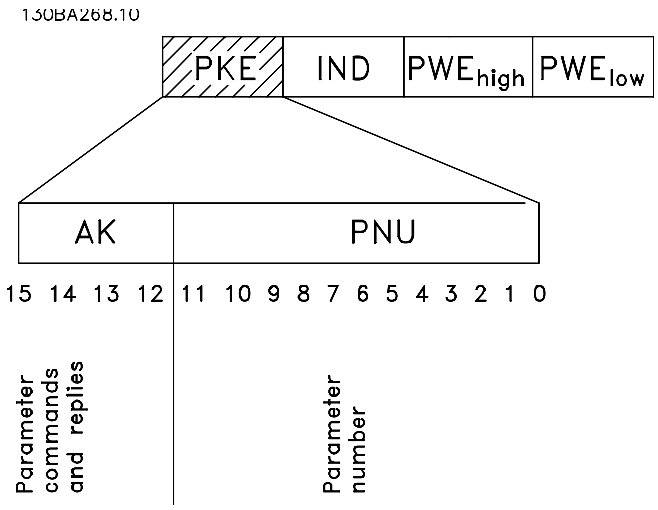


Text block:
The text block is used to read or write texts via the data block.



11.4.7 The PKE Field

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



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

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

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):

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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.

11.4.8 Parameter Number (PNU)

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

11.4.9 Index (IND)

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

NOTE!
Only the low byte is used as an index.

11.4.10 Parameter Value (PWE)

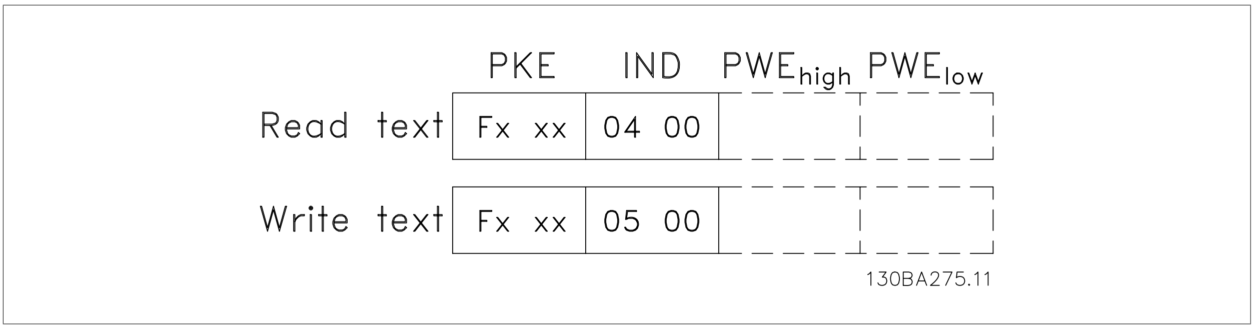
The parameter value block consists of 2 words (4 bytes), and the value depends on the defined command (AK). The master prompts for a parameter value when the PWE block contains no value. To change a parameter value (write), write the new value in the PWE block and send from the master to the slave.

When a slave responds to a parameter request (read command), the present parameter value in the PWE block is transferred and returned to the master. If a parameter contains not a numerical value but several data options, e.g., par. 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).

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

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

Some parameters contain text that can be written to via the serial bus. To write a text via the PWE block, set the parameter command (AK) to 'F' Hex. The index character's high-byte must be "5".



11.4.11 Data Types Supported by AutomationDrive FC 300

Unsigned means that there is no operational sign in the message.

Data types	Description
3	Integer 16
4	Integer 32
5	Unsigned 8
6	Unsigned 16
7	Unsigned 32
9	Text string
10	Byte string
13	Time difference
33	Reserved
35	Bit sequence

11.4.12 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.

par. 4-12 *Motor Speed Low Limit [Hz]* has a conversion factor of 0.1.
To preset the minimum frequency to 10 Hz, transfer the value 100. A conversion factor of 0.1 means that the value transferred is multiplied by 0.1. The value 100 is thus perceived as 10.0.

Conversion table

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

11.4.13 Process Words (PCD)

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

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

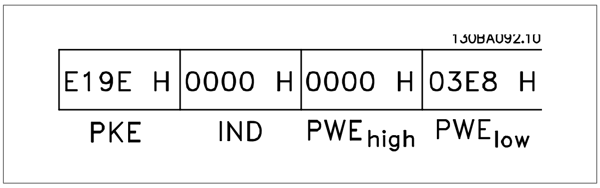
11.5 Examples

11.5.1 Writing a Parameter Value

Change par. 4-14 *Motor Speed High Limit [Hz]* to 100 Hz.
Write the data in EEPROM.

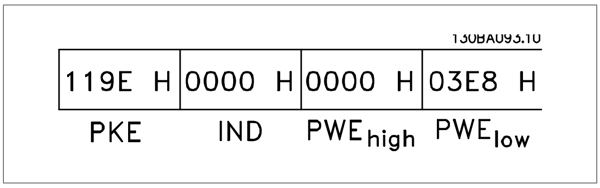
PKE = E19E Hex - Write single word in par. 4-14 *Motor Speed High Limit [Hz]*
IND = 0000 Hex
PWEHIGH = 0000 Hex
PWELOW = 03E8 Hex - Data value 1000, corresponding to 100 Hz, see Conversion.

The message will look like this:



Note: par. 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.

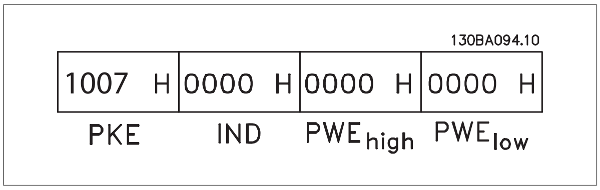
The response from the slave to the master will be:



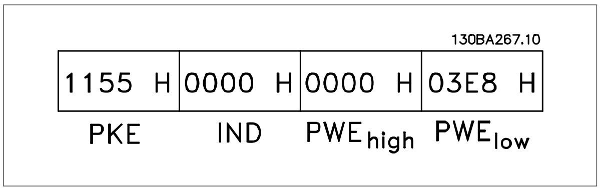
11.5.2 Reading a Parameter Value

Read the value in par. 3-41 *Ramp 1 Ramp-up Time*

PKE = 1155 Hex - Read parameter value in par. 3-41 *Ramp 1 Ramp-up Time*
IND = 0000 Hex
PWEHIGH = 0000 Hex
PWELOW = 0000 Hex



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



NOTE!
3E8 Hex corresponds to 1000 decimal. The conversion index for par. 3-41 *Ramp 1 Ramp-up Time* is -2, i.e., 0.01.
par. 3-41 *Ramp 1 Ramp-up Time* is of the type *Unsigned 32*.

11.6 Modbus RTU Overview

11.6.1 Assumptions

This instruction manual assumes that the installed controller supports the interfaces in this document and that all the requirements stipulated in the controller, as well as the adjustable frequency drive, are strictly observed, along with all limitations therein.

11.6.2 What the User Should Already Know

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

11.6.3 Modbus RTU Overview

Regardless of the type of physical communication networks, the Modbus RTU Overview describes the process a controller uses to request access to another device. This includes, among other things, how it will respond to requests from another device, and how errors will be detected and reported. It also establishes a common format for the layout and contents of message fields.

While communicating over a Modbus RTU network, the protocol determines how each controller will learn its device address, recognize a message addressed to it, determine the kind of action to be taken and extract any data or other information contained in the message. If a reply is required, the controller will construct the reply message and send 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 will occur.

11.6.4 Adjustable Frequency Drive with Modbus RTU

The adjustable frequency drive communicates in Modbus RTU format over the built-in RS-485 interface. Modbus RTU provides access to the control word and bus reference of the adjustable frequency drive.

The control word allows the modbus master to control several important functions of the adjustable frequency drive:

- Start
- Stop of the adjustable frequency drive in various ways:
  Coast stop
  Quick stop
  DC Brake stop
  Normal (ramp) stop
- Reset after a fault trip
- Run at a variety of preset speeds
- Run in reverse
- Change the active set-up
- Control the adjustable frequency drive's built-in relay

The bus reference is commonly used for speed control. It is also possible to access the parameters, read their values, and where possible, write values to them. This permits a range of control options, including controlling the setpoint of the adjustable frequency drive when its internal PI controller is used.

11.7 Network Configuration

To enable Modbus RTU on the adjustable frequency drive, set the following parameters:

Parameter Number	Parameter name	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)

11.8 Modbus RTU Message Framing Structure

11.8.1 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 below.

Start bit	Data byte								Stop/ parity	Stop

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

11.8.2 Modbus RTU Message Structure

The transmitting device places a Modbus RTU message into a frame with a known beginning and ending point. This allows receiving devices to begin at the start of the message, read the address portion, determine which device is addressed (or all devices, if the message is broadcast), and to recognize when the message is completed. Partial messages are detected, and errors are set as a result. Characters for transmission must be in hexadecimal 00 to FF format in each field. The adjustable frequency drive continuously monitors the network bus, also during 'silent' intervals. When the first field (the address field) is received, each adjustable frequency drive or device decodes it to determine which device is being addressed. Modbus RTU messages addressed to zero are broadcast messages. No response is permitted for broadcast messages. A typical message frame is shown 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

11.8.3 Start / Stop Field

Messages start with a silent period of at least 3.5 character intervals. This is implemented as a multiple of character intervals at the selected network baud rate (shown as Start T1-T2-T3-T4). The first field to be transmitted is the device address. Following the last transmitted character, a similar period of at least 3.5 character intervals marks the end of the message. A new message can begin after this period. The entire message frame must be transmitted as a continuous stream. If a silent period of more than 1.5 character intervals occurs before completion of the frame, the receiving device flushes the incomplete message and assumes that the next byte 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 time-out (no response from the slave), since the value in the final CRC field will not be valid for the combined messages.

11.8.4 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.

11.8.5 Function Field

The function field of a message frame contains 8 bits. Valid codes are in the range of 1-FF. Function fields are used to send messages between master and 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.*

11.8.6 Data Field

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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.

11.8.7 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.

11.8.8 Coil Register Addressing

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

Coil Number	Description	Signal Direction
1-16	Adjustable frequency drive control word (see table below)	Master to slave
17-32	Adjustable frequency driver speed or setpoint reference Range 0x0–0xFFFF (-200% ... ~200%)	Master to slave
33-48	Adjustable frequency drive status word (see table below)	Slave to master
49-64	Open-loop mode: adjustable frequency drive output frequency Closed-loop mode: Adjustable frequency drive feedback signal	Slave to master
65	Parameter write control (master to slave) 0 = Parameter changes are written to the RAM of the adjustable frequency drive. 1 = Parameter changes are written to the RAM and EEPROM of the adjustable frequency drive.	Master to slave
66-65536	Reserved	

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)

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)

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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).

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

11.8.9 How to Control the Adjustable Frequency Drive

This section describes codes that can be used in the function and data fields of a Modbus RTU message. For a complete description of all the message fields, please refer to the section *Modbus RTU Message Framing Structure.*

11.8.10 Function Codes Supported by Modbus RTU

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

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

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

11.8.11 Modbus Exception Codes

For a full explanation of the structure of an exception code response, please refer to the section *Modbus RTU Message Framing Structure, 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.

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11.9 How to Access Parameters

11.9.1 Parameter Handling

The PNU (Parameter Number) is translated from the register address contained in the Modbus read or write message. The parameter number is translated to Modbus as (10 x parameter number) DECIMAL.

11.9.2 Storage of Data

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

11.9.3 IND

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

11.9.4 Text Blocks

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

11.9.5 Conversion Factor

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

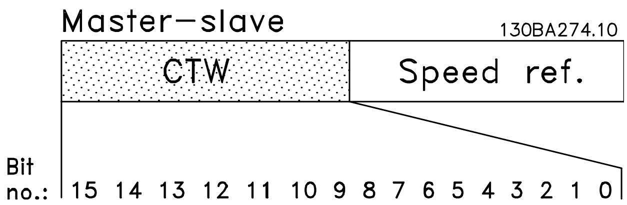
11.9.6 Parameter Values

Standard Data Types
Standard data types are int16, int32, uint8, uint16 and uint32. They are stored as 4x registers (40001–4FFFF). The parameters are read using function 03HEX "Read Holding Registers." Parameters are written using the function 6HEX "Preset Single Register" for 1 register (16 bits), and the function 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).

11.10 Danfoss FC Control Profile

11.10.1 Control Word According to FC Profile(par. 8-10 *Control Profile* = FC profile)



Bit	Bit value = 0	Bit value = 1
00	Reference value	external selection lsb
01	Reference value	external selection msb
02	DC brake	Ramp
03	Coasting	No coasting
04	Quick stop	Ramp
05	Hold output frequency	use ramp
06	Ramp stop	Start
07	No function	Reset
08	No function	Jog
09	Ramp 1	Ramp 2
10	Data invalid	Data valid
11	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

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 par. 3-10 *Preset Reference* according to the following table:

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

NOTE!
Make a selection in par. 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 par. 2-01 *DC Brake Current* and par. 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.

NOTE!
Make a selection in par. 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 par. 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 (par. 5-10 *Terminal 18 Digital Input* to par. 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 (par. 5-10 *Terminal 18 Digital Input* to par. 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.

NOTE!
Make a selection in par. 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 par. 3-19 *Jog Speed [RPM]*.

Bit 09, Selection of ramp 1/2:

Bit 09 = "0": Ramp 1 is active (par. 3-41 *Ramp 1 Ramp-up Time* to par. 3-42 *Ramp 1 Ramp-down Time*). Bit 09 = "1": Ramp 2 (par. 3-51 *Ramp 2 Ramp-up Time* to par. 3-52 *Ramp 2 Ramp-down Time*) is active.

Bit 10, Data not valid/Data valid:

Tell the adjustable frequency drive whether to use or ignore the control word. Bit 10 = ’0’: The control word is ignored. Bit 10 = ’1’: The control word is used. This function is relevant because the message always contains the control word, regardless of the message type. 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 par. 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 par. 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

The function is only possible when *Multi Set-ups* is selected in par. 0-10 *Active Set-up*.

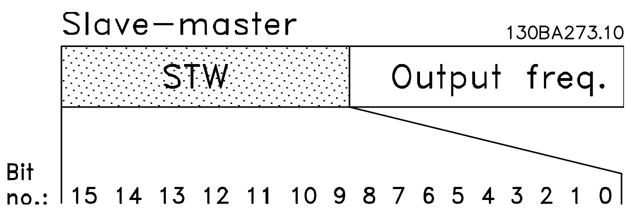
NOTE!

Make a selection in par. 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 par. 8-54 *Reverse Select*. Bit 15 causes reversing only when Ser. communication, Logic or or Logic and is selected.

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



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

Explanation of the Status Bits

Bit 00, Control not ready/ready:

Bit 00 = '0': The adjustable frequency drive trips. Bit 00 = '1': The adjustable frequency drive controls are ready but the power component does not necessarily receive any power supply (in case of external 24 V supply to controls).

Bit 01, Drive ready:

Bit 01 = ’1’: The adjustable frequency drive is ready for operation but the coasting command is active via the digital inputs or via serial communication.

Bit 02, Coasting stop:

Bit 02 = ’0’: The adjustable frequency drive releases the motor. Bit 02 = ’1’: The adjustable frequency drive starts the motor with a start command.

Bit 03, No error/trip:

Bit 03 = ’0’: The adjustable frequency drive is not in fault mode. Bit 03 = ’1’: The adjustable frequency drive trips. To re-establish operation, enter [Reset].

Bit 04, No error/error (no trip):

Bit 04 = ’0’: The adjustable frequency drive is not in fault mode. Bit 04 = “1”: The adjustable frequency drive shows an error but does not trip.

Bit 05, Not used:

Bit 05 is not used in the status word.

Bit 06, No error / triplock:

Bit 06 = ’0’: The adjustable frequency drive is not in fault mode. Bit 06 = “1”: The adjustable frequency drive is tripped and locked.

Bit 07, No warning/warning:

Bit 07 = ’0’: There are no warnings. Bit 07 = ’1’: A warning has occurred.

Bit 08, Speed≠ reference/speed = reference:

Bit 08 = ’0’: The motor is running but the present speed is different from the preset speed reference. For example, 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 activate on the control unit or *Local control* in par. 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.

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Bit 10, Out of frequency limit:

Bit 10 = ’0’: The output frequency has reached the value in par. 4-11 *Motor Speed Low Limit [RPM]* or par. 4-13 *Motor Speed High Limit [RPM]*. Bit 10 = "1": The output frequency is within the defined limits.

Bit 11, No operation/in operation:

Bit 11 = ’0’: The motor is not running. Bit 11 = ’1’: The adjustable frequency drive has a start signal or the output frequency is greater than 0 Hz.

Bit 12, Drive OK/stopped, autostart:

Bit 12 = ’0’: There is no temporary overtemperature on the inverter. Bit 12 = ’1’: The inverter stops because of overtemperature but the unit does not trip and will resume operation once the over temperature stops.

Bit 13, Voltage OK/limit exceeded:

Bit 13 = ’0’: There are no voltage warnings. Bit 13 = ’1’: The DC voltage in the adjustable frequency drive’s intermediate circuit is too low or too high.

Bit 14, Torque OK/limit exceeded:

Bit 14 = '0': The motor current is lower than the torque limit selected in par. 4-18 *Current Limit*. Bit 14 = '1': The torque limit in par. 4-18 *Current Limit* is exceeded.

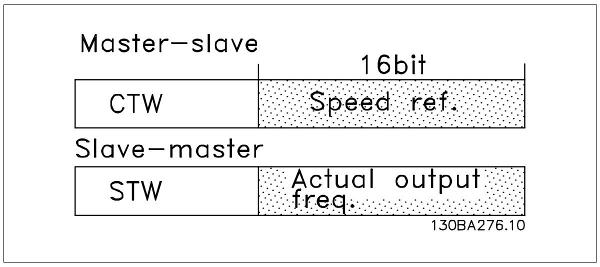
Bit 15, Timer OK/limit exceeded:

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%.

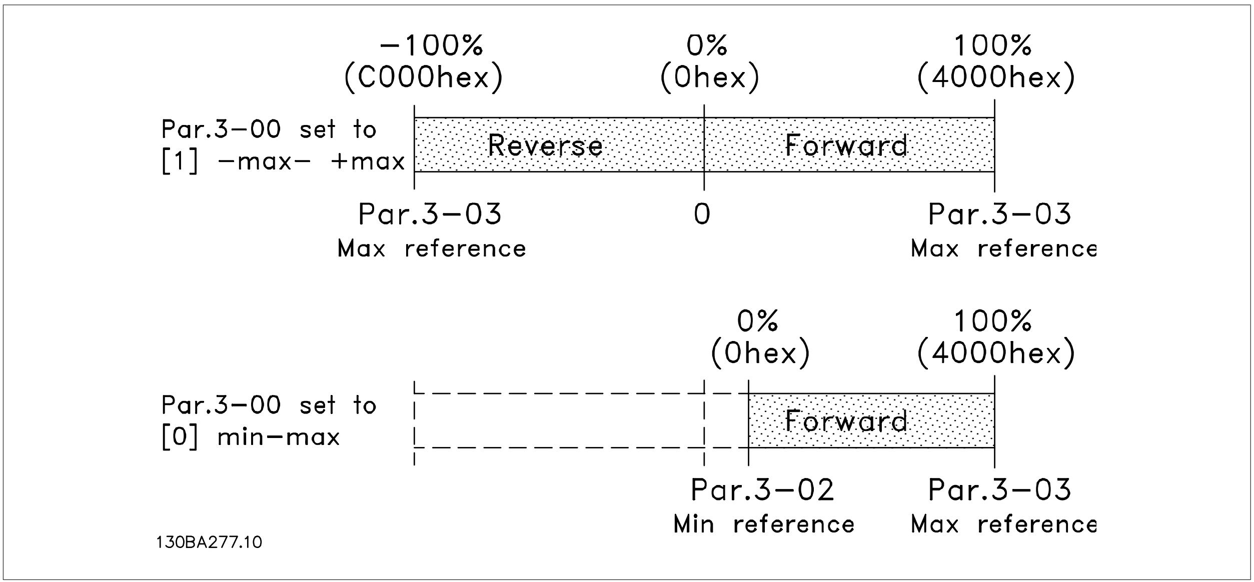
NOTE!
All bits in the STW are set to '0' if the connection between the Interbus option and the adjustable frequency drive is lost, or if an internal communication problem has occurred.

11.10.3 Bus Speed Reference Value

Speed reference value is transmitted to the adjustable frequency drive in a relative value expressed as %. The value is transmitted in the form of a 16-bit word; in integers (0-32767) the value 16384 (4000 Hex) corresponds to 100%. Negative figures are formatted by means of 2's complement. The Actual Output frequency (MAV) is scaled in the same way as the bus reference.



The reference and MAV are scaled as follows:



11.10.4 PROFIdrive Control Profile

This section describes the functionality of the control word and status word in the PROFIdrive profile. Select this profile by setting par. 8-10 *Control Word Profile*.

11.10.5 Control Word according to PROFIdrive Profile (CTW)

The control word is used to send commands from a master (a PC, for example) to a slave.

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

Explanation of the Control Bits

Bit 00, OFF 1/ON 1

Normal ramp stop using the ramp times of the actual selected ramp.

Bit 00 = "0" leads to the stop and activation of the output relay 1 or 2 if the output frequency is 0 Hz and if [Relay 123] has been selected in par. 5-40 *Function Relay*.

When bit 00 = "1", the adjustable frequency drive is in State 1: “Switching on inhibited”.

Please refer to the PROFIdrive State Transition Diagram at the end of this section.

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Bit 01, OFF 2/ON 2

Coasting stop

When bit 01 = "0", a coasting stop and activation of the output relay 1 or 2 occurs if the output frequency is 0 Hz and if [Relay 123] has been selected in par. 5-40 *Function Relay*.

When bit 01 = "1", the adjustable frequency drive is in State 1: “Switching on inhibited”. Please refer to the PROFIdrive State Transition Diagram at the end of this section.

Bit 02, OFF 3/ON 3

Quick stop using the ramp time of par. 3-81 *Quick Stop Ramp Time*. When bit 02 = "0", a quick stop and activation of the output relay 1 or 2 occurs if the output frequency is 0 Hz and if [Relay 123] has been selected in par. 5-40 *Function Relay*.

When bit 02 = "1", the adjustable frequency drive is in State 1: “Switching on inhibited”.

Please refer to the PROFIdrive State Transition Diagram at the end of this section.

Bit 03, Coasting/No coasting

Coasting stop bit 03 = "0" leads to a stop. When bit 03 = "1", the adjustable frequency drive can start if the other start conditions are satisfied.

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

Bit 04, Quick stop/Ramp

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

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

Bit 05, Hold frequency output/Use ramp

When bit 05 = "0", the current output frequency is maintained even if the reference value is modified.
When bit 05 = "1", the adjustable frequency drive can perform its regulating function again; operation occurs according to the respective reference value.

Bit 06, Ramp stop/Start

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

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

Bit 07, No function/Reset

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

Bit 08, Jog 1 OFF/ON

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

Bit 09, Jog 2 OFF/ON

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

Bit 10, Data invalid/valid

Is used to tell the adjustable frequency drive whether the control word is to be used or ignored. Bit 10 = "0" causes the control word to be ignored, Bit 10 = "1" causes the control word to be used. This function is relevant, because the control word is always contained in the message, regardless of which type of message is used, i.e., it is possible to turn off the control word if you do not wish to use it in connection with updating or reading parameters.

Bit 11, No function/Slow-down

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

Bit 12, No function/Catch up

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

Bits 13/14, Set-up selection

Bits 13 and 14 are used to choose between the four parameter set-ups according to the following table:

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

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

Bit 15, No function/Reverse

Bit 15 = "0" causes no reversing.
Bit 15 = "1" causes reversing.
Note: In the factory setting reversing is set to *digital* in par. 8-54 *Reverse Select*.

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

11.10.6 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

Explanation of the Status Bits

Bit 00, Control not ready/ready
When bit 00 = "0", bit 00, 01 or 02 of the control word is "0" (OFF 1, OFF 2 or OFF 3) - or the adjustable frequency drive is switched off (trip).
When bit 00 = "1", the adjustable frequency drive control is ready, but there is not necessarily power supply to the unit present (in the event of external 24 V supply of the control system).

Bit 01, VLT not ready/ready
Same significance as bit 00, however, there is a supply 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 par. 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 par. 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 par. 4-52 *Warning Speed Low* and par. 4-53 *Warning Speed High*. When bit 10 = "1", the output frequency is within the indicated limits.

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

Bit 12, Drive OK/Stopped, autostart
When bit 12 = "0", there is no temporary overloading of the inverter.
When bit 12 = "1", the inverter has stopped due to overloading. However, the adjustable frequency drive has not switched off (trip) and 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 par. 4-16 *Torque Limit Motor Mode* and par. 4-17 *Torque Limit Generator Mode*. When bit 14 = "1", the limit selected in par. 4-16 *Torque Limit Motor Mode* or par. 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%.

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