MAKING MODERN LIVING POSSIBLE

Design Guide
VLT® AQUA Drive FC 202

110–1400 kW

www.danfoss.com/drives

THE REAL DRIVE

Contents

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1 How to Read this Design Guide

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1.1.2 Available Literature

- VLT® AQUA Drive FC 202, 0.25–90 kW, Instruction Manual provides the necessary information for getting the adjustable frequency drive up and running.
- VLT® AQUA Drive FC 202, 110–400 kW, D-Frame Instruction Manual provide installation, startup, and basic information for the newest D-frame models.
- VLT® AQUA Drive FC 202 High Power Instruction Manual provides the necessary information for getting the HP adjustable frequency drive up and running.
- VLT® AQUA Drive FC 202, 110–1400 kW, Design Guide provides all technical information about the frame D, E, and F adjustable frequency drive and customer design and applications.
- VLT® AQUA Drive FC 202 Programming Guide provides information on how to program and includes complete parameter descriptions.
- VLT® AQUA Drive FC 202 Profibus.
- VLT® AQUA Drive FC 202 DeviceNet.
- Output Filters Design Guide.
- VLT® AQUA Drive FC 202 Cascade Controller.
- Application Note: Submersible Pump Application
- Application Note: Master/Follower Operation Application
- Application Note: Drive Closed-loop and Sleep Mode
- Instruction: Analog I/O Option MCB109
- Instruction: Panel through mount kit
- VLT® Active Filter Instruction Manual.

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

Symbols
The following symbols are used in this manual.

⚠WARNING

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

⚠CAUTION

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

CAUTION

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

NOTICE!

Indicates highlighted information to regard with attention to avoid mistakes or operate equipment at less than optimal performance.

Table 1.1 Approvals

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
Horsepower	hp
Kilohertz	kHz
Local Control Panel	LCP
Meter	m
Millihenry Inductance	mH
Milliampere	mA
Millisecond	ms
Minute	min
Motion Control Tool	MCT
Nanofarad	nF
Newton Meters	Nm
Nominal motor current	$I_{M,N}$
Nominal motor frequency	$f_{M,N}$
Nominal motor power	$P_{M,N}$
Nominal motor voltage	$U_{M,N}$
Permanent Magnet motor	PM motor
Protective Extra Low Voltage	PELV
Printed Circuit Board	PCB
Rated Inverter Output Current	I_{INV}
Revolutions Per Minute	RPM
Regenerative terminals	Regen
Second	sec.
Synchronous Motor Speed	n_s
Torque limit	T_{LIM}
Volts	V
The maximum output current	$I_{DRIVE,MAX}$
The rated output current supplied by the adjustable frequency drive	$I_{DRIVE,N}$

Table 1.2 Abbreviations

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1.1.4 Definitions

Adjustable frequency drive:

$I_{VLT,MAX}$
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
Stop the connected motor with LCP and the digital inputs.
Functions are divided into two groups.
Functions in group 1 have higher priority than functions in group 2.

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

Table 1.3 Control Command

Motor:

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

f_M
The motor frequency.

f_{MAX}
The maximum motor frequency.

f_{MIN}
The minimum motor frequency.

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

I_M
The motor current.

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

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

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

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

U_M
The instantaneous motor voltage.

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

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 Command.

References:

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

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

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

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

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

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

Miscellaneous:

Analog Inputs
The analog inputs are used for controlling various functions of the 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.

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

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

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

CT Characteristics
Constant torque characteristics used for positive displacement pumps and blowers.

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

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

DSP
Digital Signal Processor.

Relay Outputs
The adjustable frequency drive features two programmable relay outputs.

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

GLCP
Graphical Local Control Panel (LCP 102)

Initializing
If initialization is carried out (*14-22 Operation Mode*), the programmable parameters of the adjustable frequency drive return to their default settings.

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

LCP
The Local Control Panel (LCP) 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, for example, in a front panel with the installation kit option.
The local control panel is available in two versions:

- Numerical LCP 101 (NLCP)
- Graphical LCP 102 (GLCP)

lsb
Least significant bit.

MCM
Short for Mille Circular Mil, an American measuring unit for cable cross-section. 1 MCM ≡ 0.00078 in^2 [0.5067 mm^2].

msb
Most significant bit.

NLCP
Numerical Local Control Panel LCP 101

Online/Offline Parameters
Changes to online parameters are activated immediately after the data value is changed. Enter [OK] to activate changes to off-line parameters.

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

RCD
Residual Current Device.

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

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

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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 SLC.

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

Trip
A state entered in fault situations, for example, 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. Do not use trip for personal safety.

Trip Locked
A state entered in fault situations when the adjustable frequency drive is protecting itself and requiring physical intervention, for example, 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. Do not use trip lock for personal safety.

VT Characteristics
Variable torque characteristics used for pumps and fans.

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

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

1.1.5 Power Factor

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

$$Power\ factor = \frac{\sqrt{3} \times U \times I1 \times COS\varphi}{\sqrt{3} \times U \times IRMS}$$

The power factor for 3-phase control:

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

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 [hp] performance.

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

In addition, a high power factor indicates that the different harmonic currents are low.
The built-in DC coils produce a high power factor, which reduces the imposed load on the line power supply.

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2 Introduction

2.1 Safety

2.1.1 Safety Note

WARNING

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

Safety Regulations

1. The adjustable frequency drive must be disconnected from line power for repairs. Make sure that the line power supply has been disconnected and that the necessary time has passed before removing motor and line power plugs.
2. [Stop/Reset] does not disconnect the equipment from line power and is not intended as a safety switch.
3. Correct protective grounding of the equipment must be established, the operator 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 currents are higher than 3.5 mA.
5. Protection against motor overload comes from *1-90 Motor Thermal Protection*. If this function is desired, set *1-90 Motor Thermal Protection* to data value *[4] ETR trip* (default value) or data value *[3] ETR warning*

NOTICE!

The function is initialized at 1.16 x rated motor current and rated motor frequency. For the North American market: The ETR functions provide class 20 motor overload protection in accordance with NEC.

6. Do not remove the plugs for the motor and 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 passed before removing motor and line power plugs.
7. The adjustable frequency drive has more voltage inputs than L1, L2, and L3, when load sharing (linking of DC intermediate circuit) and external 24 V DC have been installed. Make sure that all voltage inputs have been disconnected and that the necessary time has passed before commencing repair work.

Installation at High Altitudes

WARNING

For installation in altitudes above 10,000 ft [3 km], (350–500 V) or 6,600 feet [2 km] (525–690 V), contact Danfoss regarding PELV.

Warning against unintended start

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

Refer to *VLT® AQUA Drive Instruction Manual* for further safety guidelines.

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⚠WARNING

DISCHARGE TIME!

Adjustable frequency drives contain DC link capacitors that can remain charged even when the adjustable frequency drive is not powered. To avoid electrical hazards, disconnect AC line power, any permanent magnet type motors, and any remote DC link power supplies, including battery backups, UPS and DC link connections to other adjustable frequency drives. Wait for the capacitors to fully discharge before performing any service or repair work. The wait time required is listed in the *Discharge Time* table. Failure to wait for the specified period of time after power has been removed to do service or repair could result in death or serious injury.

Rating [kW]	380–480 V	525–690 V
110–315	20 minutes	
45–400		20 minutes
315-1000	40 minutes	
450–1200		30 minutes

Table 2.1 DC Capacitor Discharge Times

2.1.2 Disposal Instructions

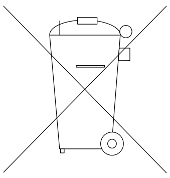	Do not dispose of equipment containing electrical components together with domestic waste. Collect it separately in accordance with local and currently valid legislation.

Table 2.2 Disposal Instructions

2.2 Software Version

2.2.1 Software Version and Approvals

VLT AQUA Drive
This manual can be used with all VLT AQUA Drive adjustable frequency drives with software version 1.95. The software version number can be found in parameter 15–43.

Table 2.3 Software Version

2.3 CE Labeling

2.3.1 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. There are three EU directives that regulate adjustable frequency drives:

The machinery directive (2006/42/EC)

Adjustable frequency drives with the integrated safety function are now falling under the Machinery Directive. Danfoss uses CE labels in accordance with the directive and will issue a declaration of conformity upon request. Adjustable frequency drives without the safety function do 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.

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

Adjustable frequency drives must be CE-labeled in accordance with the Low-voltage Directive of January 1, 1997. The directive applies to all electrical equipment and appliances used in the 50–1000 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.

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The EMC directive (2004/108/EC)
EMC is short for electromagnetic compatibility. The presence of electromagnetic compatibility means that the mutual interference between different components/ appliances does not affect the way the appliances work. The EMC directive came into effect January 1, 1996. Danfoss CE labels in accordance with the directive and issues a declaration of conformity upon request. To carry out EMC-compatible installation, see the instructions in this Design Guide. Additionally, find specifications of which standards the Danfoss products comply with. The filters presented in the specifications are part of the product range. Furthermore, Danfoss offers other types of assistance to ensure optimum EMC result.

2.3.2 What Is Covered

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

1. The adjustable frequency drive is sold directly to the end consumer, for example, to a DIY market. The end consumer is a layman who installs the adjustable frequency drive for use with a household appliance. 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 designed by professionals of the trade. The adjustable frequency drive and the finished plant do not have to be CE-labeled under the EMC directive. However, the unit must comply with the basic EMC requirements of the directive. Compliance 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 (an air-conditioning system, for example). 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 the manufacturer chooses to use only CE-labeled components, there is no need to test the entire system.

2.3.3 Danfoss Adjustable frequency drive and CE Labeling

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

CE-labeling can cover many different specifications so check the CE label to ensure that it covers the relevant applications.

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

If following the instructions for EMC-compatible installation and filtering, the CE label also applies.

Chapter 5.10 EMC-compatible Installation offers detailed instructions for EMC-compatible installation. Furthermore, Danfoss specifies which our products comply with.

2.3.4 Compliance with EMC Directive 2004/108/EC

The primary users of the adjustable frequency drive are trade professionals, who use it as a complex component forming part of a larger appliance, system, or installation. The responsibility for the final EMC properties of the appliance, system, or installation rests with the installer. As an aid to the installer, Danfoss has prepared EMC installation guidelines for the Power Drive system. If the EMC-compatible instructions for installation are followed, the standards and test levels stated for power drive systems are complied with. See *chapter 2.10 Immunity Requirements*.

2.4 Air Humidity

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].

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2.5 Aggressive Environments

An adjustable frequency drive contains many mechanical and electronic components. All are to some extent vulnerable to environmental effects.

CAUTION

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

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

Liquids can be carried through the air and condense in the adjustable frequency drive and can cause corrosion of components and metal parts. Steam, oil, and salt water can cause corrosion of components and metal parts. In such environments, use equipment with enclosure rating IP54/IP55. As an extra protection, coated printed circuit boards can be ordered as an option.

Airborne Particles such as dust can 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 dusty environments, use equipment with enclosure rating IP54/IP55 or a cabinet for IP00/IP20/NEMA 1 equipment.

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

Such chemical reactions damage the electronic components quickly. 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.

NOTICE!

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 by observing existing installations in this environment. Typical indicators of harmful airborne liquids are water or oil on metal parts, or corrosion of metal parts.

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

D and E enclosures have a stainless steel backchannel option to provide more protection in aggressive environments. Proper ventilation is still required for the internal components of the adjustable frequency drive. Contact Danfoss for more information.

2.6 Vibration and Shock

The adjustable frequency drive has been tested according to the procedure based on the following 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

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2

2.7 Adjustable Frequency Drive Benefits

2.7.1 Why use an adjustable frequency drive for controlling fans and pumps?

An adjustable frequency drive takes advantage of the fact that centrifugal fans and pumps follow the laws of proportionality for such fans and pumps. For further information, see the text and *Figure 2.1*.

2.7.2 The Clear Advantage - Energy Savings

The clear advantage of using an adjustable frequency drive for controlling the speed of fans or pumps lies in the electricity savings.
Compared to alternative control systems and technologies, an adjustable frequency drive is the optimum energy control system for controlling fan and pump systems.

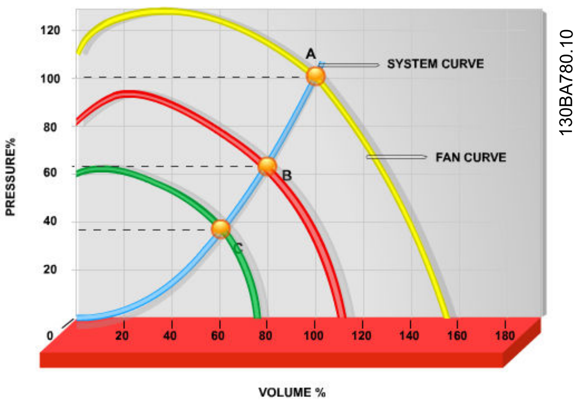

Figure 2.1 Fan Curves (A, B and C) for Reduced Fan Volumes

More than 50% energy savings can be obtained in typical applications when an adjustable frequency drive is used to reduce fan capacity to 60%.

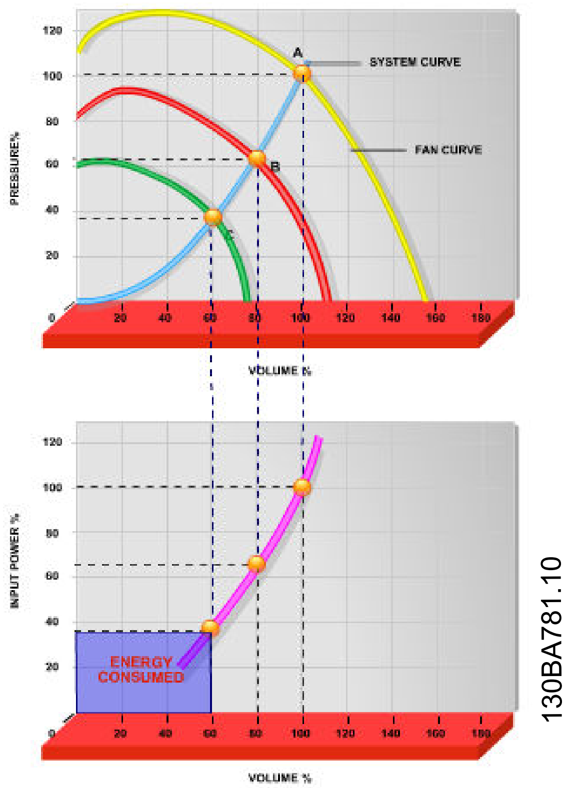

Figure 2.2 Energy Savings

2.7.3 Example of Energy Savings

As can be seen in *Figure 2.3*, the flow is controlled by changing the RPM. Reducing the speed only 20% from the rated speed reduces the flow by 20%. This reduction occurs because the flow is directly proportional to the RPM. The consumption of electricity, however, is 50% lower.
If the system in question must supply a flow that corresponds to 100% only a few days in a year, while the average is below 80% of the rated flow for the remainder of the year, the amount of energy saved is even more than 50%.

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Q = Flow	P = Power
Q_1 = Rated flow	P_1 = Rated power
Q_2 = Reduced flow	P_2 = Reduced power
H = Pressure	n = Speed regulation
H_1 = Rated pressure	n_1 = Rated speed
H_2 = Reduced pressure	n_2 = Reduced speed

Table 2.4 Laws of Proportionality

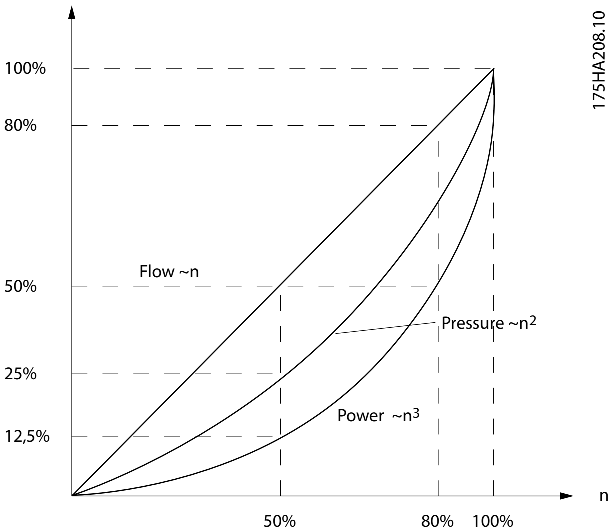

Figure 2.3 Dependence of Flow, Pressure and Power Consumption on RPM

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

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

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

2.7.4 Example with Varying Flow Over One Year

Figure 2.4 is calculated based on pump characteristics obtained from a pump datasheet.
The result obtained shows energy savings in excess of 50% at the given flow distribution over a year. The pay back period depends on the price per kWh and the price of the adjustable frequency drive. In this example, it is less than a year when compared with valves and constant speed.

Energy savings

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

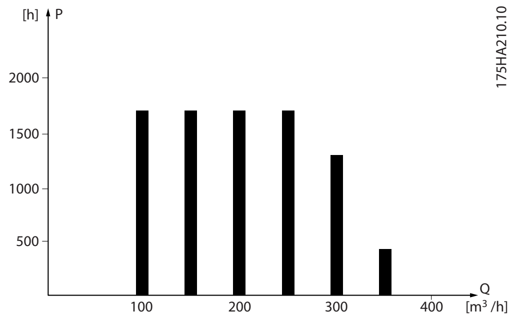

Figure 2.4 Flow Distribution over 1 Year

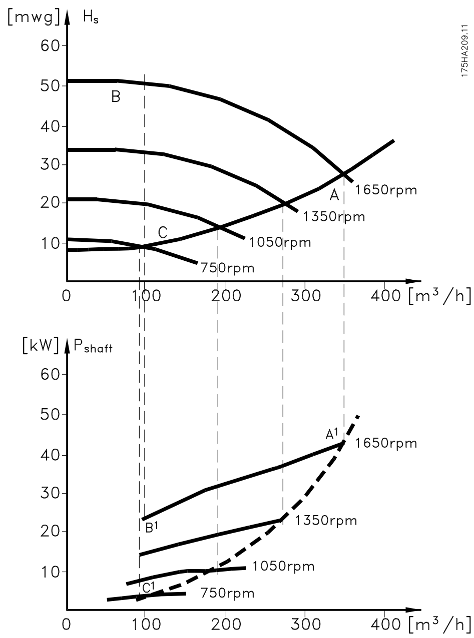

Figure 2.5 Energy Savings in a Pump Application

m^3/h	Distri-bution		Valve regulation		Adjustable frequency drive control	
	%	Hours	Power	Consump-tion	Power	Consump-tion
			A_1 - B_1	kWh	A_1 - C_1	kWh
350	5	438	42.5	18,615	42.5	18,615
300	15	1314	38.5	50,589	29.0	38,106
250	20	1752	35.0	61,320	18.5	32,412
200	20	1752	31.5	55,188	11.5	20,148
150	20	1752	28.0	49,056	6.5	11,388
100	20	1752	23.0	40,296	3.5	6,132
Σ	100	8760		275,064		26,801

Table 2.5 Energy Savings - Calculation

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2.7.5 Better Control

If an adjustable frequency drive is used for controlling the flow or pressure of a system, improved control is obtained. An adjustable frequency drive can vary the speed of the fan or pump, obtaining variable control of flow and pressure.
Furthermore, an adjustable frequency drive can quickly adapt the speed of the fan or pump to new flow or pressure conditions in the system.
Simple control of process (flow, level, or pressure) utilizing the built-in PID control.

2.7.6 Cos φ Compensation

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

2.7.7 Star/delta starter or soft-starter not required

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

As shown in *Figure 2.6*, an adjustable frequency drive does not consume more than rated current.

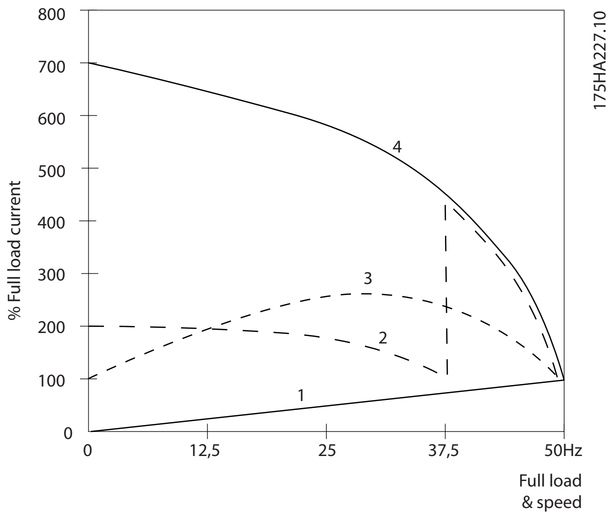

Figure 2.6 Current Consumption with an Adjustable Frequency Drive

1	VLT® AQUA Drive FC 202
2	Star/delta starter
3	Soft-starter
4	Start directly on line power

Table 2.6 Legend to *Figure 2.6*

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2.8 Control Structures

2.8.1 Control Principle

An adjustable frequency drive rectifies AC voltage from line power into DC voltage, after which DC voltage is converted into AC power 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.

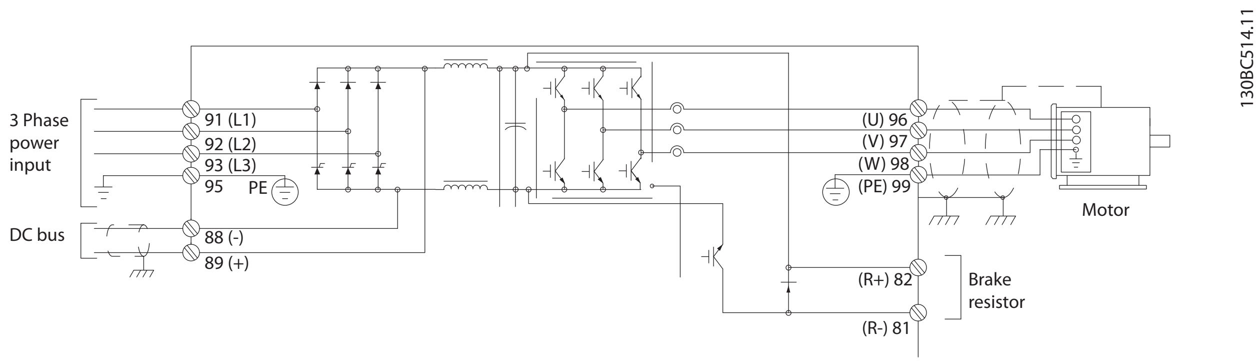

Figure 2.7 Example Control Frequency

The control terminals provide for wiring feedback, reference, and other input signals to the adjustable frequency drive, output of adjustable frequency drive status and fault conditions, relays to operate auxiliary equipment, and serial communication interface. 24 V common power is also provided. Control terminals are programmable for various functions by selecting parameter options described in the main menu or the quick menus. Most control wiring is customer supplied unless factory ordered. A 24 V DC power supply is also provided for use with the adjustable frequency drive control inputs and outputs.

Table 2.7 describes the functions of the control terminals. Many of these terminals have multiple functions determined by parameter settings. Some options provide more terminals. See *Figure 2.9* for terminal locations.

NOTICE!

The example provided does not show optional equipment.

Terminal No.	Function
01, 02, 03 and 04, 05, 06	Two form C output relays. Maximum 240 V AC, 2 A. minimum 24 V DC, 10 mA, or 24 V AC, 100 mA. Can be used for indicating status and warnings. Physically located on the power card.
12, 13	24 V DC power supply to digital inputs and external transducers. The maximum output current is 200 mA.
18, 19, 27, 29, 32, 33	Digital inputs for controlling the adjustable frequency drive. R=2 kΩ. Less than 5 V=logic 0 (open). Greater than 10 V=logic 1 (closed). Terminals 27 and 29 are programmable as digital/pulse outputs.
20	Common for digital inputs.
37	0–24 V DC input for safety stop (some units).
39	Common for analog and digital outputs.
42	Analog and digital outputs for indicating values such as frequency, reference, current, and torque. The analog signal is 0/4 to 20 mA at a maximum of 500 Ω. The digital signal is 24 V DC at a minimum of 500 Ω.
50	10 V DC, 15 mA maximum analog supply voltage for potentiometer or thermistor.
53, 54	Selectable for 0–10 V DC voltage input, R=10 kΩ, or analog signals 0/4 to 20 mA at a maximum of 200 Ω. Used for reference or feedback signals. A thermistor can be connected here.
55	Common for terminals 53 and 54.
61	RS-485 common.
68, 69	RS-485 interface and serial communication.

Table 2.7 Terminal Control Functions

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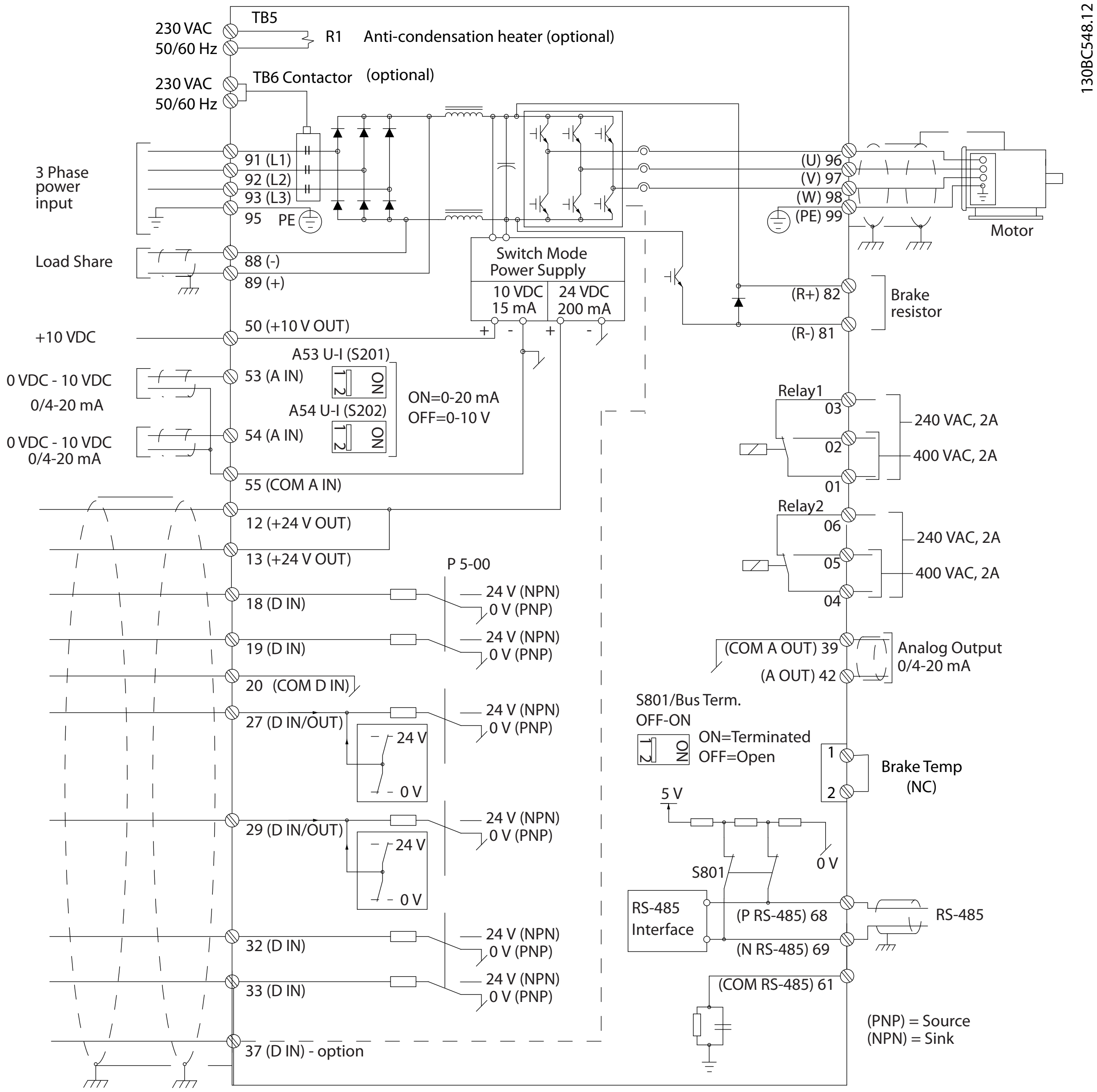

Figure 2.8 D-frame Interconnect Diagram

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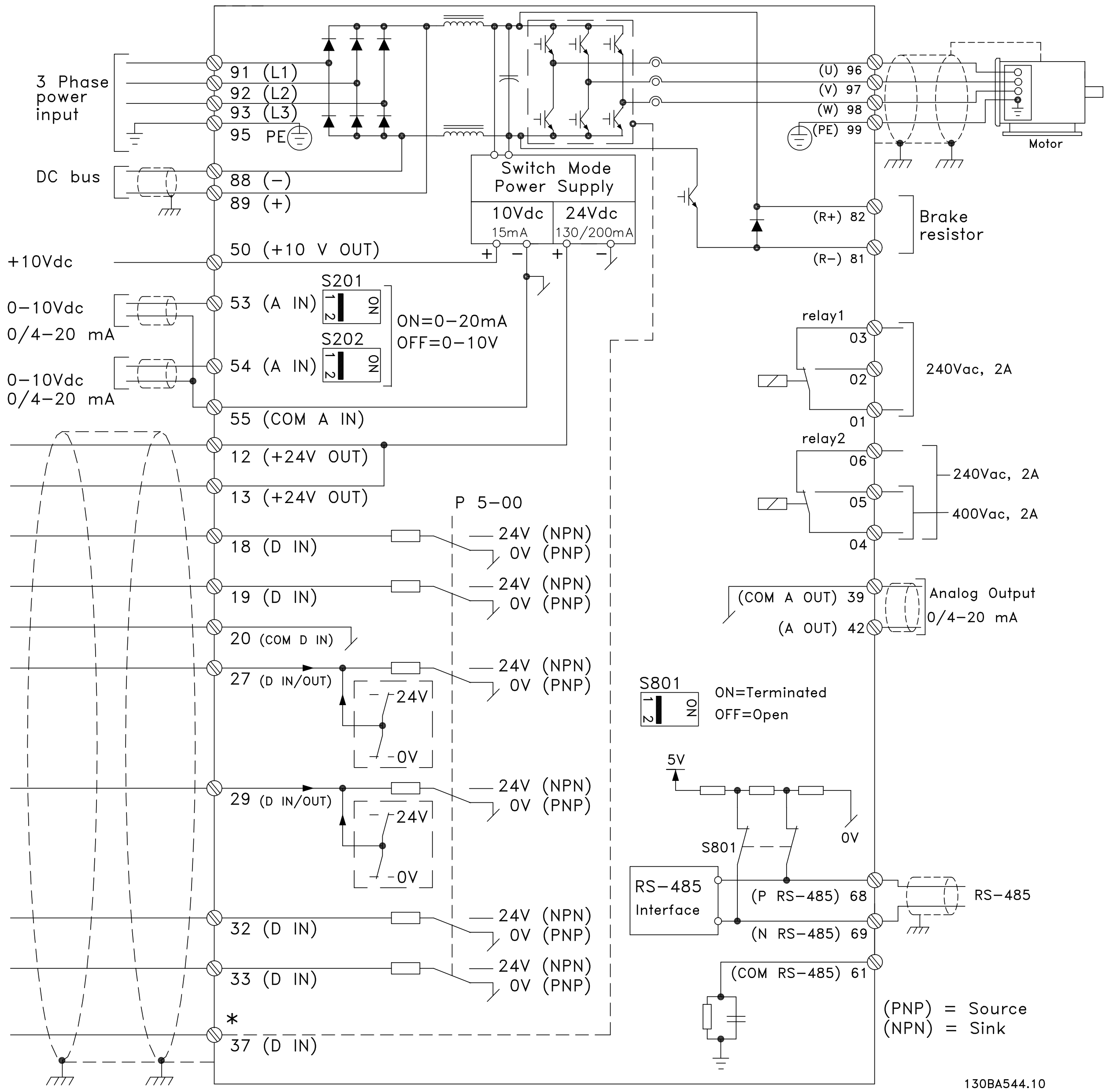

Figure 2.9 E- and F-frame Interconnect Diagram

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2.8.2 Control Structure Open-loop

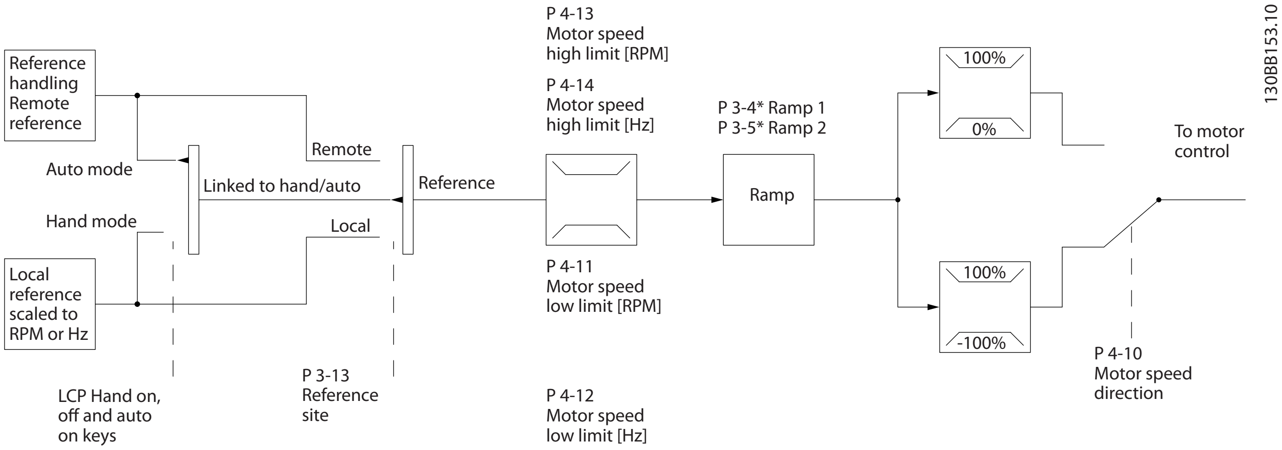

Figure 2.10 Open-loop Structure

In the configuration shown in *Figure 2.10*, *1-00 Configuration Mode* is set to *[0] Open-loop*. The resulting reference from the reference handling system or the local reference is received and fed through the ramp limitation and speed limitation before being sent to the motor control.
The maximum frequency allowed limits the output from the motor control.

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

The adjustable frequency drive can be operated manually via the LCP or remotely via analog/digital inputs or serial bus. If allowed in *0-40 [Hand on] Key on LCP*, *0-41 [Off] Key on LCP*, *0-42 [Auto on] Key on LCP*, and *0-43 [Reset] Key on LCP*, it is possible to start and stop the adjustable frequency drive by LCP using the [HandOn] 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 set by pressing the navigation keys [▲] and [▼].

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 in parameter group *5–1* Digital Inputs* or parameter group *8–5* Serial Communication*.

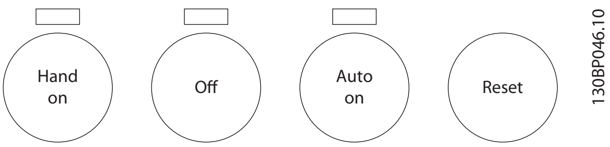

Figure 2.11 LCP Control Keys

Hand OffAutoLCP Keys	**Reference Site*3-13 Reference Site***	**Active Reference**
Hand	Linked to Hand/Auto	Local
Hand ⇒ Off	Linked to Hand/Auto	Local
Auto	Linked to Hand/Auto	Remote
Auto ⇒ Off	Linked to Hand/Auto	Remote
All keys	Local	Local
All keys	Remote	Remote

Table 2.8 Conditions for either Local or Remote Reference

Table 2.8 shows under which conditions either the local reference or the remote reference is active. One of them is always active, but both cannot be active at the same time.

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

Local reference is restored at power-down.

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2.8.4 Control Structure Closed-loop

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

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

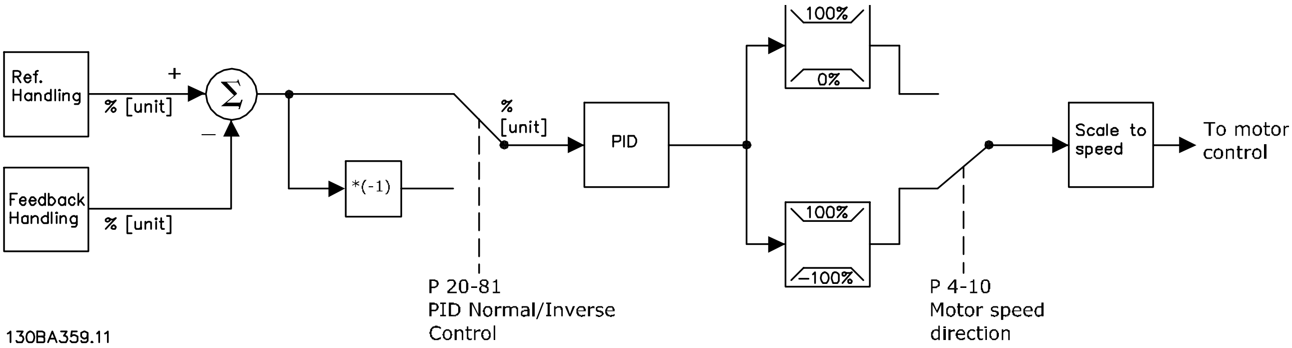

Figure 2.12 Block Diagram of Closed-loop Controller

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

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2.8.5 Feedback Handling

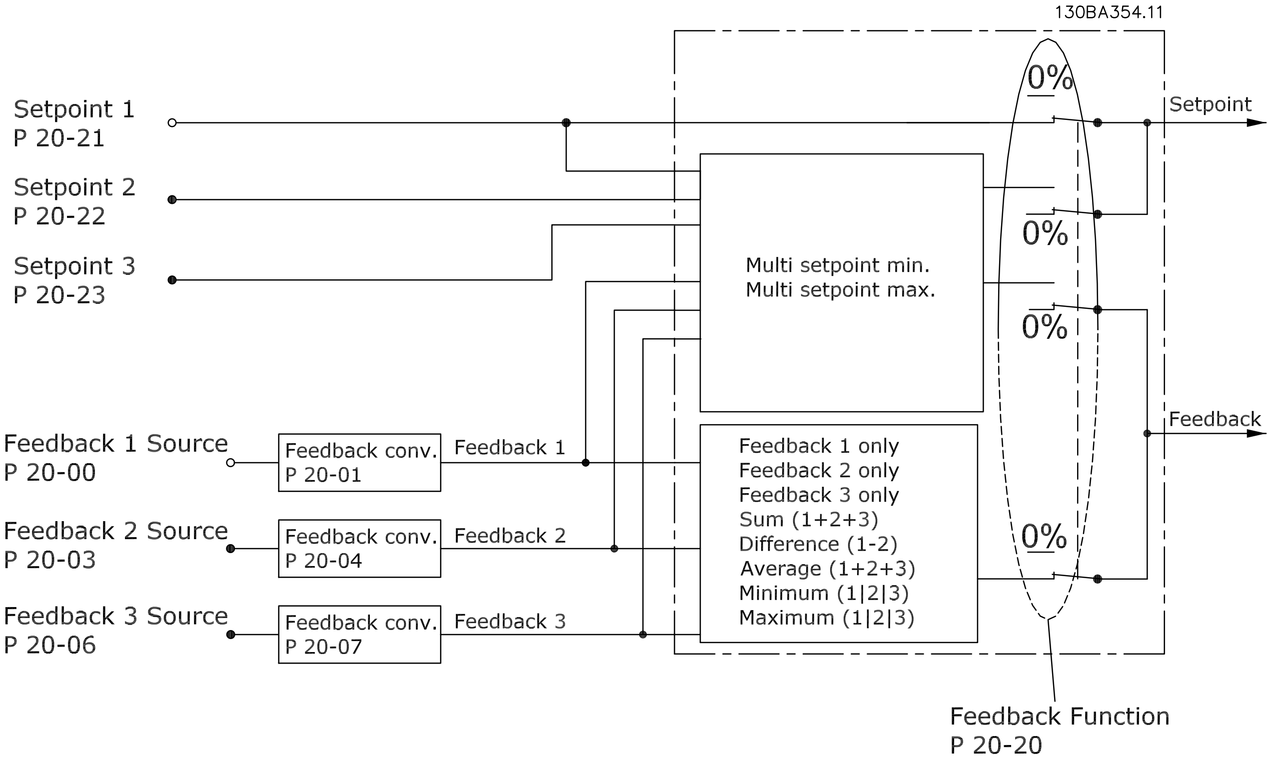

Figure 2.13 Block Diagram of Feedback Signal Processing

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

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

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

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

Example:
A two zone, two setpoint application Zone 1 setpoint is 217.6 psi [15 bar] and the feedback is 79.8 psi [5.5 bar]. Zone 2 setpoint is 63.8 psi [4.4 bar] and the feedback is 66.7 psi [4.6 bar]. If *[14] Multi-Setpoint Max* is selected, Zone 1 setpoint and feedback are sent to the PID controller, since it has the smaller difference (feedback is higher than setpoint, resulting in a negative difference). If *[13] Multi-Setpoint Min* is selected, Zone 2 setpoint and feedback is sent to the PID controller, since it has the larger difference (feedback is lower than setpoint, resulting in a positive difference).

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2.8.6 Feedback Conversion

In some applications, it could be useful to convert the feedback signal. One example is using a pressure signal to provide flow feedback. Since the square root of pressure is proportional to flow, the square root of the pressure signal yields a value proportional to the flow. For an example, see *Figure 2.14*.

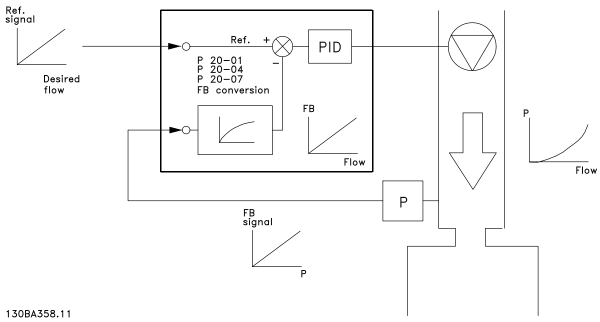

Figure 2.14 Feedback Conversion

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2.8.7 Reference Handling

Details for Open-loop and Closed-loop Operation

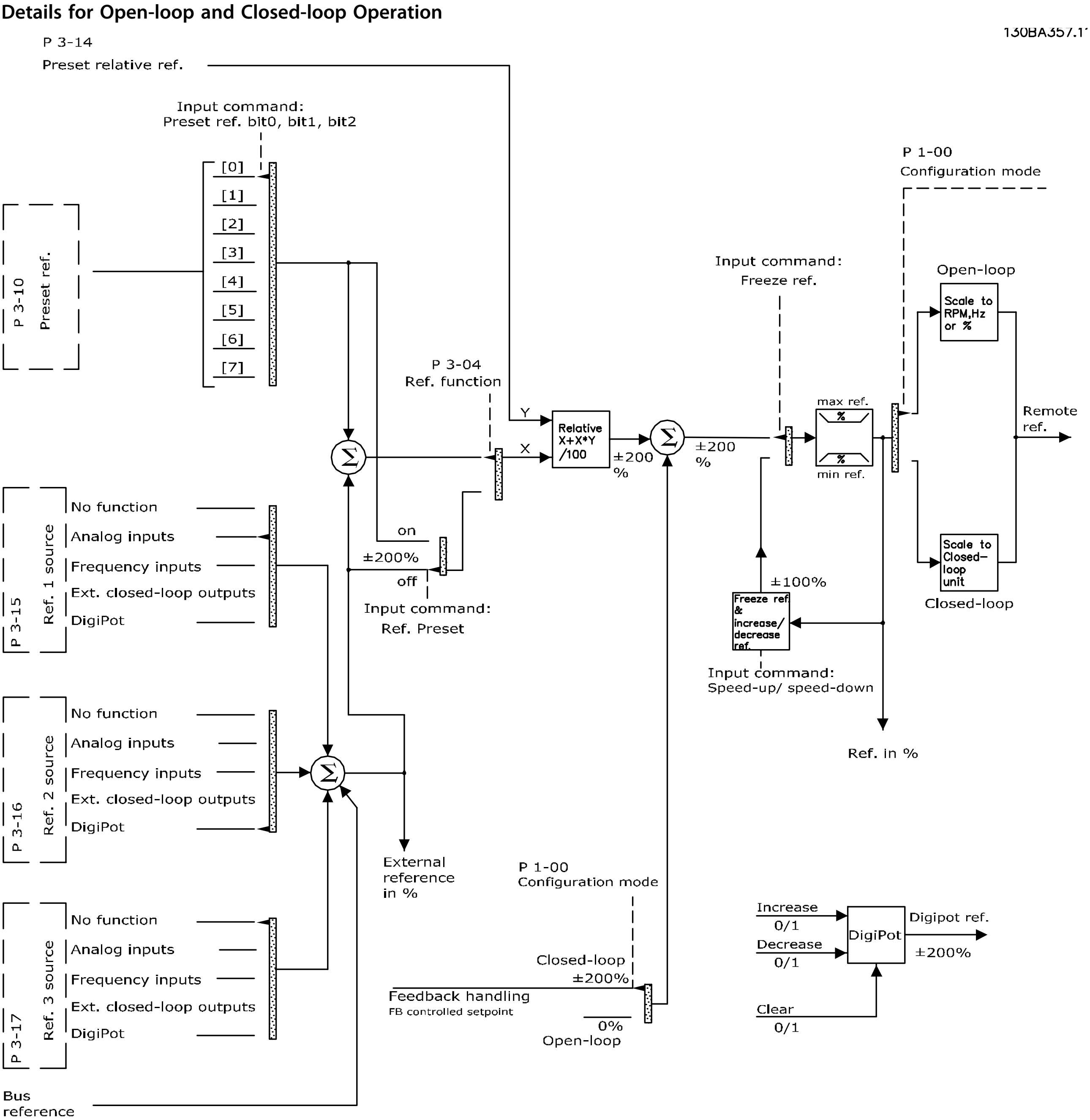

Figure 2.15 Block Diagram Showing Remote Reference

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The Remote Reference is comprised of:

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

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

The scaled reference is calculated as follows:

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

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

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

2.8.8 Example of Closed-loop PID Control

The following is an example of a closed-loop control for a booster pump application:

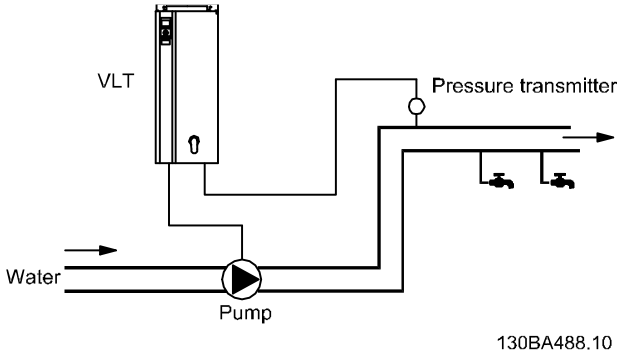

Figure 2.16 Closed-loop PID Control

In a water distribution system, the pressure must be maintained at a constant value. The desired pressure (setpoint) is set between 0–145 psi [0–10 bar] using a 0–10 V potentiometer or a parameter. The pressure sensor has a range of 0–145 psi [0–10 bar] and uses a two-wire transmitter to provide a 4–20 mA signal. The output frequency range of the adjustable frequency drive is 10–50 Hz.

1. Start/Stop via switch connected between terminals 12 (+24 V) and 18.
2. Pressure reference via a potentiometer (0–145 psi [0–10 bar], 0–10 V) connected to terminals 50 (+10 V), 53 (input) and 55 (common).
3. Pressure feedback via transmitter (0–145 psi [0–10 bar], 4–20 mA) connected to terminal 54. Switch S202 behind the local control panel set to ON (current input).

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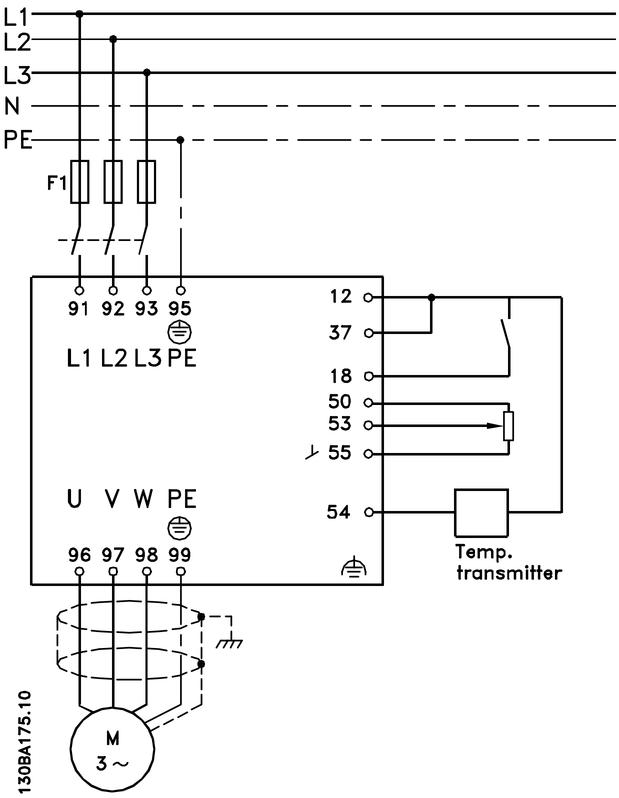

Figure 2.17

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2.8.9 Programming Order

Function	Par. no.	Setting
1) Make sure that the motor runs properly. Do the following:		
Set the motor parameters using nameplate data.	1–2*	As specified by motor nameplate
Run Automatic Motor Adaptation.	1–29	[1] *Enable complete AMA* and then run the AMA function.
2) Check that the motor is running in the right direction.		
Run Motor Rotation Check.	1–28	If the motor runs in the wrong direction, remove power temporarily and reverse two of the motor phases.
3) Make sure that the adjustable frequency drive limits are set to safe values		
Make sure that the ramp settings are within the capabilities of the drive and the allowed application operating specifications.	3–41 3–42	60 s. 60 s. Depends on motor/load size! Also active in hand mode.
Prohibit the motor from reversing (if necessary)	4–10	*[0] Clockwise*
Set acceptable limits for the motor speed.	4–12 4–14 4–19	10 Hz, *Motor min speed* 50 Hz, *Motor max speed* 50 Hz, *Drive max output frequency*
Switch from open-loop to closed-loop.	1–00	*[3] Closed-loop*
4) Configure the feedback to the PID controller.		
Select the appropriate reference/feedback unit.	20–12	*[71] Bar*
5) Configure the setpoint reference for the PID controller.		
Set acceptable limits for the setpoint reference.	3–02 3–03	0 Bar 10 Bar
Choose current or voltage by switches S201/S202		
6) Scale the analog inputs used for setpoint reference and feedback.		
Scale Analog Input 53 for the pressure range of the potentiometer (0–145 psi [0–10 bar], 0–10 V).	6–10 6–11 6–14 6–15	0 V 10 V (default) 0 psi [0 Bar] 145 psi [10 Bar]
Scale Analog Input 54 for pressure sensor (0–145 psi [0–10 bar], 4–20 mA)	6–22 6–23 6–24 6–25	4 mA 20 mA (default) 0 Bar 145 psi [10 Bar]
7) Tune the PID controller parameters.		
Adjust the closed-loop controller, if needed.	20–93 20–94	See *chapter 2.8.11 Manual PID Adjustment*.
8) Finished!		
Save the parameter settings to the LCP for safekeeping.	0–50	*[1] All to LCP*

Table 2.9 Programming Closed-loop PID

2.8.10 Tuning the Closed-loop Controller

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

2.8.11 Manual PID Adjustment

1. Start the motor
2. Set *20-93 PID Proportional Gain* to 0.3 and increase it until the feedback signal begins to oscillate. If necessary, start and stop the adjustable frequency drive or make step changes in the setpoint reference to attempt to cause oscillation. Next reduce the PID Proportional Gain until the feedback signal stabilizes. Then reduce the proportional gain by 40–60%.
3. Set *20-94 PID Integral Time* to 20 s. and reduce it until the feedback signal begins to oscillate. If necessary, start and stop the adjustable frequency drive or make step changes in the setpoint reference to attempt to cause oscillation. Next, increase the PID Integral Time until the feedback signal stabilizes. Then increase of the Integral Time by 15–50%.
4. Use *20-95 PID Differentiation Time* only for fast-acting systems. The typical value is 25% of *20-94 PID Integral Time*. Use the differential function only when the setting of the proportional gain and the integral time has been fully optimized. Make sure that oscillations of the feedback signal are sufficiently dampened by the low-pass filter for the feedback signal (*6-16 Terminal 53 Filter Time Constant*, *6-26 Terminal 54 Filter Time Constant*, *5-54 Pulse Filter Time Constant #29* or *5-59 Pulse Filter Time Constant #33* as required).

2.9 General Aspects of EMC

2.9.1 General Aspects of EMC Emissions

Electrical interference is most commonly conducted at frequencies in the range 150 kHz to 30 MHz. Airborne interference from the adjustable frequency drive system in the range 30 MHz to 1 GHz is generated from the inverter, motor cable, and the motor.
As shown in *Figure 2.18*, capacitive currents in the motor cable coupled with a high dU/dt from the motor voltage generate leakage currents.
The use of a shielded motor cable increases the leakage current (see *Figure 2.18*) because shielded cables have higher capacitance to ground than non-shielded cables. If the leakage current is not filtered, it causes greater interference on line power in the radio frequency range below 5 MHz. Since the leakage current (I_1) is carried back to the unit through the shield (I_3), in principle, there is only a small electromagnetic field (I_4) from the shielded motor cable according to *Figure 2.18*.

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 the motor enclosure. The best way to connect them is by using integrated shield clamps to avoid twisted shield ends (pigtails). These increase the shield impedance at higher frequencies, which reduces the shield effect and increases the leakage current (I_4).
If a shielded cable is used for serial communication bus, relay, control cable, signal interface, and brake, the shield must be mounted on the enclosure at both ends. In some situations, however, it is necessary to break the shield to avoid current loops.

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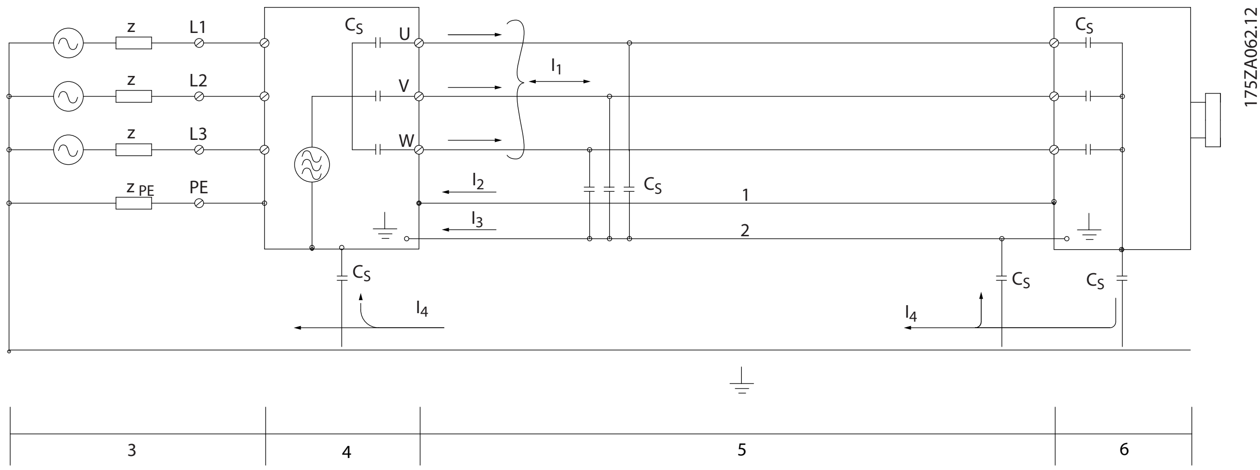

Figure 2.18 Leakage Currents

Figure 2.18 shows an example of a 6-pulse adjustable frequency drive, but could be applicable to a 12-pulse as well.

If placing the shield on a mounting plate for the adjustable frequency drive, the mounting plate must be made of metal, because the shield currents must be conveyed back to the unit. Ensure good electrical contact from the mounting plate through the mounting screws to the adjustable frequency drive chassis.

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

To reduce the interference level from the entire system (unit and 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) comes from the control electronics. See *chapter 5.10 EMC-compatible Installation* for more information on EMC.

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2.9.2 Emission Requirements

According to the EMC product standard for adjustable speed adjustable frequency drives EN/IEC 61800-3:2004, the EMC requirements depend on the environment in which the adjustable frequency drive is installed. Four categories are defined in the EMC product standard. The definitions of the four categories together with the requirements for line power supply voltage conducted emissions are given in *Table 2.10*.

Category	**Definition**	**Conducted emission requirement according to the limits given in EN 55011**
C1	Adjustable frequency drives installed in the first environment (home and office) with a supply voltage less than 1,000 V.	Class B
C2	Adjustable frequency drives installed in the first environment (home and office) with a supply voltage less than 1,000 V. These adjustable frequency drives are not plug-in and cannot be moved and are intended to for professional installation and commissioning.	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 1,000 V or rated current equal to or above 400 A or intended for use in complex systems.	No limit line Make an EMC plan

Table 2.10 Emission Requirements

When the generic emission standards are used, the adjustable frequency drives are required to comply with *Table 2.11*

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

Table 2.11 Limits

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2.9.3 EMC Test Results (Emission)

The test results in *Table 2.12* have been 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	**Phase type**	**Conducted emission** Maximum shielded cable length			**Radiated emission**	
		Industrial environment		Housing, trades and light industries	Industrial environment	Housing, trades, and light industries
Set-up:	**S / T**	EN 55011 Class A2	EN 55011 Class A1	EN 55011 Class B	EN 55011 Class A1	EN 55011 Class B
H2 (6-pulse)		feet [meter]	feet [meter]	feet [meter]		
150–1350 hp [110–1000 kW] 380–480 V	**T4**	165 [50]	No	No	No	No
60–1600 hp [45–1200 kW] 525–690 V	**T7**	500 [150]	No	No	No	No
H4 (6-pulse)						
150–1350 hp [110–1000 kW] 380–480 V	**T4**	500 [150]	500 [150]	No	Yes	No
150–550 hp [110–400 kW] 525–690 V	**T7**	500 [150]	100 [30]	No	No	No
B2 (12-pulse)						
350–1075 hp [250–800 kW] 380–480 V	**T4**	500 [150]	No	No	No	No
475–1600 hp [355–1200 kW] 525–690 V	**T7**	500 [150]	No	No	No	No
B4 (12-pulse)						
350–1075 hp [250–800 kW] 380–480 V	**T4**	500 [150]	500 [150]	No	Yes	No
475–1600 hp [355–1200 kW] 525–690 V	**T7**	500 [150]	250 [25]	No	No	No

Table 2.12 EMC Test Results (Emission)

WARNING

In a domestic environment, this product has the potential to cause radio interference, in which case supplementary mitigation measures are required. This type of power drive system is not intended to be used on a low-voltage public network which supplies domestic premises. Radio frequency interference is expected when used on such a network.

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2.9.4 General Aspects of Harmonics Emission

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 with a Fourier analysis and split up into sine-wave currents with different frequencies, such as harmonic currents I_n with 50 Hz (or 60 Hz) as the basic frequency:

	I_1	I_5	I_7
[Hz]	50	250	350
	60	300	420

Table 2.13 Harmonic Currents

The harmonics do not affect the power consumption directly but increase the heat losses in the installation (transformer, cables). In plants with a high percentage of rectifier load, maintain harmonic currents at a low level to avoid overload of the transformer and high temperature in the cables.

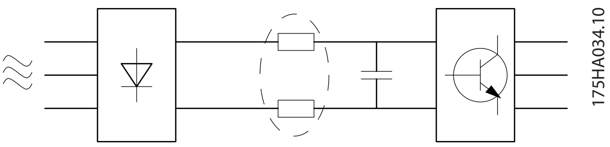

Figure 2.19 Harmonics

NOTICE!

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

To ensure low harmonic currents, the adjustable frequency drive is equipped with DC link inductors as standard, to reduce the input current I_{RMS} by 40%.

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

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

(U_N% of U)

2.9.5 Harmonics Emission Requirements

Equipment connected to the public supply network

Options:	Definition:
1	IEC/EN 61000-3-2 Class A for 3-phase balanced equipment (for professional equipment only up to 1.5 hp [1 kW] total power).
2	IEC/EN 61000-3-12 Equipment 16 A-75 A and professional equipment as from 1.5 hp [1 kW] up to 16 A phase current.

Table 2.14 Harmonics Emission Standards

2.9.6 Harmonics Test Results (Emission)

Power sizes P110 - P450 in T4 also complies with IEC/EN 61000-3-12 even though not required because currents are above 75 A.

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

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

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

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

Compliance with various system level guidelines:
The harmonic current data in the table are given in accordance with IEC/EN61000-3-12 regarding the Power Drive Systems product standard. They can be used as the basis for calculation of the influence the harmonic current has on the power supply system and for the documentation of compliance with relevant regional guidelines: IEEE 519 -1992; G5/4.

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2.10 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 as well as the lower requirements for home and office environment with a large safety margin.

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

See *Table 2.15*.

Voltage range: 380–480 V, 525–600 V, 525–690 V					
Basic standard	**Electrical interference IEC 61000-4-4**	**Surge IEC 61000-4-5**	**ESD IEC 61000-4-2**	**Radiated electromagnetic field IEC 61000-4-3**	**RF common mode voltage IEC 61000-4-6**
Acceptance criterion	**B**	**B**	**B**	**A**	**A**
Line	4 kV CM	2 kV/2Ω DM 4 kV/12Ω CM	—	—	10 V_{RMS}
Motor	4 kV CM	4 kV/2 Ω 1)	—	—	10 V_{RMS}
Brake	4 kV CM	4 kV/2 Ω1)	—	—	10 V_{RMS}
Load sharing	4 kV CM	4 kV/2 Ω 1)	—	—	10 V_{RMS}
Control wires	2 kV CM	2 kV/2 Ω1)	—	—	10 V_{RMS}
Standard bus	2 kV CM	2 kV/2 Ω1)	—	—	10 V_{RMS}
Relay wires	2 kV CM	2 kV/2 Ω 1)	—	—	10 V_{RMS}
Application and serial communication options	2 kV CM	2 kV/2 Ω 1)	—	—	10 V_{RMS}
LCP cable	2 kV CM	2 kV/2 Ω 1)	—	—	10 V_{RMS}
External 24V DC	2 V CM	0.5 kV/2 Ω DM 1 kV/12 Ω CM	—	—	10 V_{RMS}
Enclosure	—	—	8 kV AD 6 kV CD	10 V/m	—

Table 2.15 EMC Immunity Form

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

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2.11 Galvanic Isolation (PELV)

2.11.1 PELV - Protective Extra Low Voltage

⚠WARNING

Installation at high altitude:
380–500 V, enclosure D, E, and F: At altitudes above 10,000 ft [3 km], contact Danfoss regarding PELV.

⚠WARNING

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

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).

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

The components that make up the electrical isolation 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 2.20*):

To maintain PELV, all connections made to the control terminals must be PELV, for example, reinforce/double insulate the thermistor.

1. Power supply (SMPS) including 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. Optocoupler, brake module.
5. Internal soft-charge, RFI and temperature measurement circuits.
6. Custom relays.

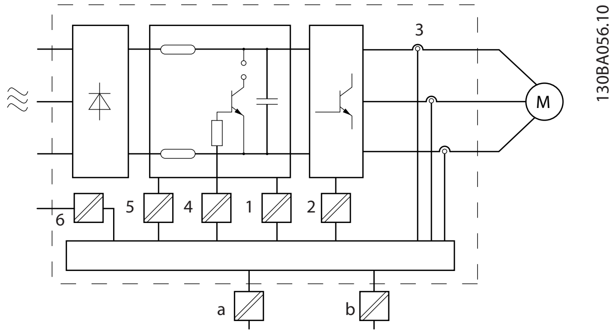

Figure 2.20 Galvanic Isolation

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

2.12 Ground Leakage Current

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

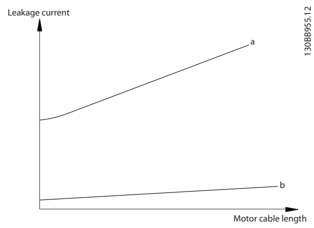

Figure 2.21 Influence of the Cable Length and Power Size on the Leakage Current. Pa>Pb

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The leakage current also depends on the line distortion.

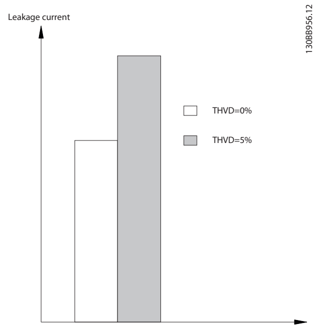

Figure 2.22 Influence of Line Distortion on Leakage Current

NOTICE!

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

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

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

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

Using RCDs

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

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

Use RCDs with a soft-charge delay to prevent faults due to transient ground currents

Dimension RCDs according to the system configuration and environmental considerations

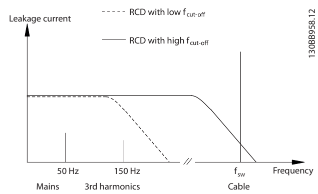

Figure 2.23 Main Contributions to Leakage Current

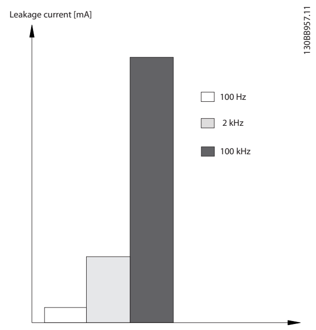

Figure 2.24 The Influence of the Cut-off Frequency of the RCD on what is responded to/measured

See also *RCD Application Note*.

2.13 Control with Brake Function

2.13.1 Selection of Brake Resistor

In certain applications, for instance, in centrifuges, it is desirable to bring the motor to a stop more rapidly than can be achieved through controlling via ramp-down or by free-wheeling. In such applications, dynamic braking with a braking resistor can be utilized. Using a brake resistor ensures that the energy is absorbed in the 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 based on the cycle time and braking time also called intermittent duty cycle. The resistor intermittent duty cycle is an indication of the duty cycle at which the resistor is active. *Figure 2.25* shows a typical braking cycle.

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

Duty Cycle = t_b/T

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

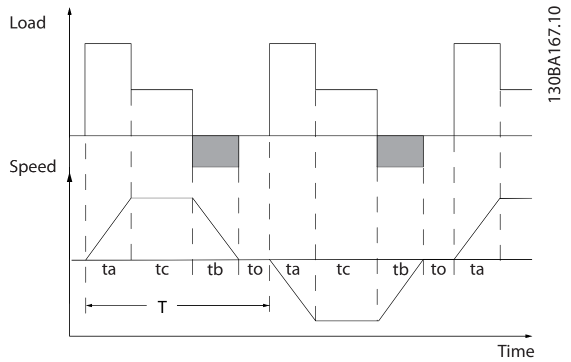

Figure 2.25 Typical Braking Cycle

Danfoss offers brake resistors with duty cycles of 10% and 40% suitable for use with the VLT® AQUA Drive FC 202. If a 10% duty cycle resistor is applied, it can absorb braking energy up to 10% of the cycle time with the remaining 90% being used to dissipate heat from the resistor.

For resistor selection information, refer to the *Brake Resistor Design Guide*.

NOTICE!

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

2.13.2 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 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 s. The brake can also monitor the power energizing and make sure that it does not exceed a limit selected in *2-12 Brake Power Limit (kW)*. In *2-13 Brake Power Monitoring*, select the function to carry out when the power transmitted to the brake resistor exceeds the limit set in *2-12 Brake Power Limit (kW)*.

⚠CAUTION

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

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

NOTICE!

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

2.14 Mechanical Brake Control

2.14.1 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.

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2.15 Extreme Running Conditions

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

Switching on the output
Switching on the output between the motor and the adjustable frequency drive is fully permitted and cannot damage the adjustable frequency drive, but it can cause fault messages to appear.

Motor-generated overvoltage
The voltage in the intermediate circuit is increased when the motor acts as a generator.

Overvoltage occurs in the following cases:

1. The load drives the motor, generating 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 can cause higher DC link voltage.

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

High temperature
High ambient temperature can cause the adjustable frequency drive to overheat.

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 lowest rated supply voltage.

The AC line voltage before the drop-out and the motor load determine how long it takes for the inverter to coast.

Static overload in VVC^{plus} mode
When the adjustable frequency drive is overloaded (the torque limit in *4-16 Torque Limit Motor Mode*/*4-17 Torque Limit Generator Mode* is reached), the controls reduces the output frequency to reduce the load.
If the overload is excessive, a current could occur that makes the adjustable frequency drive cut out after approx. 5–10 s.

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

2.15.1 Motor Thermal Protection

Danfoss uses motor thermal protection to keep the motor from being overheated. It is an electronic feature that simulates a bimetal relay based on internal measurements. The characteristic is shown in *Figure 2.26*

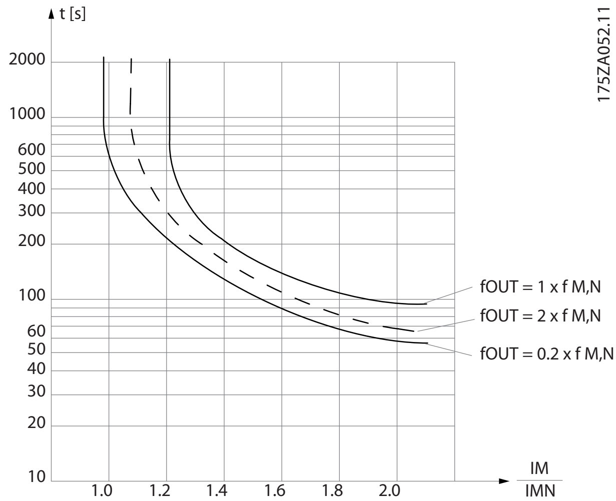

Figure 2.26 Motor Thermal Protection

In *Figure 2.26*, the X-axis is showing the ratio between I_{motor} and I_{motor} nominal. The Y-axis is showing the time in seconds before the ETR cuts off and trips the adjustable frequency drive. The curves are showing the characteristic nominal speed at twice the nominal speed and at 0.2x the nominal speed.

It is clear that at lower speed the ETR cuts off at lower heat due to less cooling of the motor. In that way, the motor is protected from being overheated even at low speed. The ETR feature calculates the motor temperature based on the actual current and speed. The calculated temperature is visible as a readout parameter in *16-18 Motor Thermal* in the adjustable frequency drive.

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The thermistor cut-out value is > 3kΩ. Integrate a thermistor (PTC sensor) in the motor for winding protection.

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

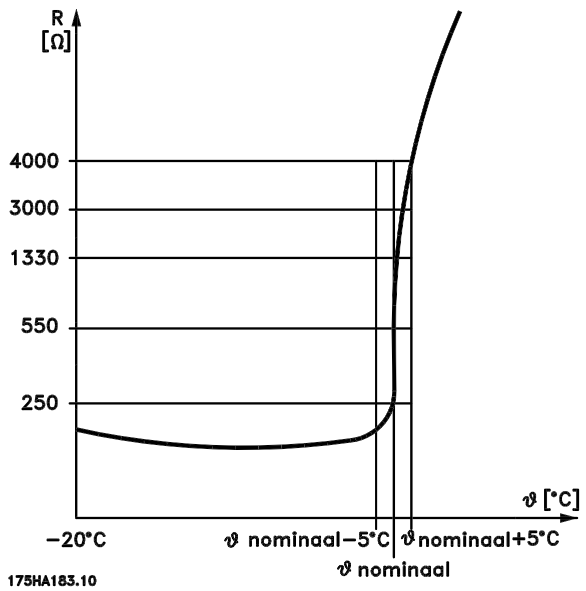

Figure 2.27 Trip

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

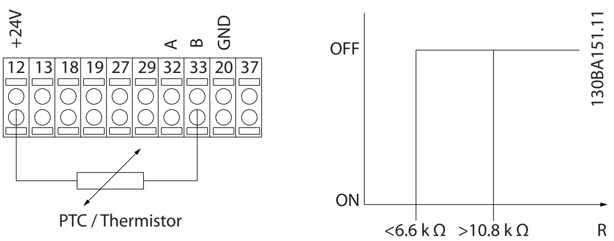

Figure 2.28 Digital Input and 24 V Power Supply

Using a digital input and 10 V as power supply:
Example: The adjustable frequency drive trips when the motor temperature is too high.
Parameter set-up:
Set *1-90 Motor Thermal Protection* to *[2] Thermistor Trip*
Set *1-93 Thermistor Source* to *[6] Digital Input 33*

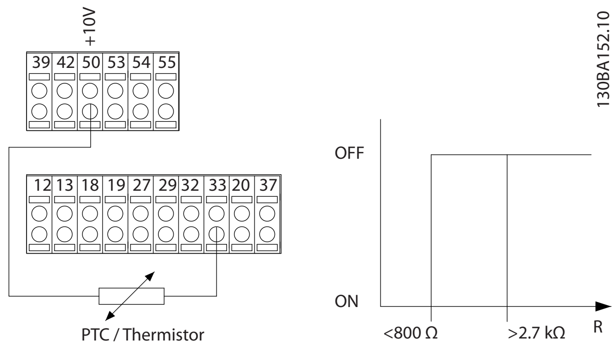

Figure 2.29 Digital Input and 10 V Power Supply

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

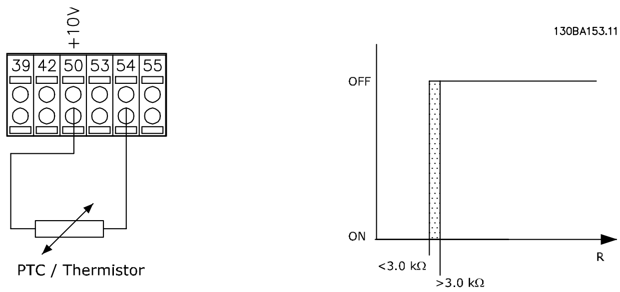

Figure 2.30 Analog Input 10 V Power Supply

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

NOTICE!

Ensure that the chosen supply voltage follows the specification of the thermistor element utilized.

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Summary
With the torque limit feature, the motor is protected from being overloaded independent of the speed. With the ETR, the motor is protected from being overheated and there is no need for any further motor protection. That means when the motor is heated up, the ETR timer controls how long the motor may run at that temperature before it is stopped in order to prevent overheating. If the motor is overloaded without reaching the temperature where the ETR shuts off the motor, the torque limit is protecting the motor and application for being overloaded.

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

2.15.2 Safe Stop Operation (optional)

The FC 202 can perform the safety function "Uncontrolled Stopping by removal of power" (as defined by draft IEC 61800-5-2) or Stop Category 0 (as defined in EN 60204-1). It is designed and approved suitable for the requirements of Safety Category 3 in EN 954-1. This functionality is called Safe Stop.
Before integration and use of FC 202 safe stop in an installation, a thorough risk analysis on the installation must be carried out in order to determine whether the FC 202 safe stop functionality and safety category are appropriate and sufficient.
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 FC 202 can be used for asynchronous and synchronous motors.

⚠WARNING

Safe Stop activation (that is, removal of 24 V DC voltage supply to terminal 37) does not provide electrical safety.

NOTICE!

The safe stop function of FC 202 can be used for asynchronous and synchronous motors. Two faults can occur in the power semiconductor and cause a residual rotation when using synchronous motors. The rotation can be calculated to Angle=360/(Number of Poles). The application using synchronous motors must consider this possibility and ensure that it is not a safety critical issue. This situation is not relevant for asynchronous motors.

NOTICE!

In order to use the safe stop functionality in conformance with the requirements of EN-954-1 Category 3, the installation of safe stop must meet a number of conditions. See *chapter 5.7 Safe Stop Installation* for further information.

NOTICE!

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 *chapter 5.7 Safe Stop Installation*.

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3 Selection

3.1 General Specifications

3.1.1 Line Power Supply 3x380–480 V AC

	N110	N132	N160	N200	N250	N315	P355	P400
Normal Overload =110% current for 60 seconds	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Typical Shaft output at 400 V [kW]	110	132	160	200	250	315	355	400
Typical Shaft output at 460 V [hp]	150	200	250	300	350	450	500	550
Enclosure IP00							E2	E2
Enclosure IP20	D3h	D3h	D3h	D4h	D4h	D4h		
Enclosure IP21/NEMA 1	D1h	D1h	D1h	D2h	D2h	D2h	E1	E1
Enclosure IP54/NEMA 12	D1h	D1h	D1h	D2h	D2h	D2h	E1	E1
Output current								
Continuous (at 3x380–440 V) [A]	212	260	315	395	480	588	658	745
Intermittent (at 3x380–440 V) [A]	233	286	347	435	528	647	724	820
Continuous (at 3x441–480 V) [A]	190	240	302	361	443	535	590	678
Intermittent (at 3x441–480 V) [A]	209	264	332	397	487	588	649	746
Continuous kVA (at 400 V AC) [kVA]	147	180	218	274	333	407	456	516
Continuous kVA (at 460 V AC) [kVA]	151	191	241	288	353	426	470	540
Max. input current								
Continuous (3x380–440 V) [A]	204	251	304	381	463	567	647	733
Continuous (3x441–480 V) [A]	183	231	291	348	427	516	580	667
Max. pre-fuses[1)] [A]	315	350	400	550	630	800	900	900
Max. cable size								
Motor (mm^2/AWG[2) 5)])	2 x 95 2 x 3/0			2 x 185 2 x 350 mcm			4 x 240 4 x 500 mcm	
Line power (mm^2/AWG[2) 5)])								
Load sharing (mm^2/AWG[2) 5)])								
Brake (mm^2/AWG[2) 5)])							2 x 185 2 x 350 mcm	
Estimated power loss at 400 V AC at rated max load [W] [3)]	2555	2949	3764	4109	5129	6663	7532	8677
Estimated power loss at 460 V AC at rated max load [W] [3)]	2557	2719	3612	3561	4558	5703	6724	7819
Weight, enclosure IP00/IP20 kg [lbs]	62 [135]			125 [275]			234 [515]	236 [519]
Weight, enclosure IP21 kg [lbs]							270 [594]	272 [598]
Weight, enclosure IP54 kg [lbs]								
Efficiency[4)]	0.98							
Output frequency [Hz]	0–590							
Heatsink overtemp. trip °F [°C]	110							
Power card ambient trip °F [°C]	167 [75]						185 [85]	

Table 3.1 Line Power Supply 3x380–480 V AC

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	P450	P500	P560	P630	P710	P800	P1M0
Normal Overload =110% current for 60 seconds	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Typical Shaft output at 400 V [kW]	450	500	560	630	710	800	1000
Typical Shaft output at 460 V [hp]	600	700	750	900	1000	1200	1350
Enclosure IP00	E2						
Enclosure IP21/NEMA 1	E1	F1/F3	F1/F3	F1/F3	F1/F3	F2/F4	F2/F4
Enclosure IP54/NEMA 12	E1	F1/F3	F1/F3	F1/F3	F1/F3	F2/F4	F2/F4
Output current							
Continuous (at 3x380–440 V) [A]	800	880	990	1120	1260	1460	1720
Intermittent (at 3x380–440 V) [A]	880	968	1089	1232	1386	1606	1892
Continuous (at 3x441–480 V) [A]	730	780	890	1050	1160	1380	1530
Intermittent (at 3x441–480 V) [A]	803	858	979	1155	1276	1518	1683
Continuous kVA (at 400 V AC) [kVA]	554	610	686	776	873	1012	1192
Continuous kVA (at 460 V AC) [kVA]	582	621	709	837	924	1100	1219
Max. input current							
Continuous (3 x 380–440 V) [A]	787	857	964	1090	1227	1422	1675
Continuous (3 x 441–480 V) [A]	718	759	867	1022	1129	1344	1490
Max. pre-fuses[1] [A]	900	1600		2000		2500	
Max. cable size							
Motor (mm²/AWG[2])	4 x 240 4 x 500 mcm	8 x 150 8 x 300 mcm				12 x 150 12 x 300 mcm	
Line power (mm²/AWG[2])		8 x 240 8 x 500 mcm					
Load sharing (mm²/AWG[2])		4 x 120 4 x 350 mcm					
Brake (mm²/AWG[2])	2 x 185 2 x 350 mcm	4 x 185 4 x 350 mcm				6 x 185 6 x 350 mcm	
Estimated power loss at 400 V AC at rated max load [W] [3]	9473	10162	11822	12512	14674	17293	19278
Estimated power loss at 460 V AC at rated max load [W] [3]	8527	8876	10424	11595	13213	16229	16624
Weight, enclosure IP00/IP20 kg [lbs]	277 [609]	-	-	-	-	-	-
Weight, enclosure IP21 kg [lbs]	313 [689]	1017/1318 [2237/2900]				1260/1561 [2772/3434]	
Weight, enclosure IP54 kg [lbs]	313 [689]	1017/1318 [2237/2900]				1260/1561 [2772/3434]	
Efficiency[4]	0.98						
Output frequency [Hz]	0–590						
Heatsink overtemp. trip °F [°C]	230 [110]	203 [95]					
Power card ambient trip	185 [85]						

Table 3.2 Line Power Supply 3x380–480 V AC

1) For type of fuse, consult the Instruction Manual.

2) American Wire Gauge.

3) The typical power loss occurs at normal conditions and is expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (eff2/eff3 border line). Lower efficiency motors add to the power loss in the adjustable frequency drive and the opposite is also true. If the switching frequency is raised from nominal, the power losses rise significantly. LCP

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and typical control card power consumptions are included. Further options and customer load can add up to 30 W to the losses (though typically only 4 W extra for a fully loaded control card or options for slot A or slot B, each).
4) Measured using 16.5 ft. [5 m] shielded motor cables at rated load and rated frequency.
5) Wiring terminals on N132, N160, and N315 adjustable frequency drives cannot receive cables one size larger.

3.1.2 Line Power Supply 3 x 525–690 V AC

	N75K	N90K	N110	N132	N160	N200
Normal Overload =110% current for 60 seconds	NO	NO	NO	NO	NO	NO
Typical Shaft output at 550 V [kW]	55	75	90	110	132	160
Typical Shaft output at 575 V [hp]	75	100	125	150	200	250
Typical Shaft output at 690 V [kW]	75	90	110	132	160	200
Enclosure IP20	D3h	D3h	D3h	D3h	D3h	D4h
Enclosure IP21	D1h	D1h	D1h	D1h	D1h	D2h
Enclosure IP54	D1h	D1h	D1h	D1h	D1h	D2h
Output current						
Continuous (at 550 V) [A]	90	113	137	162	201	253
Intermittent (60 s overload) (at 550 V) [A]	99	124	151	178	221	278
Continuous (at 575/690 V) [A]	86	108	131	155	192	242
Intermittent (60 s overload) (at 575/690 V) [kVA]	95	119	144	171	211	266
Continuous kVA (at 550 V) [kVA]	86	108	131	154	191	241
Continuous kVA (at 575 V) [kVA]	86	108	130	154	191	241
Continuous kVA (at 690 V) [kVA]	103	129	157	185	229	289
Max. input current						
Continuous (at 550 V) [A]	89	110	130	158	198	245
Continuous (at 575 V) [A]	85	106	124	151	189	234
Continuous (at 690 V) [A]	87	109	128	155	197	240
Max. cable size: line power, motor, brake, and load share (mm^2/AWG[2)])	2x95 (2x3/0)					
Max. external electrical fuses [A]	160	315	315	315	350	350
Estimated power loss at 575 V [W] [3)]	1,161	1,426	1,739	2,099	2,646	3,071
Estimated power loss at 690 V [W][3)]	1,203	1,476	1,796	2,165	2,738	3,172
Weight, enclosures IP20, IP21, IP54 kg [lbs]	62 [135]					
Efficiency [4)]	0.98					
Output frequency [Hz]	0–590					
Heatsink overtemp. trip °F [°C]	230 [110]					
Power card ambient trip °F [°C]	167 [75]					

Table 3.3 Line Power Supply 3 x 525–690 V AC

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3

	N250	N315	N400	P450	P500	P560
Normal Load	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Typical Shaft output at 550 V [kW]	200	250	315	355	400	450
Typical Shaft output at 575 V [hp]	300	350	400	450	500	600
Typical Shaft output at 690 V [kW]	250	315	400	450	500	560
Enclosure IP00				E2	E2	E2
Enclosure IP20	D4h	D4h	D4h			
Enclosure IP21	D2h	D2h	D2h	E1	E1	E1
Enclosure IP54	D2h	D2h	D2h	E1	E1	E1
Output current						
Continuous (at 550 V) [A]	303	360	418	470	523	596
Intermittent (60 s overload) (at 550 V) [A]	333	396	460	517	575	656
Continuous (at 575/690 V) [A]	290	344	400	450	500	570
Intermittent (60 s overload) (at 575/690 V) [kVA]	319	378	440	495	550	627
Continuous kVA (at 550 V) [kVA]	289	343	398	448	498	568
Continuous kVA (at 575 V) [kVA]	289	343	398	448	498	568
Continuous kVA (at 690 V) [kVA]	347	411	478	538	598	681
Max. input current						
Continuous (at 550 V) [A]	299	355	408	453	504	574
Continuous (at 575 V) [A]	286	339	390	434	482	549
Continuous (at 690 V) [A]	296	352	400	434	482	549
Max. cable size: line power, motor, brake, and load share (mm^2 / AWG[2)])	2x185 (2x350 mcm)					
Max. external electrical fuses [A]	400	500	550	700	700	900
Estimated power loss at 575 V [W] [3)]	3,719	4,460	5,023	5,323	6,010	7,395
Estimated power loss at 690 V [W] [3)]	3,848	4,610	5,150	5,529	6,239	7,653
Weight, enclosure IP20, IP21, IP54 kg [lbs]	125 [275]					
Efficiency [4)]	0.98					
Output frequency [Hz]	0–590		0–525			
Heatsink overtemp. trip °F [°C]	230 [110]				203 [95]	
Power card ambient trip °F [°C]	176 [80]					

Table 3.4 Line Power Supply 3 x 525–690 V AC

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	P630	P710	P800	P900	P1M0	P1M2	P1M4
Normal Load							
Typical Shaft output at 550 V [kW]	500	560	670	750	850	1000	1100
Typical Shaft output at 575 V [hp]	650	750	950	1050	1150	1350	1550
Typical Shaft output at 690 V [kW]	630	710	800	900	1000	1200	1400
Enclosure IP00	E2						
Enclosure IP21	E1	F1/F3	F1/F3	F1/F3	F2/F4	F2/F4	F2/F4
Enclosure IP54	E1	F1/F3	F1/F3	F1/F3	F2/F4	F2/F4	F2/F4
Output current							
Continuous (at 550 V) [A]	630	763	889	988	1108	1317	1479
Intermittent (60 s overload) (at 550 V) [A]	693	839	978	1087	1219	1449	1627
Continuous (at 575/690 V) [A]	630	730	850	945	1060	1260	1415
Intermittent (60 s overload) (at 575/690 V) [kVA]	693	803	935	1040	1166	1386	1557
Continuous kVA (at 550 V) [kVA]	600	727	847	941	1056	1255	1409
Continuous kVA (at 575 V) [kVA]	627	727	847	941	1056	1255	1409
Continuous kVA (at 690 V) [kVA]	753	872	1016	1129	1267	1506	1691
Max. input current							
Continuous (at 550 V) [A]	607	743	866	962	1079	1282	1440
Continuous (at 575 V) [A]	607	711	828	920	1032	1227	1378
Continuous (at 690 V) [A]	607	711	828	920	1032	1227	1378
Max cable size							
Motor (mm²/AWG[2)])	4x240 (4x500 mcm)	8x150 (8x300 mcm)			12x150 (12x300 mcm)		
Line power (mm²/AWG[2)])		8x240 (8x500 mcm)			8x240 (8x500 mcm)		
Load sharing (mm²/AWG[2)])		4x185 (4x350 mcm)			6x185 (6x350 mcm)		
Brake (mm²/AWG[2)])	2x185 (2x350 mcm)						
Max. external electrical fuses [A]	900	1600	1600	1600	1600	2000	2500
Estimated power loss at 575 V [W] [3)]	8209	9500	10872	12316	13731	16190	18536
Estimated power loss at 690 V [W] [3)]	8495	9863	11304	12798	14250	16821	19247
Weight, enclosure IP20, IP21, IP54 kg [lbs]	125 [275]						
Efficiency [4)]	0.98						
Output frequency [Hz]	0–525						
Heatsink overtemp. trip °F [°C]	230 [110]	203 [95]	221 [105]	203 [95]		221 [105]	203 [95]
Power card ambient trip °F [°C]	185 [85]						

Table 3.5 Line Power Supply 3 x 525–690 V AC

1) For type of fuse, consult the Instruction Manual.

2) American Wire Gauge.

3) The typical power loss occurs at normal conditions and is expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (eff2/eff3 border line). Lower efficiency motors add to the power loss in the adjustable frequency drive and the opposite is also true. If the switching frequency is raised from nominal, the power losses rise significantly. LCP and typical control card power consumptions are included. Further options and customer load can add up to 30 W to the losses (though typically only 4 W extra for a fully loaded control card or options for slot A or slot B, each).

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

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Frame size	Description	Maximum weight, kg [lbs]
D5h	D1h ratings+disconnect and/or brake chopper	166 (255)
D6h	D1h ratings+contactor and/or circuit breaker	129 (285)
D7h	D2h ratings+disconnect and/or brake chopper	200 (440)
D8h	D2h ratings+contactor and/or circuit breaker	225 (496)

Table 3.6 D5h–D8h Weights

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3.1.3 12-Pulse Specifications

Line Power Supply 380–480 V AC										
	P315	**P355**	**P400**	**P450**	**P500**	**P560**	**P630**	**P710**	**P800**	**P1M0**
Normal overload 110% for 1 Minute	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Typical Shaft Output [kW] at 400 V	315	355	400	450	500	560	630	710	800	1000
Typical Shaft Output [HP] at 460 V	450	500	550/600	600	650	750	900	1000	1200	1350
IP 21/ NEMA 1	F8/F9				F10/F11				F12/F13	
IP 54 / NEMA 12	F8/F9				F10/F11				F12/F13	
Output Current										
Continuous (at 380–440 V)	600	658	745	800	880	990	1120	1260	1460	1720
Intermittent (60 second overload at 380–440 V)	660	724	820	880	968	1089	1232	1386	1606	1892
Continuous (at 400 V)	416	456	516	554	610	686	776	873	1,012	1,192
Intermittent (60 second overload at 460–500 V)	457	501	568	610	671	754	854	960	1,113	1,311
Continuous (at 441–500 V)	540	590	678	730	780	890	1,050	1,160	1,380	1,530
Intermittent (60 second overload) (at 441–500 V)	594	649	746	803	858	979	1,155	1,276	1,518	1,683
Continuous (at 460 V)	430	470	540	582	621	709	837	924	1,100	1,219
Continuous (at 500 V)	473	517	594	640	684	780	920	1,017	1,209	1,341
Max Input Current										
Continuous (3x380–440v) [A]	590	647	733	787	857	964	1,090	1,227	1,422	1,675
Continuous (3x441–480v) [A]	531	580	667	718	759	867	1,022	1,129	1,344	1,490
Max. external electrical fuses[1)]	700	700	700	700	900	900	900	1,500	1,500	1,500
Max Cable Size:										
Motor (mm^2 /AWG[2)])	8 x 300 MCM (8 x 150)								12 x 300 MCM (8 x 150)	
Line power (mm^2 /AWG[2)])	8 x 500 MCM (8 x 250)									
Regeneration terminals (mm^2/AWG[2)])	4 x 250 MCM (4 x 120)									
Brake (mm^2 /AWG[2)])	2 x 350 MCM (2 x 185)				4 x 350 MCM (4 x 185)					
Estimated Power loss at 400 V AC at rated max. load (W) [3)]	6705	7532	8677	9473	10162	11822	12512	14674	17293	19278
Estimated Power loss at 460 V AC at rated max. load (W) [3)]	6705	6724	7819	8527	8876	10424	11595	13213	16229	16624
F9/F11/F13 Max. additional losses for A1, RFI, CB or disconnect & contactor	682	766	882	963	1054	1093	1230	2280	2236	2541
Weight Enclosure IP21 kg (lb)	263	270	272	313	1004 (2214)				1246 (2747)	
Weight enclosure IP 54 kg (lb)	(580)	(595)	(600)	(690)						
Efficiency[4)]	0.98									
Output Frequency	0–590 Hz									
Heatsink overtemp. trip	230 °F [110 °C]				203 °F [95 °C]					
Power card ambient trip	185 °F [85 °C]									

Table 3.7 Line Power Supply 380–480 V AC

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Line Power Supply 525–690 V AC										
	P450	**P500**	**P560**	**P630**	**P710**	**P800**	**P900**	**P1M0**	**P1M2**	**P1M4**
Normal overload 110% for 1 Minute	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Typical Shaft Output [HP] at 525–550 V	355	400	450	500	560	670	750	850	1000	1100
Typical Shaft Output [kW] at 690	450	500	560	630	710	800	900	1000	1200	1400
Typical Shaft Output [HP] at 575	450	500	600	650	750	950	1050	1150	1350	1550
IP 21/ NEMA 1 at 525 V	F8/F9				F10/F11			F12/F13		
IP 21/ NEMA 1 at 575 V	F8/F9				F10/F11			F12/F13		
IP 21/ NEMA 1 at 690 V	F8/F9				F10/F11			F12/F13		
Output Current										
Continuous (6 x 525–550 V) [A]	470	523	596	630	763	889	988	1108	1317	1479
Intermittent (6 x 550 V)	515	575	656	693	839	978	1087	1219	1449	1627
Continuous (6 x 551–690 V) [A]	450	500	570	630	730	850	945	1060	1260	1415
Intermittent (6 x 551–690 V) [A]	495	550	627	693	803	935	1040	1166	1386	1557
Continuous KVA (550 V) [KVA]	448	498	568	600	727	847	941	1056	1255	1409
Continuous KVA (575 V) [KVA]	448	498	568	627	727	847	941	1056	1255	1409
Continuous KVA (690 V) [KVA]	538	598	681	753	872	1016	1129	1267	1506	1691
Max Input Current										
Continuous (6 x 550v) [A]	453	504	574	607	743	866	962	1079	1282	1440
Continuous (6 x 575v) [A]	434	482	549	607	711	828	920	1032	1227	1378
Continuous (6 x 690 V) [A]	434	482	549	607	711	828	920	1032	1227	1378
Max. external electrical fuses[1)]	630	630	630	630	900	900	900	1600	2000	2500
Max Cable Size:										
Motor (mm^2 /AWG[2)])	8 x 300 MCM (8 x 150)							12 x 300 MCM (12 x 150)		
Line power (mm^2 /AWG[2)])	8 x 500 MCM (8 x 250)									
Regeneration terminals (mm^2/AWG[2)])	4 x 250 MCM (4 x 120)									
Brake (mm^2 /AWG[2)])	4 x 350 MCM (4 x 185)									
Estimated Power loss at 690 V AC at rated max. load (W) [3)]	4974	5623	7018	7793	8933	10310	11692	12909	15358	17602
Estimated Power loss at 575 V AC at rated max. load (W) [3)]	5128	5794	7221	8017	9212	10659	12080	13305	15865	18173
Weight Enclosure IP21 kg (lb)	440/656 (970/1446)			880/1096 (1940/2416)				1022/1238 (2253/2729)		
Weight enclosure IP 54 kg (lb)										
Efficiency[4)]	0.98									
Output Frequency	0–525 Hz									
Heatsink overtemp trip	230 °F [110 °C]				203 °F [95 °C]	221 °F [105 °C]	203 °F [95 °C]	203 °F [95 °C]	221 °F [105 °C]	203 °F [95 °C]
Power card ambient trip	185 °F [85 °C]									

Table 3.8 Line Power Supply 525–690 V AC

1) For type of fuse, consult the Instruction Manual

2) American Wire Gauge

3) The typical power loss is at normal conditions and expected to be within +/- 15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (eff2/eff3 border line). Lower efficiency motors add to the power loss in the adjustable frequency drive and the opposite is also true. If the switching frequency is raised from nominal, the power losses rise significantly. LCP and typical control card power consumptions are included. Further options and customer load can add up to 30 W to the losses (though typically only 4 W extra for a fully loaded control card or options for slot A or slot B, each)

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

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Protection and Features

- Electronic thermal motor protection against overload.
- Temperature monitoring of the heatsink ensures that the adjustable frequency drive trips when the temperature reaches 203 °F ± 10 °F [95 °C ± 5 °C]. An overload temperature cannot be reset until the temperature of the heatsink is below 158 °F ± 10 °F [70 °C ± 5 °C] (Guideline - these temperatures vary for different power sizes and enclosures). VLT® AQUA Drive has an auto derating function to prevent its heatsink reaching 203 °F [95 °C].
- 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 high.
- The adjustable frequency drive is protected against ground faults on motor terminals U, V, W.

Line power supply

Supply terminals (6-pulse)	L1, L2, L3
Supply terminals (12-pulse)	L1-1, L2-1, L3-1, L1-2, L2-2, L3-2
Supply voltage	380–480 V ±10%
Supply voltage	525–600 V ±10%
Supply voltage	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 lowest rated supply voltage. Power-up and full torque cannot be expected at AC line voltage lower than 10% below the lowest rated supply voltage.

Supply frequency	50/60 Hz +4/-6%

The adjustable frequency drive power supply is tested in accordance with IEC61000-4-28, 50 Hz +4/-6%.

Max. temporary imbalance between line phases	3.0% of rated supply voltage
True Power Factor (λ)	≥ 0.9 nominal at rated load
Displacement Power Factor (cosφ) near unity	(> 0.98)
Switching on input supply L1, L2, L3 (power-ups) ≥ enclosure type D, E, F	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, 480/600 V maximum.

Motor output (U, V, W)

Output voltage	0–100 % of supply voltage
Output frequency	0–590 Hz
Switching on output	Unlimited
Ramp times	1–3600 s

Torque characteristics

Starting torque (Constant torque)	maximum 110% for 1 minute*
Starting torque	maximum 135% up to 0.5 s*
Overload torque (Constant torque)	maximum 110% for 1 minute*

**Percentage relates to nominal torque of VLT AQUA Drive.*

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Cable lengths and cross-sections

Max. motor cable length, shielded/armored	500 ft [150 m]
Max. motor cable length, non-shielded/unarmored	985 ft [300 m]
Max. cross-section to motor, line power, load sharing, and brake *	
Maximum cross-section to control terminals, rigid wire	1.5 mm^2/16 AWG (2 x 0.75 mm^2)
Maximum cross-section to control terminals, flexible cable	1 mm^2/18AWG
Maximum cross-section to control terminals, cable with enclosed core	0.5 mm^2/20AWG
Minimum cross-section to control terminals	0.00039 in^2 [0.25 mm^2]

** See chapter 3.1 General Specifications for more information!*

Control card, RS-485 serial communication

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

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

Analog inputs

Number of analog inputs	2
Terminal number	53, 54
Modes	Voltage or current
Mode select	Switch S201 and switch S202
Voltage mode	Switch S201/switch S202 = OFF (U)
Voltage level	0 to + 10 V (scaleable)
Input resistance, R_i	approx. 10 kΩ
Max. voltage	± 20 V
Current mode	Switch S201/switch S202 = ON (I)
Current level	0/4 to 20 mA (scaleable)
Input resistance, R_i	approx. 200 Ω
Max. current	30 mA
Resolution for analog inputs	10 bit (+ sign)
Accuracy of analog inputs	Max. error 0.5% of full scale
Bandwidth	200 Hz

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

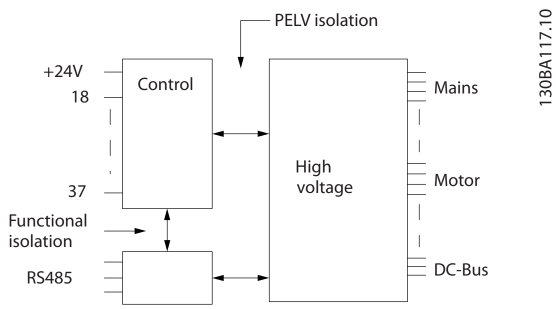

Figure 3.1 PELV Isolation of Analog Inputs

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Analog output	
Number of programmable analog outputs	1
Terminal number	42
Current range at analog output	0/4–20 mA
Max. resistor load to common at analog output	500 Ω
Accuracy on analog output	Max. error: 0.8% of full scale
Resolution on analog output	8 bit

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

Digital inputs	
Programmable digital inputs	4 (6)
Terminal number	18, 19, 27 [1)], 29 [1)], 32, 33,
Logic	PNP or NPN
Voltage level	0–24 V DC
Voltage level, logic'0' PNP	< 5 V DC
Voltage level, logic'1' PNP	> 10 V DC
Voltage level, logic '0' NPN	> 19 V DC
Voltage level, logic '1' NPN	< 14 V DC
Maximum voltage on input	28 V DC
Input resistance, R_i	approx. 4 kΩ

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

Digital output	
Programmable digital/pulse outputs	2
Terminal number	27, 29 [1)]
Voltage level at digital/frequency output	0–24 V
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.

Pulse inputs	
Programmable pulse inputs	2
Terminal number pulse	29, 33
Max. frequency at terminal, 29, 33	110 kHz (push-pull driven)
Max. frequency at terminal, 29, 33	5 kHz (open collector)
Min. frequency at terminal 29, 33	4 Hz
Voltage level	see 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

Control card, 24 V DC output	
Terminal number	12, 13
Max. load	200 mA

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

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Relay outputs

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

1) IEC 60947 parts 4 and 5
The relay contacts are galvanically isolated from the rest of the circuit by reinforced isolation (PELV).
2) Overvoltage Category II
3) UL applications 300 V AC 2A

Control card, 10 V DC output

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

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

Control characteristics

Resolution of output frequency at 0–590 Hz	±0.003 Hz
System response time (terminals 18, 19, 27, 29, 32, 33)	≤ 2 ms
Speed control range (open-loop)	1:100 of synchronous speed
Speed accuracy (open-loop)	30–4000 rpm: Maximum error of ±8 rpm

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

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Surroundings	
Enclosure type D1h/D2h/E1/E2	IP00/chassis
Enclosure type D3h/D4h	IP20/chassis
Enclosure type D1h/D2h, E1, F1-F4, F8-F13	IP21/Type 1, IP54/Type 12
Vibration test enclosure D/E/F	1 g
Maximum relative humidity	5%–95% (IEC 721-3-3; Class 3K3 (non-condensing) during operation
Aggressive environment (IEC 721-3-3), coated	class 3C3
Test method according to IEC 60068-2-43 H2S (10 days)	
Ambient temperature (at 60 AVM switching mode)	Max. 113 °F [45 °C]
Maximum ambient temperature with reduced load	167 °F [55 °C]

Derating for high ambient temperature, see chapter 3.5 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 without derating	3300 ft [1000 m]
Maximum altitude above sea level with derating	10000 ft [3000 m]

Derating for high altitude, see chapter 3.5 Special Conditions

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

See chapter 3.5 Special Conditions for more information.

Control card performance	
Scan interval	5 ms

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

CAUTION

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

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3.2 Efficiency

Efficiency of the adjustable frequency drive (η_{DRIVE})
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%, in case of part loads.

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 slightly when the switching frequency is set to a value of above 5 kHz. The efficiency is slightly reduced when the AC line voltage is 480 V, or if the motor cable is longer than 100 ft [30 m].

Adjustable frequency drive efficiency calculation
Calculate the efficiency of the adjustable frequency drive at different speeds and loads based on *Figure 3.2*. The factor in this graph must be multiplied with the specific efficiency factor listed in the specification tables in *chapter 3.1.1 Line Power Supply 3x380–480 V AC* and *chapter 3.1.2 Line Power Supply 3 x 525–690 V AC*.

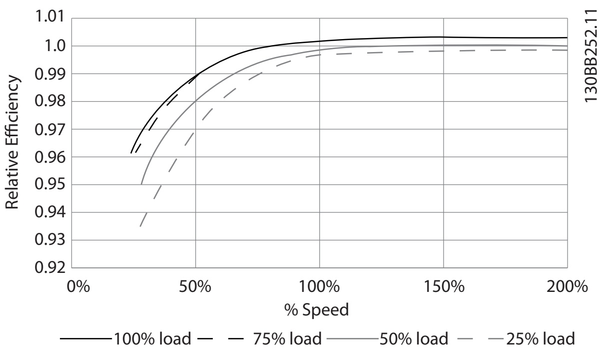

Figure 3.2 Typical Efficiency Curves

Example: Assume a 160 kW, 380–480 V AC adjustable frequency drive at 25% load at 50% speed. *Figure 3.2* shows 0.97 - rated efficiency for a 160 kW adjustable frequency drive is 0.98. The actual efficiency is then: 0.97x 0.98=0.95.

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

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

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

In general, the switching frequency does not affect the efficiency of small motors. Motors from 15 hp [11 kW] and up have their efficiency improved (1–2%) because the shape of the motor current sine wave 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_{DRIVE}) is multiplied by the efficiency of the motor (η_{MOTOR}):
$\eta_{SYSTEM} = \eta_{DRIVE} \times \eta_{MOTOR}$

3.3 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 3.3 ft. [1 m] from the unit:

Enclosure	**Full fan speed** [dBA]
N110	71
N132	71
N160	72
N200	74
N250	75
N315	73
E1/E2 *	74
E1/E2 **	83
F1/F2/F3/F4	80
F8/F9/F10/F11/F12/F13	84.5
* 450 hp [315 kW], 380–480 V AC. 600 hp [450 kW] and 650 hp [500 kW], 525–690 V AC only. ** Remaining E1+E2 power sizes.	

Table 3.9 Acoustic Noise Levels

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3.4 Peak Voltage on Motor

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

- the motor cable (type, cross-section, length, shielded or non-shielded)
- 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 (330 ft [100 m]), the rise time and peak voltage increases.

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

To obtain approximate values for cable lengths and voltages not mentioned here, use the following rules of thumb:

1. Rise time increases/decreases proportionally with cable length.
2. U_{PEAK} = DC link voltage x 1.9
   (DC link voltage = AC line voltage x 1.35).
3. $dU/dt = \frac{0.8 \times UPEAK}{Risetime}$

Data are measured according to IEC 60034-17.
Cable lengths are in meters.

Cable Length Specifications:

Adjustable frequency drive N110 - N315, T4/380–500 V				
Cable length (ft [m])	**AC line voltage [V]**	**Rise time [μsec]**	**Vpeak [kV]**	**dU/dt [kV/μsec]**
100 [30]	400	0.26	1.180	2.109

Table 3.10 N110 - N315, T4/380–500 V

Adjustable frequency drive P400 - P1M0, T4/380–500 V				
Cable length (ft [m])	**AC line voltage [V]**	**Rise time [μsec]**	**Vpeak [kV]**	**dU/dt [kV/μsec]**
100 [30]	500	0.71	1.165	1.389
100 [30]	400	0.61	0.942	1.233
100 [30]	500 [1]	0.80	0.906	0.904
100 [30]	400 [1]	0.82	0.760	0.743

Table 3.11 P400 - P1M0, T4/380–500 V

1) With Danfoss dU/dt filter.

N110-N160, T7 (525–690 V)				
Cable length (ft [m])	**AC line voltage [V]**	**Rise time [μsec]**	**Vpeak [kV]**	**dU/dt [kV/μsec]**
500 [150]	690	0.36	2135	2.197

Table 3.12 N110-N160, T7 (525–690 V)

N200-N400, T7 (525–690 V)				
Cable length (ft [m])	**AC line voltage [V]**	**Rise time [μsec]**	**Vpeak [kV]**	**dU/dt [kV/μsec]**
500 [150]	690	0.46	2210	1.744

Table 3.13 N200-N400, T7 (525–690 V)

Adjustable frequency drive P450 - P1M4, T7/525–690 V				
Cable length (ft [m])	**AC line voltage [V]**	**Rise time [μsec]**	**Vpeak [kV]**	**dU/dt [kV/μsec]**
100 [30]	690	0.57	1.611	2.261
100 [30]	575	0.25		2.510
100 [30]	690 [1)]	1.13	1.629	1.150

Table 3.14 P450 - P1M4, T7/525–690 V

1) With Danfoss dU/dt filter.

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3.5 Special Conditions

3.5.1 Purpose of Derating

Consider derating when using the adjustable frequency drive at low air pressure (heights), at low speeds, with long motor cables, cables with a large cross-section or at high ambient temperature. The required action is described in this section.

3.5.2 Derating for Low Air Pressure

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

Below 3,300 ft [1,000 m] altitude, no derating is necessary but above 3,300 ft [1,000 m], the ambient temperature (T_{AMB}) or max. output current (I_{out}) derate in accordance with

An alternative is to lower the ambient temperature at high altitudes and 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.

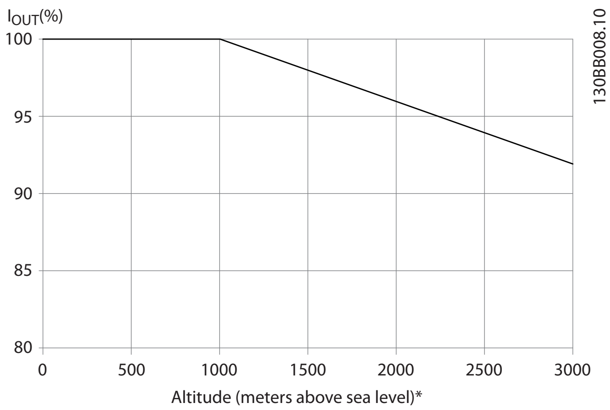

Figure 3.3 Derating of Output Current Versus Altitude at $T_{AMB, MAX}$

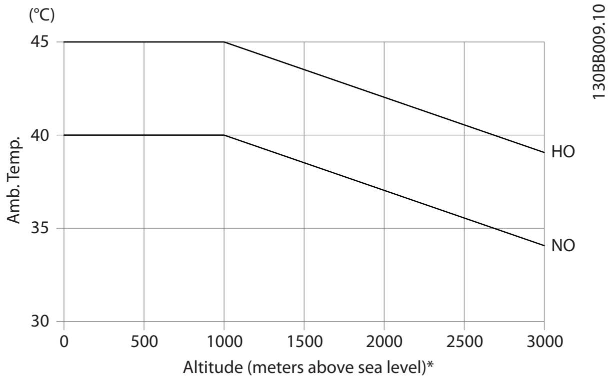

Figure 3.4 Derating of Output Current Versus Altitude at $T_{AMB, MAX}$

3.5.3 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)

In constant torque applications, it is possible for a motor to draw full current while operating at slow speeds. In such cases, the cooling fins do not adequately cool the motor, causing it to overheat. When the motor is operating continuously at less than half its rated speed, apply more cooling.

Alternately, an oversized motor can be used to reduce the load level. However, the size of the motor is limited to one size larger than that specified by the adjustable frequency drive.

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.

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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 more cooling or derating of the motor.

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

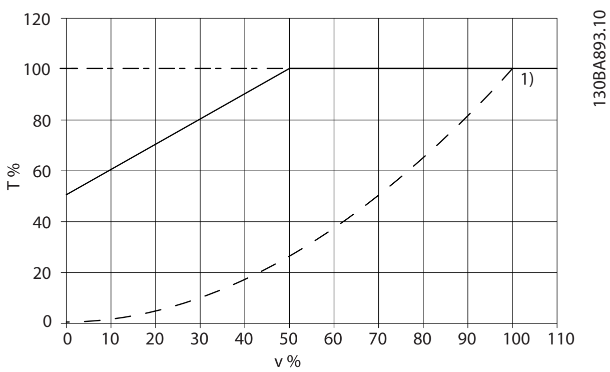

Figure 3.5 Maximum Load for a Standard Motor at 104 °F [40 °C]

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

Table 3.15 Legend to *Figure 3.5*

NOTICE!

Oversynchronous speed operation results in the available motor torque decreasing inversely proportional with the increase in speed. Consider this decrease during the design phase to avoid overloading the motor.

3.5.4 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 adjustable frequency drive. The capability to reduce the output current automatically extends the acceptable operating conditions even further.

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3.5.5 Derating for Ambient Temperature

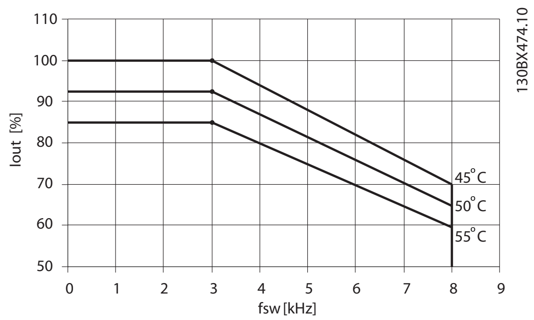
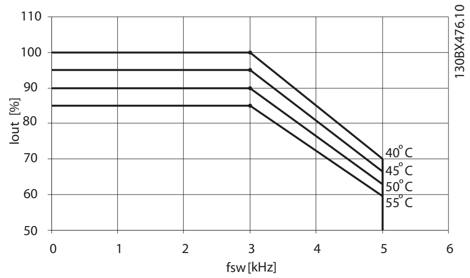
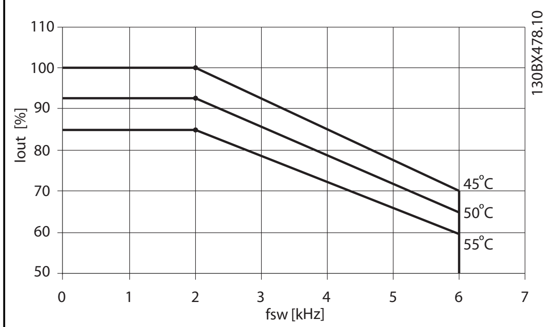
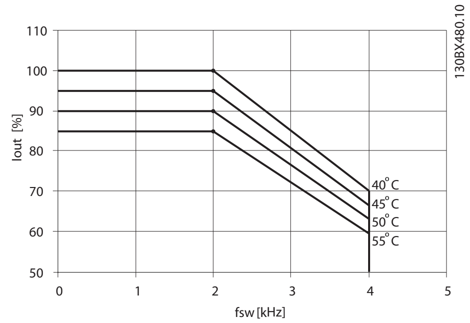
Frame model	Normal overload NO, 110% 60 AVM	Normal overload NO, 110% SFAVM
D-Frame N110 to N315 380–500 V		
E & F-Frame P355 to P1M0 380–500 V		

Table 3.16 Derating Tables for Adjustable Frequency Drives Rated 380–500 V (T5)

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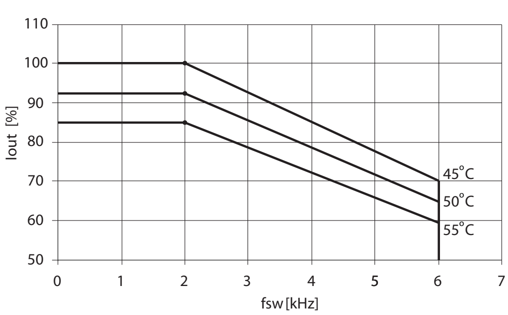
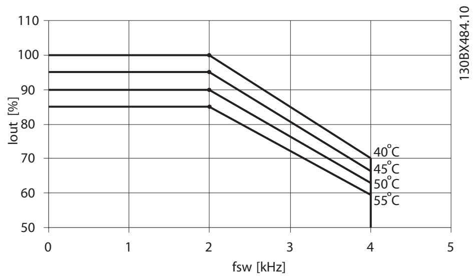
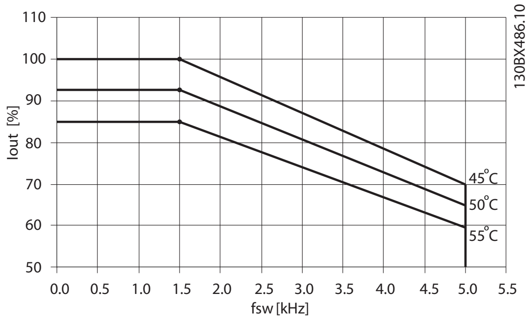
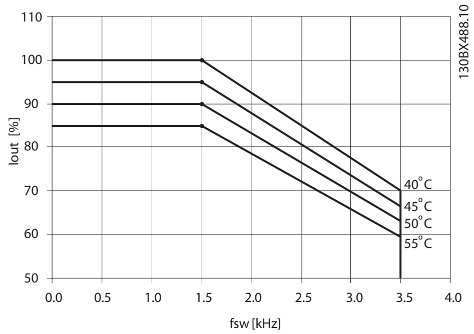
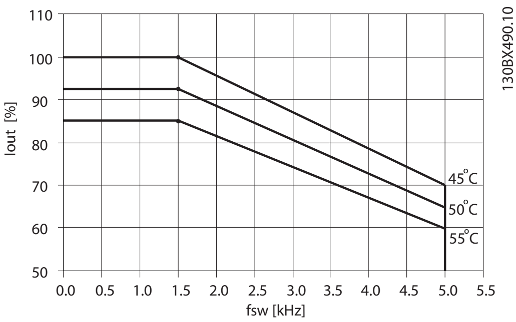
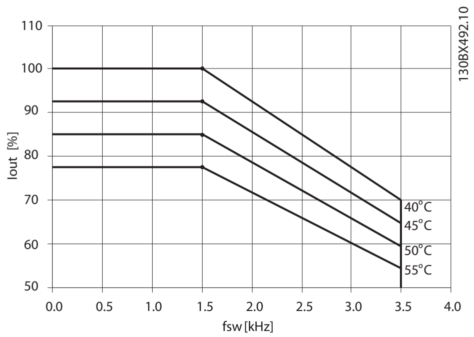
Frame model	Normal overload NO, 110% 60 AVM	Normal overload NO, 110% SFAVM
D-Frame **N110 to N315** **525–690 V**		
D-Frame **N400** **525–690 V**		
E & F-Frame **P450 to P1M0** **525–690 V**		

Table 3.17 Derating Tables for Adjustable Frequency Drives Rated 525–690 V (T7)

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3.6 Options and Accessories

Danfoss offers a wide range of options and accessories for adjustable frequency drives.

3.6.1 General Purpose Input Output Module MCB 101

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

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

- MCB 101 option module
- Extended LCP frame
- Terminal cover

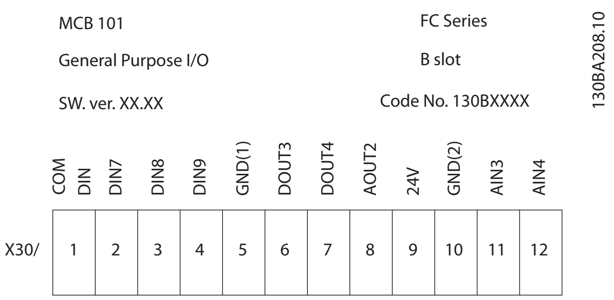

Figure 3.6 MCB 101

Galvanic isolation in the MCB 101
If using the internal 24 V power supply (terminal 9) to switch digital inputs 7, 8 or 9, establish the connection between terminal 1 and 5, which is illustrated in *Figure 3.7*.

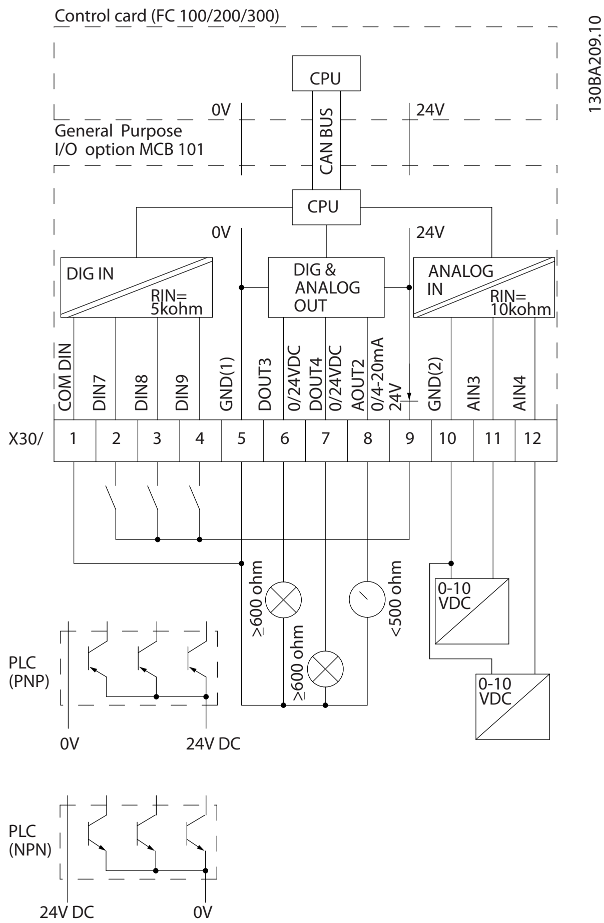

Figure 3.7 Principle Diagram

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3.6.2 Digital Inputs - Terminal X30/1-4

Parameters for set-up: 5–16, 5–17 and 5–18				
Number of digital inputs	Voltage level	Voltage levels	Tolerance	Max. Input impedance
3	0–24 V DC	PNP type: Common = 0V Logic “0”: Input < 5 V DC Logic “0”: Input > 10 V DC NPN type: Common = 24 V Logic “0”: Input > 19 V DC Logic “0”: Input < 14 V DC	± 28 V continuous ± 37 V in minimum 10 sec.	Approx. 5 kΩ

Table 3.18 Digital Inputs - Terminal X30/1-4

3.6.3 Analog Voltage Inputs - Terminal X30/10-12

Parameters for set-up: 6–3*, 6–4* and 16–76				
Number of analog voltage inputs	Standardized input signal	Tolerance	Resolution	Max. Input impedance
2	0–10 V DC	± 20 V continuously	10 bits	Approx. 5 KΩ

Table 3.19 Analog Voltage Inputs - Terminal X30/10-12

3.6.4 Digital Outputs - Terminal X30/5-7

Parameters for set-up: 5–32 and 5–33			
Number of digital outputs	Output level	Tolerance	Max. impedance
2	0 V or 2 V DC	± 4 V	≥ 600 Ω

Table 3.20 Digital Outputs - Terminal X30/5-7

3.6.5 Analog Outputs - Terminal X30/5+8

Parameters for set-up: 6–6* and 16–77			
Number of analog outputs	Output signal level	Tolerance	Max. impedance
1	0/4–20 mA	± 0.1 mA	< 500 Ω

Table 3.21 Analog Outputs - Terminal X30/5+8

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3.6.6 Relay Option MCB 105

The MCB 105 option includes three SPDT contacts and must be fitted into option slot B.

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

Table 3.22 Electrical Data

[1)] *IEC 947 part 4 and 5*

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

- Relay Module MCB 105
- Extended LCP frame and enlarged terminal cover
- Label for covering access to switches S201, S202, and S801
- Cable strips for fastening cables to relay module

How to add the MCB 105 option:

- See the mounting instructions at the beginning of the section Options and Accessories.
- The power to the live part connections on relay terminals must be disconnected.
- Do not mix live parts with control signals (PELV).
- Select the relay functions in *5-40 Function Relay* [6–8], *5-41 On Delay, Relay* [6–8] and *5-42 Off Delay, Relay* [6–8].

(Index [6] is relay 7, index [7] is relay 8, and index [8] is relay 9)

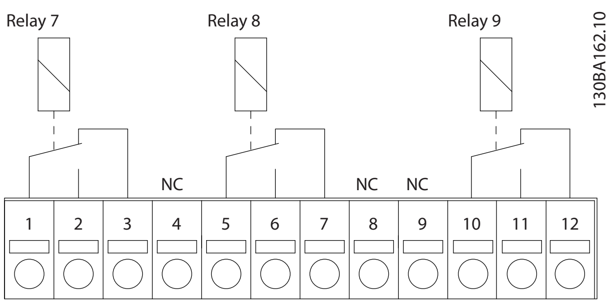

Figure 3.8 Wiring the Terminals

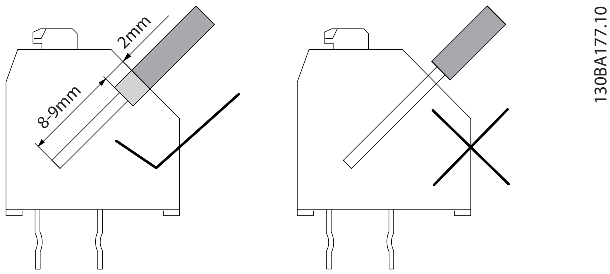

Figure 3.9 Wiring the Terminals

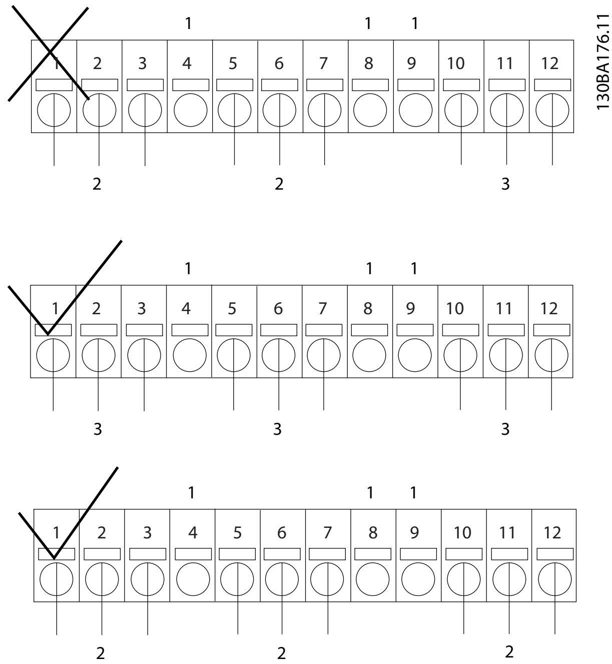

Figure 3.10 1) NC
2) Live part
3) PELV

⚠WARNING

Do not combine low voltage parts and PELV systems. At a single fault, the whole system can become dangerous to touch and it could result in death or serious injury.

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3.6.7 24 V Backup Option MCB 107 (Option D)

External 24 V DC Supply

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

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

Table 3.23 External 24 V DC Supply Specifications

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 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 supplies the control circuit, the internal 24 V supply is automatically disconnected.

3.6.8 Analog I/O option MCB 109

The Analog I/O card is supposed to be used in the following cases:

- For providing a battery backup of the clock function on the control card
- As a general extension of the analog I/O selection available on the control card, for example, for multi-zone control with three pressure transmitters
- To turn an adjustable frequency drive into a decentral I/O block for supporting a building management system with inputs for sensors and outputs for operating dampers and valve actuators
- To support Extended PID controllers with I/Os for setpoint inputs, transmitter/sensor inputs, and outputs for servos.transmitter/sensor inputs

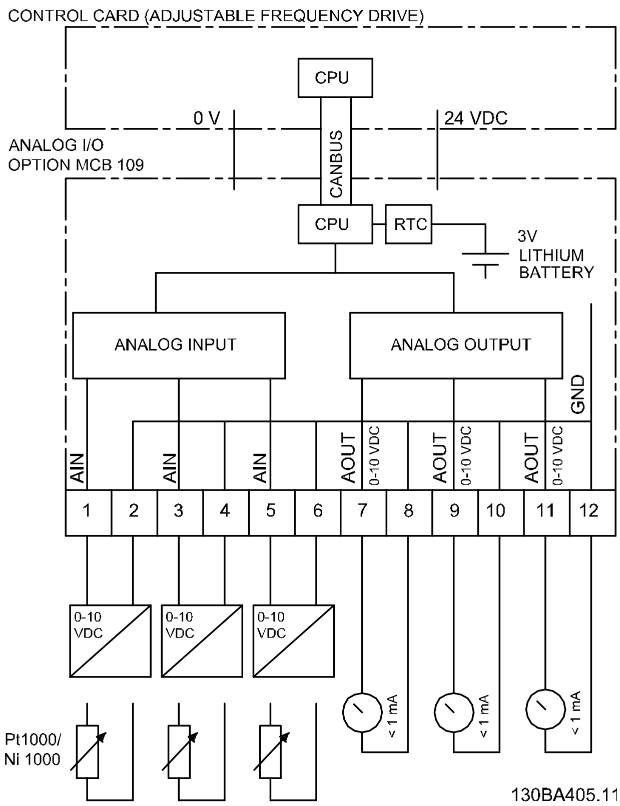

Figure 3.11 Principle Diagram for Analog I/O Mounted in the Adjustable Frequency Drive

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Analog I/O configuration
3 x analog inputs, capable of handling following:

- 0–10 V DC

OR

- 0–20 mA (voltage input 0–10 V) by mounting a 510 Ω resistor across terminals (see NOTE)
- 4–20 mA (voltage input 2–10 V) by mounting a 510 Ω resistor across terminals (see NOTE)
- Ni1000 temperature sensor of 1,000 Ω at 32 °F [0 °C]. Specifications according to DIN43760
- Pt1000 temperature sensor of 1,000Ω at 32 °F [0 °C]. Specifications according to IEC 60751

3 x Analog Outputs supplying 0–10 V DC.

NOTICE!

Note the values available within the different standard groups of resistors:
E12: Closest standard value is 470 Ω, creating an input of 449.9 Ω and 8.997 V.
E24: Closest standard value is 510 Ω, creating an input of 486.4 Ω and 9.728 V.
E48: Closest standard value is 511 Ω, creating an input of 487.3 Ω and 9.746 V.
E96: Closest standard value is 523 Ω, creating an input of 498.2 Ω and 9.964 V.

Analog inputs - terminal X42/1-6
Parameter group for read out: *18-3* Analog Readouts*. For more information, consult the Programming Guide.

Parameter groups for set-up: *26-0* Analog I/O Mode, 26-1* Analog Input X42/1, 26-2* Analog Input X42/3 and 26-3* Analog Input X42/5*. For more information, consult the Programming Guide.

3 x analog inputs	Operating range	Resolution	Accuracy	Sampling	Max load	Impedance
Used as temperature sensor input	-58 °F to +302 °F [-50 °C to +150 °C]	11 bits	-58 °F [-50 °C] ±1 °K 302 °F [+150 °C] ±2 °K	3 Hz	-	-
Used as voltage input	0–10 V DC	10 bits	0.2% of full scale at cal. temperature	2.4 Hz	+/- 20 V continuously	Approximately 5 kΩ

Table 3.24 Analog Inputs

When used for voltage, analog inputs are scalable by parameters for each input.

When used for temperature sensor, analog inputs scaling is preset to necessary signal level for specified temperature span.

When analog inputs are used for temperature sensors, it is possible to read out the feedback value in both °C and °F.

When operating with temperature sensors, maximum cable length to connect sensors is 270 ft [82 m] non-shielded/non-twisted wires.

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Analog outputs - terminal X42/7-12
Parameter group for reading out and writing: 18-3*. For more information, consult the Programming Guide.
Parameter groups for set-up: *26-4* Analog Out X42/7, 26-5* Analog Out X42/9 and 26-6* Analog Out X42/11*. For more information, consult the Programming Guide.

3 x analog outputs	Output signal level	Resolution	Linearity	Max load
Volt	0–10 V DC	11 bits	1% of full scale	1 mA

Table 3.25 Analog Outputs

Analog outputs are scalable by parameters for each output.
The function assigned is selectable via a parameter and has the same options as for analog outputs on the control card.

For a more detailed description of parameters, refer to the Programming Guide.

Real-time clock (RTC) with backup
The data format of RTC includes year, month, date, hour, minutes, and weekday.
Accuracy of clock is better than ± 20 ppm at 77 °F [25 °C].

The built-in lithium backup battery lasts on average for minimum 10 years, when the adjustable frequency drive is operating at 104 °F [40 °C] ambient temperature. If the battery backup pack fails, the analog I/O option must be replaced.

Cascade control is a common control system used to control parallel pumps or fans in an energy-efficient way.

The cascade controller option provides the capability to control multiple pumps configured in parallel in a way that makes them appear as a single larger pump.

To satisfy the required system output for flow or pressure when using cascade controllers, the individual pumps are automatically turned on (staged) and turned off (de-staged) as needed. The speed of pumps connected to VLT® AQUA Drive FC 202 is also controlled to provide a continuous range of system output.

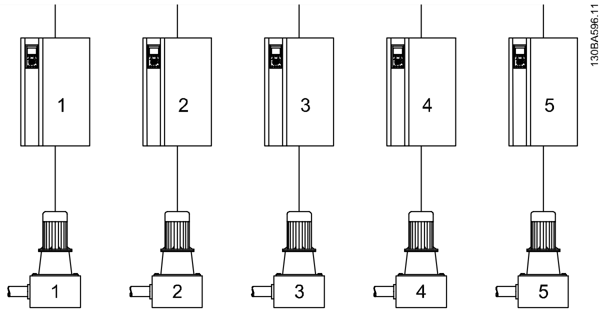

Figure 3.12 Cascade Control of Multiple Pumps

The cascade controllers are optional hardware and software components that can be added to the VLT® AQUA Drive FC 202. It consists of an option board containing three relays that is installed in the B option location on the drive. Once options are installed, the parameters to support the cascade controller functions are available through the control panel in parameter group *27-** Extended Cascade Control*. The extended cascade controller offers more functionality than the basic cascade controller. It can be used to extend the basic cascade with three relays and even to eight relays with the advanced cascade control card installed.

While the cascade controller is designed for pumping applications and this document describes the cascade controller for this application, it is also possible to use the cascade controllers for any application requiring multiple motors configured in parallel.

Master/follower operation
The cascade controller software runs from a single VLT AQUA Drive with the cascade controller option card installed. This adjustable frequency drive is referred to as the master drive. It controls a set of pumps each controlled by an adjustable frequency drive or connected directly to line power through a contactor or through a soft starter.

Each additional adjustable frequency drive in the system is referred to as a follower drive. These adjustable frequency drives do not need the cascade controller option card installed. They are operated in open-loop mode and receive their speed reference from the master drive. The pumps connected to these adjustable frequency drives are referred to as variable-speed pumps.

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Each additional pump connected to line power through a contactor or through a soft starter is referred to as a fixed-speed pump.

Each pump, variable-speed or fixed-speed, responds to a relay in the master drive. The adjustable frequency drive with the cascade controller option card installed has five relays available for controlling pumps. Two relays are standard in the adjustable frequency drive and an additional three relays are found on the option card MCO 101 or eight relays and seven digital inputs on option card MCO 102.

The cascade controller can control a mix of variable-speed and fixed-speed pumps. Possible configurations are described in more detail in *chapter 3.6.9 General Description*. For simplicity of description within this manual, pressure and flow are used to describe the variable output of the set of pumps controlled by the cascade controller.

3.6.9 General Description

The cascade controller software runs from a single VLT® AQUA Drive FC 202 with the cascade controller option card installed. This adjustable frequency drive is referred to as the master drive. It controls a set of pumps each controlled by an adjustable frequency drive or connected directly to line power through a contactor or through a soft starter.

Each additional adjustable frequency drive in the system is referred to as a follower drive. These adjustable frequency drives do not need the cascade controller option card installed. They are operated in open-loop mode and receive their speed reference from the master drive. The pumps connected to these adjustable frequency drives are referred to as variable-speed pumps

Each additional pump connected to line power through a contactor or through a soft starter is referred to as a fixed-speed pump.

Each pump, variable-speed or fixed-speed, responds to a relay in the master drive. The adjustable frequency drive with the cascade controller option card installed has five relays available for controlling pumps. Two relays are standard in the adjustable frequency drive and an additional three relays are found on the option card MCO 101 or eight relays and seven digital inputs on option card MCO 102.

The cascade controller can control a mix of variable-speed and fixed-speed pumps. Possible configurations are described in more detail in the next section. For simplicity of description within this manual, pressure and flow are used to describe the variable output of the set of pumps controlled by the cascade controller.

3.6.10 Extended Cascade Controller MCO 101

The MCO 101 option includes three change-over contacts and can be inserted into option slot B.

Maximum terminal load (AC)	240 V AC 2 A
Maximum terminal load (DC)	24 V DC 1 A
Minimum terminal load (DC)	5 V 10 mA
Maximum switching rate at rated load/min load	6 min^{-1}/20 s^{-1}

Table 3.26 Electrical Data

WARNING

Warning Dual supply

NOTICE!

Place the label on the LCP frame as shown (UL-approved).

How to add the MCO 101 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 cradle from the FC 202.
- Fit the MCO 101 option in slot B.
- Connect the control cables and fasten the cables by the enclosed cable strips.
- Various systems must not be mixed.
- Fit the extended cradle and terminal cover.
- Replace the LCP.
- Connect power to the adjustable frequency drive.

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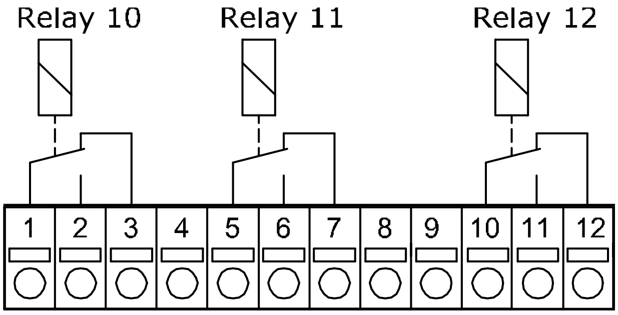

Figure 3.13 Wiring the Terminals

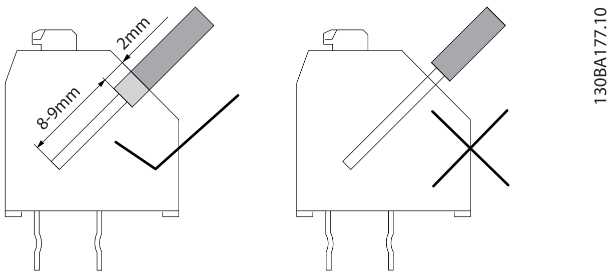

Figure 3.14 Wiring the Terminals

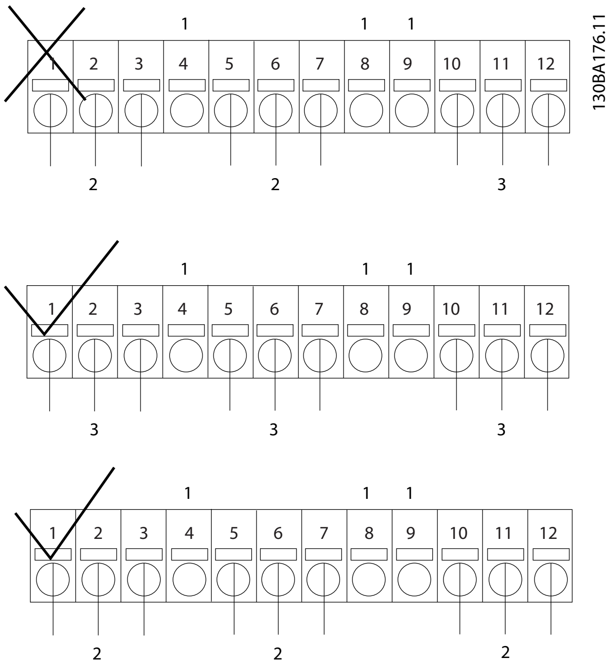

Figure 3.15 Terminals

1	NC
2	Live part
3	PELV

Table 3.27 Legend to *Figure 3.15*

WARNING

Do not combine low voltage parts and PELV systems.

3.6.11 Brake Resistors

In applications where the motor is used as a brake, energy is generated in the motor and sent back into the adjustable frequency drive. If the energy cannot be transported back to the motor, it increases the voltage in the drive DC line. In applications with frequent braking and/or high inertia loads, this increase leads to an overvoltage trip in the drive and finally a shutdown. Brake resistors are used to dissipate the excess energy resulting from the regenerative braking. The resistor is selected in respect to its ohmic value, its power dissipation rate, and its physical size. Danfoss offers a wide variety of different resistors that are specially designed to our adjustable frequency drives. See *chapter 2.13 Control with Brake Function* for the dimensioning of brake resistors. Code numbers can be found in *chapter 4 How to Order*.

3.6.12 Remote Mounting Kit for LCP

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

Enclosure	**IP66 front**
Max. cable length between and unit	10 ft [3 m]
Communication std	RS-485

Table 3.28 Technical Data

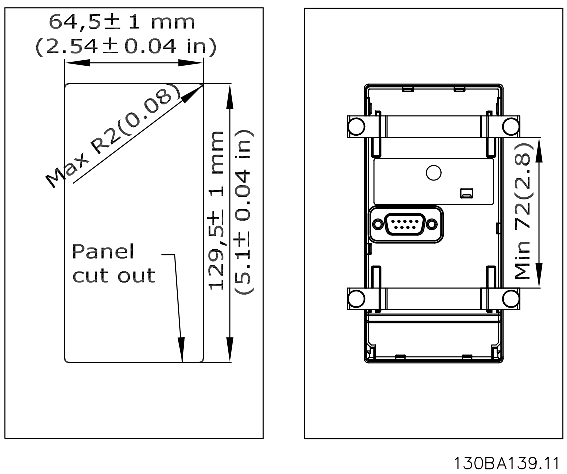

Figure 3.16

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LCP Kits

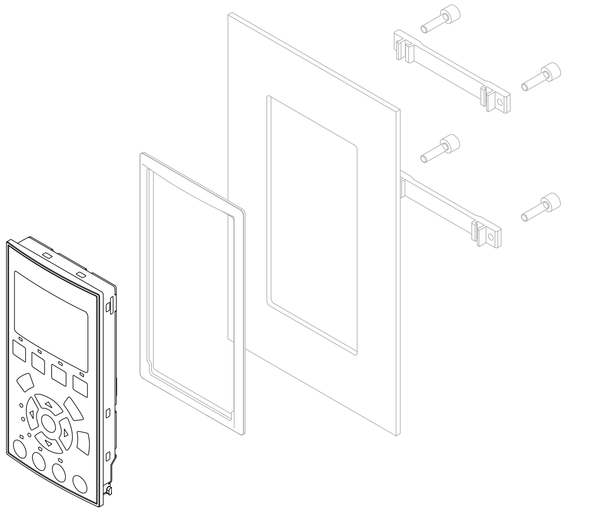

Figure 3.17 LCP kit with graphical LCP, fasteners, 10 ft [3 m] cable, and gasket.
Ordering No. 130B1113

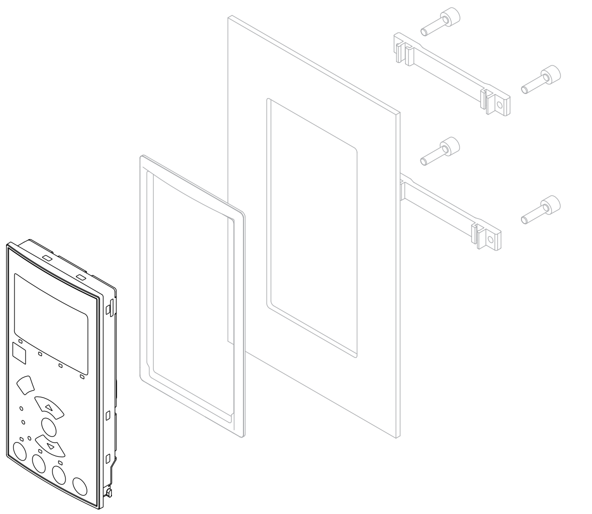

Figure 3.18 LCP kit with numerical LCP, fasteners, and gasket.
Ordering No. 130B1114

3.6.13 Input Filters

The 6-pulse diode rectifier causes the harmonic current distortion. The harmonic currents affect the installed serial equipment identical to reactive currents. Consequently, harmonic current distortion can result in overheating of the supply transformer, cables and so on. Depending on the impedance of the power grid, harmonic current distortion can lead to voltage distortion also affecting other equipment powered by the same transformer. Voltage distortion is increasing losses, causes premature aging and worst of all erratic operation. The built-in DC coil reduces most harmonics, but if more reduction is needed, Danfoss offers two types of passive filters.

The Danfoss AHF 005 and AHF 010 are advanced harmonic filters, not to be compared with traditional harmonic trap filters. The Danfoss harmonic filters have been specially designed to match the Danfoss adjustable frequency drives.

AHF 010 is reducing the harmonic currents to less than 10% and the AHF 005 is reducing harmonic currents to less than 5% at 2% background distortion and 2% imbalance.

3.6.14 Output Filters

The high-speed switching of the adjustable frequency drive produces some secondary effects, which influence the motor and the enclosed environment. Two different filter types, the dU/dt and the sine-wave filters, are in place to address these side effects.

dU/dt filters
The combination of rapid voltage and current increase cause motor insulation stresses. The rapid energy changes can also be reflected back to the DC line in the inverter and cause shutdown. The dU/dt filter is designed to reduce the voltage rise time/the rapid energy change in the motor and by that intervention avoid premature aging and flashover in the motor insulation. dU/dt filters have a positive influence on the radiation of magnetic noise in the cable that connects the adjustable frequency drive to the motor. The voltage wave form is still pulse shaped, but the dU/dt ratio is reduced in comparison with the installation without filter.

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Sine-wave filters
Sine-wave filters are designed to allow only low frequencies to pass. High frequencies are shunted away which results in a sinusoidal phase to phase voltage waveform and sinusoidal current waveforms.
With the sinusoidal waveforms, the use of special adjustable frequency drive motors with reinforced insulation is no longer needed. The acoustic noise from the motor is also damped as a consequence of the wave condition.
Besides the features of the dU/dt filter, the sine-wave filter also reduces insulation stress and bearing currents in the motor thus leading to prolonged motor lifetime and longer periods between services. Sine-wave filters enable use of longer motor cables in applications where the motor is installed far from the adjustable frequency drive. The length is unfortunately limited because the filter does not reduce leakage currents in the cables.

3.7 High Power Options

CAUTION

A door fan is required on the enclosure to remove the heat losses not contained in the backchannel of the adjustable frequency 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 (that is, Rittal Therm software). If the adjustable frequency drive is the only heat generating component in the enclosure, the minimum airflow required at an ambient temperature of 113 °F [45 °C] for the D3h and D4h adjustable frequency drive is 391 m^3/h (230 cfm). The minimum airflow required at an ambient temperature of 113 °F [45 °C] for the E2 adjustable frequency drive is 782 m^3/h (460 cfm).

3.7.1 Installation of Backchannel Cooling Kit in Rittal Enclosures

This section describes the installation of IP00/IP20/chassis adjustable frequency drives with backchannel cooling kits in Rittal enclosures. In addition to the enclosure, a floor mounting pedestal is required.

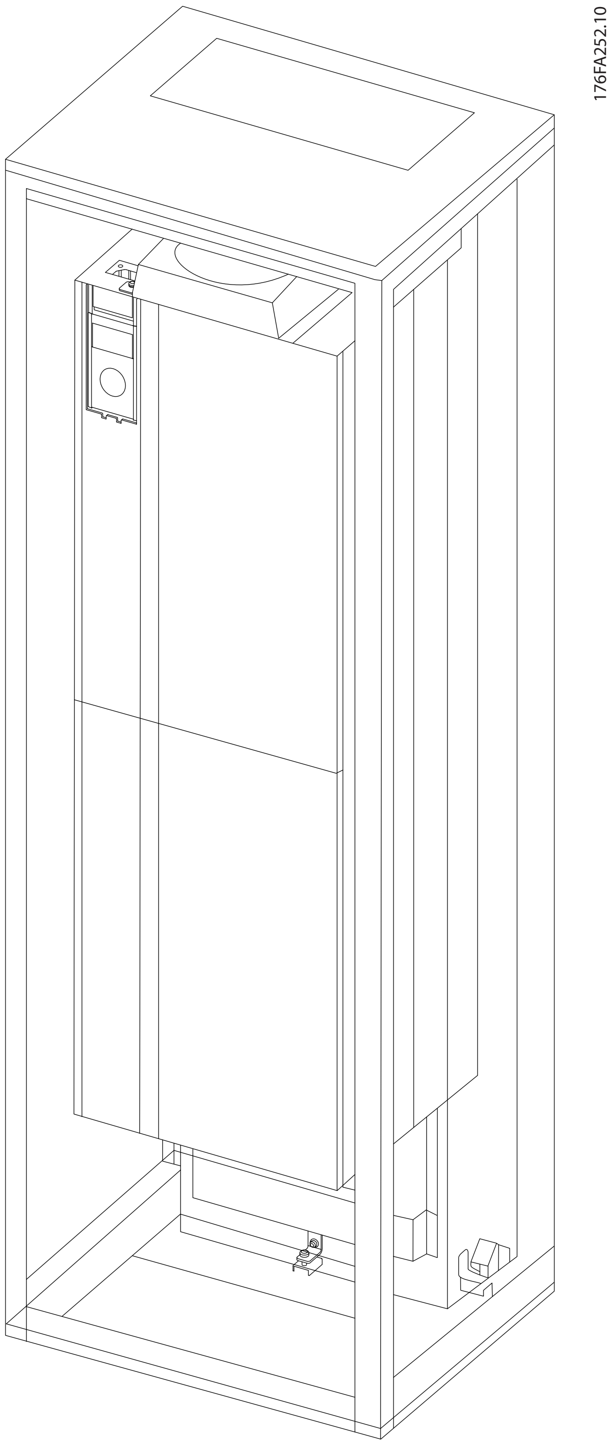

Figure 3.19 Installation of IP00/IP20/Chassis in Rittal TS8 Enclosure.

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The minimum enclosure dimension is:

- D3h frame: Depth 19.7 in [500 mm] and width 15.7 in [400 mm]
- D4h frame: Depth 19.7 in [500 mm] and width 23.6 in [600 mm]
- E2 frameUnit Size 52: Depth 19.7 in [500 mm] and width 23.6 in [600 mm].

The maximum depth and width must comply with the installation requirements. When using multiple adjustable frequency drives in one enclosure, mount each on its own back panel and support each along the mid-section of the panel. The backchannel cooling kits do not support the "in frame" mounting of the panel (see Rittal TS8 catalog for details). The cooling kits listed in *Table 3.29* are suitable for use only with IP00/IP20 chassis adjustable frequency drives in Rittal TS8 IP 20 and UL and NEMA 1 and IP 54 and UL and NEMA 12 enclosures.

⚠CAUTION

For the E2 frames Unit Size 52, it is important to mount the plate at the absolute rear of the Rittal enclosure due to the weight of the adjustable frequency drive.

Rittal TS-8 Enclosure	Frame D3h Kit Part No.	Frame D4h Kit Part No.	Frame E2 Part No.
70.87 in [1800 mm]	176F3625	176F3628	Not possible
78.74 in [2000 mm]	176F3629	176F3630	176F1850
86.61 in [2200 mm]			176F0299

Table 3.29 Ordering Information

See the *Duct Kit Instruction Manual, 175R5640,* for further information regarding the E-frame kit.

External ducts
If more duct work is added externally to the Rittal cabinet, the pressure drop in the ducting must be calculated. See *chapter 5.2.7 Cooling and Airflow* for further information.

3.7.2 Outside Installation/NEMA 3R Kit for Rittal Enclosures

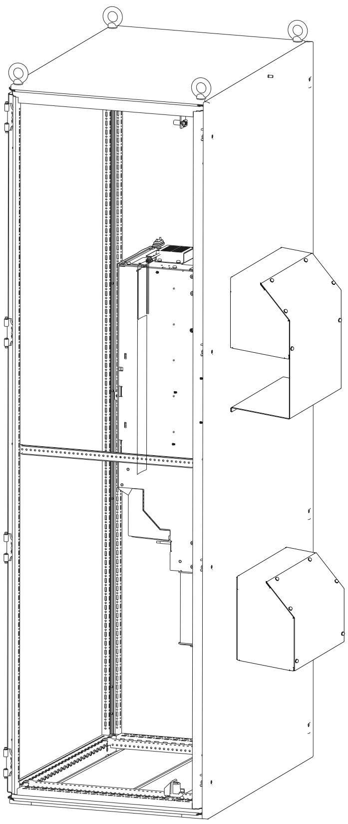

Figure 3.20 Cutaway Side View of Cabinet

This section is for the installation of NEMA 3R kits available for the adjustable frequency drive frames D3h, D4h and E2. These kits are designed and tested to be used with IP00/IP20/Chassis versions of these frames in Rittal TS8 NEMA 3R or NEMA 4 enclosures. The NEMA-3R enclosure is an outdoor enclosure that provides a degree of protection against rain and ice. The NEMA-4 enclosure is an outdoor enclosure that provides a greater degree of protection against weather and hosed water.
The minimum enclosure depth is 19.7 in [500 mm] (23.6 in [600 mm] for E2 frame) and the kit is designed for a 23.6 in [600 mm] (31.5 in [800 mm] for E2 frame) wide enclosure. Other enclosure widths are possible; however, more Rittal hardware is required. Consult the installation requirements for the maximum depth and width.

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NOTICE!

The current rating of adjustable frequency drives in D3h and D4h frames are derated by 3%, when adding the NEMA 3R kit. Adjustable frequency drives in E2 frames require no derating.

Frame Size	Part Number	Instruction Number
D3h	176F3633	177R0460
D4h	176F3634	177R0461
E2	176F1852	176R5922

Table 3.30 NEMA-3R Kit Ordering Information

3.7.3 Installation on Pedestal

This section describes the installation of a pedestal unit available for the adjustable frequency drives frames D1h, D2h, D5h, and D6h. The pedestal allows these adjustable frequency drives to be floor-mounted. The front of the pedestal has openings for input air to the power components.

The adjustable frequency drive connector plate must be installed to provide adequate cooling air to the control components of the adjustable frequency drive and to maintain the IP21 (NEMA 1) or IP54 (NEMA 12) enclosure ratings.

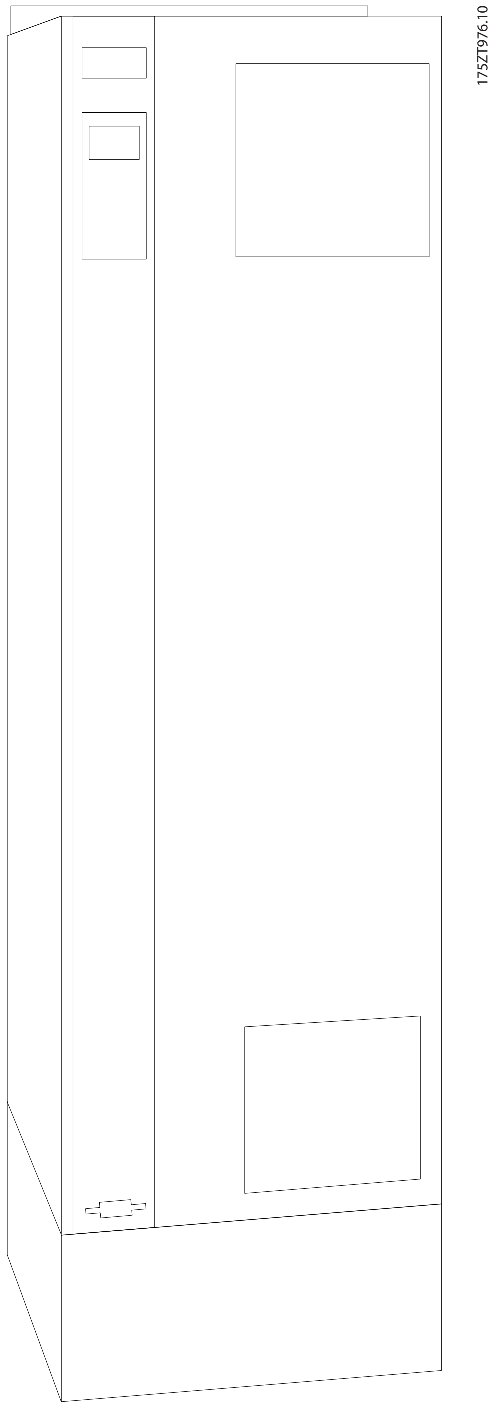

Figure 3.21 Adjustable Frequency Drive Mounted on a Pedestal

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The ordering numbers and heights for the pedestals are shown in *Table 3.31*

Frame Size	Part Number	Instruction Number	Height (in [mm])
D1h	176F3631	177R0452	400
D2h	176F3632	177R0453	400
D5h/D6h	176F3452	177R0500	200
D7h/D8h	Included with unit	Included with unit	200
E1	Included with unit	Included with unit	200

Table 3.31 Pedestal Ordering Information

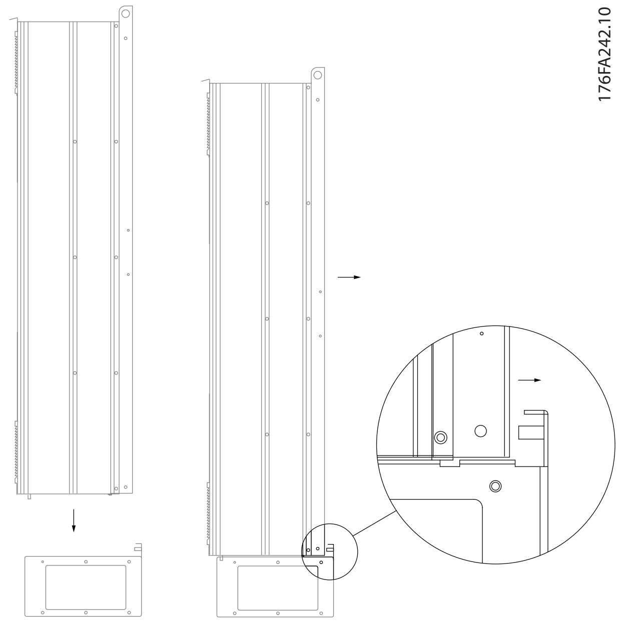

Figure 3.22 Mounting of the Adjustable Frequency Drive to the Pedestal

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3.7.4 Installation of Input Plate Options

This section is for the field installation of input option kits for E-frame adjustable frequency drives.
Do not attempt to remove RFI filters from input plates. Removal of RFI filters from the input plates can cause damage.

NOTICE!

Where RFI filters are available, there are two different types of RFI filters depending on the input plate combination and the RFI filters interchangeable. Field installable kits in certain cases are the same for all voltages.

	380–480 V (hp [kW]) 380–500 V (hp [kW])	Fuses	Disconnect Fuses	RFI	RFI Fuses	RFI Disconnect Fuses
E1	FC102/FC202: 450 [315] FC302: 350 [250]	176F0253	176F0255	176F0257	176F0258	176F0260
	FC102/FC202: 475–600 [355–450] FC302: 450–550 [315–400]	176F0254	176F0256	176F0257	176F0259	176F0262

Table 3.32 Input Options

	525–690 V (hp [kW])	Fuses	Disconnect Fuses	RFI	RFI Fuses	RFI Disconnect Fuses
E1	FC102/FC202: 600–650 [450–500] FC302: 475–550 [355–400]	176F0253	176F0255	Not Applicable	Not Applicable	Not Applicable
	FC102/FC202: 750–850 [560–630] FC302: 650–750 [500–560]	176F0254	176F0258	Not Applicable	Not Applicable	Not Applicable

Table 3.33 Input Options

NOTICE!

For further information, see the Instruction Sheet, *175R5795*

3.7.5 Installation of Line Power Shield for Adjustable Frequency Drives

This section is for the installation of a line power shield for the adjustable frequency drive. It is not possible to install in the IP00/ Chassis versions as these enclosures include a standard a metal cover. These shields satisfy VBG-4 requirements.

Ordering numbers:
Frame E1: 176F1851

NOTICE!

For further information, see the Instruction Sheet, *175R5923*

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3.7.6 D-frame Options

3.7.6.1 Load Share Terminals

Load share terminals enable the connection of the DC circuits of several adjustable frequency drives. Load share terminals are available in IP20 adjustable frequency drives and extend out the top of the adjustable frequency drive. A terminal cover, supplied with the adjustable frequency drive, must be installed to maintain the IP20 rating of the enclosure. *Figure 3.23* shows both the covered and uncovered terminals.

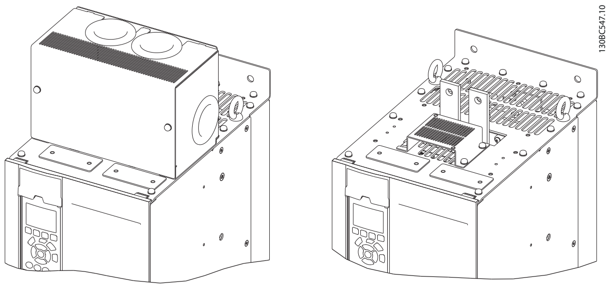

Figure 3.23 Load Share or Regeneration Terminal with Cover (L) and without Cover (R)

3.7.6.2 Regeneration Terminals

Regen (regeneration) terminals can be supplied for applications that have a regenerative load. A regenerative unit, supplied by a third party, connects to the regen terminals so that power can be regenerated back onto line power, resulting in energy savings. Regen terminals are available in IP20 adjustable frequency drives and extend out the top of the adjustable frequency drive. A terminal cover, supplied with the adjustable frequency drive, must be installed to maintain the IP20 rating of the enclosure. *Figure 3.23* shows both the covered and uncovered terminals.

3.7.6.3 Anti-condensation Heater

An anti-condensation heater can be installed inside the adjustable frequency drive to prevent condensation from forming inside the enclosure when the unit is turned off. Customer-supplied 230 V AC controls the heater. For best results, operate the heater only when the unit is not running and turn off the heater when the unit is running.

A 2.5 amp time-delay fuse, such as the Bussmann LPJ-21/2SP, is recommended to protect the heater.

3.7.6.4 Brake Chopper

A brake chopper can be supplied for applications that have a regenerative load. The brake chopper connects to a brake resistor, which consumes the braking energy, preventing an overvoltage fault on the DC bus. The brake chopper is automatically activated when the DC bus voltage exceeds a specified level, depending on the nominal voltage of the adjustable frequency drive.

3.7.6.5 Line Power Shield

The line power shield is a Lexan cover installed inside the enclosure to provide protection according to VBG-4 accident-prevention requirements.

3.7.6.6 Ruggedized Printed Circuit Boards

Ruggedized boards are available for marine and other applications that experience higher than average vibration.

NOTICE!

Ruggedized boards are required for the D-Frame adjustable frequency drives to meet marine approval requirements.

3.7.6.7 Heatsink Access Panel

An optional heatsink access panel is available to facilitate cleaning of the heatsink. Debris buildup is typical in environments prone to airborne contaminants, such as in the textile industry.

3.7.6.8 Line Power Disconnect

The disconnect option is available in both varieties of option cabinets. The position of the disconnect changes based on the size of the options cabinet and whether other options are present. *Table 3.34* provides more detail about which disconnects are used.

Voltage	Adjustable frequency drive model	Disconnect manufacturer and type
380–500 V	N110T5–N160T4	ABB OT400U03
	N200T5–N315T4	ABB OT600U03
525–690 V	N75KT7–N160T7	ABB OT400U03
	N200T7–N400T7	ABB OT600U03

Table 3.34 Line Power Disconnect Information

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3.7.6.9 Contactor

A customer-supplied 230 V AC 50/60 Hz signal powers the contactor.

Voltage	Adjustable frequency drive model	Contactor manufacturer and type	IEC utilization category
380–500 V	N110T5–N160T4	GE CK95BE311N	AC-3
	N200T5–N250T4	GE CK11CE311N	AC-3
	N315T4	GE CK11CE311N	AC-1
525–690 V	N75KT7–N160T7	GE CK95BE311N	AC-3
	N200T7–N400T7	GE CK11CE311N	AC-3

Table 3.35 Contactor Information

NOTICE!

In applications requiring UL listing, when the adjustable frequency drive is supplied with a contactor, the customer must provide external fusing to maintain the UL rating of the adjustable frequency drive and a short circuit current rating of 100,000 A. See *chapter 5.3.8 Fuse Specifications* for fuse recommendations.

3.7.6.10 Circuit Breaker

Table 3.36 provides details on the type of circuit breaker provided as an option with the various units and power ranges.

Voltage	Adjustable frequency drive model	Circuit breaker manufacturer and type
380–500 V	N110T5–N132T5	ABB T5L400TW
	N160T5	ABB T5LQ400TW
	N200T5	ABB T6L600TW
	N250T5	ABB T6LQ600TW
	N315T5	ABB T6LQ800TW
525–690 V	N75KT7–N160T7	ABB T5L400TW
	N200T7–N315T7	ABB T6L600TW
	N400T7	ABB T6LQ600TW

Table 3.36 Circuit Breaker Information

3.7.7 Frame Size F Options

Space Heaters and Thermostat
Mounted on the cabinet interior of frame size F adjustable frequency drives, space heaters controlled via automatic thermostat help control humidity inside the enclosure, extending the lifetime of components in damp environments. The thermostat default settings turn on the heaters at 10 °C (50 °F) and turn them off at 15.6 °C (60 °F).

Cabinet Light with Power Outlet
A light mounted on the cabinet interior of frame size F adjustable frequency drives increases visibility during servicing and maintenance. The housing includes a power outlet for temporarily powering tools or other devices, available in two voltages:

- 230 V, 50 Hz, 2.5A, CE/ENEC
- 120 V, 60 Hz, 5A, UL/cUL

Transformer Tap Set-up
If the cabinet light & outlet and/or the space heaters & thermostat are installed, Transformer T1 requires that taps be set to the proper input voltage. A 380–480/500 V adjustable frequency drive is initially set to the 525 V tap and a 525–690 V adjustable frequency drive is set to the 690 V tap to ensure no overvoltage of secondary equipment occurs if the tap is not changed before power is applied. See *Table 3.37* to set the proper tap on TB3 located in the rectifier cabinet. For location in the adjustable frequency drive, see *chapter 5.4.2 Power Connections*.

Input voltage range [V]	Tap to select [V]
380–440	400
441–490	460
491–550	525
551–625	575
626–660	660
661–690	690

Table 3.37 Transformer Tap

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, which 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. The RCD requires an external “window-type” current transformer (supplied and installed by the customer).

- Integrated into the safe-stop circuit of the adjustable frequency drive
- IEC 60755 Type B device monitors AC, pulsed DC, and pure DC ground fault currents

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- LED bar graph indicator of the ground fault current level from 10–100% of the setpoint
- Fault memory
- [Test/Reset] key

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.

NOTICE!

Only one insulation resistance monitor can be connected to each ungrounded (IT) system.

- Integrated into the safe-stop circuit of the adjustable frequency drive
- LCD display of the ohmic value of the insulation resistance
- Fault Memory
- [Info], [Test] and [Reset] keys

IEC Emergency Stop with Pilz Safety Relay
Includes a redundant 4-wire emergency-stop push button mounted on the front of the enclosure and a Pilz relay that monitors it with the safe-stop circuit and the line power contactor located in the options cabinet.

Safe Stop + Pilz Relay
Provides a solution for the "Emergency Stop" option without the contactor in F-Frame adjustable frequency drives.

Manual Motor Starters
Provides 3-phase power for electric blowers often required for larger motors. Power for the starters is provided from the load side of any supplied contactor, circuit breaker, or disconnect switch. Power is fused before each motor starter, and is off when the incoming power to the adjustable frequency drive is off. Up to two starters are allowed (one if a 30 A, fuse-protected circuit is ordered) and are integrated into the safe-stop circuit.
Unit features include:

- Operation switch (on/off)
- Short-circuit and overload protection with test function
- Manual reset function

30 A, 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 adjustable frequency drive is off
- Power for the fused protected terminals is provided from the load side of any supplied contactor, circuit breaker, or disconnect switch.

24 V DC Power Supply

- 5 A, 120 W, 24 V DC
- Protected against output overcurrent, overload, short-circuits and overtemperature
- For powering customer-supplied accessory devices such as sensors, PLC I/O, contactors, temperature probes, LEDs and/or other electronic hardware
- Diagnostics include a dry DC-ok contact, a green DC-ok LED, and a red overload LED

External Temperature Monitoring
Designed for monitoring temperatures of external system components, such as the motor windings and/or bearings. Includes five universal input modules. The modules are integrated into the safe-stop circuit (requires purchase of safe-stop) and can be monitored via a serial communication bus network (requires the purchase of a separate module/bus coupler).

Universal inputs (5)
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

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4 How to Order

4.1 Ordering Form

4.1.1 Drive Configurator

It is possible to design a VLT® AQUA Drive FC 202 adjustable frequency drive according to the application requirements by using the ordering number system.

To order standard adjustable frequency drives and adjustable frequency drives with integral options, send a type code string describing the product to the Danfoss sales office. An example type code:

FC-202N132T4E21H2XGCXXXSXXXXAXBKCXXXXDX

The meaning of the characters in the string can be located in the pages containing the ordering numbers in *chapter 4.1 Ordering Form*. In the example above, a Profibus LON works option and a general purpose I/O option is included in the adjustable frequency drive.

Ordering numbers for VLT AQUA Drive standard variants can also be located in the chapter *chapter 4.2 Ordering Numbers*.

Use the web-based Drive Configurator, to configure the right adjustable frequency drive for the right application and generate the type code string. The Drive Configurator automatically generates an eight-digit sales number for the local sales office.
Furthermore,it´s possible to establish a project list with several products and send it to a Danfoss sales representative.

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

NOTICE!

Type code information includes frame sizes A, B and C. For detailed information on these products, reference the relevant design guide.

4.1.2 Type Code String

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
F	C	-	2	0	2					T					H						X	X	S	X	X	X	X	A		B		C					D	

130BC529.10

Figure 4.1 Type Code

Description	Position	Possible Choice
Product Group	1–3	FC
Drive Series	4–6	202
Generation Code	7	N
Power Rating	8–10	100–550 [75–400 kW]
AC Line Voltage	11–12	T4: 380–480 V AC T7: 525–690 V AC

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Description	Position	Possible Choice
Enclosure	13–15	E20: IP20 (chassis - for installation in external enclosure) E21: IP21 (NEMA 1) E54: IP54 (NEMA 12) E2M: IP21 (NEMA 1) with line power shield E5M: IP54 (NEMA 12) with line power shield C20: IP20 (chassis - for installation in external enclosure) + stainless steel backchannel H21: IP21 (NEMA 1) + heater H54: IP54 (NEMA 12) + heater
RFI filter	16–17	H2: RFI filter, class A2 (standard) H4: RFI filter class A1[1)]
Brake	18	X: No brake IGBT B: Brake IGBT mounted T: Safe stop U: Brake chopper + safe stop R: Regeneration terminals S: Brake + regeneration (IP 20 only)
Display	19	G: Graphical local control panel N: Numerical local control panel X: No local control panel
Coating PCB	20	C: Coated PCB R: Ruggedized PCB
Line Power Option	21	X: No line power option 3: Line power disconnect and fuse 4: Line power contactor + fuses 7: Fuse A: Fuse and load sharing (IP20 only) D: Load share terminals (IP20 only) E: Line power disconnect + contactor + fuses J: Circuit breaker + fuses
Adaptation	22	X: Standard cable entries Q: Heatsink access panel
Adaptation	23	X: No adaptation
Software release	24–27	Current software
Software language	28	
The various options are described further in this Design Guide. 1): Available for all D frames.		

Table 4.1 Ordering Type Code for D-frame Adjustable frequency drives

Description	Pos	Possible choice
Product group	1–3	FC
Drive series	4–6	202
Power rating	8–10	600–850 [450–630 kW]
Phases	11	Three phases (T)
AC line voltage	11- 12	T 4: 380–500 V AC T 7: 525–690 VAC

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Description	Pos	Possible choice
Enclosure	13- 15	E00: IP00/Chassis - for installation in external enclosure C00: IP00/Chassis (for installation in external enclosure) w/ stainless steel backchannel E21: IP 21/NEMA Type 1 E54: IP 54/NEMA Type 12 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)]
Brake	18	B: Brake IGBT mounted X: No brake IGBT R: Regeneration terminals
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
Line power option	21	X: No line power option 3: Line power disconnect and fuse 5: Line power disconnect, Fuse, and Load sharing 7: Fuse A: Fuse and Load sharing D: Load sharing
Adaptation	22	Reserved
Adaptation	23	Reserved
Software release	24- 27	Current software
Software language	28	
A options	29–30	AX: No options A0: MCA 101 Profibus DP V1 A4: MCA 104 DeviceNet AN: MCA 121 Ethernet IP
B options	31–32	BX: No option BK: MCB 101 General purpose I/O option BP: MCB 105 Relay option BO:MCB 109 Analog I/O option BY: MCO 101 Extended Cascade Control
C_0 options	33–34	CX: No options
C_1 options	35	X: No options 5: MCO 102 Advanced Cascade Control
C option software	36–37	XX: Standard software
D options	38–39	DX: No option D0: DC backup
The various options are described further in this Design Guide.		
1): Available for all E frames 380–480/500 V AC only 2) Consult factory for applications requiring maritime certification		

Table 4.2 Ordering Type Code for E-Frame Adjustable Frequency Drives

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4

4.2 Ordering Numbers

4.2.1 Ordering Numbers: Options and Accessories

Type	Description	Ordering no.	
Miscellaneous hardware			
Profibus D-Sub 9	Connector kit for IP20	130B1112	
MCF 103	USB Cable 14 in [350 mm], IP55/66	130B1155	
MCF 103	USB Cable 26 in [650 mm], IP55/66	130B1156	
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	
LCP			
LCP 101	Numerical Local Control Panel (NLCP)	130B1124	
LCP 102	Graphical Local Control Panel (GLCP)	130B1107	
LCP cable	Separate LCP cable, 10 ft [3 m]	175Z0929	
LCP kit	Panel mounting kit including graphical LCP, fasteners, 10 ft [3 m] cable and gasket	130B1113	
LCP kit	Panel mounting kit including numerical LCP, fasteners and gasket	130B1114	
LCP kit	Panel mounting kit for all LCPs including fasteners, 10 ft [3 m] cable and gasket	130B1117	
LCP kit	Panel mounting kit for all LCPs including fasteners and gasket - without cable	130B1170	
LCP kit	Panel mounting kit for all LCPs including fasteners, 26 ft [8 m] cable, connectors and gasket for IP55/66 enclosures	130B1129	
Options for Slot A Uncoated/Coated		**Uncoated**	**Coated**
MCA 101	Profibus option DP V0/V1	130B1100	130B1200
MCA 104	DeviceNet option	130B1102	130B1202
MCA 108	LON works	130B1106	130B1206
Options for Slot B			
MCB 101	General purpose Input Output option	130B1125	130B1212
MCB 105	Relay option	130B1110	130B1210
MCB 109	Analog I/O option	130B1143	130B1243
MCB 114	PT 100 / PT 1000 sensor input	130B1172	10B1272
MCO 101	Extended Cascade Control	130B1118	130B1218
Option for Slot C			
MCO 102	Advanced Cascade Control	130B1154	130B1254
Option for Slot D			
MCB 107	24 V DC backup	130B1108	130B1208

Table 4.3 Ordering Numbers: Options and Accessories

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Type	Description	Ordering no.	
External Options			
Ethernet IP	Ethernet	130B1119	130B1219
Spare Parts			
Control board VLT® AQUA Drive FC 202	With Safe Stop Function		130B1167
Control board VLT® AQUA DriveFC 202	Without Safe Stop Function		130B1168
Accessory Bag Control Terminals		130B0295	
1) Only IP21/> 15 hp [11 kW]			

Table 4.4 Ordering Numbers: Options and Accessories

Options can be ordered as factory built-in options, see ordering information.
For information on serial communication bus and application option compatibility with older software versions, contact your Danfoss supplier.

4.2.2 Ordering Numbers: Advanced Harmonic Filters

Harmonic filters are used to reduce line harmonics.

For detailed information on advanced harmonic filters, see the AHF design guide

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

Code number AHF005 IP00 IP20	Code number AHF010 IP00 IP20	Filter current rating	Typical motor	VLT model and current ratings		Losses		Acoustic noise	Frame size	
						AHF005	AHF010			
		[A]	(hp [kW])	[kW]	[A]	[W]	[W]	[dBA]	AHF005	AHF010
130B1446 130B1251	130B1295 130B1214	204	150 [110]	N110	204	1080	742	<75	X6	X6
130B1447 130B1258	130B1369 130B1215	251	175 [132]	N132	251	1195	864	<75	X7	X7
130B1448 130B1259	130B1370 130B1216	304	250 [160]	N160	304	1288	905	<75	X7	X7
130B3153 130B3152	130B3151 130B3136	325	Paralleling for 475 hp [355 kW]			1406	952	<75	X8	X7
130B1449 130B1260	130B1389 130B1217	381	300 [200]	N200	381	1510	1175	<77	X8	X7
130B1469 130B1261	130B1391 130B1228	480	350 [250]	N250	472	1852	1542	<77	X8	X8
2x130B1448 2x130B1259	2x130B1370 2x130B1216	608	450 [315]	N315	590	2576	1810	<80		

Table 4.5 Advanced Harmonic Filters 380–415 V, 50 Hz, D-Frame

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Code number AHF005 IP00 IP20	Code number AHF010 IP00 IP20	Filter current rating	Typical motor	VLT model and current ratings		Losses		Acou-stic noise	Frame size	
						AHF 005	AHF 010			
		[A]	(hp [kW])	[kW]	[A]	[W]	[W]	[dBA]	AHF 005	AHF 010
2x130B3153 2x130B3152	2x130B3151 2x130B3136	650	475 [355]	P355	647	2812	1904	<80		
130B1448+130B1449 130B1259+130B1260	130B1370+130B1389 130B1216+130B1217	685	550 [400]	P400	684	2798	2080	<80		
2x130B1449 2x130B1260	2x130B1389 2x130B1217	762	600 [450]	P450	779	3020	2350	<80		
130B1449+130B1469 130B1260+130B1261	130B1389+130B1391 130B1217+130B1228	861	650 [500]	P500	857	3362	2717	<80		
2x130B1469 2x130B1261	2x130B1391 2x130B1228	960	750 [560]	P560	964	3704	3084	<80		
3x130B1449 3x130B1260	3x130B1389 3x130B1217	1140	850 [630]	P630	1090	4530	3525	<80		
2x130B1449+130B1469 2x130B1260+130B1261	2x130B1389+130B1391 2x130B1217+130B1228	1240	950 [710]	P710	1227	4872	3892	<80		
3x130B1469 3x1301261	3x130B1391 3x130B1228	1440	1075 [800]	P800	1422	5556	4626	<80		
2x130B1449+2x130B1469 2x130B1260+2x130B1261	2x130B1389+2x130B1391 2x130B1217+2x130B1228	1720	1000	P1000	1675	6724	5434	<80		

Table 4.6 Advanced Harmonic Filters 380–415 V, 50 Hz, E- and F-Frames

Code number AHF005 IP00 IP20	Code number AHF010 IP00 IP20	Filter current rating	Typical motor	VLT model and current ratings		Losses		Acoustic noise	Frame size	
						AHF005	AHF010			
		[A]	(hp [kW])	[kW]	[A]	[W]	[W]	[dBA]	AHF005	AHF010
130B3131 130B2869	130B3090 130B2500	204	150 [110]	N110	204	1080	743	<75	X6	X6
130B3132 130B2870	130B3091 130B2700	251	175 [132]	N132	251	1194	864	<75	X7	X7
130B3133 130B2871	130B3092 130B2819	304	250 [160]	N160	304	1288	905	<75	X8	X7
130B3157 130B3156	130B3155 130B3154	325	Paralleling for 475 hp [355 kW]			1406	952	<75	X8	X7
130B3134 130B2872	130B3093 130B2855	381	300 [200]	N200	381	1510	1175	<77	X8	X7
130B3135 130B2873	130B3094 130B2856	480	350 [250]	N250	472	1850	1542	<77	X8	X8
2x130B3133 2x130B2871	2x130B3092 2x130B2819	608	450 [315]	N315	590	2576	1810	<80		

Table 4.7 Advanced Harmonic Filters, 380–415 V, 60 Hz, D-Frame

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Code number AHF005 IP00 IP20	Code number AHF010 IP00 IP20	Filter current rating	Typical motor	VLT model and current ratings		Losses		Acou-stic noise	Frame size	
						AHF 005	AHF 010			
		[A]	(hp [kW])	[kW]	[A]	[W]	[W]	[dBA]	AHF 005	AHF 010
2x130B3157 2x130B3156	2x130B3155 2x130B3154	650	450 [315]	P355	647	2812	1904	<80		
130B3133+130B3134 130B2871+130B2872	130B3092+130B3093 130B2819+130B2855	685	475 [355]	P400	684	2798	2080	<80		
2x130B3134 2x130B2872	2x130B3093 2x130B2855	762	550 [400]	P450	779	3020	2350	<80		
130B3134+130B3135 130B2872+130B3135	130B3093+130B3094 130B2855+130B2856	861	600 [450]	P500	857	3362	2717	<80		
2x130B3135 2x130B2873	2x130B3094 2x130B2856	960	650 [500]	P560	964	3704	3084	<80		
3x130B3134 3x130B2872	3x130B3093 3x130B2855	1140	750 [560]	P630	1090	4530	3525	<80		
2x130B3134+130B3135 2x130B2872+130B2873	2x130B3093+130B3094 2x130B2855+130B2856	1240	850 [630]	P710	1227	4872	3892	<80		
3x130B3135 3x130B2873	3x130B3094 3x130B2856	1440	950 [710]	P800	1422	5556	4626	<80		
2x130B3134+2x130B3135 2x130B2872+2x130B2873	2x130B3093+2x130B3094 2x130B2855+2x130B2856	1722	1075 [800]	P1M0	1675	6724	5434	<80		

Table 4.8 Advanced Harmonic Filters, 380–415 V, 60 Hz, E- and F-Frames

Code number AHF005 IP00 IP20	Code number AHF010 IP00 IP20	Filter current rating	Typical motor	VLT model and current ratings		Losses		Acoustic noise	Frame size	
						AHF005	AHF010			
		[A]	[HP]	[HP]	[A]	[W]	[W]	[dBA]	AHF005	AHF010
130B1799 130B1764	130B1782 130B1496	183	150	N110	183	1080	743	<75	X6	X6
130B1900 130B1765	130B1783 130B1497	231	200	N132	231	1194	864	<75	X7	X7
130B2200 130B1766	130B1784 130B1498	291	250	N160	291	1288	905	<75	X8	X7
130B2257 130B1768	130B1785 130B1499	355	300	N200	348	1406	952	<75	X8	X7
130B3168 130B3167	130B3166 130B3165	380	Used for paralleling at 475 hp [355 kW]			1510	1175	<77	X8	X7
130B2259 130B1769	130B1786 130B1751	436	350	N250	436	1852	1542	<77	X8	X8
130B1900+ 130B2200 130B1765+ 130B1766	130B1783+ 130B1784 130B1497+ 130B1498	522	450	N315	531	2482	1769	<80		

Table 4.9 Advanced Harmonic Filters 440–480 V, 60 Hz, D-Frame

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Code number AHF005 IP00/IP20	Code number AHF010 IP00/IP20	Filter current rating	Typical motor	VLT model and current ratings		Losses		Acoustic noise	Frame size	
						AHF005	AHF010			
		[A]	[HP]	(hp [kW])	[A]	[W]	[W]	[dBA]	AHF005	AHF010
2x130B2200 2x130B1766	2x130B1784 2x130B1498	582	500	P355	580	2576	1810	<80		
130B2200+ 130B3166 130B1766+ 130B3167	130B1784+ 130B3166 130B1498+ 130B3165	671	550	P400	667	2798	2080	<80		
2x130B2257 2x130B1768	2x130B1785 2x130B1499	710	600	P450	711	2812	1904	<80		
2x130B3168 2x130B3167	2x130B3166 2x130B3165	760	650	P500	759	3020	2350	<80		
2x130B2259 2x130B1769	2x130B1786 2x130B1751	872	750	P560	867	3704	3084	<80		
3x130B2257 3x130B1768	3x130B1785 3x130B1499	1065	900	P630	1022	4218	2856	<80		
3x130B3168 3x130B3167	3x130B3166 3x130B3165	1140	1000	P710	1129	4530	3525	<80		
3x130B2259 3x130B1769	3x130B1786 3x130B1751	1308	1200	P800	1344	5556	4626	<80		
2x130B2257+ 2x130B2259 2x130B1768+ 2x130B1768	2x130B17852x 130B1785 +2x130B1786 2x130B1499+ 2x130B1751	1582	1350	P1M0	1490	6516	5988	<80		

Table 4.10 Advanced Harmonic Filters, 440–480 V, 60 Hz, E- and F-Frames

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Code number AHF005 IP00/IP20	Code number AHF010 IP00/IP20	Filter current rating	Typical motor	VLT model and current ratings		Losses		Acoustic noise	Frame size	
		50 Hz				AHF005	AHF010			
		[A]	[HP]	[kW]	[A]	[W]	[W]	[dBa]	AHF005	AHF010
130B5269 130B5254	130B5237 130B5220	87	75	N75K	85	962	692	<72	X6	X6
130B5270 130B5255	130B5238 130B5221	109	100	N90K	106	1080	743	<72	X6	X6
130B5271 130B5256	130B5239 130B5222	128	125	N110	124	1194	864	<72	X6	X6
130B5272 130B5257	130B5240 130B5223	155	150	N132	151	1288	905	<72	X7	X7
130B5273 130B5258	130B5241 130B5224	197	200	N160	189	1406	952	<72	X7	X7
130B5274 130B5259	130B5242 130B5225	240	250	N200	234	1510	1175	<75	X8	X8
130B5275 130B5260	130B5243 130B5226	296	300	N250	286	1852	1288	<75	X8	X8
2x130B5273 2x130B5258	130B5244 130B5227	366	350	N315	339	2812	1542	<75		X8
2x130B5273 2x130B5258	130B5245 130B5228	395	400	N400	395	2812	1852	<75		X8

Table 4.11 Advanced Harmonic Filters, 600 V, 60 Hz

Code number AHF005 IP00/IP20	Code number AHF010 IP00/IP20	Filter current rating	Typical motor	VLT model and Current Ratings		Losses		Acoustic noise	Frame size	
		50 Hz				AHF005	AHF010			
		[A]	[HP]	[kW]	[A]	[W]	[W]	[dBa]	AHF005	AHF010
2x130B5274 2x130B5259	2x130B5242 2x130B5225	480	500	P500	482	3020	2350			
2x130B5275 2x130B5260	2x130B5243 2x130B5226	592	600	P560	549	3704	2576			
3x130B5274 3x130B5259	2x130B5244 2x130B5227	732	650	P630	613	4530	3084			
3x130B5274 3x130B5259	2x130B5244 2x130B5227	732	750	P710	711	4530	3084			
3x130B5275 3x130B5260	3x130B5243 3x139B5226	888	950	P800	828	5556	3864			
4x130B5274 4x130B5259	3x130B5244 3x130B5227	960	1050	P900	920	6040	4626			
4x130B5275 4x130B5260	3x130B5244 3x130B5227	1098	1150	P1M0	1032	7408	4626			
	4x130B5244 4x130B5227	1580	1350	P1M2	1227		6168			

Table 4.12 Advanced Harmonic Filters, 600 V, 60 Hz

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Code number AHF005 IP00/IP20	Code number AHF010 IP00/IP20	Filter current rating 50 Hz	VLT model and current ratings: Typical motor size	500–550 V		Typical motor size	551–690 V		Losses AHF005	Losses AHF010	Acoustic noise	Frame size AHF005	Frame size AHF010
		[A]	[kW]	[kW]	[A]	[kW]	[kW]	[A]	[W]	[W]	[dBa]	AHF005	AHF010
130B5024	130B5325	77	45	N55K	71	75	N75K	76	841	488	<72	X6	X6
130B5169	130B5287												
130B5025	130B5326	87	55	N75K	89				962	692	<72	X6	X6
130B5170	130B5288												
130B5026	130B5327	109	75	N90K	110	90	N90K	104	1080	743	<72	X6	X6
130B5172	130B5289												
130B5028	130B5328	128	90	N110	130	110	N110	126	1194	864	<72	X6	X6
130B5195	130B5290												
130B5029	130B5329	155	110	N132	158	132	N132	150	1288	905	<72	X7	X7
130B5196	130B5291												
130B5042	130B5330	197	132	N160	198	160	N160	186	1406	952	<72	X7	X7
130B5197	130B5292												
130B5066	130B5331	240	160	N200	245	200	N200	234	1510	1175	<75	X8	X7
130B5198	130B5293												
130B5076	130B5332	296	200	N250	299	250	N250	280	1852	1288	<75	X8	X8
130B5199	130B5294												
2x130B5042	130B5333	366	250	N315	355	315	N315	333	2812	1542			X8
2x130B5197	130B5295												
2x130B5042	130B5334	395	315	N355	381	400			2812	1852			X8
130B5042 +130B5066	130B5330 +130B5331	437	355	N400	413	500	N400	395	2916	2127			
130B5197 +130B5198	130B5292 +130B5293												

Table 4.13 Advanced Harmonic Filters, 500–690 V, 50 Hz

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Code number AHF005 IP00/IP20	Code number AHF010 IP00/IP20	Filter current rating	VLT model and current ratings						Losses		Acoustic noise	Frame size	
		50 Hz	Typical motor size	500–550 V		Typical motor size	551–690 V		AHF005	AHF010			
		[A]	(hp [kW])	[kW]	[A]	(hp [kW])	[kW]	[A]	[W]	[W]	[dBa]	AHF005	AHF010
130B5066 +130B5076	130B5331 +130B5332	536	550 [400]	P450	504	750 [560]	P500	482	3362	2463			
130B5198 +130B5199	130B5292 +130B5294												
2 x130B5076	2x130B5332	592	600 [450]	P500	574	850 [630]	P560	549	3704	2576			
2 x130B5199	2x130B5294												
130B5076 +2x130B5042	130B5332 +130B5333	662	650 [500]	P560	642	950 [710]	P630	613	4664	2830			
130B5199 +2x130B5197	130B5294 +130B5295												
4x130B5042	2x130B5333	732	750 [560]	P630	743	1075 [800]	P710	711	5624	3084			
4x130B5197	2x130B5295												
3x130B5076	3x130B5332	888	900 [670]	P710	866	1200 [900]	P800	828	5556	3864			
3x130B5199	3x130B5294												
2x130B5076 +2x130B5042	2x130B5332 +130B5333	958	1000 [750]	P800	962	1350 [1000]	P900	920	6516	4118			
2x130B5199 +2x130B5197	2x130B5294 +130B5295												
6x130B5042	3x130B5333	1098	1150 [850]	P1M0	1079		P1M0	1032	8436	4626			
6x130B5197	3x130B5295												

Table 4.14 Advanced Harmonic Filters, 500–690 V, 50 Hz

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4.2.3 Ordering Numbers: Sine-Wave Filter Modules, 380–690 V AC

400 V, 50 Hz		460 V, 60 Hz		500 V, 50 Hz		Frame Size	Filter Ordering Number	
[kW]	[A]	[HP]	[A]	[kW]	[A]		IP00	IP23
90	177	125	160	110	160	D1h/D3h	130B3182	130B3183
110	212	150	190	132	190	D1h/D3h	130B3184	130B3185
132	260	200	240	160	240	D1h/D3h, D2h/D4h, D13		
160	315	250	302	200	302	D2h/D4h, D13	130B3186	130B3187
200	395	300	361	250	361	D2h/D4h, D13		
250	480	350	443	315	443	D2h/D4h, D13, E1/E2, E9, F8/F9	130B3188	130B3189
315	600	450	540	355	540	E1/E2, E9, F8/F9	130B3191	130B3192
355	658	500	590	400	590	E1/E2, E9, F8/F9		
400	745	600	678	500	678	E1/E2, E9, F8/F9	130B3193	130B3194
450	800	600	730	530	730	E1/E2, E9, F8/F9		
450	800	600	730	530	730	F1/F3, F10/F11, F18	2X130B3186	2X130B3187
500	880	650	780	560	780	F1/F3, F10/F11, F18	2X130B3188	2X130B3189
560	990	750	890	630	890	F1/F3, F10/F11, F18		
630	1120	900	1050	710	1050	F1/F3, F10/F11, F18	2X130B3191	2X130B3192
710	1260	1000	1160	800	1160	F1/F3, F10/F11, F18		
710	1260	1000	1160	800	1160	F2/F4, F12/F13	3X130B3188	3X130B3189
800	1460					F2/F4, F12/F13		
		1200	1380	1000	1380	F2/F4, F12/F13	3X130B3191	3X130B3192
1000	1720	1350	1530	1100	1530	F2/F4, F12/F13		

Table 4.15 Sine Wave Filter Modules, 380–500 V

525 V, 50 Hz		575 V, 60 Hz		690 V, 50 Hz		Frame Size	Filter Ordering Number	
[kW]	[A]	[HP]	[A]	[kW]	[A]		IP00	IP23
75	113	100	108	90	108	D1h/D3h	130B4118	130B4119
90	137	125	131	110	131	D1h/D3h	130B4121	130B4124
110	162	150	155	132	155	D1h/D3h		
132	201	200	192	160	192	D1h/D3h, D2h/D4h	130B4125	130B4126
160	253	250	242	200	242	D2h/D4h		
200	303	300	290	250	290	D2h/D4h	130B4129	130B4151
250	360			315	344	D2h/D4h, F8/F9		
		350	344	355	380	D2h/D4h, F8/F9	130B4152	130B4153
315	429	400	400	400	410	D2h/D4h, F8/F9		
		400	410			E1/E2, F8/F9	130B4154	130B4155
355	470	450	450	450	450	E1/E2, F8/F9		
400	523	500	500	500	500	E1/E2, F8/F9		
450	596	600	570	560	570	E1/E2, F8/F9	130B4156	130B4157
500	630	650	630	630	630	E1/E2, F8/F9		
500	659			630	630	F1/F3, F10/F11	2X130B4129	2X130B4151
		650	630			F1/F3, F10/F11	2X130B4152	2X130B4153
560	763	750	730	710	730	F1/F3, F10/F11		
670	889	950	850	800	850	F1/F3, F10/F11	2X130B4154	2X130B4155
750	988	1050	945	900	945	F1/F3, F10/F11		
750	988	1050	945	900	945	F2/F4, F12/F13	3X130B4152	3X130B4153
850	1108	1150	1060	1000	1060	F2/F4, F12/F13		
1000	1317	1350	1260	1200	1260	F2/F4, F12/F13	3X130B4154	3X130B4155

Table 4.16 Sine-wave Filter Modules 525–690 V

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NOTICE!

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

NOTICE!

See also *Output Filter Design Guide*

4

4.2.4 Ordering Numbers: dU/dt Filters

Typical application ratings													
380–480 V [T4]				525–690 V [T7]									
400 V, 50 Hz		460 V, 60 Hz		525 V, 50 Hz		575 V, 60 Hz		690 V, 50 Hz		Frame Size	Filter ordering number	
[kW]	[A]	[HP]	[A]	[kW]	[A]	[HP]	[A]	[kW]	[A]		IP00	IP23
90	177	125	160	90	137	125	131			D1h/D3h	130B2847	130B2848
110	212	150	190	110	162	150	155	110	131	D1h/D3h		
132	260	200	240	132	201	200	192	132	155	D1h/D3h, D2h/D4h, D13		
160	315	250	302	160	253	250	242	160	192	D2h/D4h, D13		
200	395	300	361	200	303	300	290	200	242	D2h/D4h, D13	130B2849	130B3850
250	480	350	443	250	360	350	344	250	290	D2h/D4h, D11 E1/E2, E9, F8/F9		
315	588	450	535	315	429	400	410	315	344	D2h/D4h, E9, F8/F9	130B2851	130B2852
355	658	500	590	355	470	450	450	355	380	E1/E2, E9, F8/F9		
								400	410	E1/E2, F8/F9		
								450	450	E1/E2, F8/F9	130B2853	130B2854
400	745	600	678	400	523	500	500	500	500	E1/E2, E9, F8/F9		
450	800	600	730	450	596	600	570	560	570	E1/E2, E9, F8/F9		
				500	630	650	630	630	630	E1/E2, F8/F9		
450	800	600	730							F1/F3, F10/F11, F18	2x130B28492	2x130B28502
500	880	650	780	500	659	650	630			F1/F3, F10/F11, F18		
								630[2]	630[2]	F1/F3, F10/F11	2x130B2851	2x130B2852
560	990	750	890	560	763	750	730	710	730	F1/F3, F10/F11, F18		
630	1120	900	1050	670	889	950	850	800	850	F1/F3, F10/F11, F18		
710	1260	1000	1160	750	988	1050	945			F1/F3, F10/F11, F18	2x130B2851	2x130B2852
								900	945	F1/F3, F10/F11	2x130B2853	2x130B2854
710	1260	1000	1160	750	988	1050	945			F2/F4, F12/F13	3x130B2849	3x130B2850
								900	945	F2/F4, F12/F13	3x130B2851	3x130B2852
800	1460	1200	1380	850	1108	1150	1060	1000	1060	F2/F4, F12/F13		
1000	1720	1350	1530	1000	1317	1350	1260	1200	1260	F2/F4, F12/F13		
				1100	1479	1550	1415	1400	1415	F2/F4, F12/F13	3x130B2853	3x130B2854

Table 4.17 dU/dt Filter Ordering Numbers

NOTICE!

See also *Output Filter Design Guide*

4.2.5 Ordering Numbers: Brake Resistors

For brake resistor selection information, refer to the *Brake Resistor Design Guide*
Use this table to determine the minimum resistance applicable to each adjustable frequency drive size.

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380–480 V AC			
Drive data			
Aqua FC202 [T4]	Pm (NO) [kW]	Number of brake choppers 1)	R_{min}
N110	110	1	3.6
N132	132	1	3
N160	160	1	2.5
N200	200	1	2
N250	250	1	1.6
N315	315	1	1.2
P355	355	1	1.2
P400	400	1	1.2
P500	500	2	0.9
P560	560	2	0.9
P630	630	2	0.8
P710	710	2	0.7
P800	800	3	0.6
P1M0	1000	3	0.5

Table 4.18 Brake Chopper Data, 380–480 V

525–690 V AC			
Drive data			
Aqua FC202 [T7]	Pm (NO) [kW]	Number of brake choppers1)	R_{min}
N75K	167 [75]	1	13.5
N90K	90	1	8.8
N110	110	1	8.2
N132	132	1	6.6
N160	160	1	4.2
N200	200	1	4.2
N250	250	1	3.4
N315	315	1	2.3
N400	400	1	2.3
P450	450	1	2.3
P500	500	1	2.1
P560	560	1	2
P630	630	1	2
P710	710	2	1.3
P800	800	2	1.1
P900	900	2	1.1
P1M0	1000	3	1
P1M2	1200	3	0.8
P1M4	1400	3	0.7

Table 4.19 Brake Chopper Data 525–690 V

R_{min}*=Minimum brake resistance that can be used with this adjustable frequency drive. If the adjustable frequency drive includes multiple brake choppers, the resistance value is the sum of all resisters in parallel*

$R_{br,\ nom}$*=Nominal resistance required to achieve 150% braking torque.*

1) Larger adjustable frequency drives include multiple inverter modules with a brake chopper in each inverter. Connect equal resistors to each brake chopper.

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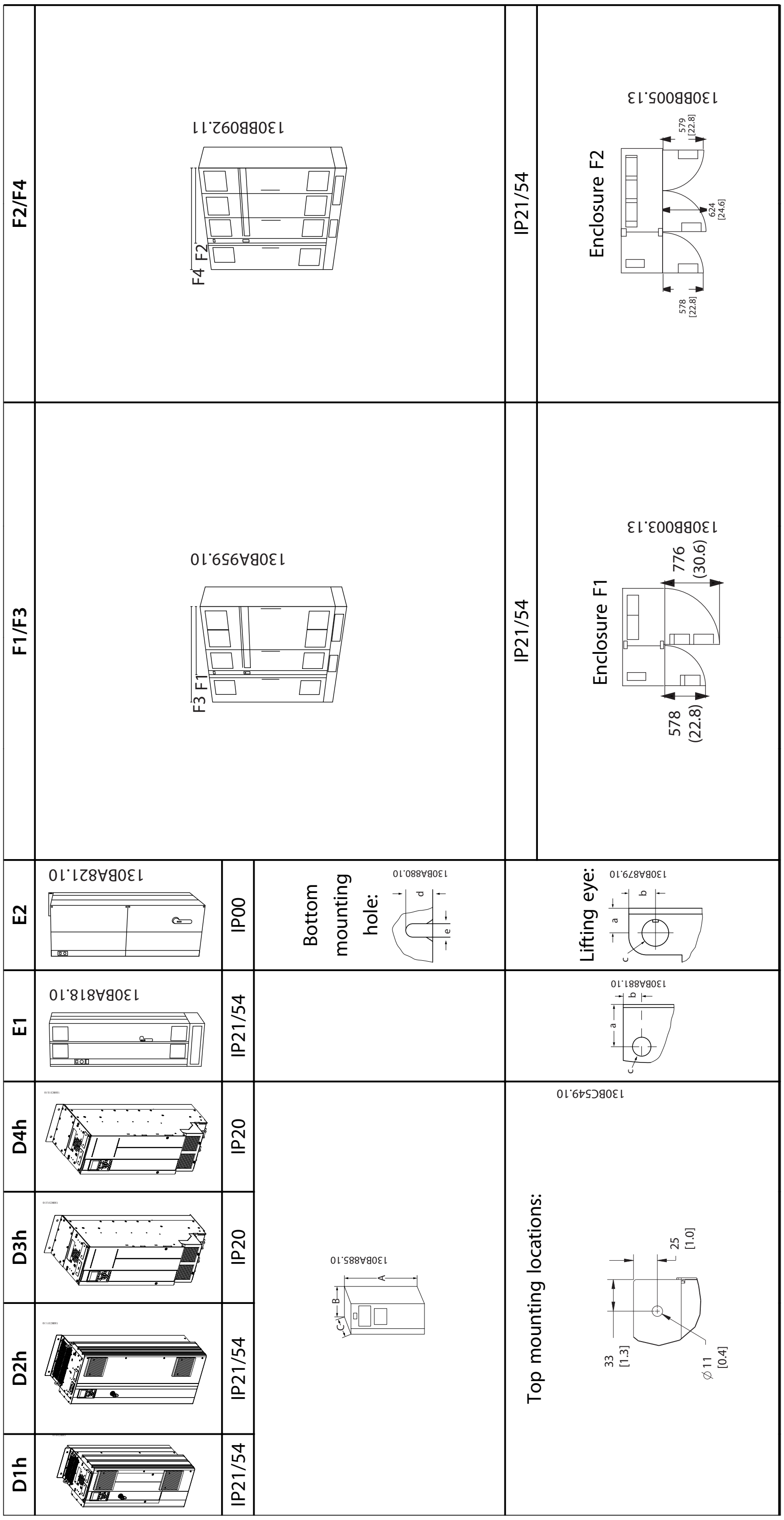
5 How to Install

5.1 Mechanical Installation



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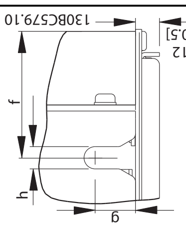
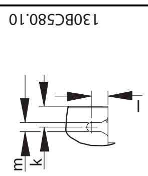
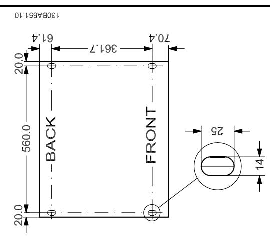
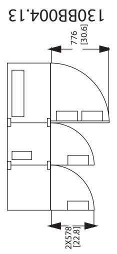
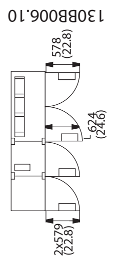
Bottom mounting locations:	Bottom mounting locations:	Base plate mount:	Enclosure F3	Enclosure F4
				

Table 5.1 Product Overview, 6-pulse Adjustable Frequency Drives

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Enclosure size [kW]		D1h	D2h	D3h*	D4h*	E1	E2*	F1	F2	F3	F4
380–480 V AC 525–690 V AC		110–160 45–160	200–315 200–400	110–160 45–160	200–315 200–400	315–450 450–630	315–450 450–630	500–710 710–900	800–1000 1000–1400	500–710 710–900	800–1000 1000–1400
Mechanical dimensions											
IP NEMA		21/54 Type 1/12	21/54 Type 1/12	20 Chassis	20 Chassis	21/54 Type 1/12	00 Chassis	21/54 Type 1/12	21/54 Type 1/12	21/54 Type 1/12	21/54 Type 1/12
Shipping dimensions ins [mm]											
Width		997	1,170	997	1,170	2,197	1,705	2,324	2,324	2,324	2,324
Height		587	587	587	587	840	831	1,569	1,962	2,159	2,559
Depth		460	535	460	535	736	736	927	927	927	927
Adjustable Frequency Drive dimensions (in [mm])											
Height											
	A	35.5 [901]	43.5 [1107]	35.75 [909]	44.25 [1122]	78.75 [2000]	61 [1547]	90 [2281]	90 [2281]	90 [2281]	90 [2281]
Width											
	B	13 [325]	16.5 [420]	10 [250]	13.75 [350]	23.75 [600]	23 [585]	55 [1400]	71 [1800]	78.75 [2000]	94.50 [2400]
Depth											
	C	15 [380]	15 [380]	14.75 [375]	14.75 [375]	19.5 [494]	19.5 [494]	24 [607]	24 [607]	24 [607]	24 [607]
Dimensions brackets [mm/inch]											
Center hole to back edge	a	Not Applicable				56/2.2	23/0.9				
Center hole to top edge	b					25/1.0	25/1.0				
Hole diameter	c					25/1.0	25/1.0				
Top of mounting slot to bottom edge	d						27/1.1				
Width of mounting slot	e						13/0.5				
Bottom mounting hole from side edge	f	63/2.5	75/3.0	Not Applicable							
Bottom mounting hole from bottom edge	g	20/0.8	20/0.8								
Width of mounting slot	h	11/0.4	11/0.4								

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Enclosure size [kW]		D1h	D2h	D3h*	D4h*	E1	E2*	F1	F2	F3	F4
380–480 V AC **525–690 V AC**		**110–160** **45–160**	**200–315** **200–400**	**110–160** **45–160**	**200–315** **200–400**	**315–450** **450–630**	**315–450** **450–630**	**500–710** **710–900**	**800–1000** **1000–1400**	**500–710** **710–900**	**800–1000** **1000–1400**
Bottom mounting hole from side edge	k	Not Applicable		25/1.0	40/1.6	Not Applicable					
Bottom mounting hole from bottom edge	l			20/0.8	20/0.8						
Width of mounting slot	m			11/0.4	11/0.4						
Max weight lbs [kg]		216 [98]	362 [164]	216 [98]	362 [164]	690 [313]	478 [277]	2242 [1017]	2681 [1260]	2906 [1318]	3441 [1561]
Contact Danfoss for more detailed information and CAD drawings for your own planning purposes. **Chassis drives are intended for installation in external enclosures*											

Table 5.2 Legend to *Table 5.1*

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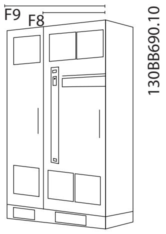
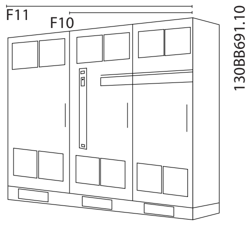
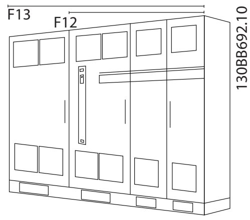
Frame size		F8	F9	F10	F11	F12	F13
							
Enclosure protection	IP	21/54	21/54	21/54	21/54	21/54	21/54
	NEMA	Type 1/Type 12	Type 1/Type 12	Type 1/Type 12	Type 1/Type 12	Type 1/Type 12	Type 1/Type 12
High overload rated power -160% overload torque		450–600 hp [315–450 kW] (380–480 V) 600–850 hp [450–630 kW] (525–690 V)	450–475 hp [315–350 kW] (380–480 V) 600–850 hp [450–630 kW] (525–690 V)	650–950 hp [500–710 kW] (380–480 V) 950–1200 hp [710–900 kW] (525–690 V)	650–950 hp [500–710 kW] (380–480 V) 950–1200 hp [710–900 kW] (525–690 V)	1075–1350 hp [800–1000 kW] (380–480 V) 1350–1875 hp [1000–1400 kW] (525–690 V)	1075–1350 hp [800–1000 kW] (380–480V) 1350–1875 hp [1000–1400 kW] (525–690 V)
Shipping dimensions (ins [mm])	Height	91.5 [2324]	91.5 [2324]	91.5 [2324]	91.5 [2324]	91.5 [2324]	91.5 [2324]
	Width	38.19 [970]	61.73 [1568]	69.29 [1760]	100.75 [2559]	85.04 [2160]	116.54 [2960]
	Depth	44.49 [1130]	44.49 [1130]	44.49 [1130]	44.49 [1130]	44.49 [1130]	44.49 [1130]
Drive dimensions (ins [mm])	Height	86.77 [2204]	86.77 [2204]	86.77 [2204]	86.77 [2204]	86.77 [2204]	86.77 [2204]
	Width	31.5 [800]	55.12 [1400]	62.99 [1600]	86.61 [2200]	78.74 [2000]	102.36 [2600]
	Depth	23.86 [606]	23.86 [606]	23.86 [606]	23.86 [606]	23.86 [606]	23.86 [606]
Max weight (lbs [kg])		986 [447]	1475 [669]	1969 [893]	2460 [1116]	2286 [1037]	2776 [1259]

Table 5.3 Product Overview, 12-pulse Adjustable Frequency Drives

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5

5.1.1 Mechanical Mounting

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

The adjustable frequency drive allows side-by-side installation. The back wall must always be solid.

Enclosure	Air space (in [mm])
D1h/D2h/D3h/D4h/D5h/D6h/D7h/D8h	8.86 [225]
E1/E2	8.86 [225]
F1/F2/F3/F4	8.86 [225]
F8/F9/F10/F11/F12/F13	8.86 [225]

Table 5.4 Required Free Air Space Above and Below Adjustable Frequency Drive

NOTICE!

If using a kit to direct the heatsink cooling air out the back of the adjustable frequency drive, the required top clearance is 4 in [100 mm].

5.1.2 Pedestal Installation of D-Frames

The D7h and D8h adjustable frequency drives are shipped with a pedestal and a wall spacer. Before securing the enclosure to the wall, install the pedestal behind the mounting flange as shown in *Figure 5.1*.

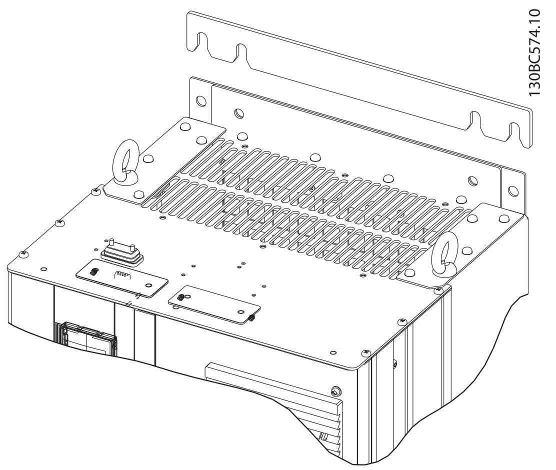

Figure 5.1 Wall Mounting Spacer

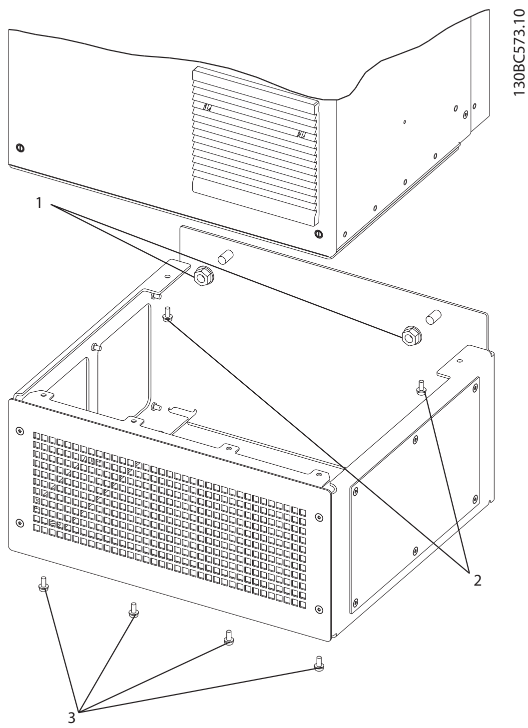

Figure 5.2 Pedestal Hardware Installation

1	Attach the pedestal to the backchannel using two M10 nuts
2	Fasten two M5 screws through the back pedestal flange into the pedestal drive mounting bracket
3	Fasten four M5 screws through the front pedestal flange into the front connector plate mounting holes

Table 5.5 Legend to *Figure 5.2*

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5.1.3 Pedestal Installation on F-Frame Drives

Pedestals on F-Frame adjustable frequency drives use eight bolts instead of four.

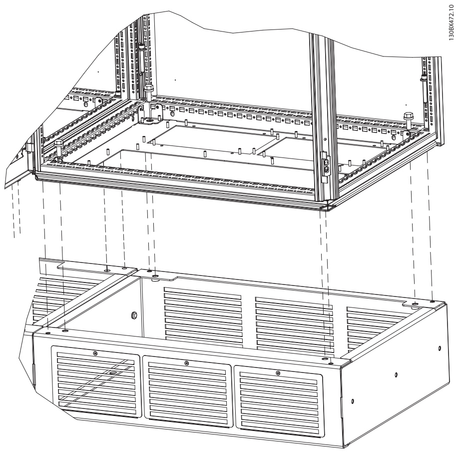

Figure 5.3 Pedestal Bolt Installation

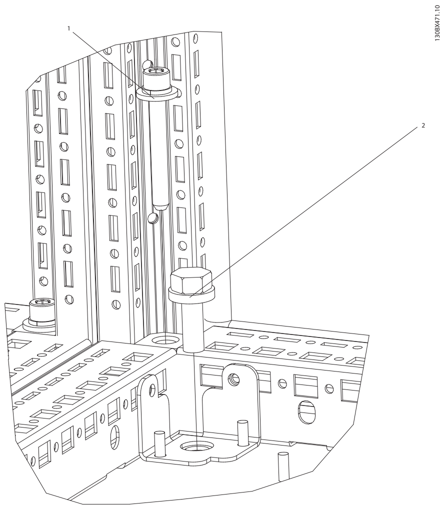

Figure 5.4 Close-up Detail

1	Install each M8x60 mm bolt with lock washer and flat washer through the frame into the threaded hole in the base. Install four bolts per cabinet
2	Install each M10x30 mm bolt with captive lock washer and flat washer through the base plate and into the threaded hole in the base. Install four bolts per cabinet

Table 5.6 Legend to *Figure 5.4*

5.1.4 Safety Requirements of Mechanical Installation

WARNING

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

CAUTION

The adjustable frequency drive is cooled with air circulation.
To protect the unit from overheating, ensure that the ambient temperature *does not exceed the maximum rated temperature*. If the ambient temperature is in the range of 113–131 °F [45 °C–55 °C], derating of the adjustable frequency drive is relevant, see *chapter 3.5.5 Derating for Ambient Temperature*.
If derating for ambient temperature is not taken into account, the service life of the adjustable frequency drive is reduced.

5.2 Pre-installation

5.2.1 Planning the Installation Site

NOTICE!

To avoid extra work during and after installation, it is important to plan the installation of the adjustable frequency drive in advance.

Select the best possible operation site by considering the following:

- 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.

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5.2.2 Receiving the Adjustable Frequency Drive

When receiving the adjustable frequency drive, make sure that the packaging is intact, and be aware of any potential damage to the unit during transport. If damage has occurred, contact the shipping company immediately to claim the damage.

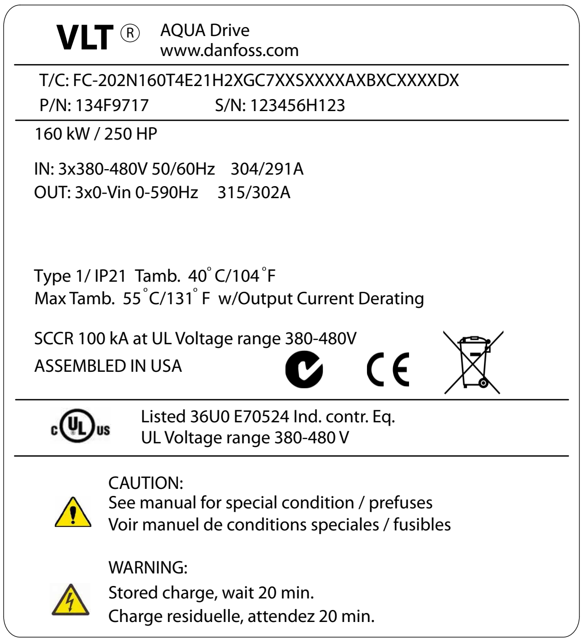

Figure 5.5 Nameplate Label

5.2.3 Transportation and Unpacking

Before unpacking the adjustable frequency drive, position it as close as possible to the final installation site. Remove the box and leave the adjustable frequency drive on the pallet as long as possible.

5.2.4 Lifting

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

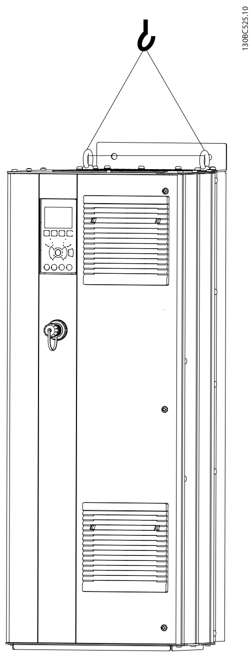

Figure 5.6 Recommended Lifting Method, D-Frame Size

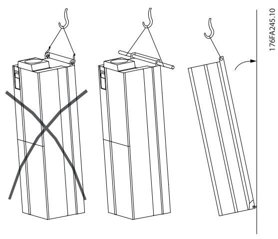

Figure 5.7 Recommended Lifting Method, E-Frame Size

WARNING

The lifting bar must be able to handle the weight of the adjustable frequency drive. See *Table 5.2* for the weight of the different frame sizes. Maximum diameter for the bar is 1 in (2.5 cm). The angle from the top of the drive to the lifting cable should be 60° or greater.

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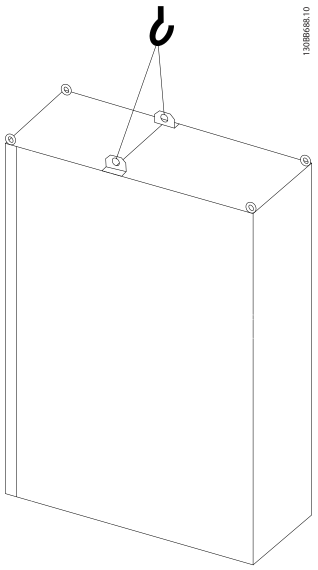

Figure 5.8 Recommended Lifting Method, Frame Sizes F1, F2, F9 and F10

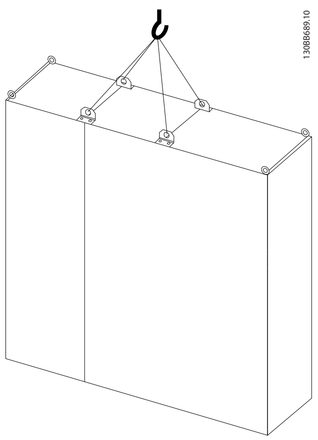

Figure 5.9 Recommended Lifting Method, Frame Sizes F3, F4, F11, F12 and F13

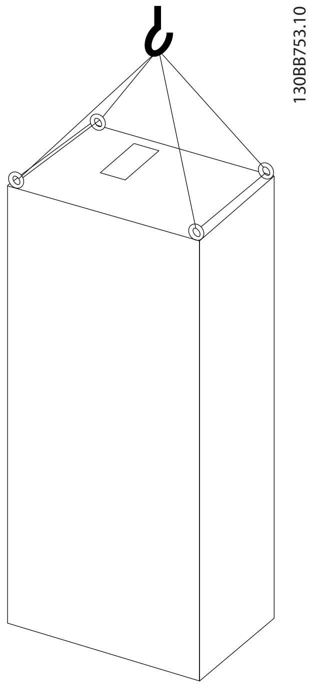

Figure 5.10 Recommended Lifting Method, Frame Sizes F8

NOTICE!

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 adjustable frequency drive to provide proper cooling. Position F-Frames on top of the plinth in the final installation location. The angle from the top of the adjustable frequency drive to the lifting cable should be 60° or greater. In addition to the drawings above, a spreader bar is an acceptable way to lift the F-Frame.

5.2.5 Tools Needed

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

- Drill with 0.4 or 0.5 in (10 mm 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 IP21 (NEMA 1) and IP54 (NEMA 12) units.
- Lifting bar to lift the unit (rod or tube max. Ø1 in [25 mm], able to lift minimum 880 lbs [400 kg].

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- Crane or other lifting aid to place the adjustable frequency drive in position.
- Use a Torx T50 tool to install the E1 in IP21 and IP54 enclosure types.

5.2.6 General Considerations

Wire access

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

NOTICE!

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

Space

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

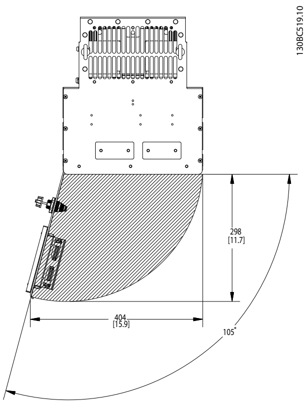

Figure 5.11 Front Clearance of IP21/IP54 Enclosure Type, Frame Size D1h, D5h, and D6h.

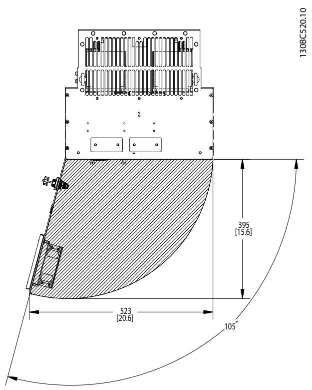

Figure 5.12 Front Clearance of IP21/IP54 Enclosure Type, Frame Size D2h, D7h, and D8h.

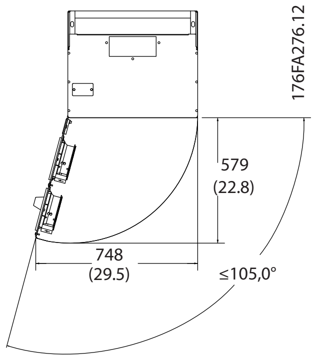

Figure 5.13 Front Clearance of IP21/IP54 Enclosure Type, Frame Size E1.

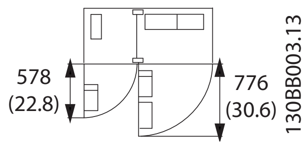

Figure 5.14 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F1

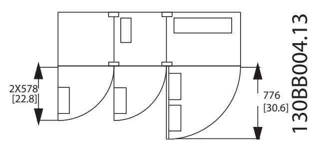

Figure 5.15 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F3

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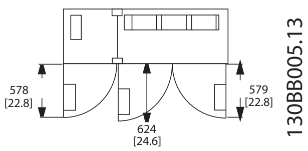

Figure 5.16 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F2

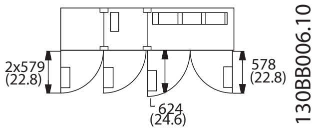

Figure 5.17 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F4

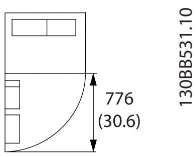

Figure 5.18 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F8

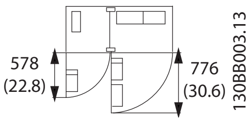

Figure 5.19 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F9

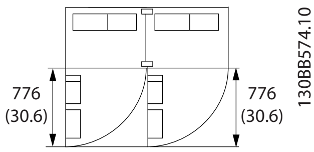

Figure 5.20 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F10

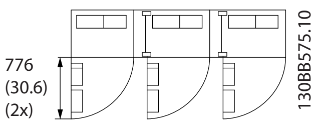

Figure 5.21 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F11

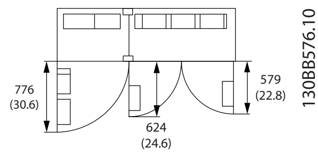

Figure 5.22 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F12

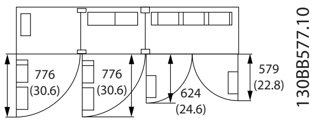

Figure 5.23 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F13

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5.2.7 Cooling and Airflow

Cooling

Cooling can be achieved either 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 be 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.

Back cooling

The backchannel air can also be ventilated in and out the back of a Rittal TS8 enclosure. Using this method, the backchannel could take air from outside the facility and return the heat losses outside the facility, thus reducing air conditioning requirements.

NOTICE!

A door fan is required on the enclosure to remove the heat losses not contained in the backchannel of the adjustable frequency 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.

Airflow

The necessary airflow over the heatsink must be ensured. The flow rate is shown in *Table 5.7*.

Drive Type	Drive size		Frame Size	Enclosure protection	Airflow m3/h (cfm)	
	380–480 V (T5)	525–690 V (T7)			Door fan(s)/ Top fan	Heatsink fan(s)
6-Pulse	N110 to N160	N75 to N160	D1h, D5h, D6h	IP21/NEMA 1 or IP54/NEMA 12	102 (60)	420 (250)
			D3h	IP20/chassis		
	N200 to N315	N200 to N400	D2h, D7h, D8h	IP21/NEMA 1 or IP54/NEMA 12	204 (120)	840 (500)
			D4h	IP20/chassis		
	-	P450 to P500	E1	IP21/NEMA 1 or IP54/NEMA 12	340 (200)	1105 (650)
			E2	IP00/chassis	255 (150)	
	P355 to P450	P560 to P630	E1	IP21/NEMA 1 or IP54/NEMA 12	340 (200)	1445 (850)
			E2	IP00/chassis	255 (150)	
	P500 to P1M0	P710 to P1M4	F1/F3, F2/F4	IP21/NEMA 1	700 (412)	985 (580)
				IP54/NEMA 12	525 (309)	
12-Pulse	P315 to P1M0	P450 to P1M4	F8/F9, F10/F11, F12/F13	IP21/NEMA 1	700 (412)	985 (580)
				IP54/NEMA 12	525 (309)	

Table 5.7 Heatsink and Front Channel Air Flow

** Airflow per fan. F-Frames contain multiple fans.*

D-Frame Cooling fans

All adjustable frequency drives in this size range are equipped with cooling fans to provide airflow along the heatsink. Units in IP21 (NEMA 1) and IP54 (NEMA 12) enclosures have a fan mounted in the enclosure door to provide more airflow to the unit. IP20 enclosures have a fan mounted to the top of the unit for more cooling. There is a small 24 V DC mixing fan mounted under the input plate. This fan operates any time the adjustable frequency drive is powered on.

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DC voltage from the power card powers the fans. The mixing fan is powered by 24 V DC from the main switch mode power supply. The heatsink fan and the door/top fan are powered by 48 V DC from a dedicated switch mode power supply on the power card. Each fan has tachometer feedback to the control card to confirm that the fan is operating correctly. On/off and speed control of the fans is provided to reduce overall acoustical noise and extend the life of the fans.

The following conditions activate fans on the D-Frame:

- Output current greater than 60% of nominal
- IGBT over-temperature
- IGBT low temperature
- Control card overtemperature
- DC hold active
- DC brake active
- Dynamic brake circuit active
- During pre-magnetization of the motor
- AMA in progress

In addition to these conditions, the fans are always started shortly after line input power is applied to the adjustable frequency drive. Once fans are started, they run for a minimum of one minute.

The following conditions activate fans on the E- and F-frames:

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

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

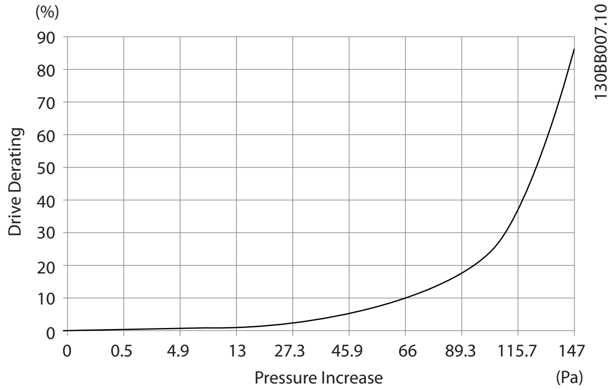

Figure 5.24 D-Frame Derating vs. Pressure Change
Adjustable Frequency Drive Air Flow: 450 cfm (765 m^3/h)

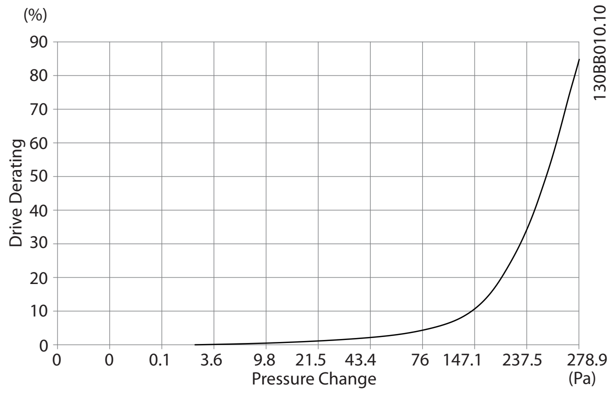

Figure 5.25 E-Frame Derating vs. Pressure Change (Small Fan), P250T5 and P355T7-P400T7
Adjustable Frequency Drive Air Flow: 650 cfm (1105 m^3/h)

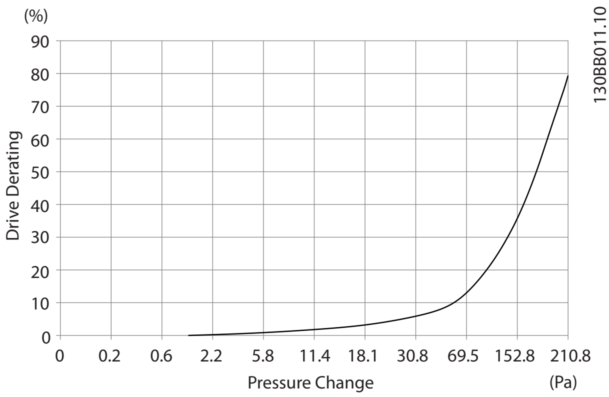

Figure 5.26 E-Frame Derating vs. Pressure Change (Large Fan), P315T5-P400T5 and P500T7-P560T7
Adjustable Frequency Drive Air Flow: 850 cfm (1445 m^3/h)

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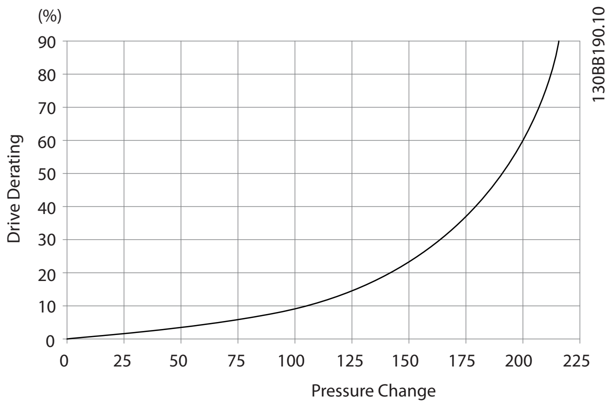

Figure 5.27 F1, F2, F3, F4 Frame Derating vs. Pressure Change Adjustable Frequency Drive Air Flow: 580 cfm (985 m³/h)

5.2.8 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.

NOTICE!

The connector plate must be fitted to the adjustable frequency drive to ensure the specified degree of protection.

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

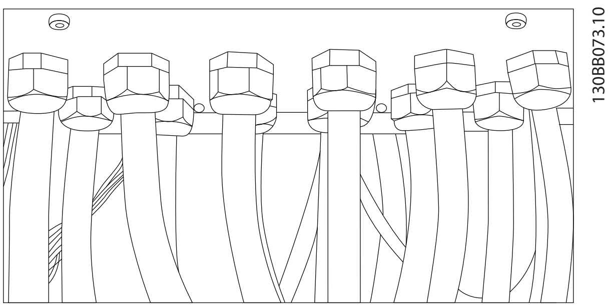

Figure 5.28 Example of Proper Installation of Connector Plate

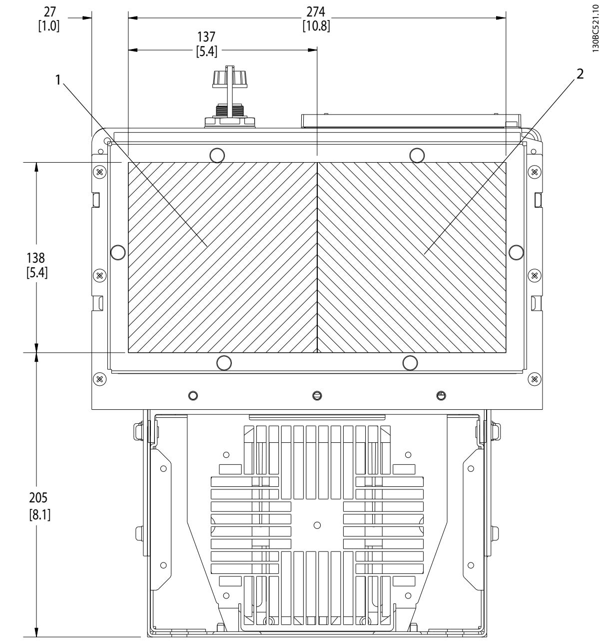

Figure 5.29 D1h, Bottom View

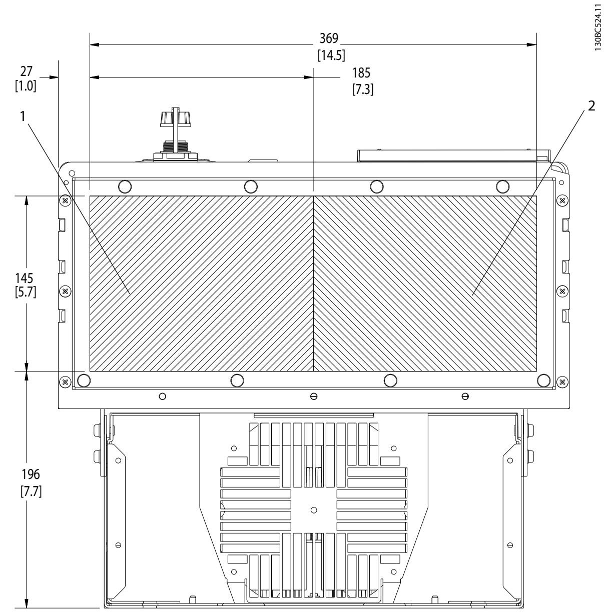

Figure 5.30 D2h, Bottom View

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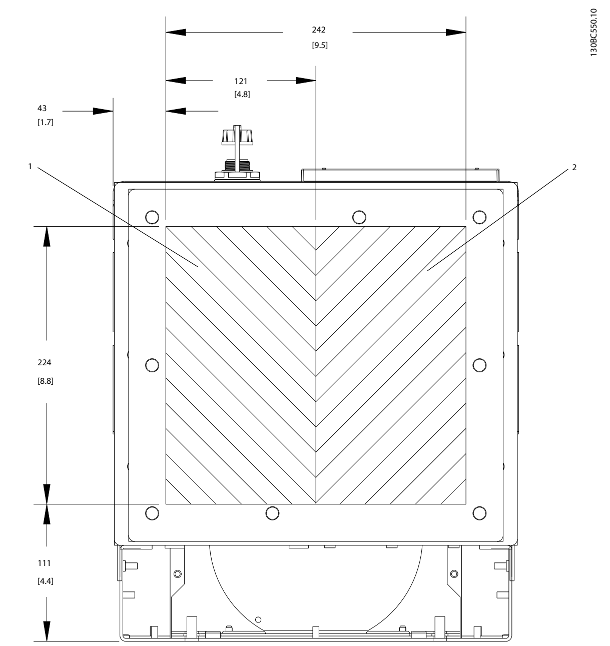

Figure 5.31 D5h & D6h, Bottom View

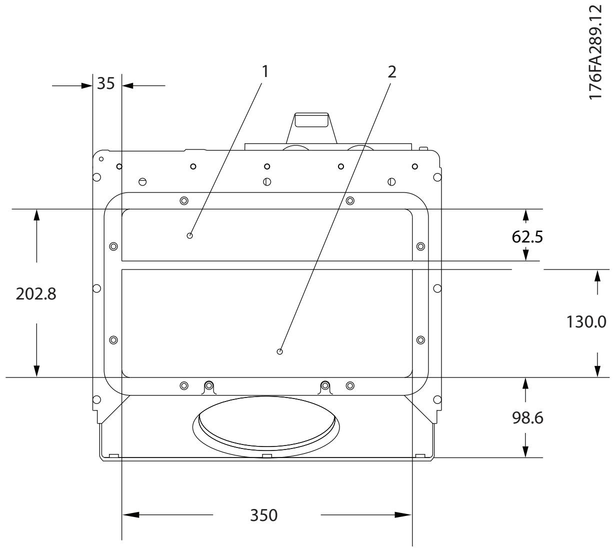

Figure 5.33 E1, Bottom View

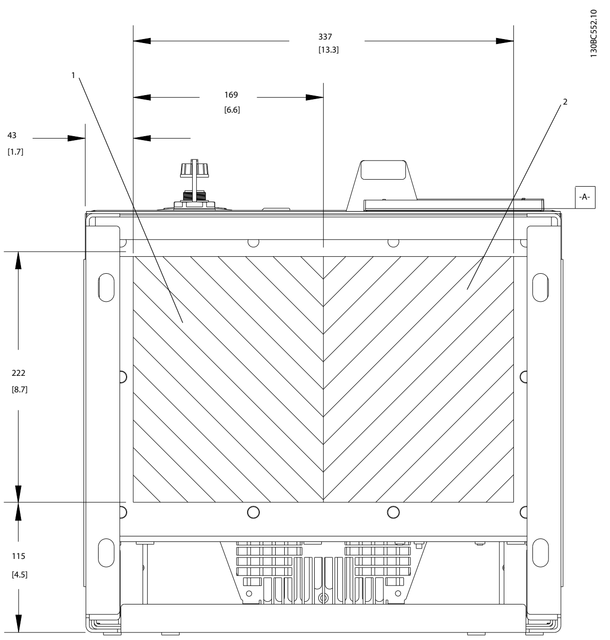

Figure 5.32 D7h & D8h, Bottom View

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

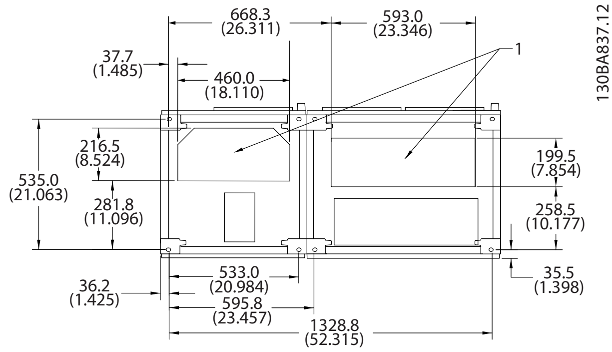

Figure 5.34 F1, Bottom View

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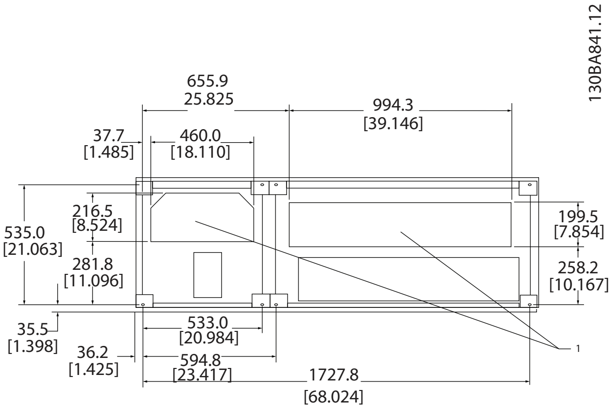

Figure 5.35 F2, Bottom View

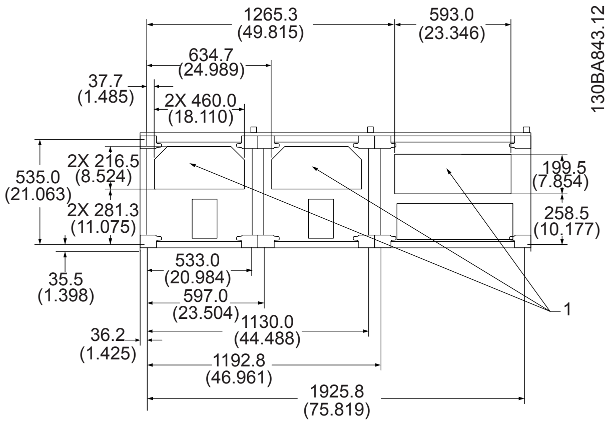

Figure 5.36 F3, Bottom View

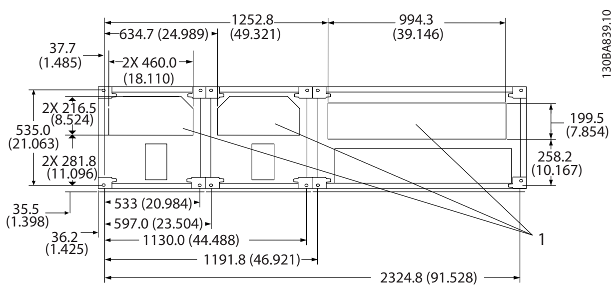

Figure 5.37 F4, Bottom View

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

NOTICE!

Cable entries viewed from the bottom of the adjustable frequency drive

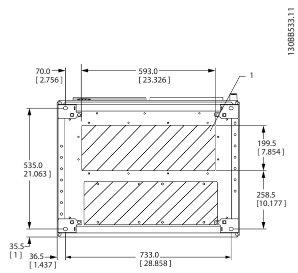

Figure 5.38 Frame Size F8

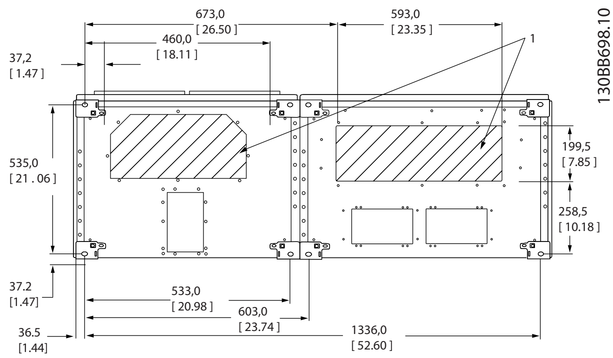

Figure 5.39 Frame Size F9

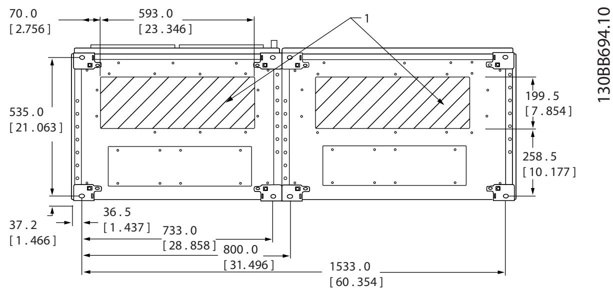

Figure 5.40 Frame Size F10

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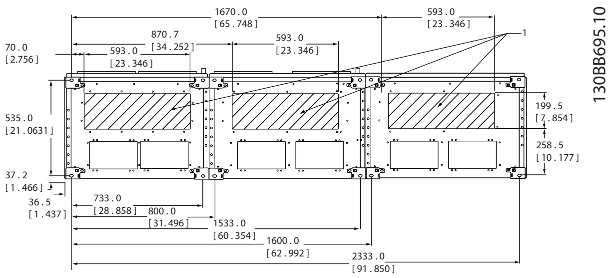

Figure 5.41 Frame Size F11

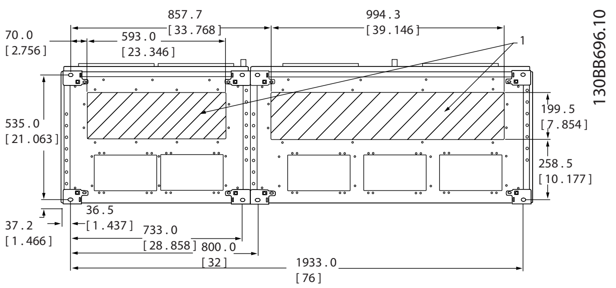

Figure 5.42 Frame Size F12

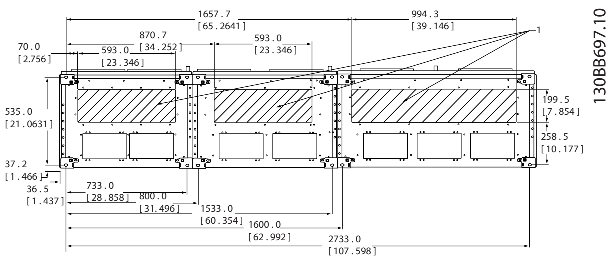

Figure 5.43 Frame Size F13

1	Place conduits in marked areas

Table 5.8 Legend to *Figure 5.38-Figure 5.43*

5.3 Electrical Installation

5.3.1 Cables General

NOTICE!

Always comply with national and local regulations on cable cross-sections.

For more information on the correct torques, see *Table 5.12*.

5.3.2 Preparing Connector Plates for Cables

1. Remove connector plate from the adjustable frequency drive. (Avoiding foreign parts falling into the adjustable frequency drive when removing knockouts).
2. Provide support for the connector plate around the hole being punched or drilled.
3. Remove debris from the hole.
4. Mount the cable entry on the adjustable frequency drive.

5.3.3 Connection to Line and Grounding

NOTICE!

The plug connector for power can be removed.

1. Make sure that the adjustable frequency drive is properly grounded. Connect to ground connection (terminal 95). Use screw from the accessory bag.
2. Place plug connector 91, 92, 93 from the accessory bag onto the terminals labeled LINE POWER at the bottom of the adjustable frequency drive.
3. Connect line power wires to the line power plug connector.

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⚠CAUTION

The ground connection cable cross-section must be at least 0.016 in² [10 mm²] or have two rated line power supply wires terminated separately according to EN 50178.

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

NOTICE!

Make sure that the AC line voltage corresponds to the AC line voltage of the adjustable frequency drive nameplate.

⚠CAUTION

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.
For IT line power and delta earth (grounded leg), AC line voltage can exceed 440 V between phase and ground.

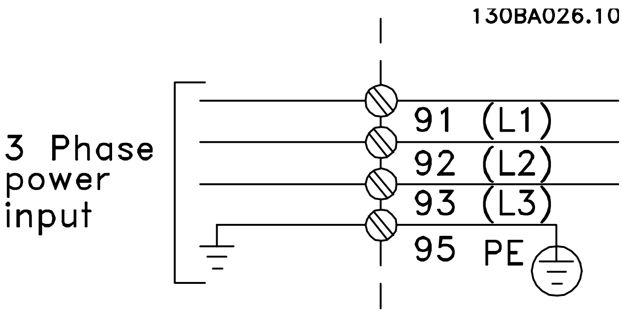

Figure 5.44 Terminals for Line Power and Grounding

5.3.4 Motor Cable Connection

NOTICE!

Shielded motor cable is recommended. If an non-shielded cable is used, some EMC requirements will not be fulfilled. For more information, see *chapter 5.10 EMC-compatible Installation*.

1. Fasten 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 terminals 96 (U), 97 (V), 98 (W) and motor cable to terminals labeled MOTOR.
5. Fasten shielded cable to decoupling plate with screws and washers from the accessory bag.

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

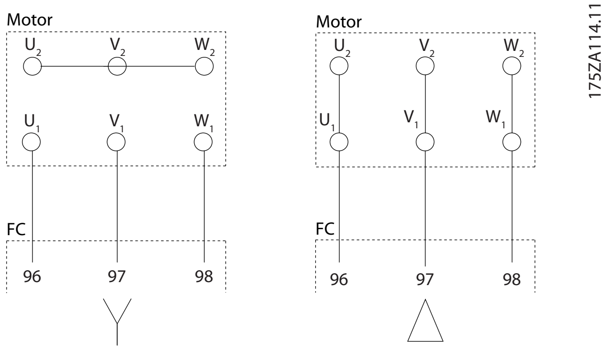

Figure 5.45 Motor Cable Connection

NOTICE!

If motors are not inverter-duty rated, fit a sine-wave filter on the output of the adjustable frequency drive.

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

Table 5.9 Motor Cable Connection

[1)]*Protected Ground Connection*

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5.3.5 Motor Cables

See *chapter 3.1 General Specifications* for maximum dimensioning of motor cable cross-section and length.

- To comply with EMC emission specifications, use a shielded/armored motor cable.
- Keep the motor cable as short as possible to reduce the noise level and leakage currents.
- Connect the motor cable shield to both the decoupling plate of the adjustable frequency drive and to the metal cabinet of the motor.
- Make the shield connections with the largest possible surface area (cable clamp) by using the supplied installation devices in the adjustable frequency drive.
- Avoid mounting with twisted shield ends (pigtails), which spoils high frequency shielding effects.
- If it is necessary to split the shield to install a motor isolator or motor relay, the shield must be continued with the lowest possible HF impedance.

F-frame Unit Size 6X requirements
F1/F3 requirements:
Motor phase cable quantities must be multiples of 2, resulting in 2, 4, 6, or 8 (one cable is not allowed) to obtain equal numbers 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 numbers of wires attached to each inverter module terminal. The wires are required to be equal length within 10% between the inverter module terminals and the first common point of a phase. The recommended common point is the motor terminals.

Output junction box requirements:
The length, a minimum of 8 ft [2.5 m], and quantity of cables must be equal from each inverter module to the common terminal in the junction box.

5.3.6 Electrical Installation of Motor Cables

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

Cable length and cross-section
The 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 - increase, and the cable length must be reduced correspondingly.

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

Aluminum conductors
Aluminum conductors are not recommended. Terminals can accept aluminum conductors but the conductor surface has to be clean, free of oxidation and sealed with neutral acid-free Vaseline grease before the conductor is connected.
Furthermore, the terminal screw must be retightened after two days due to the softness of the aluminum. It is crucial to keep the connection a gas-tight joint, otherwise the aluminum surface will oxidize again.

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5.3.7 Fuses

Branch circuit protection:
To protect the installation against electrical and fire hazard, all branch circuits in an installation, switchgear or machine, must be short-circuit and overcurrent-protected according to the national/international regulations.

Short circuit protection:
The adjustable frequency drive must be protected against short circuit in order to prevent electrical or fire hazard. Danfoss recommends using the fuses mentioned in *Table 5.10* and *Table 5.11* to protect service personnel or other equipment in case of an internal failure in the unit. The adjustable frequency drive provides full short circuit protection in a short-circuit on the motor output.

Overcurrent protection:
To avoid fire hazard doe to overheating of the cables in the installation, provide overload protection. Overcurrent protection must always be provided in accordance with national regulations. The adjustable frequency drive is equipped with internal overcurrent protection that can be used for upstream overload protection (UL applications excluded). See *4-18 Current Limit*. Fuses must be designed for protection in a circuit capable of supplying a maximum of 100,000 A_{rms} (symmetrical), 500 V/600 V maximum.

5.3.8 Fuse Specifications

Enclosure size	Power [kW]	Recommended fuse size	Recommended Max. fuse
D	N110T4	aR-315	aR-315
	N132T4	aR-350	aR-350
	N165	aR-400	aR-400
	N200T4	aR-550	aR-550
	N250T4	aR-630	aR-630
	N315T4	aR-800	aR-700
E	P355-P450	aR-900	aR-900
F	P500-P560	aR-1600	aR-1600
	P630-P710	aR-2000	aR-2000
	P800-P1M0	aR-2500	aR-2500

Table 5.10 380–480 V, Fuse Recommendations, Frame Sizes D, E and F

Enclosure size	Power [kW]	Recommended fuse size	Recommended Max. fuse
D	N75K	aR-160	aR-160
	N90K-N160	aR-160	aR-160
	N200-N400	aR-550	aR-550
E	P450-P500T7	aR-700	aR-700
	P560-P630T7	aR-900 (500–560)	aR-900 (500–560)
F	P710-P1M0T7	aR-1600	aR-1600
	P1M2T7	aR-2000	aR-2000
	P1M4T7	aR-2500	aR-2500

Table 5.11 525–690 V, Fuse Recommendations, Frame Sizes D, E and F

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5.3.9 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 with a screwdriver.

5.3.10 Control Terminals

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

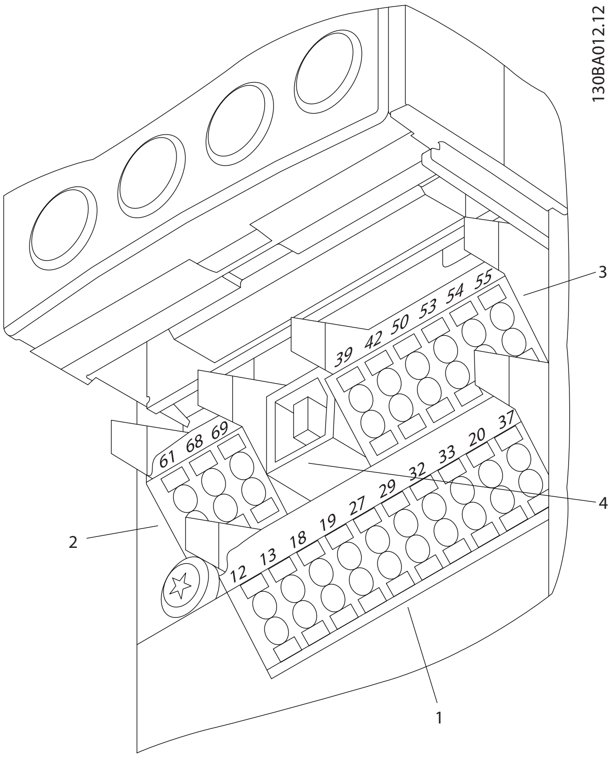

Figure 5.46 Control Terminals (all Frame Sizes)

5.3.11 Control Cable Terminals

To mount the cable to the terminal:

1. Strip isolation of 0.34–0.39 in [9–10 mm]
2. Insert a screwdriver[1)] in the rectangular 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]

Wiring to Control Terminals

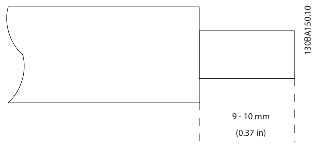

Figure 5.47

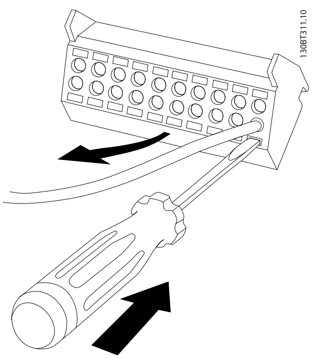

Figure 5.48

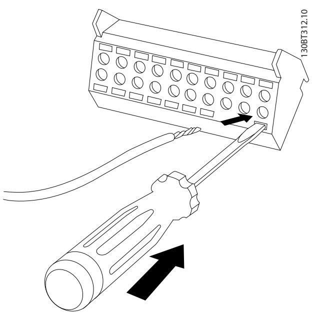

Figure 5.49

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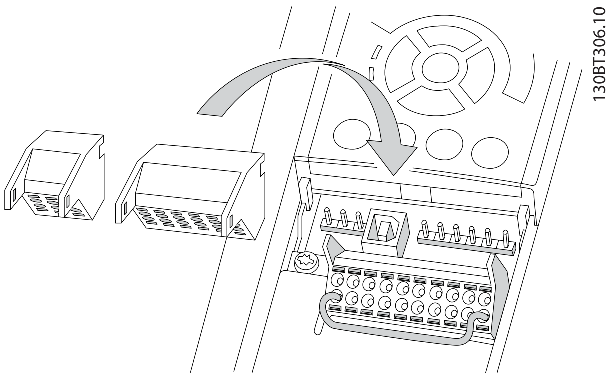

Figure 5.50 Control Cable Terminals

5.3.12 Basic Wiring Example

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

Default settings:
18 = Start
27 = stop inverse

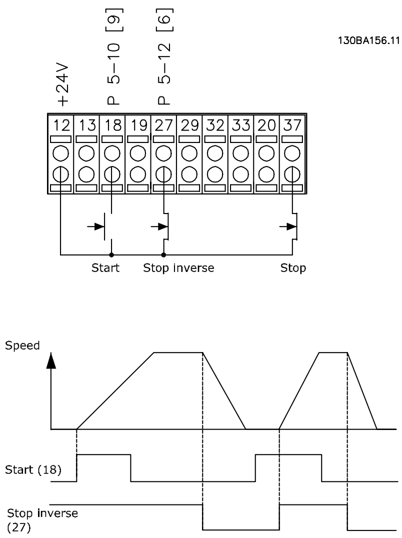

Figure 5.51 Terminal 37 available with Safe Stop Function only!

5.3.13 Control Cable Length

Digital in/digital out
Dependent on what electronics are being used, it is possible to calculate the maximum cable impedance based on the 4 kΩ adjustable frequency drive input impedance.

Analog in/analog out
Again the electronics used puts a limitation on the cable length.

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5.3.14 Electrical Installation, Control Cables

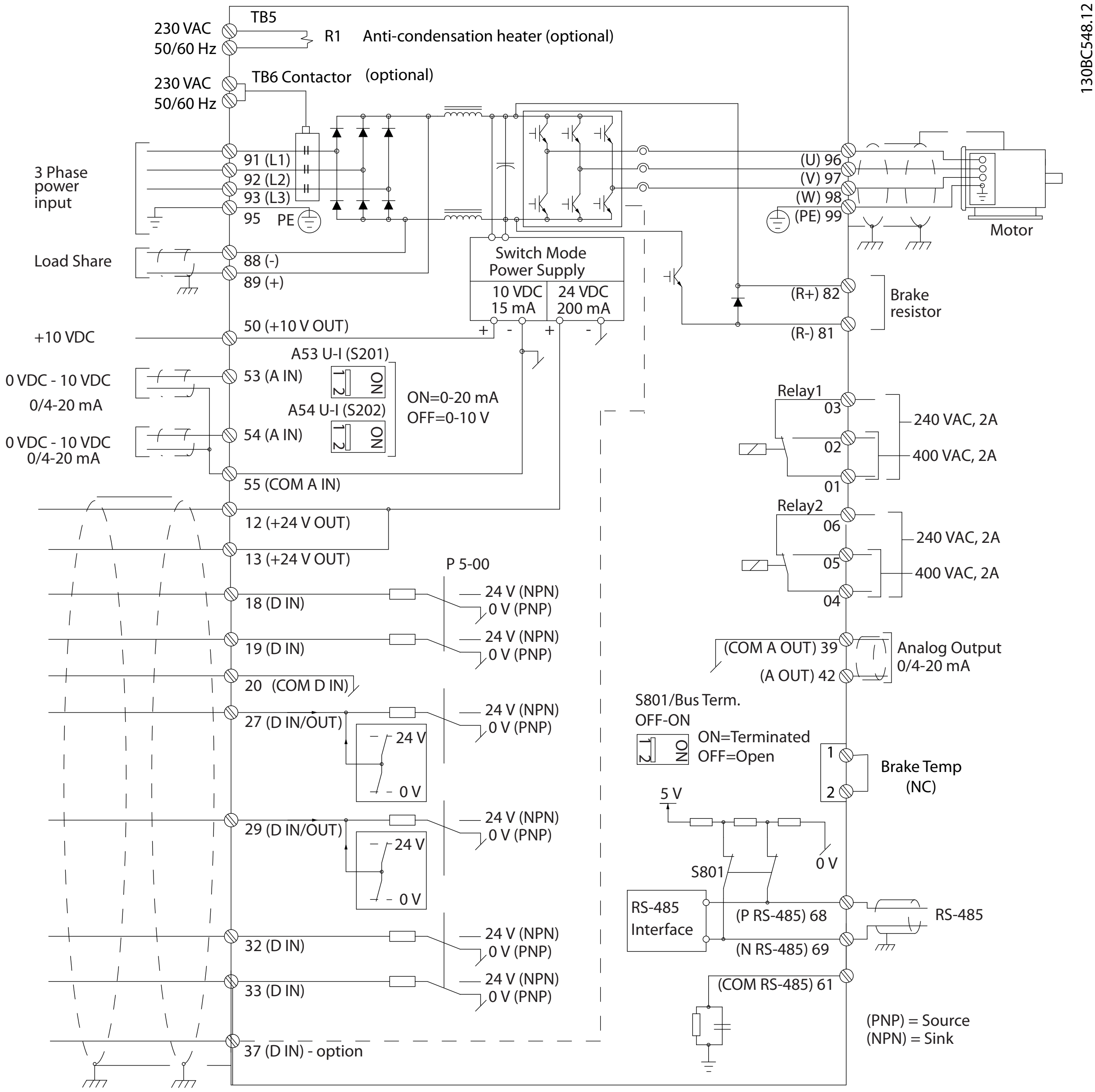

Figure 5.52 Interconnect Diagram for D-frames

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5

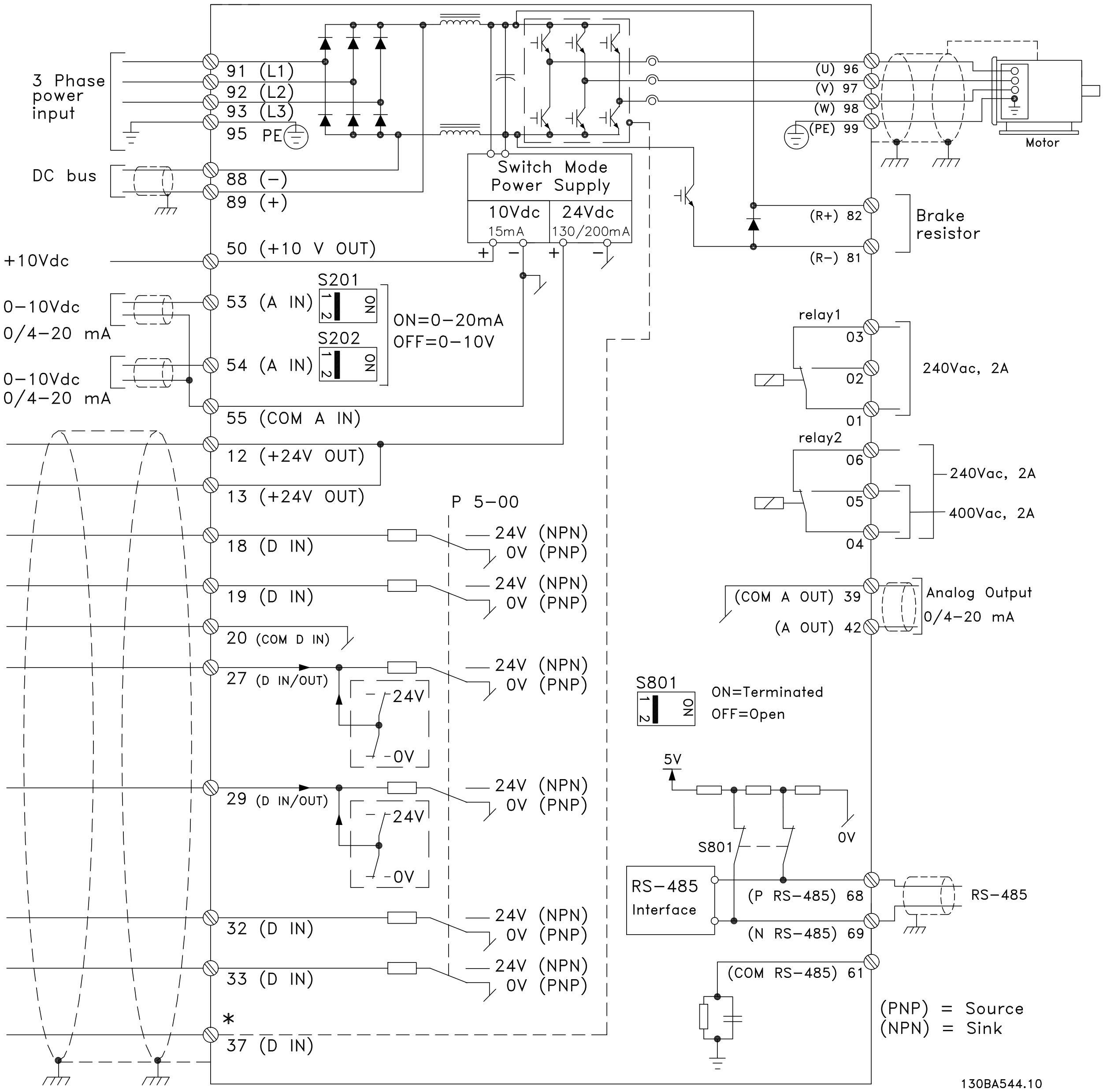

Figure 5.53 Interconnect Diagram E-frames and F-frame (6-pulse)

*Safe Stop input available with Safe Stop Function only.

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

In this case, 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) to avoid ground currents from both groups to affect other groups. For example, switching on the digital input disturbs the analog input signal.

NOTICE!

Control cables must be shielded.

Use a clamp from the accessory bag to connect the shield to the adjustable frequency drive decoupling plate for control cables.

See *chapter 5.10.3 Grounding of Shielded/Armored Control Cables* for the correct termination of control cables.

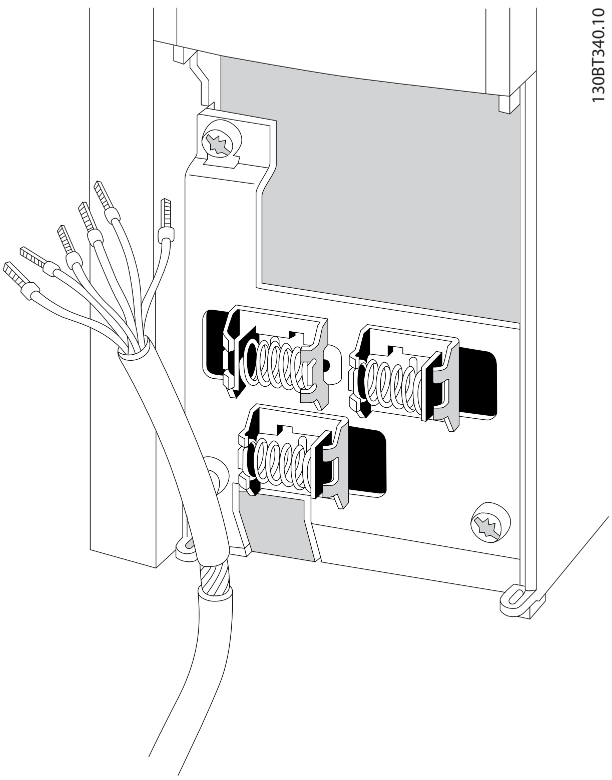

Figure 5.54 Shielded Control Cable

5

5.3.15 12-Pulse Control Cables

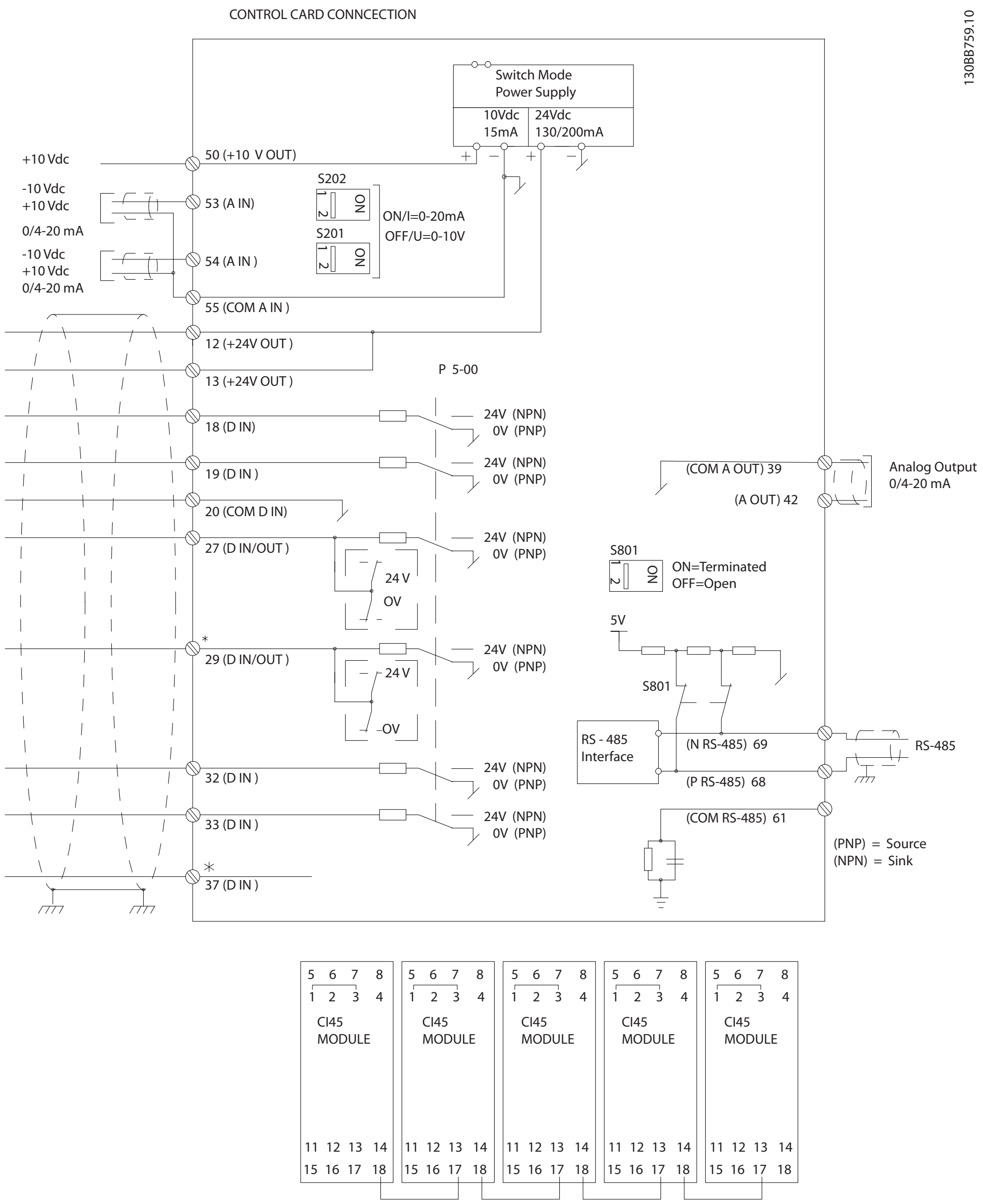

Figure 5.55 Control Cable Diagram

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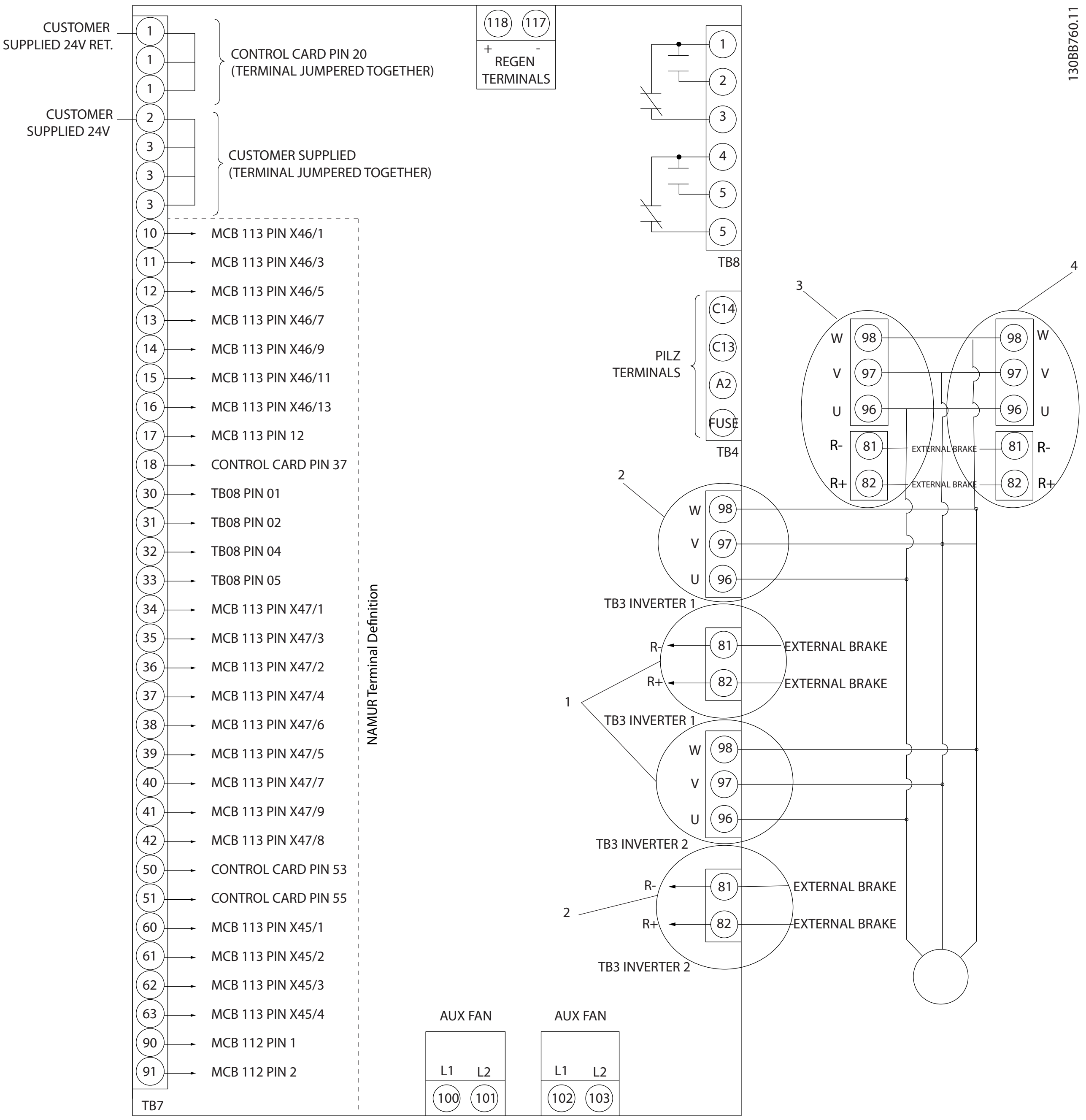

Figure 5.56 Diagram Showing all Electrical Terminals without Options

Terminal 37 is the input to be used for Safe Stop. For instructions on Safe Stop installation, refer to ***chapter 5.7 Safe Stop Installation*****.**

1) F8/F9 = (1) set of terminals.

2) F10/F11 = (2) sets of terminals.

3) F12/F13 = (3) sets of terminals.

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

In such cases, break the shield or insert a 100 nF capacitor between shield and chassis if needed.

The digital and analog inputs and outputs must be connected separately to the adjustable frequency drive common inputs (terminal 20, 55, 39) to avoid ground currents from both groups to affect other groups. For example, switching on the digital input disturbs the analog input signal.

Input polarity of control terminals

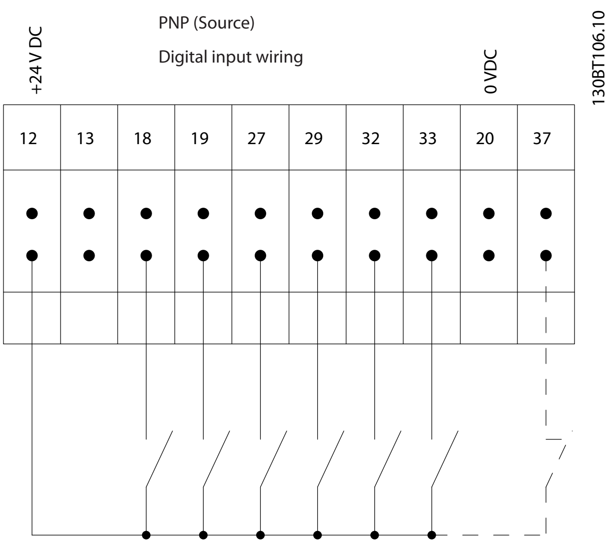

Figure 5.57 Input Polarity of Control Terminals

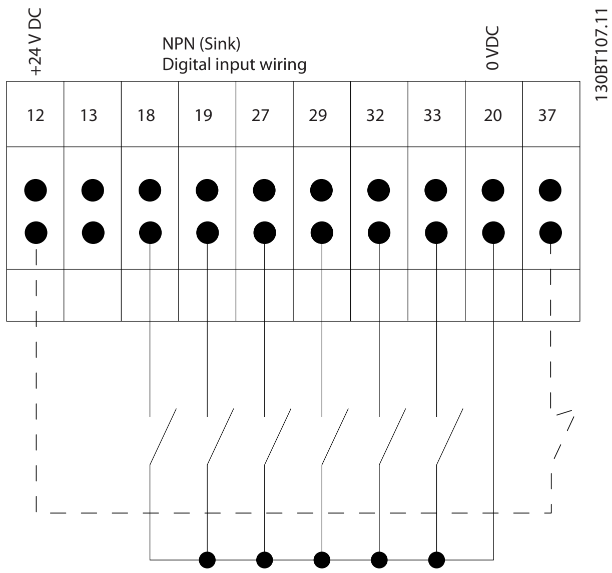

Figure 5.58 Input Polarity of Control Terminals

NOTICE!

Control cables must be shielded/armored.

Connect the wires as described in the Instruction Manual for the adjustable frequency drive. Remember to connect the shields in a proper way to ensure optimum electrical immunity.

5.3.16 Switches S201, S202 and S801

Switches S201 (A53) and S202 (A54) are used to select a current (0–20 mA) or a voltage (0–10 V) configuration of the analog input terminals 53 and 54 respectively.

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

See *Figure 5.52* and *Figure 5.53*.

Default setting:

S201 (A53) = OFF (voltage input)

S202 (A54) = OFF (voltage input)

S801 (Bus termination) = OFF

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NOTICE!

Change switch position at power-off only.

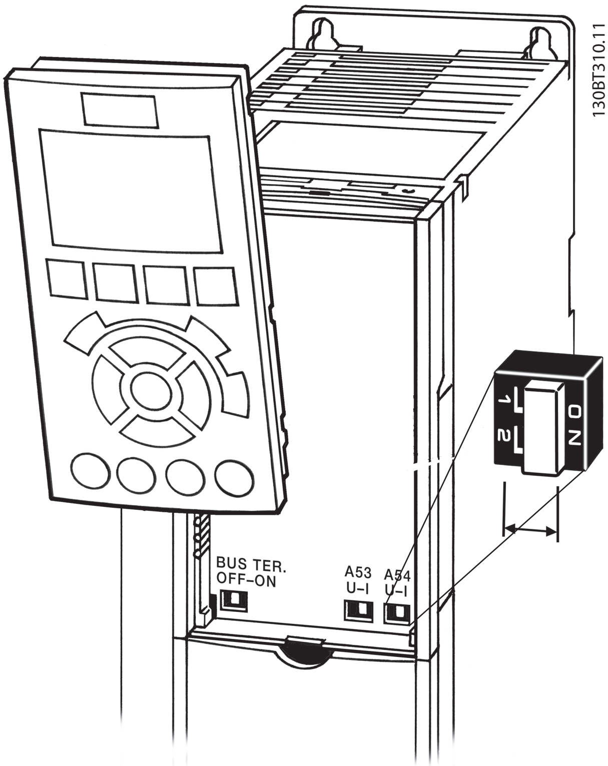

Figure 5.59 Switch Locations

5

5.4 Connections - Frame Sizes D, E and F

5.4.1 Torque

When tightening electrical connections, it is important to tighten with the correct torque. Torque that is too low or too high results in a bad electrical connection. Use a torque wrench for correct torque.

NOTICE!

Always use a torque wrench to tighten the bolts.

Frame size	Terminal		Size	Torque nominal [Nm (in-lbs)]	Torque range [Nm (in-lbs)]
D1h/D3h	Line power Motor Load sharing Regeneration		M10	29.5 (261)	19-40 (168-354)
	Ground Brake		M8	14.5 (128)	8.5-20.5 (75-181)
D2h/D4h	Line power Motor Regeneration Load Sharing Ground		M10	29.5 (261)	19-40 (168-354)
	Brake		M8		8.5-20.5 (75-181)
E	Line power		M10	19.1 (169)	17.7-20.5 (156-182)
	Motor				
	Load Sharing				
	Ground				
	Regen		M8	9.5 (85)	8.8-10.3 (78.2-90.8 in-lbs.)
	Brake				
F	Line power		M10	19.1 (169)	17.7-20.5 (156-182 in-lbs.)
	Motor				
	Load Sharing				
	Regen:	DC-	M8	9.5 (85)	8.8-10.3 (78.2-90.8)
		DC+	M10	19.1 (169)	17.7-20.5 (156-182)
	F8-F9 Regen		M10	19.1 (169)	17.7-20.5 (156-182.)
	Ground		M8	9.5 (85)	8.8-10.3 (78.2-90.8)
	Brake				

Table 5.12 Terminal Tightening Torques

5.4.2 Power Connections

Cabling and fusing

NOTICE!

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 and 194 °F [75 and 90 °C] copper conductors are thermally acceptable for the adjustable frequency drive to use in non-UL applications.

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The power cable connections are situated as shown in *Figure 5.60*. Dimensioning of cable cross-section must be done in accordance with the current ratings and local legislation. See *chapter 3.1 General Specifications* 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 are listed in the Instruction Manual. Always ensure that proper fusing is done according to local regulations.

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

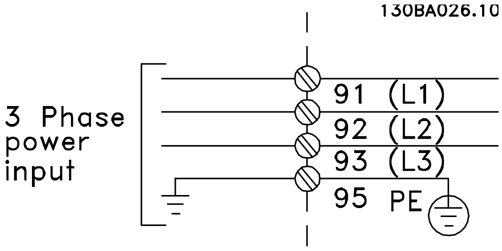

Figure 5.60 Power Cable Connections

NOTICE!

The motor cable must be shielded/armored. If a non-shielded/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 *chapter 5.10 EMC-compatible Installation*.

See *chapter 3.1 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 decoupling 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) by using the supplied installation devices within the adjustable frequency drive.

Cable length and cross-section

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

Switching frequency

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

Term. no.	**96**	**97**	**216 [98]**	**99**	
	U	V	W	PE[1)]	Motor voltage 0–100% of AC line voltage. 3 wires out of motor
	U1	V1	W1	PE[1)]	Delta-connected
	W2	U2	V2		6 wires out of motor
	U1	V1	W1	PE[1)]	Star-connected U2, V2, W2 U2, V2, and W2 to be interconnected separately.

Table 5.13 Motor Cable Connection

[1)]*Protected Ground Connection*

NOTICE!

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.

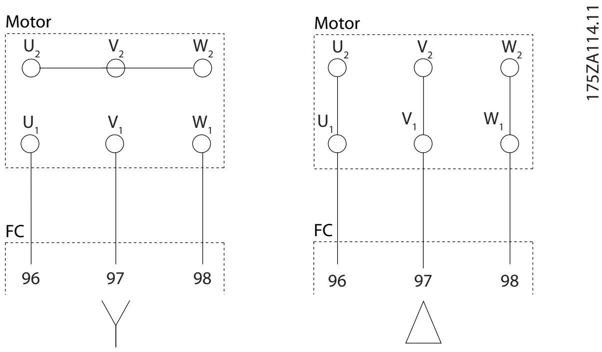

Figure 5.61 Motor Cable Connection

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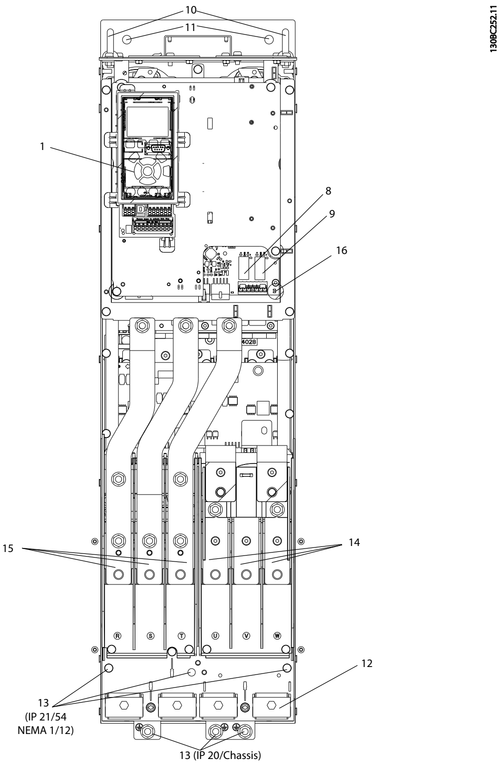

Figure 5.62 D-Frame Interior Components

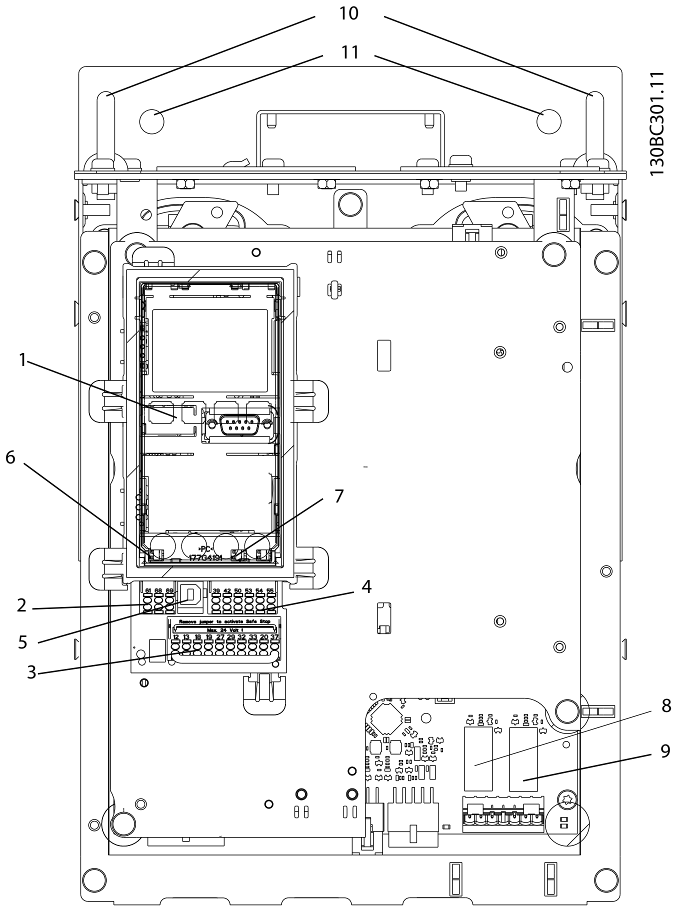

Figure 5.63 Close-up View: LCP and Control Functions

1	LCP (Local Control Panel)	9	Relay 2 (04, 05, 06)
2	RS-485 serial bus connector	10	Lifting ring
3	Digital I/O and 24 V power supply	11	Mounting slot
4	analog I/O connector	12	Cable clamp (PE)
5	USB connector	13	Ground
6	Serial bus terminal switch	14	Motor output terminals 96 (U), 97 (V), 98 (W)
7	Analog switches (A53), (A54)	15	Line power input terminals 91 (L1), 92 (L2), 93 (L3)
8	Relay 1 (01, 02, 03)		

Table 5.14 Legend to *Figure 5.62* and *Figure 5.63*.

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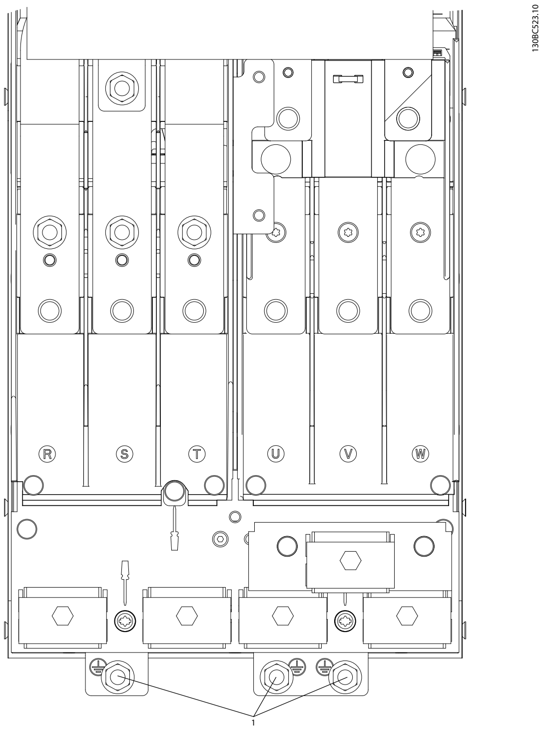

Figure 5.64 1) Position of Ground Terminals IP20 (chassis), D-Frame Sizes

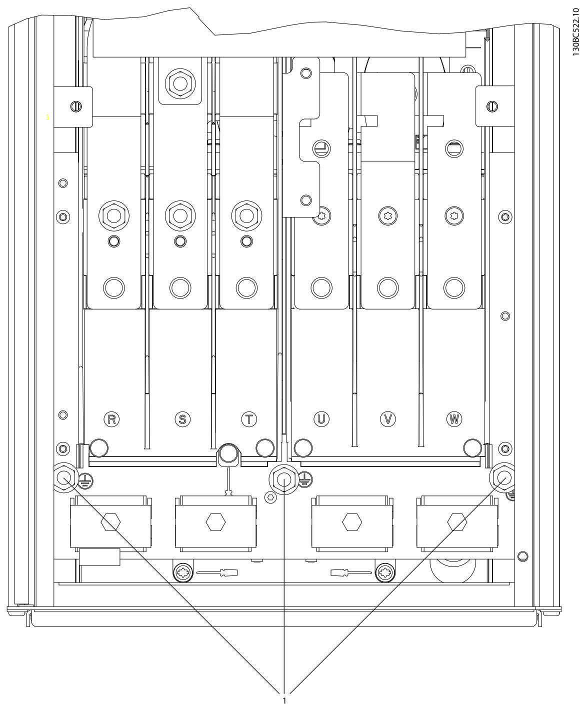

Figure 5.65 1) Position of Ground Terminals IP21 (NEMA type 1) and IP54 (NEMA type 12), D-Frame Sizes

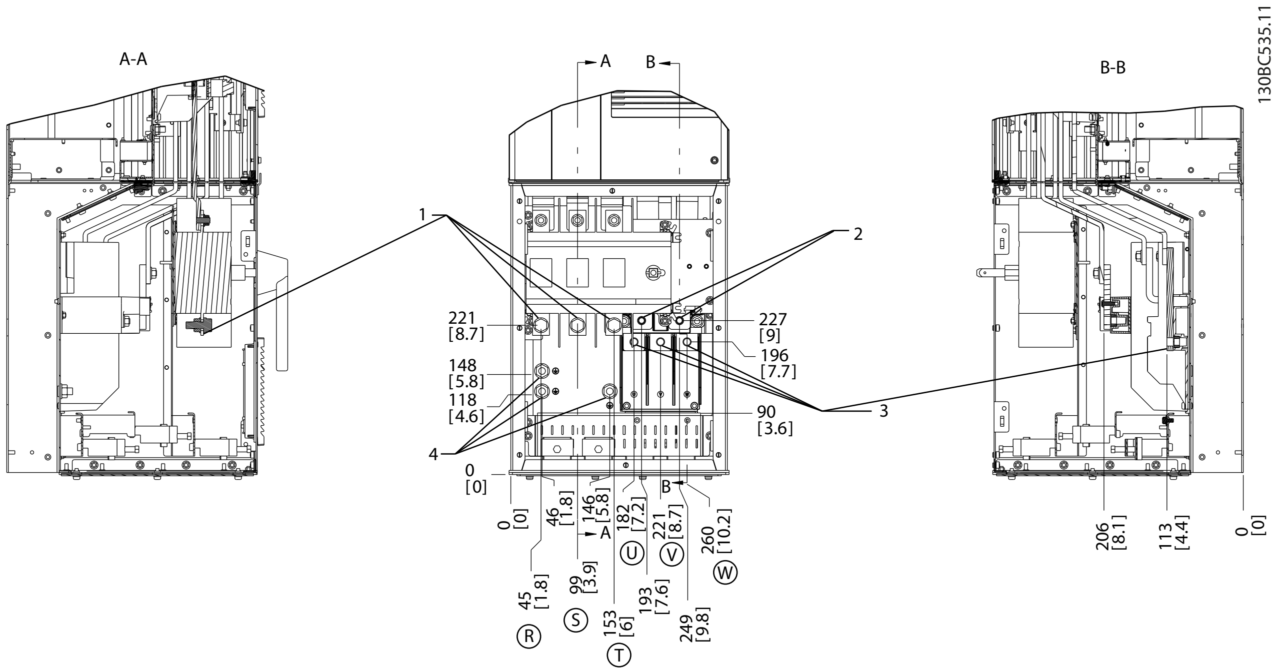

Figure 5.66 Terminal Locations, D5h with Disconnect Option

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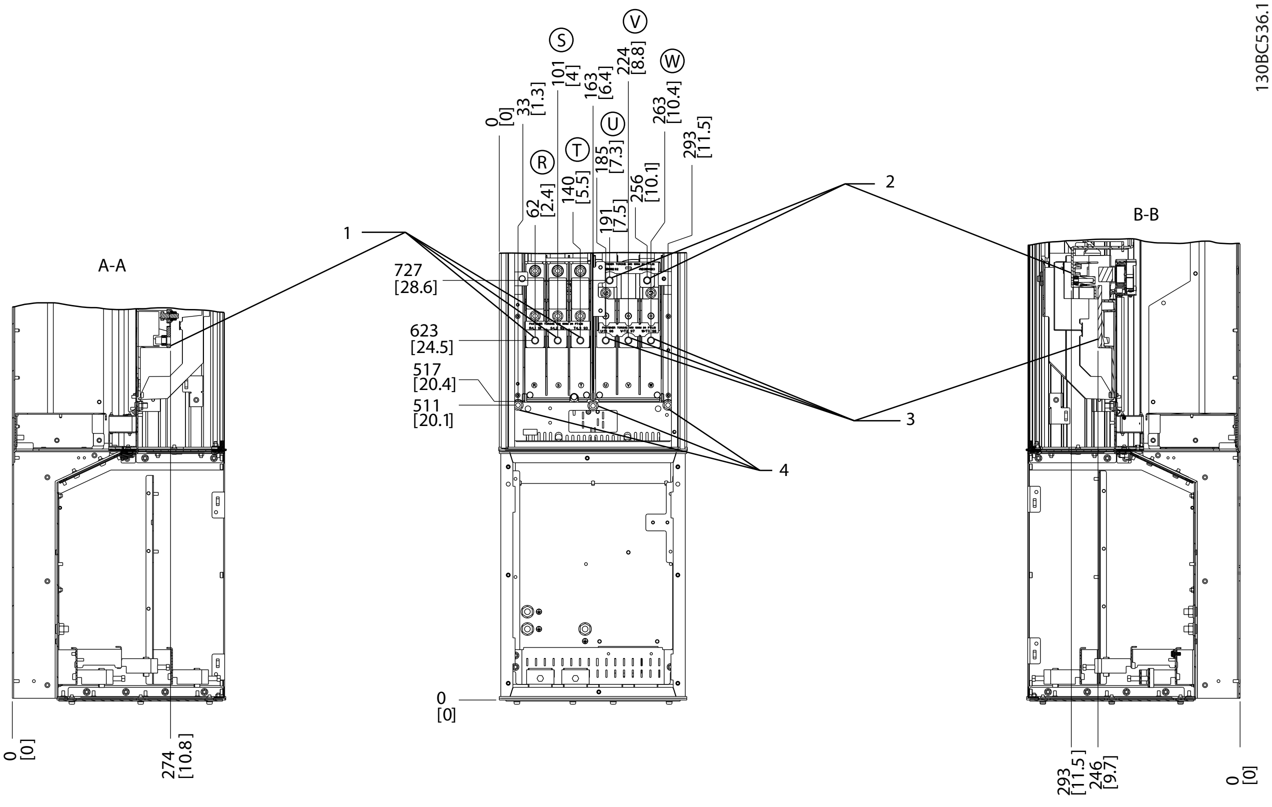

Figure 5.67 Terminal Locations, D5h with Brake Option

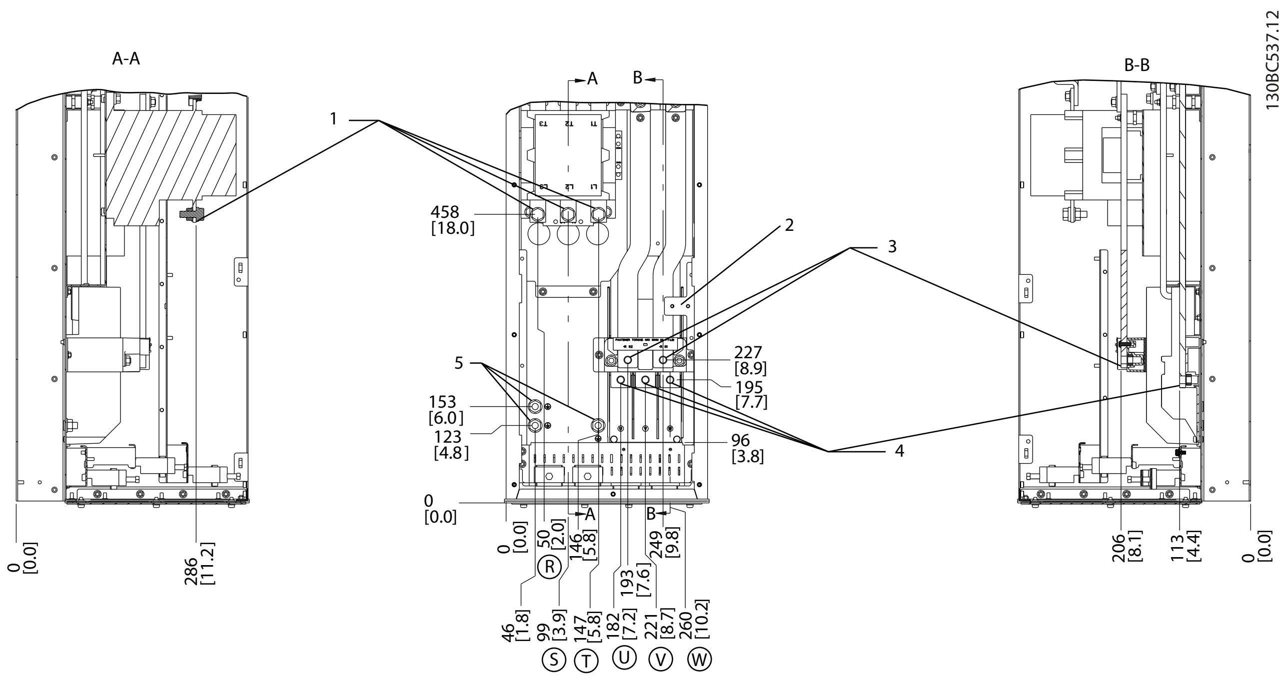

Figure 5.68 Terminal Locations, D6h with Contactor Option

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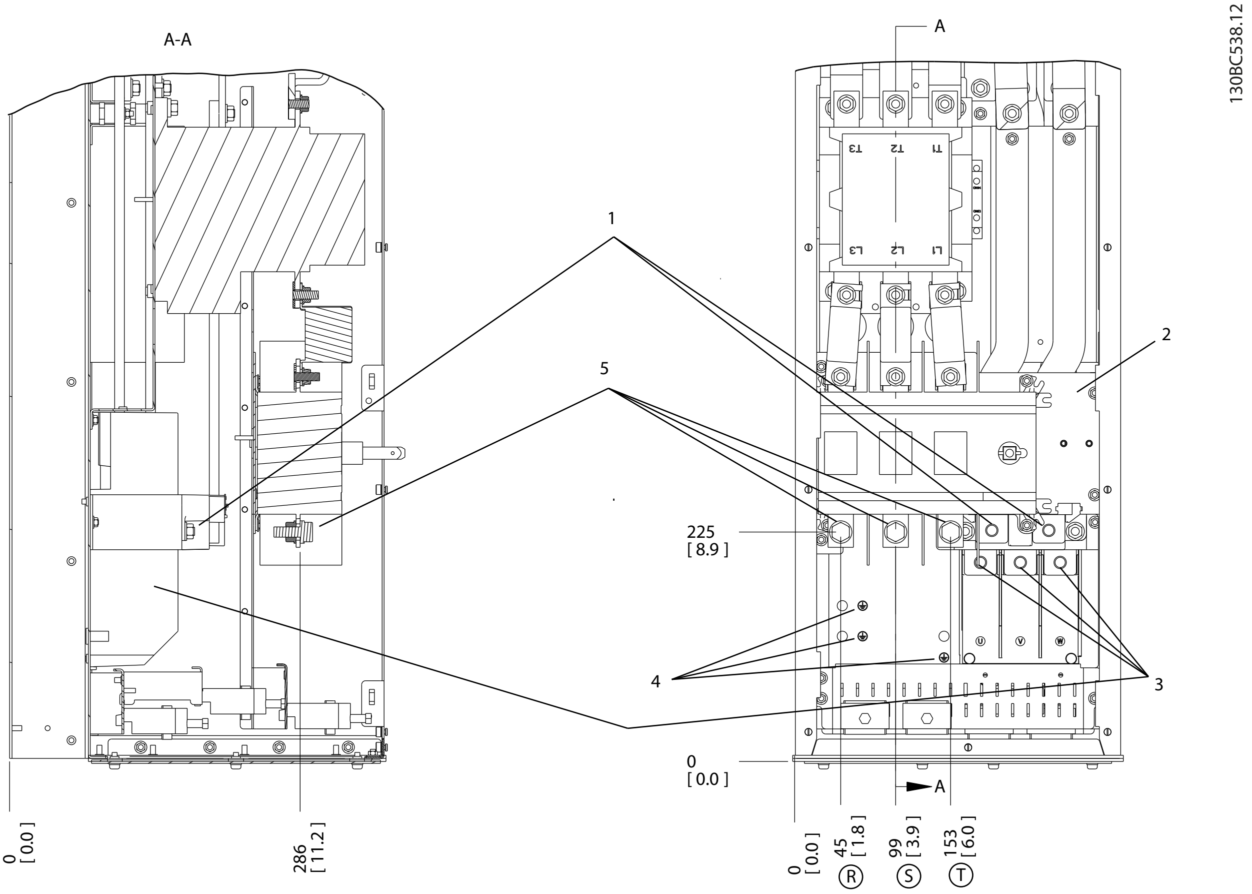

Figure 5.69 Terminal Locations, D6h with Contactor and Disconnect Options

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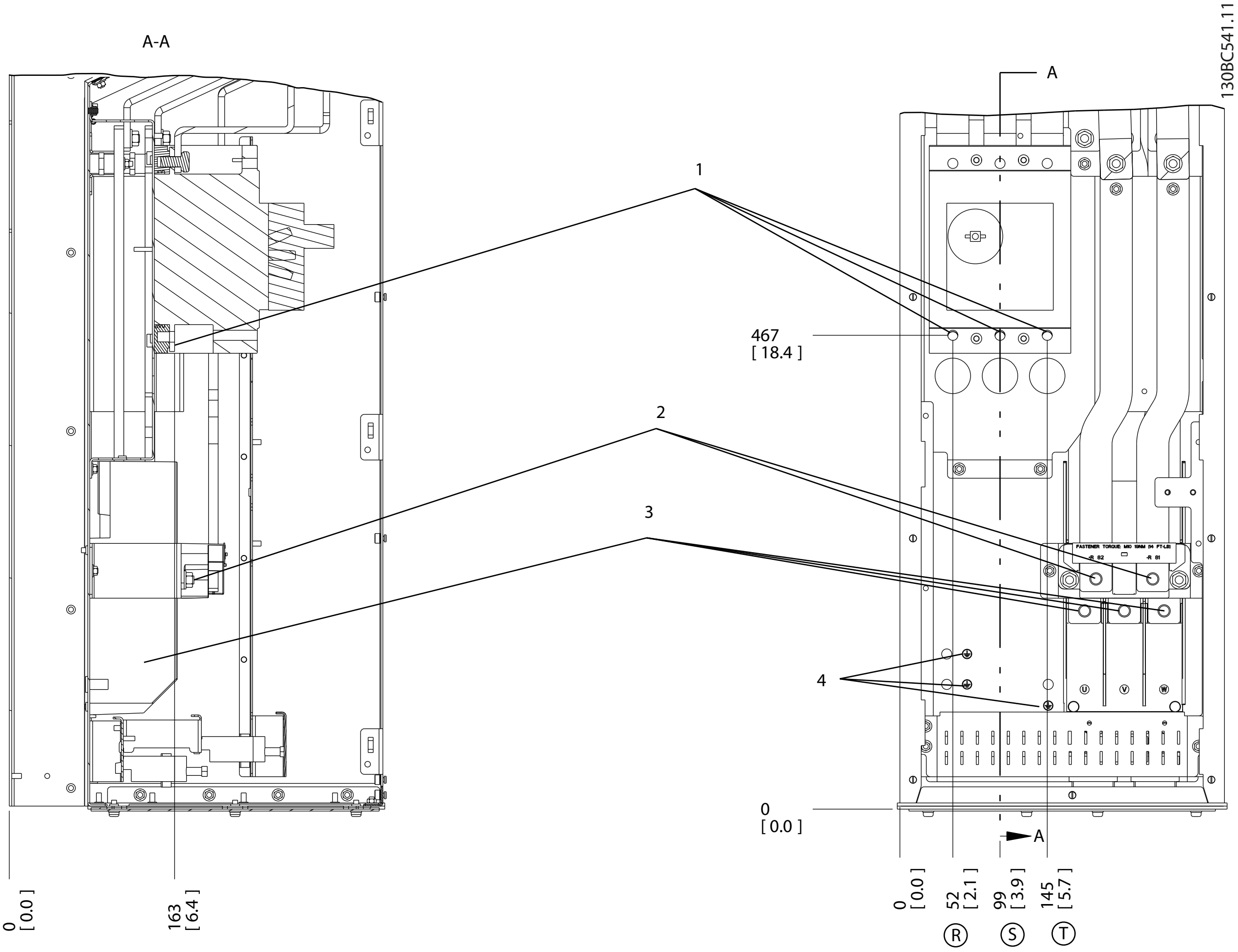

Figure 5.70 Terminal Locations, D6h with Circuit Breaker Option

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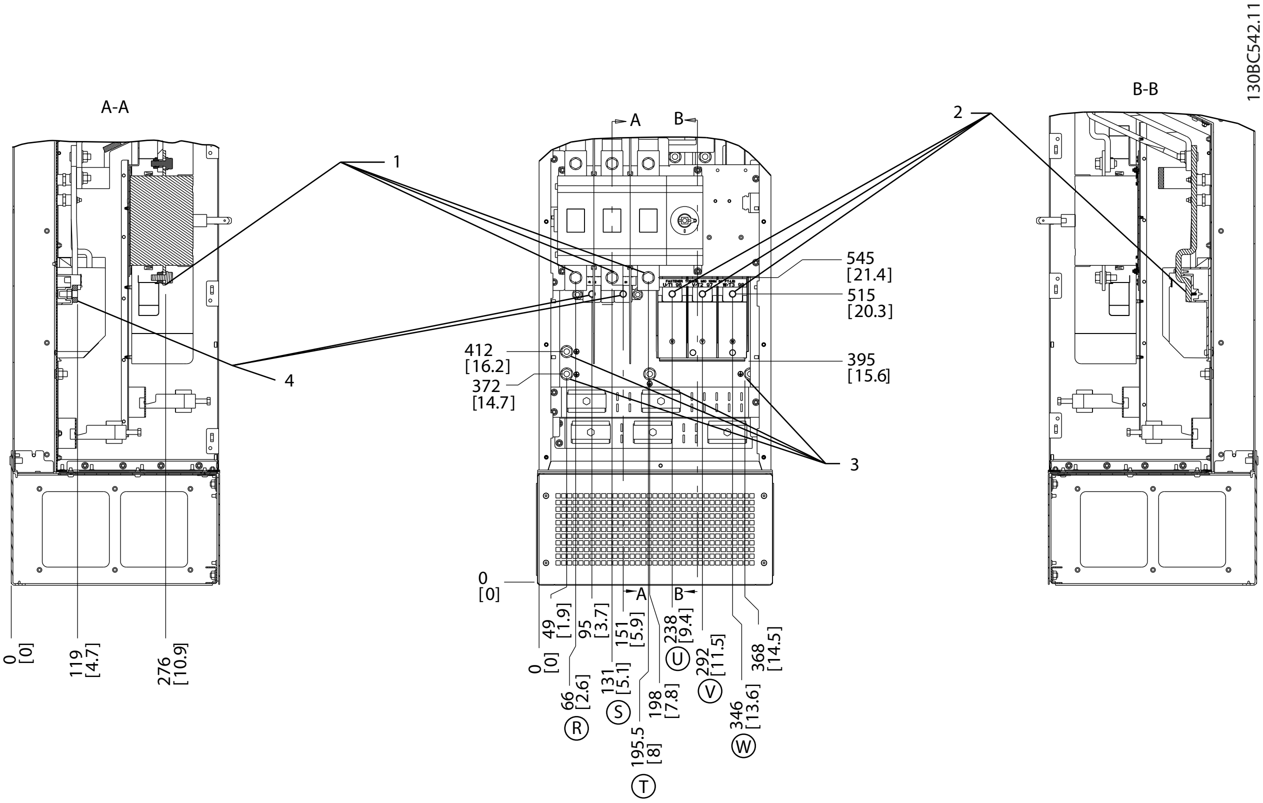

Figure 5.71 Terminal Locations, D7h with Disconnect Option

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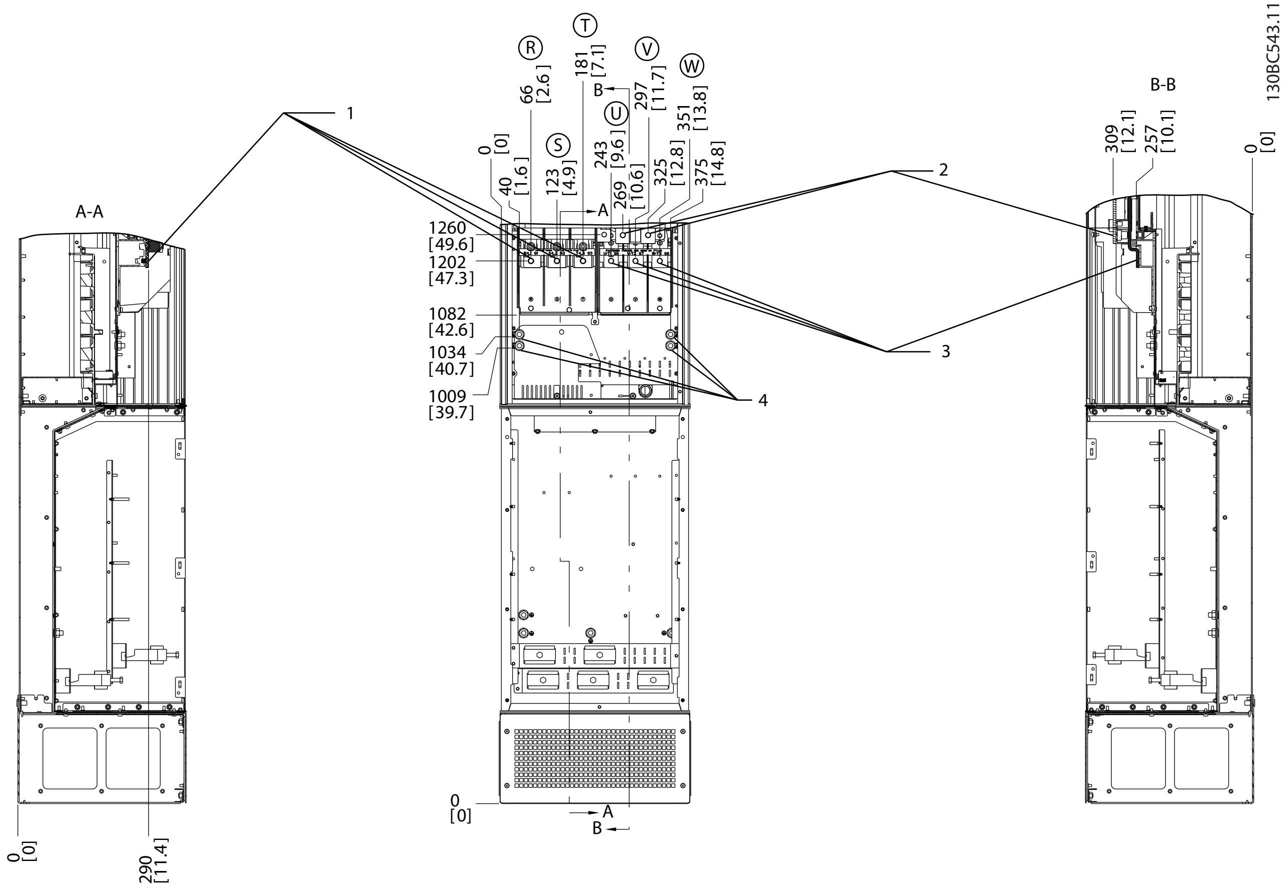

Figure 5.72 Terminal Locations, D7h with Brake Option

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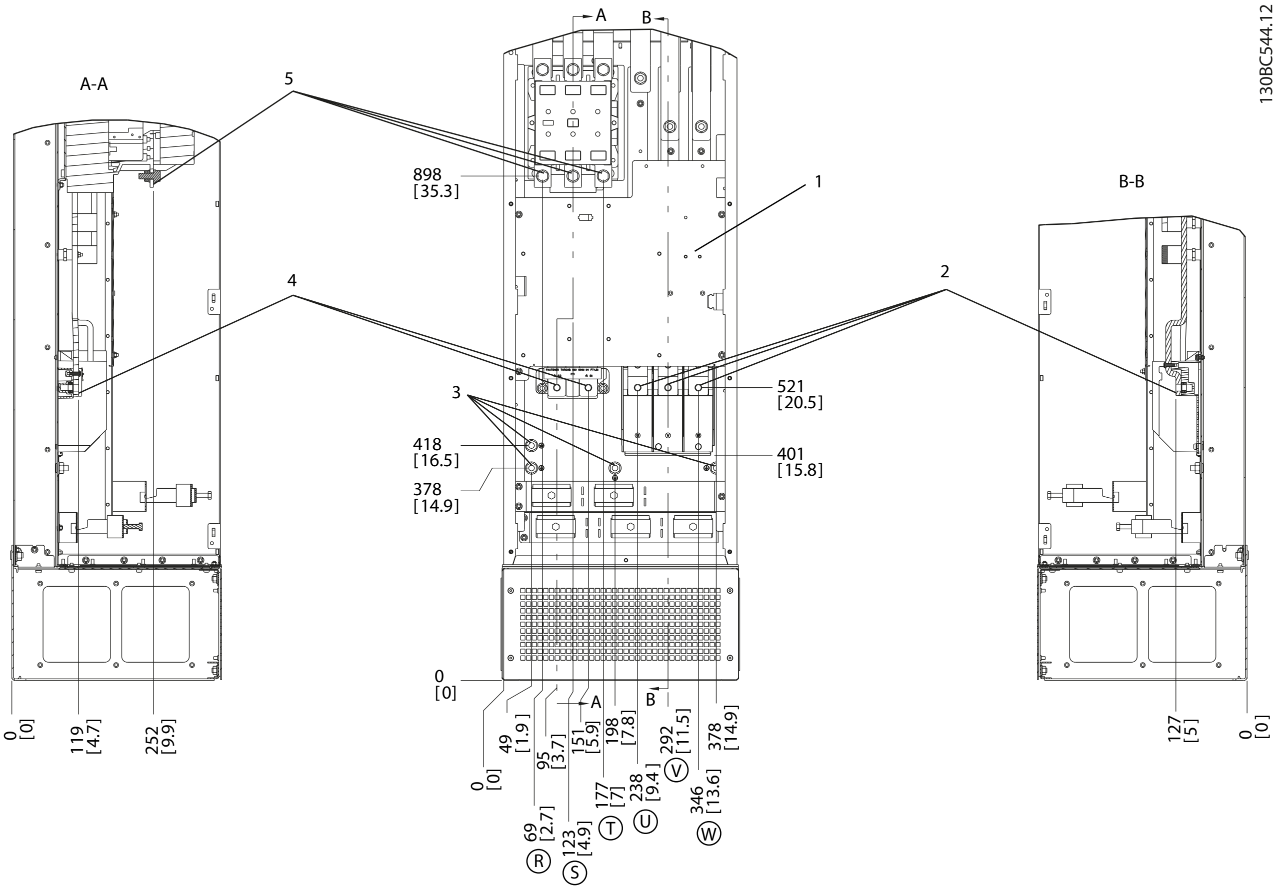

Figure 5.73 Terminal Locations, D8h with Contactor Option

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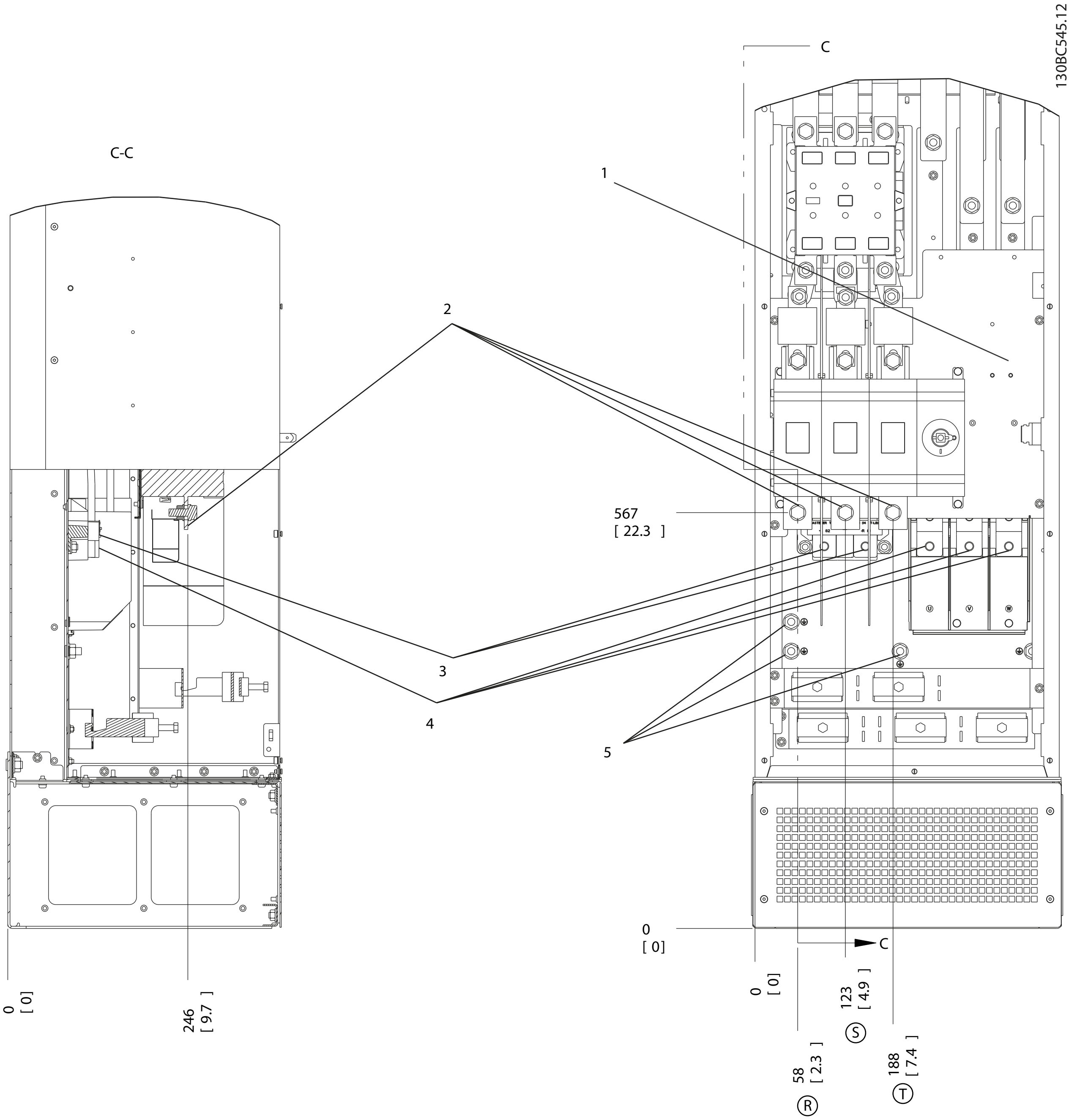

Figure 5.74 Terminal Locations, D8h with Contactor and Disconnect Options

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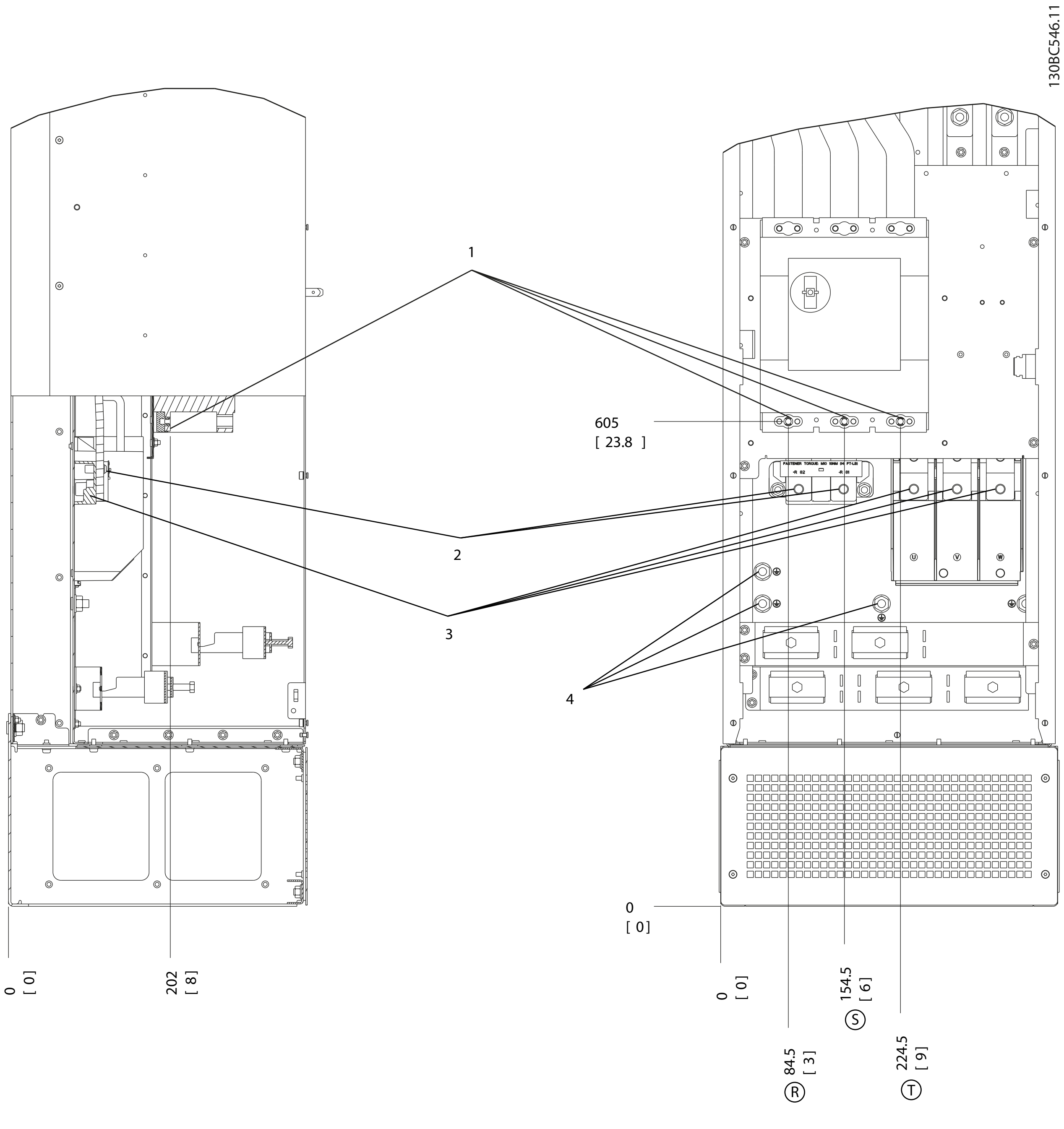

Figure 5.75 Terminal Locations, D8h with Circuit Breaker Option

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Terminal Locations - E1

Take the following position of the terminals into consideration when designing the cable access.

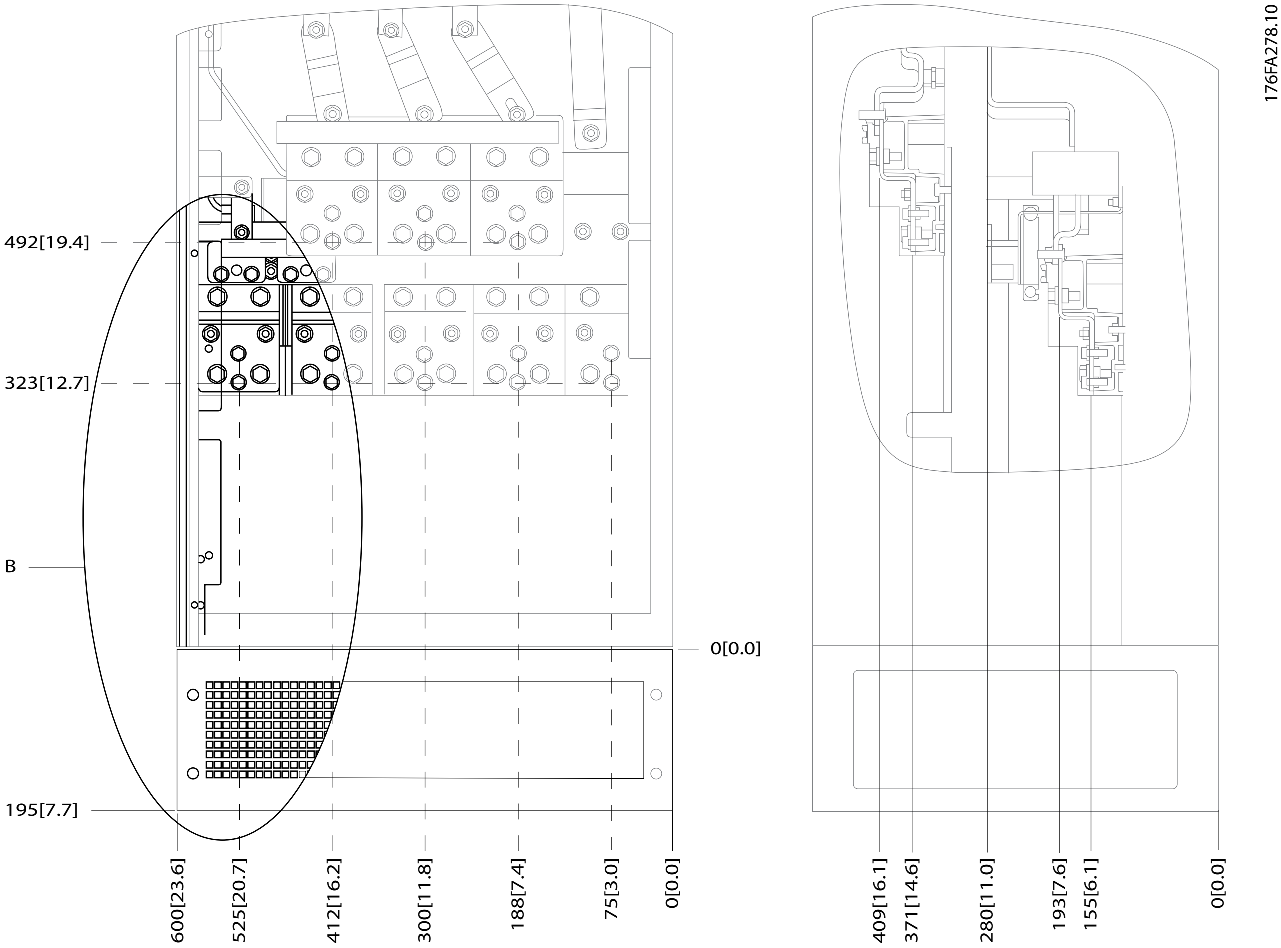

Figure 5.76 IP21 (NEMA Type 1) and IP54 (NEMA Type 12) Enclosure Power Connection Positions

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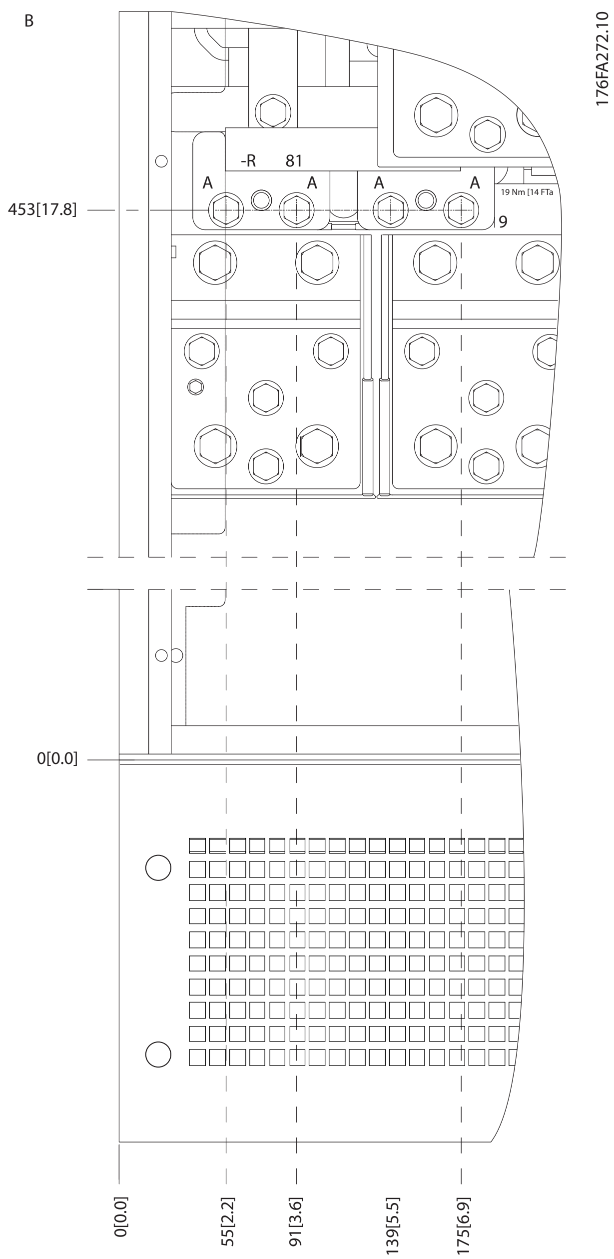

Figure 5.77 IP21 (NEMA type 1) and IP54 (NEMA type 12) Enclosure Power Connection Positions (detail B)

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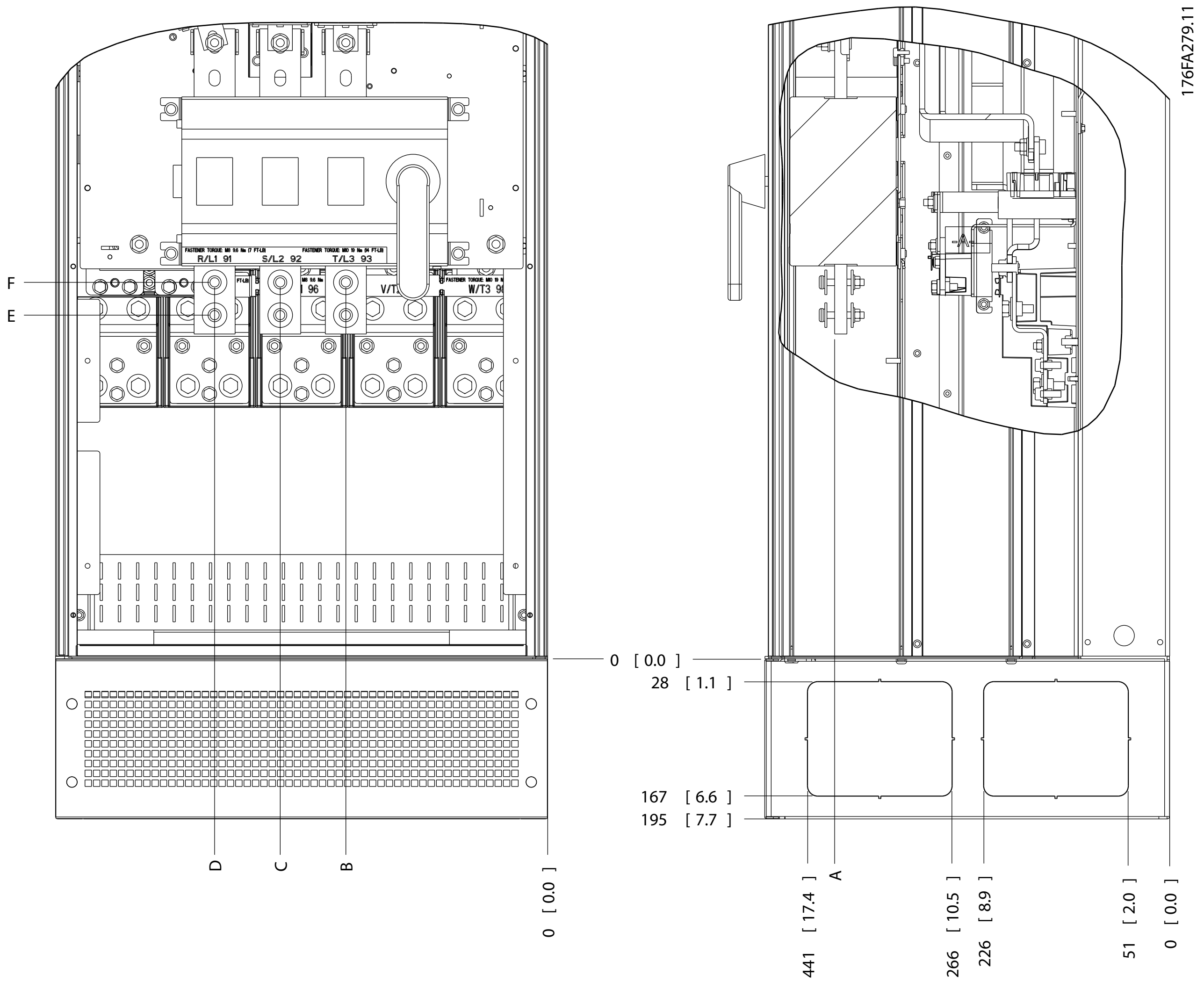

Figure 5.78 IP21 (NEMA type 1) and IP54 (NEMA type 12) Enclosure Power Connection Position of Disconnect Switch

Frame size	Unit type	Dimension for disconnect terminal					
E1	IP54/IP21 UL and NEMA1/NEMA12						
	350/450 hp [250/315 kW] (400 V) and 475/600–650/850 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
	450/475–550/600 hp [315/355-400/450 kW] (400 V)	371 (14.6)	371 (14.6)	341 (13.4)	431 (17.0)	431 (17.0)	455 (17.9)

Table 5.15 Legend to *Figure 5.78*

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Terminal locations - Frame Size E2

Consider the following position of the terminals when designing the cable access.

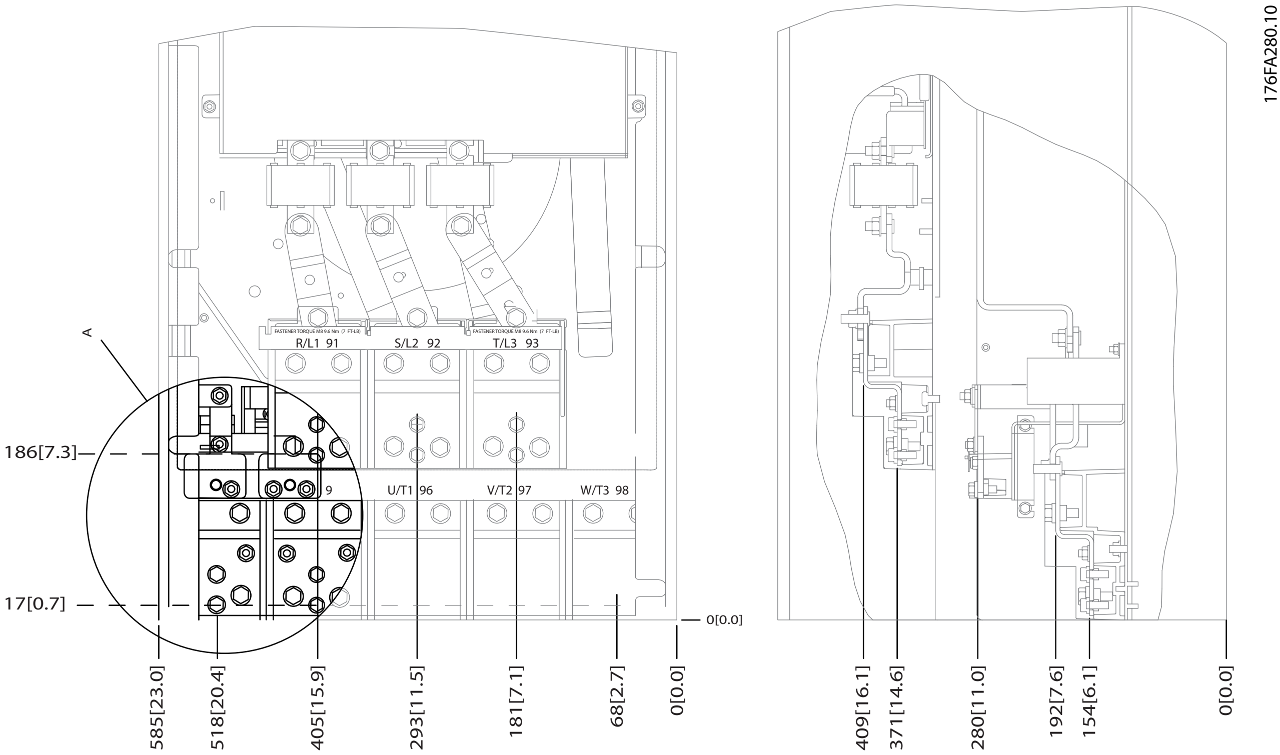

Figure 5.79 IP00 Enclosure Power Connection Positions

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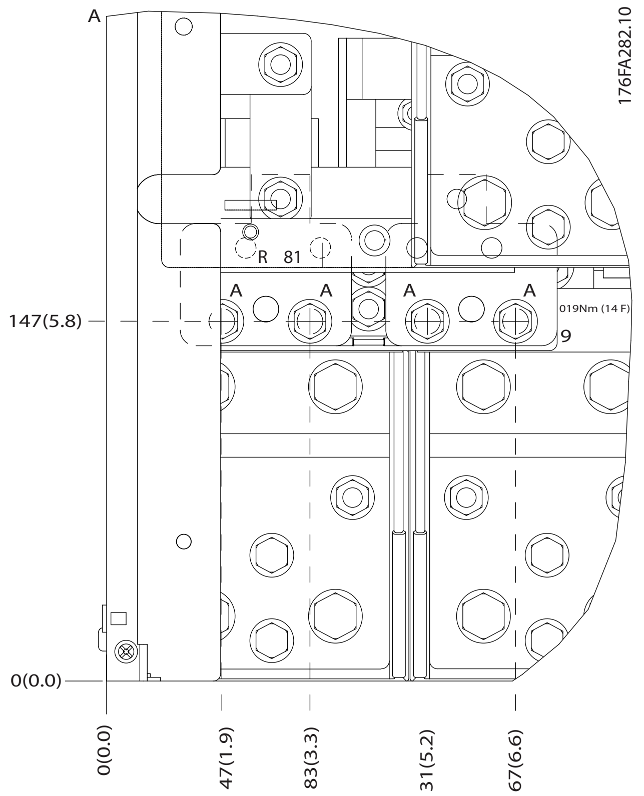

Figure 5.80 IP00 Enclosure Power Connection Positions

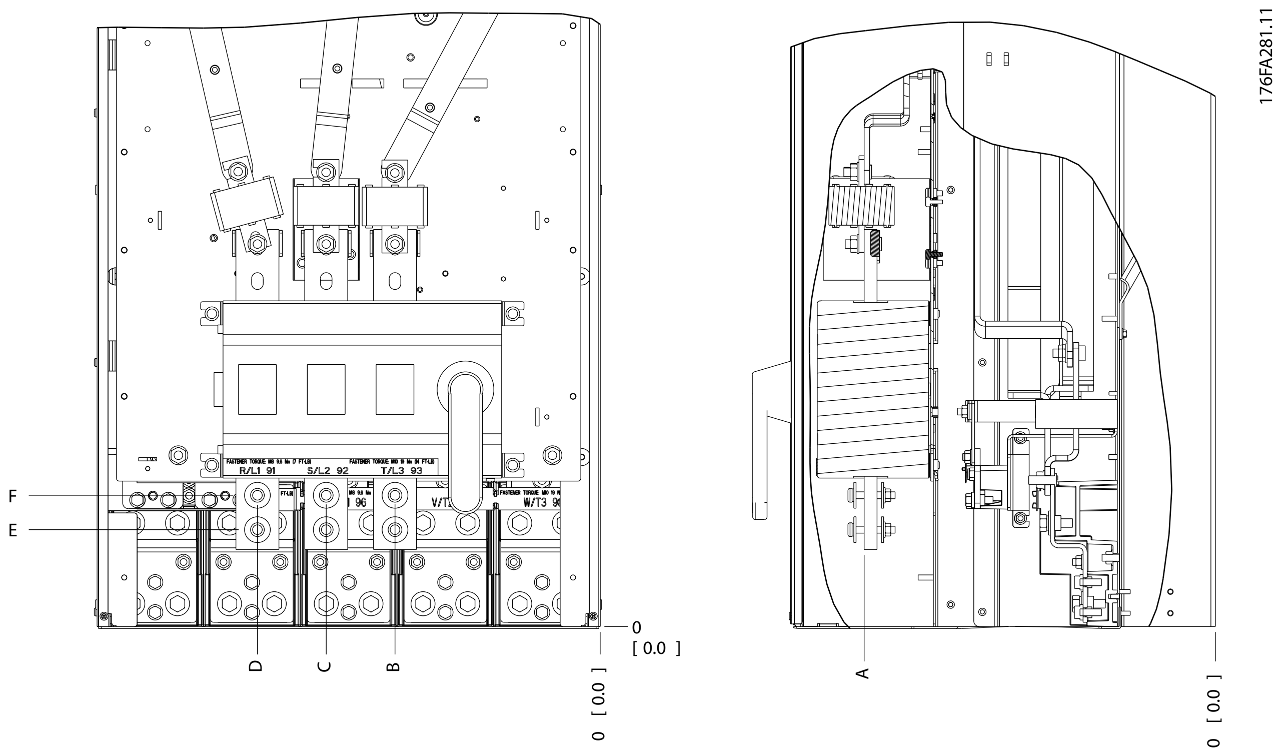

Figure 5.81 IP00 Enclosure Power Connections, Position of Disconnect Switch

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NOTICE!

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 use of up to four cables with cable lugs or use of standard box lug. Ground is connected to a relevant termination point in the adjustable frequency drive.

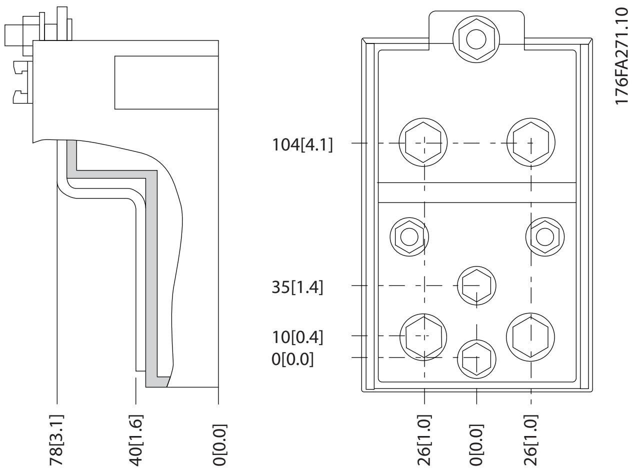

Figure 5.82 Terminal in Detail

NOTICE!

Power connections can be made to positions A or B

Frame size	Unit type	Dimension for disconnect terminal					
	IP00/CHASSIS	A	B	C	D	E	F
E2	350/450 hp [250/315 kW] (400 V) and 475/600–650/850 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
	450/475–550/600 hp [315/355-400/450 kW] (400 V)	383 (15.1)	244 (9.6)	334 (13.1)	424 (16.7)	109 (4.3)	149 (5.8)

Table 5.16 Power Connections

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Terminal locations - Frame size F1 and F3

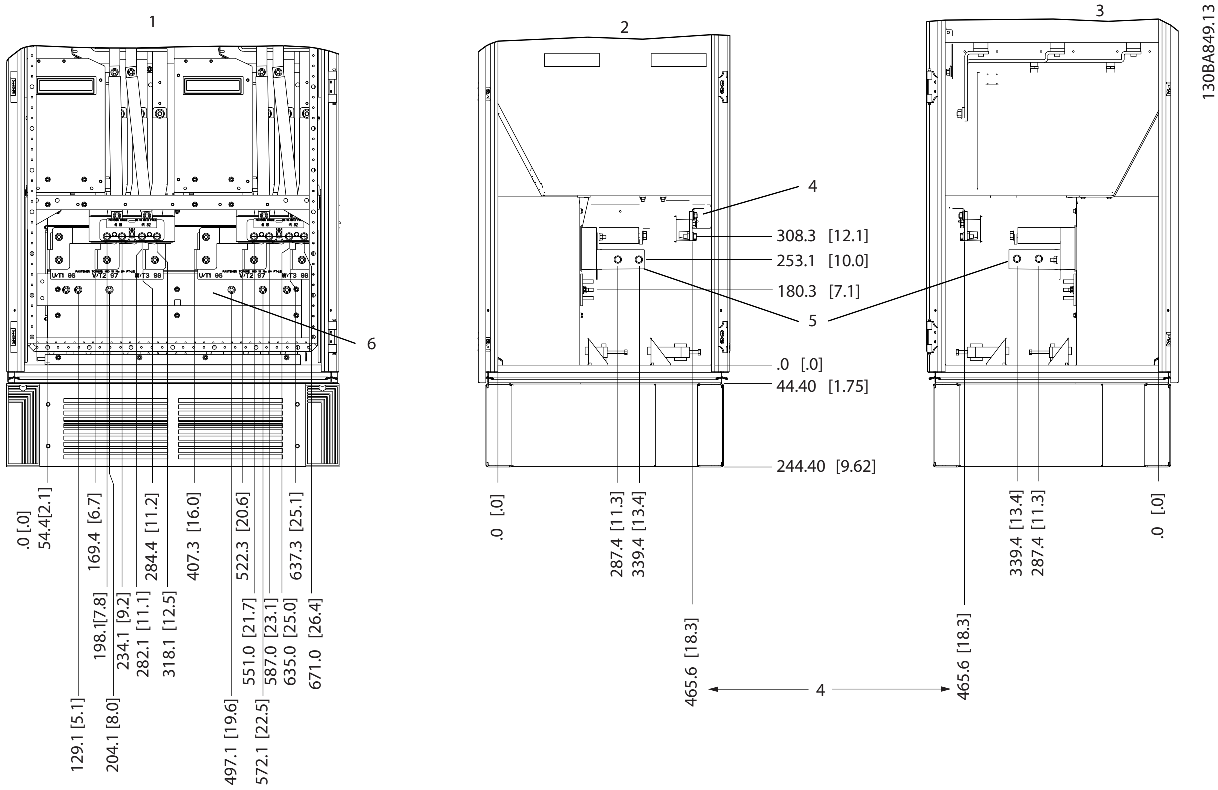

Figure 5.83 Terminal Locations - Inverter Cabinet - F1 and F3 (Front, Left and Right Side View). The connector plate is 1.65 in [42 mm] below .0 level.
1) Earth ground bar
2) Motor terminals
3) Brake terminals

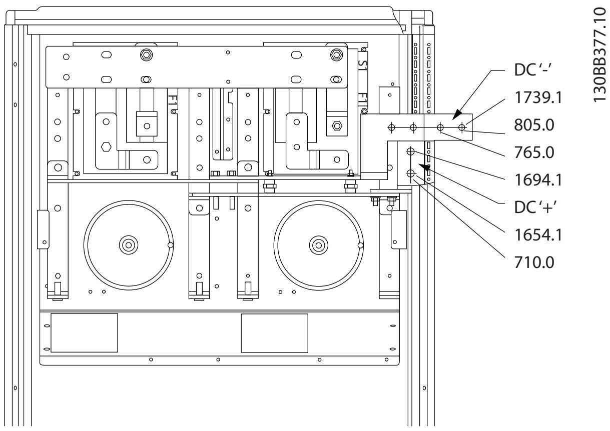

Figure 5.84 Terminal Locations - Regeneration Terminals - F1 and F3

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Terminal locations - Frame size F2 and F4

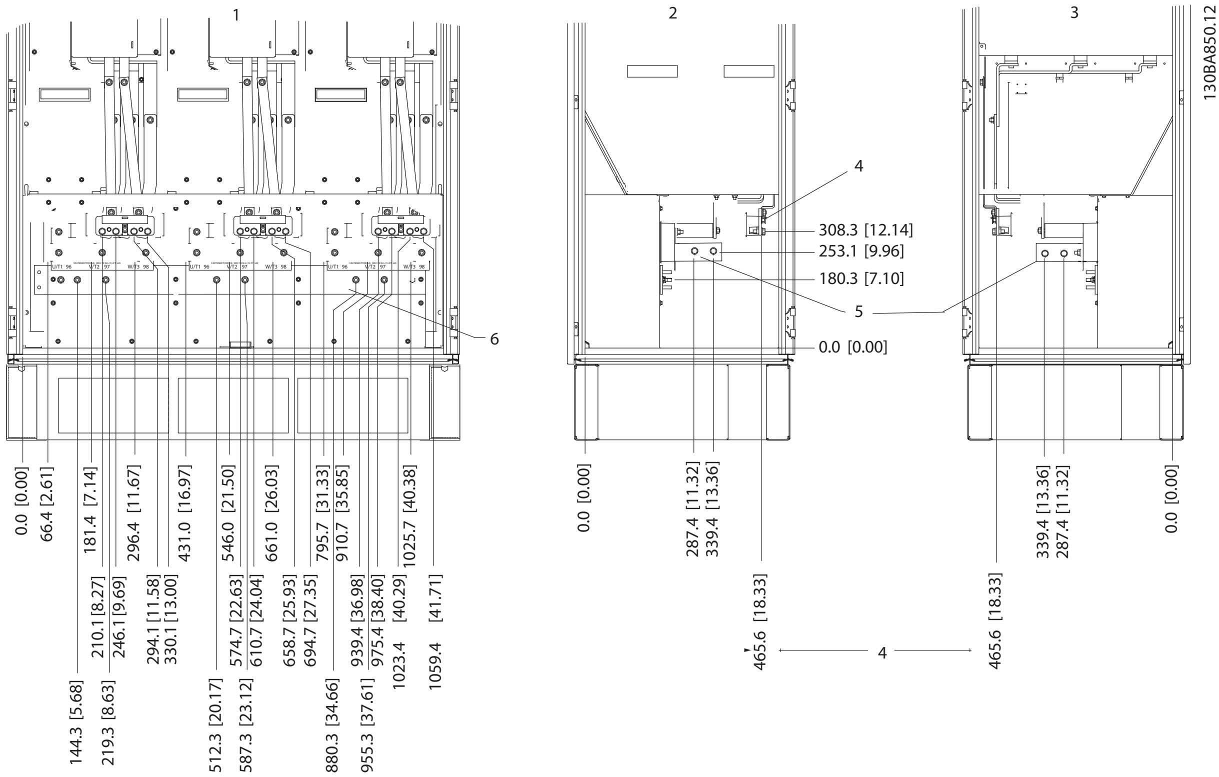


Figure 5.85 Terminal Locations - Inverter Cabinet - F2 and F4 (Front, Left and Right Side View). The connector plate is 1.65 in [42 mm] below .0 level.
1) Earth ground bar

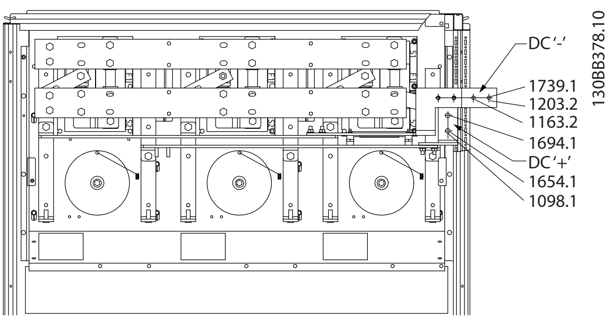
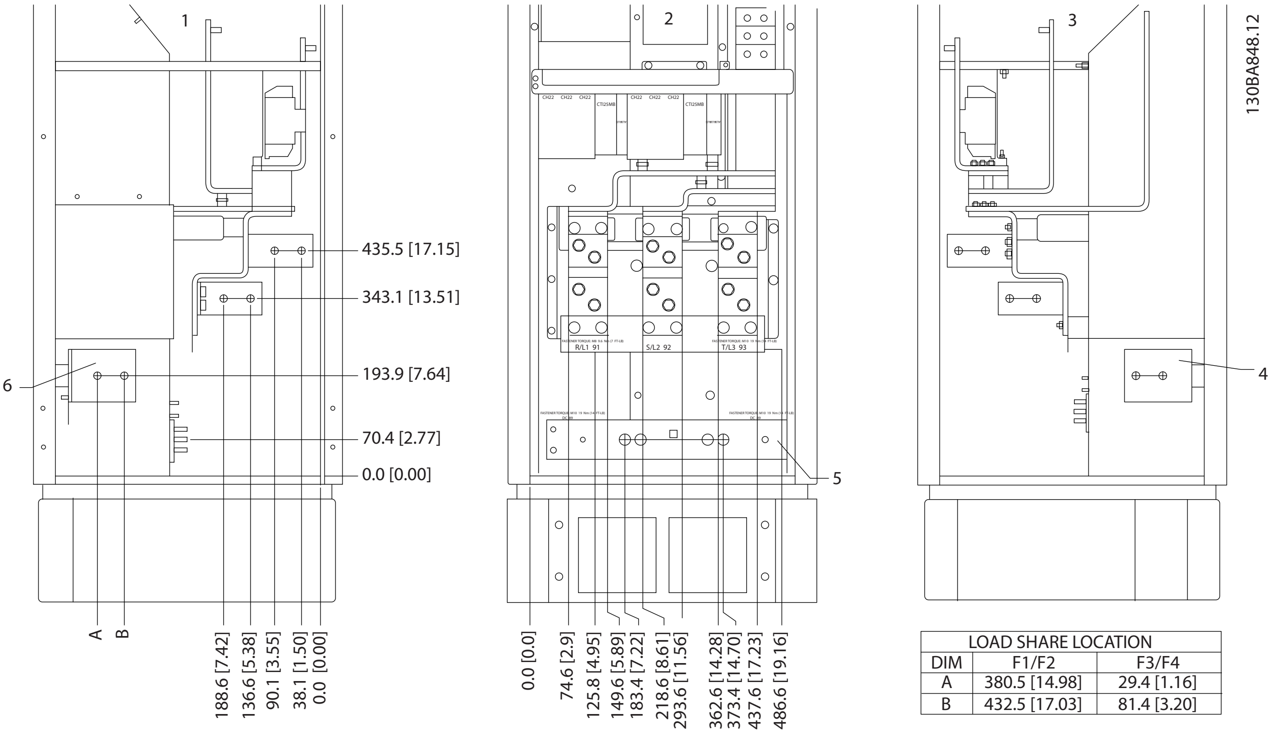


Figure 5.86 Terminal Locations - Regeneration Terminals - F2 and F4

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



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

Figure 5.87 Terminal Locations - Rectifier (Left, Front and Right Side View). The connector plate is 1.65 in [42 mm] below .0 level.

1) Load Share Terminal (-)

2) Ground bar

3) Load share Terminal (+)

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Terminal locations - Options Cabinet (F3 and F4)

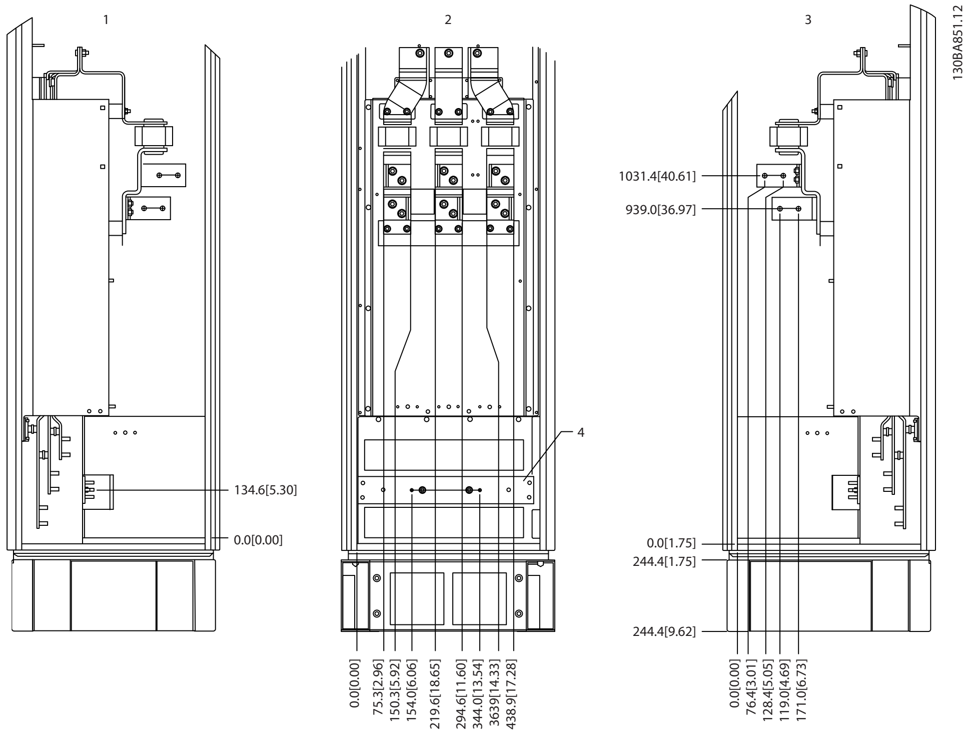

Figure 5.88 Terminal Locations - Options Cabinet (Left, Front and Right Side View). The connector plate is 1.65 in [42 mm] below .0 level.
1) Earth ground bar

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

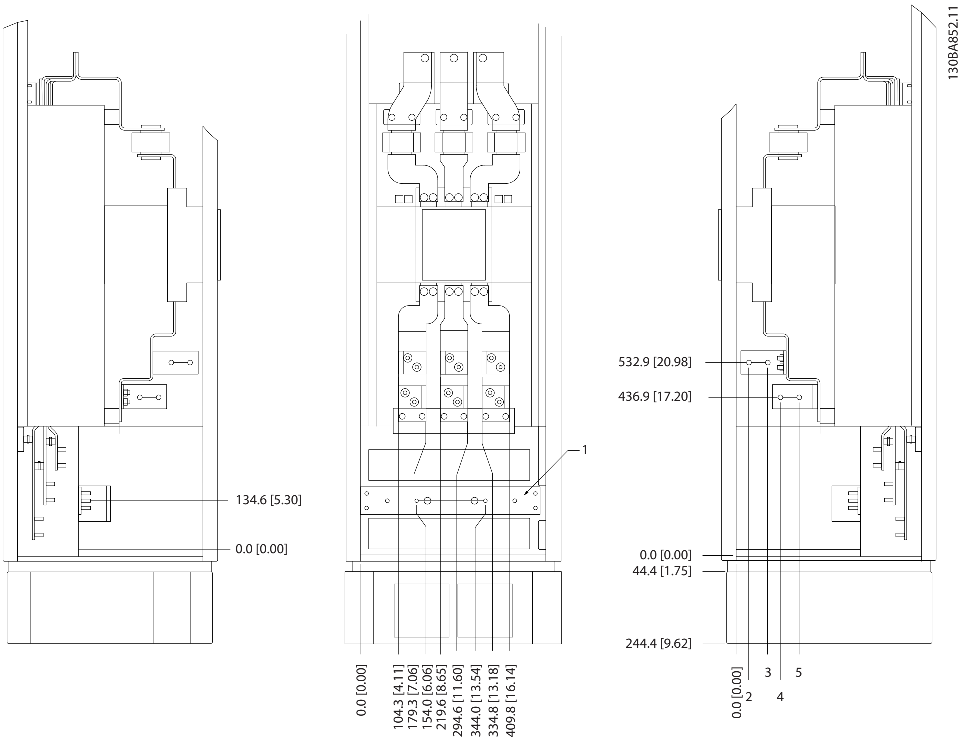

Figure 5.89 Terminal Locations - Options Cabinet with Circuit Breaker/Molded Case Switch (Left, Front and Right Side View). The connector plate is 1.65 in [42 mm] below .0 level.
1) Earth ground bar

Power size	2	3	4	5
600 hp [450 kW] (480 V), 850–950 hp [630–710 kW] (690 V)	34.9	86.9	122.2	174.2
650–1075 hp [500–800 kW] (480 V), 1075–1350 hp [800–1000 kW] (690 V)	46.3	98.3	119.0	171.0

Table 5.17 Dimension for Terminal

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5.4.3 Power Connections 12-Pulse Drives

Cabling and Fusing

NOTICE!

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 and 194 °F [75 and 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 in *Figure 5.90*. Dimensioning of cable cross-section must be done in accordance with the current ratings and local legislation. See *chapter 3.1 General Specifications* for details.

For protection of the adjustable frequency drive, the recommended fuses must be used or the unit must be fitted with built-in fuses. Recommended fuses can be seen in *chapter 5.3.7 Fuses* . Always ensure that proper fusing is made according to local regulations.

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

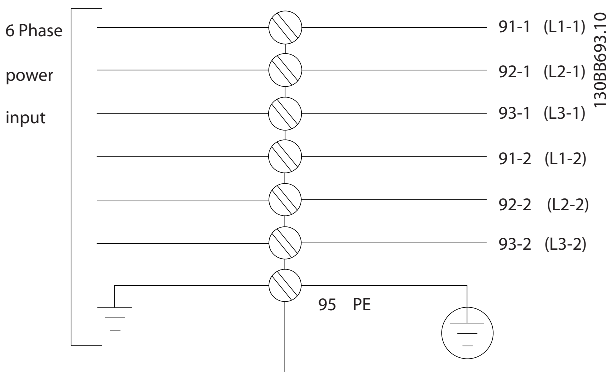

Figure 5.90 AC line input connections

NOTICE!

The motor cable must be shielded/armored. If a non-shielded/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 *chapter 5.10 EMC-compatible Installation*.

See *chapter 3.1 General Specifications* for correct dimensioning of motor cable cross-section and length.

5

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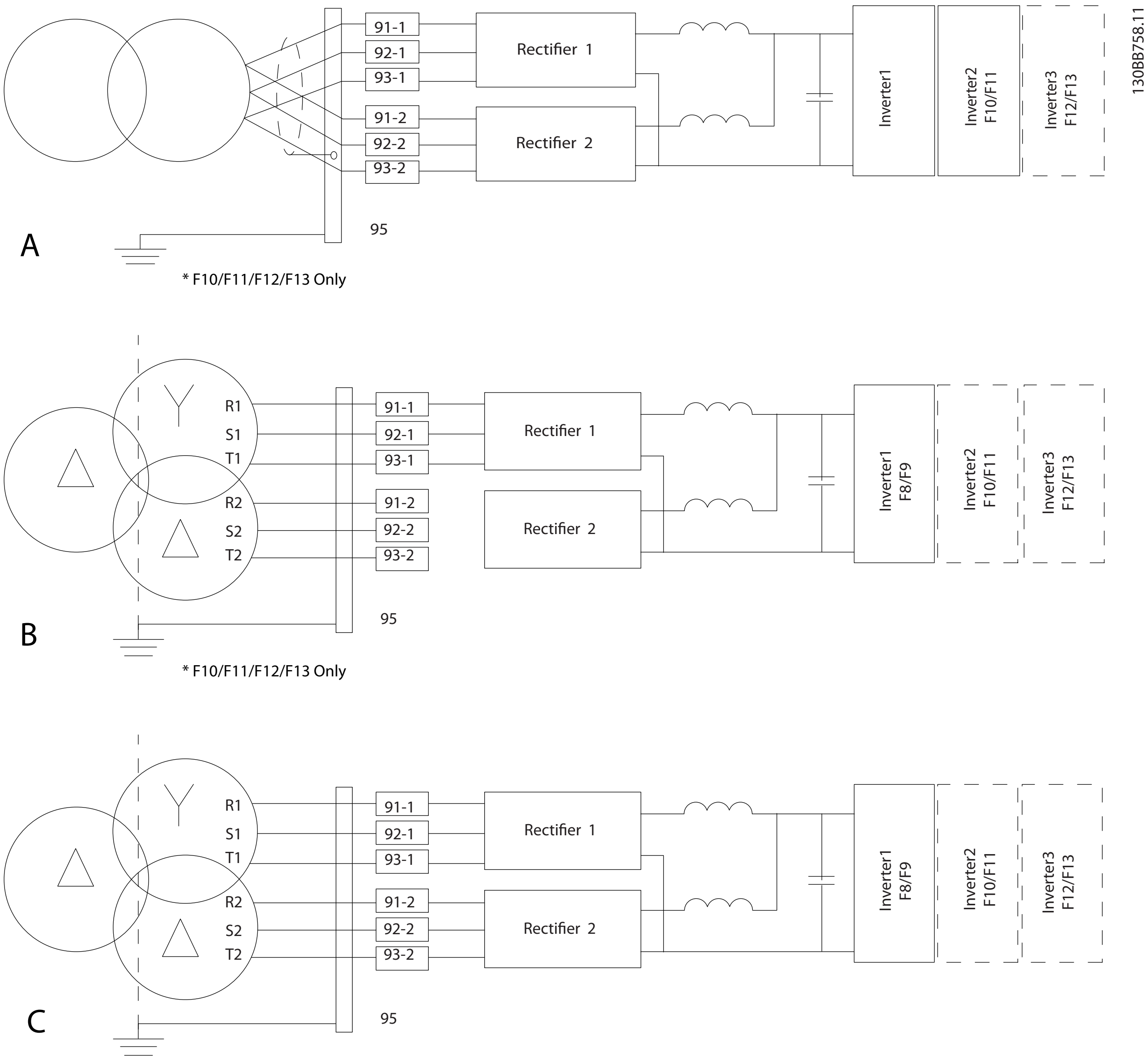

Figure 5.91

A) 6-Pulse Connection1), 2), 3)

B) Modified 6-Pulse Connection2), 3), 4)

C) 12-Pulse Connection3), 5)

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Notes:

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

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

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

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

5) No paralleling of line cabling is shown here. 12-pulse as a 6-pulse should have line cable requirements of equal number of cables and lengths.

NOTICE!

Line cables should be of equal length (±10%) and the same wire size for all three phases on both rectifier sections. A 12-pulse adjustable frequency drive used as a 6-pulse should have line cables of equal numbers and lengths.

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 decoupling 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 instruction in *14-01 Switching Frequency*.

Term. no.	96	97	216 [98]	99	
	U	V	W	PE[1]	Motor voltage 0–100% of AC line voltage. 3 wires out of motor
	U1	V1	W1	PE[1]	Delta-connected
	W2	U2	V2		6 wires out of motor
	U1	V1	W1	PE[1]	Star-connected U2, V2, W2 U2, V2, and W2 to be interconnected separately.

Table 5.18 Terminals

1) Protected Ground Connection

NOTICE!

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.

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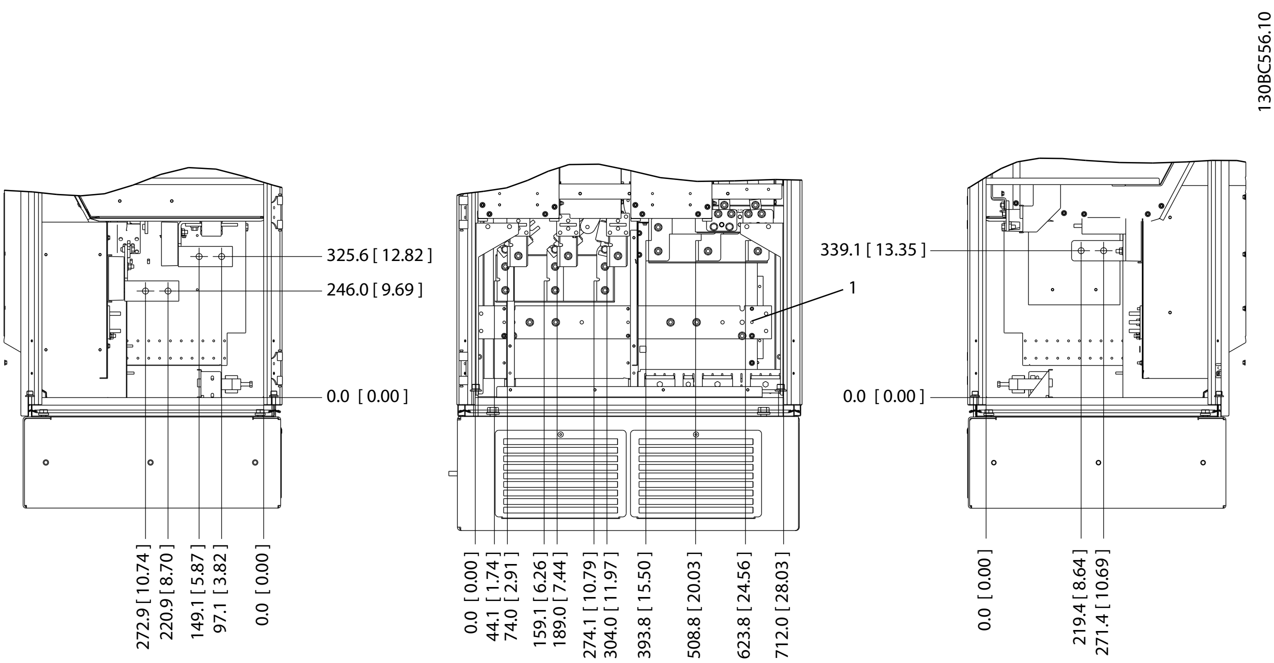

Figure 5.92 F8 (Front, Left and Right Side Views)

1) Ground bar

The connector plate is 1.65 in [42 mm] below Ø level

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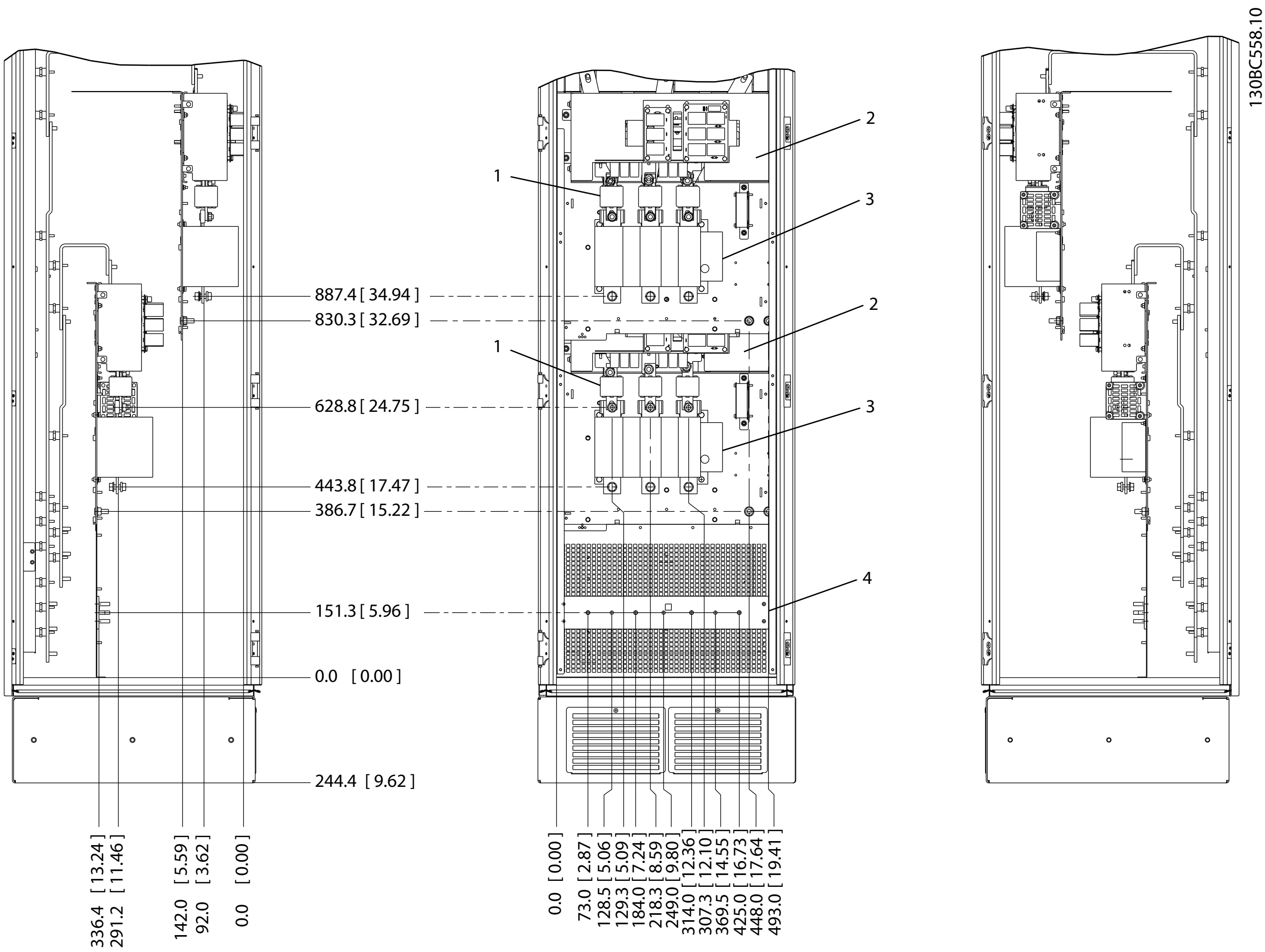

Figure 5.93 F9 Input Options Cabinet with Disconnect and Fuses

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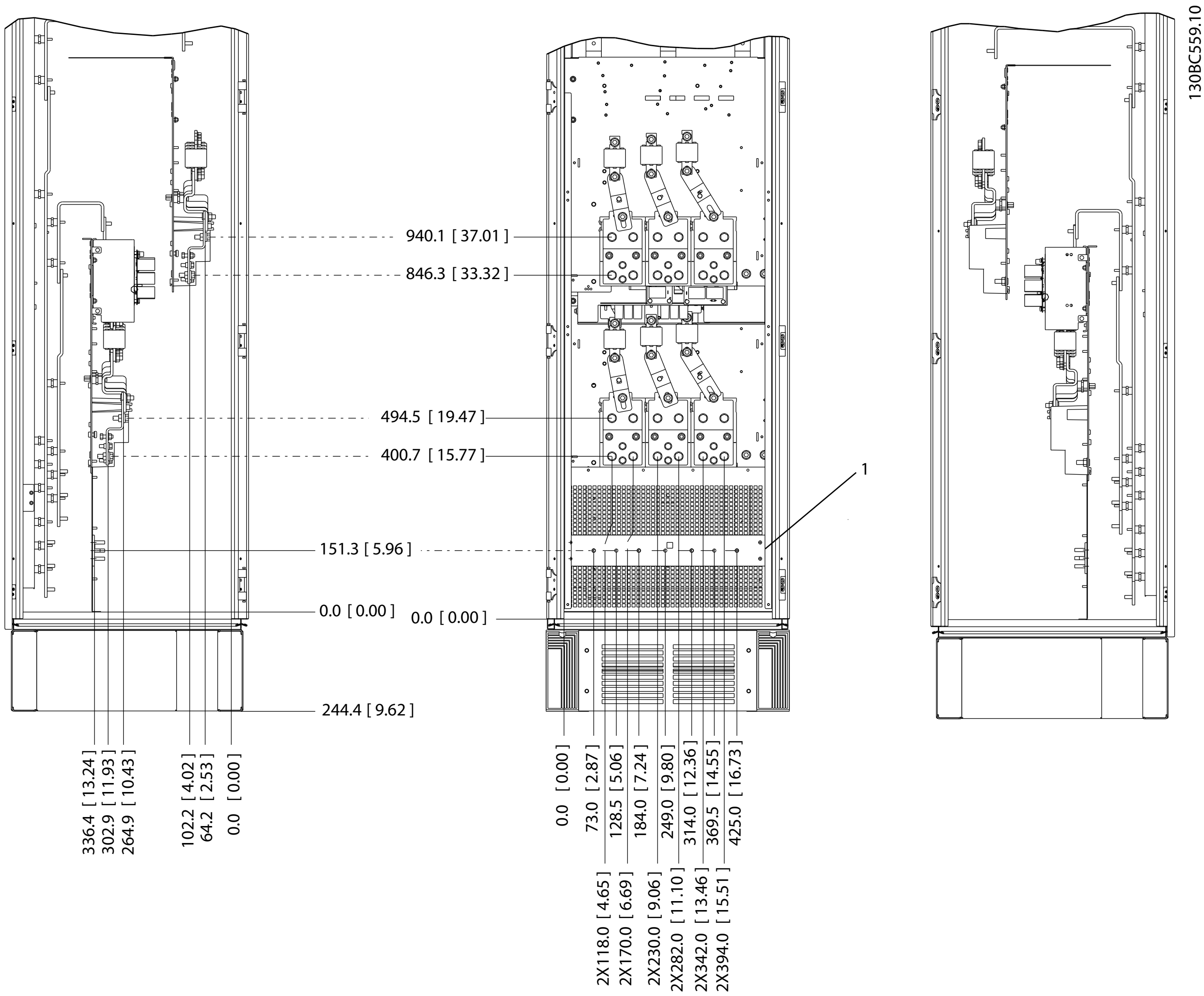

Figure 5.94 F9 Input Options Cabinet with Fuse only

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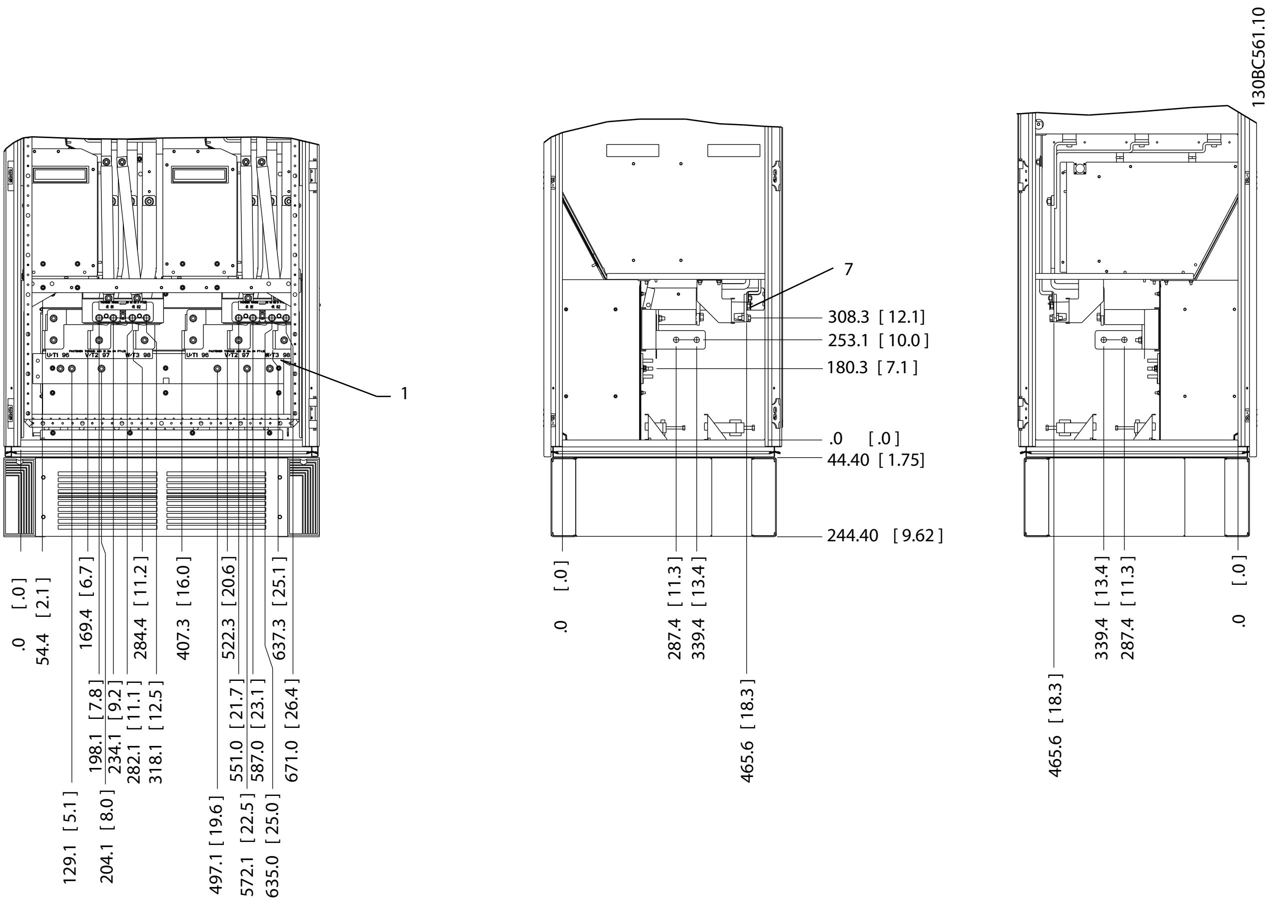

Figure 5.95 F10/F11 Inverter Cabinet

1) Ground bar

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5

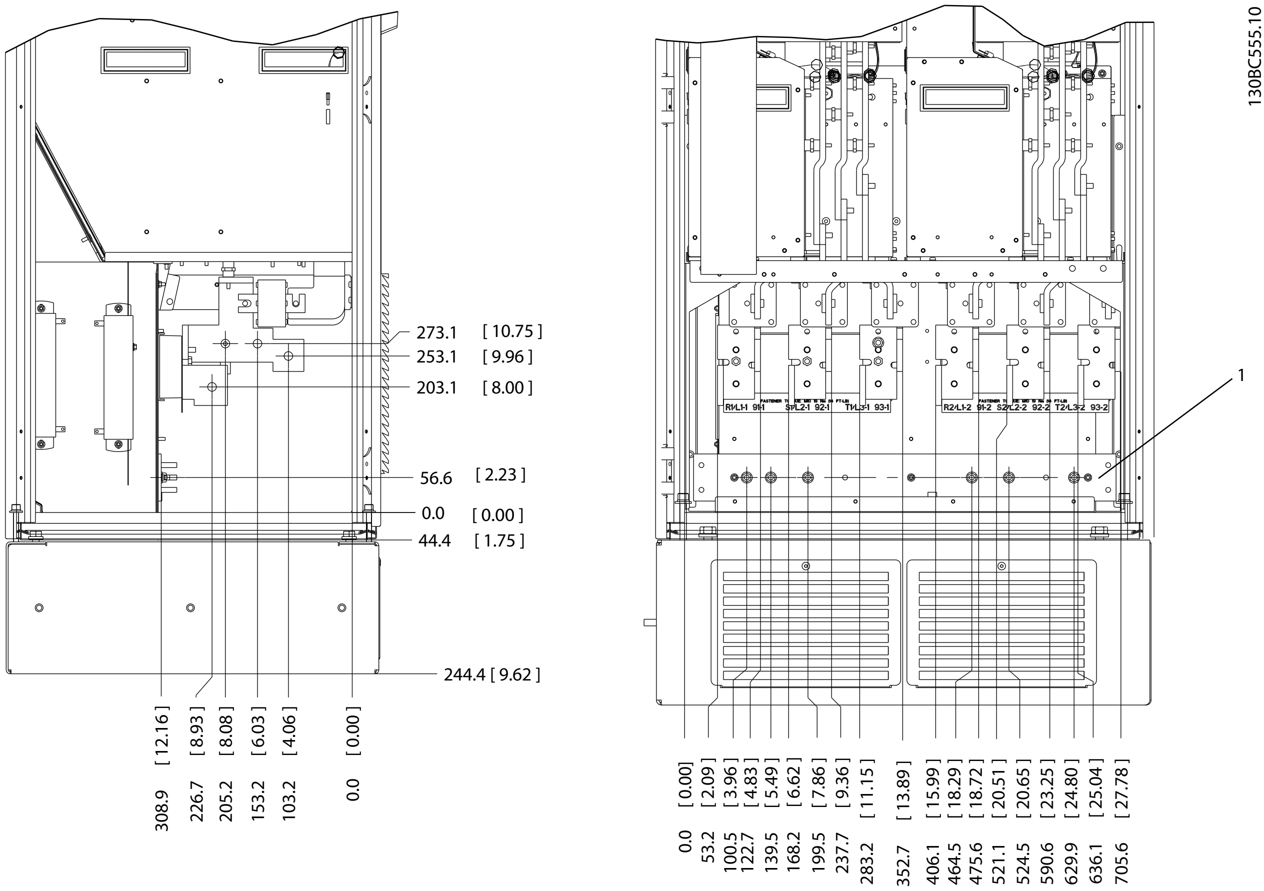

Figure 5.96 F10/F12 Rectifier Cabinet

1) Earth ground bar

The connector plate is 1.65 in [42 mm] below Ø level

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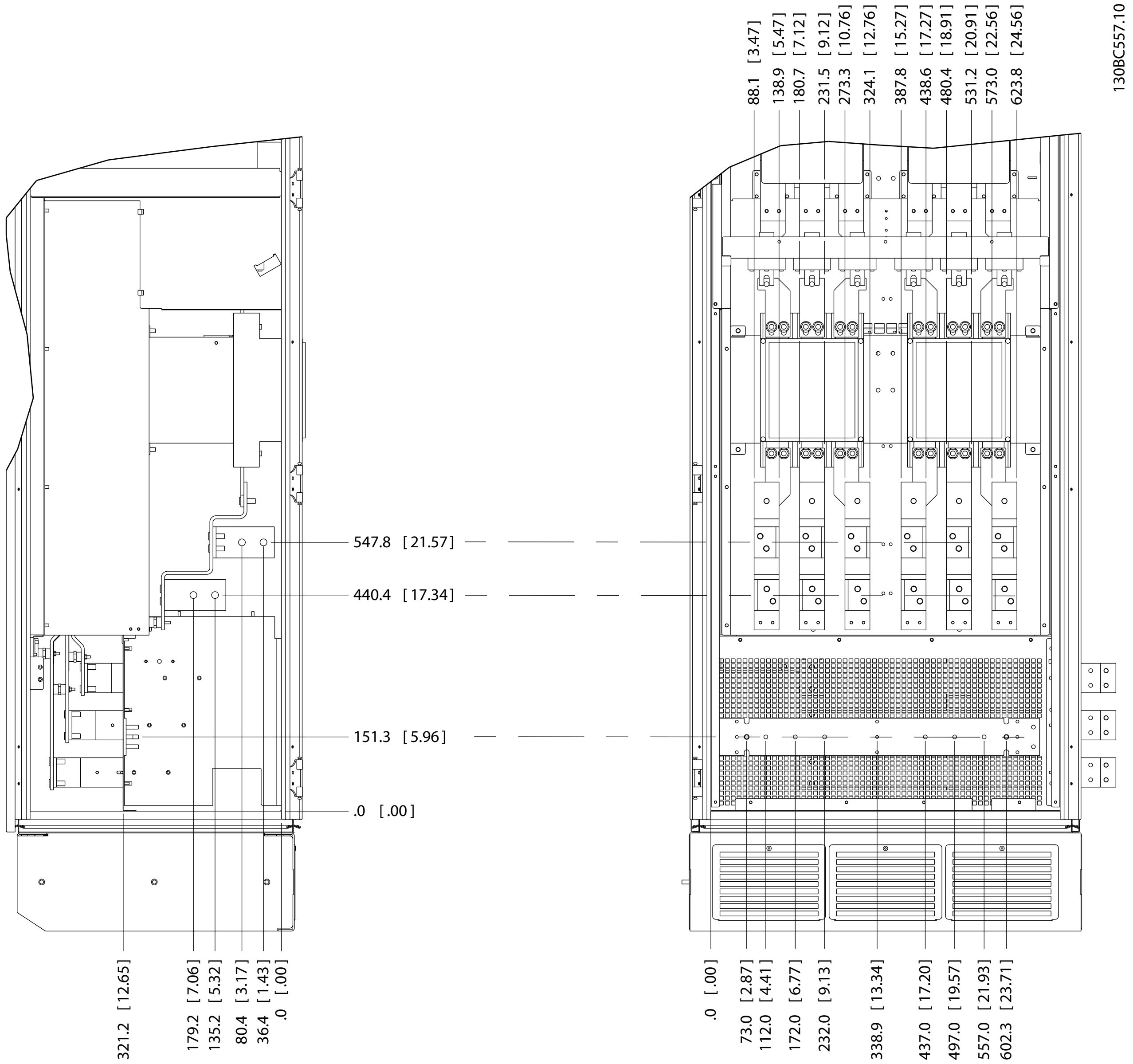

Figure 5.97 F11/F13 Input Option Cabinet with Disconnect and Fuses

1) Ground bar

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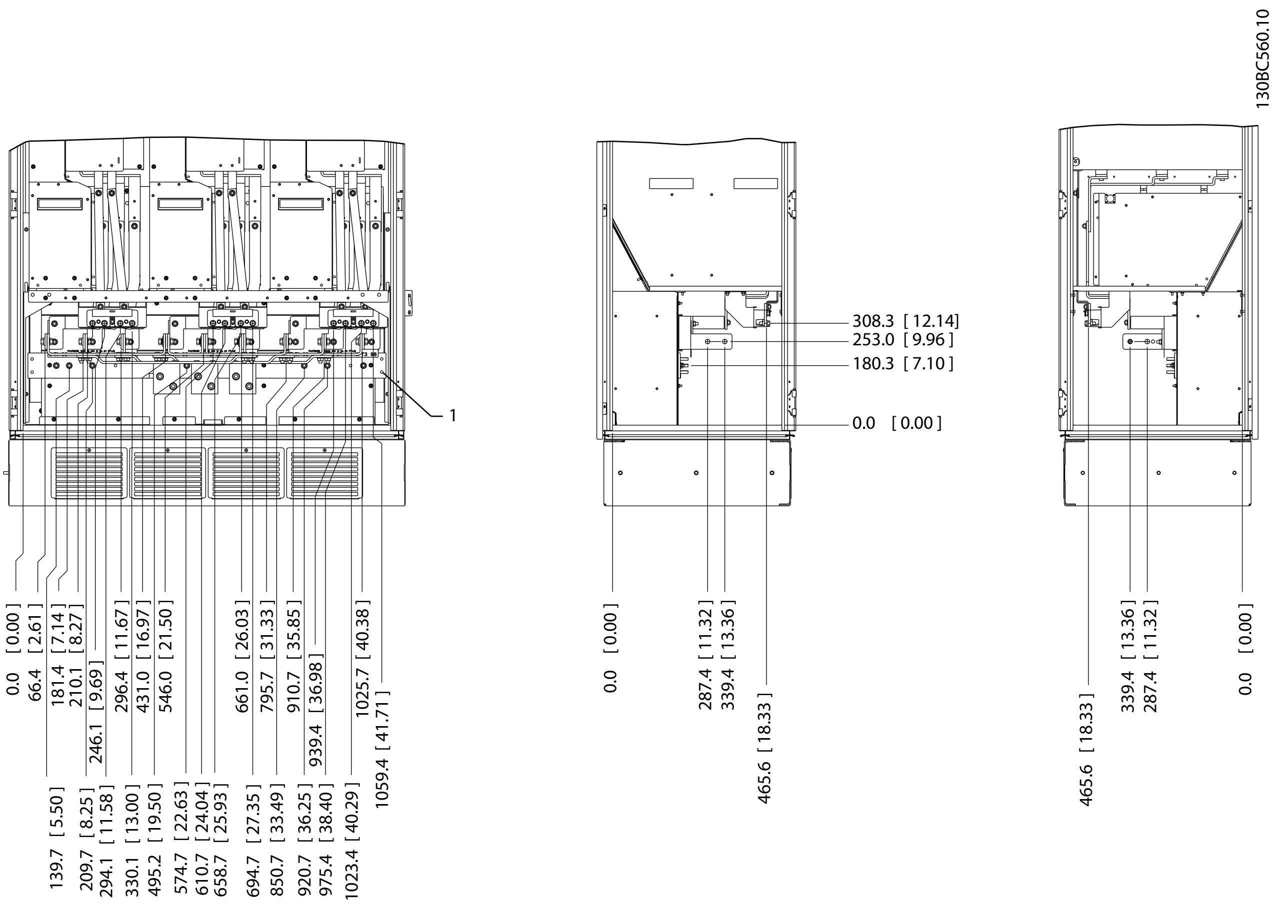

Figure 5.98 F12/F13 Inverter Cabinet, Front, Left and Right Side Views)

1) Ground bar

The connector plate is 1.65 in [42 mm] below Ø level

5.4.4 Shielding against Electrical Noise

F-Frame size units only
Before mounting the line power cable, mount the EMC metal cover to ensure best EMC performance.

NOTICE!

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

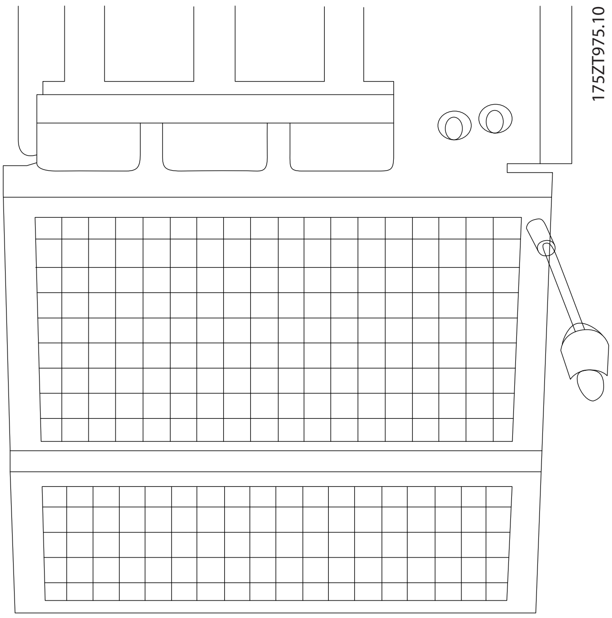

Figure 5.99 Mounting of EMC shield

5.4.5 External Fan Power Supply

Frame sizes E and F
If the adjustable frequency drive is supplied by DC or if the fan must run independently of the line power supply, an external power supply can be applied. The connection is made on the power card.

Terminal no.	Function
100, 101	Auxiliary supply S, T
102, 103	Internal supply S, T

Table 5.19 External Power Supply

The connector located on the power card provides the connection of line voltage for the cooling fans. The fans are connected at the factory to connect to 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. Use a 5 Amp fuse for protection. In UL applications, use a LittelFuse KLK-5 or equivalent.

5

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5.5 Input Options

5.5.1 Line Power Disconnects

Frame size	Power	Type
380–500 V		
D5h/D6h	N110-N160	ABB OT400U03
D7h/D8h	N200-N400	ABB OT600U03
E1/E2	P250	ABB OETL-NF600A
E1/E2	P315-P400	ABB OETL-NF800A
F3	P450	Merlin Gerin NPJF36000S12AAYP
F3	P500-P630	Merlin Gerin NRKF36000S20AAYP
F4	P710-P800	Merlin Gerin NRKF36000S20AAYP
525–690 V		
D5h/D6h	N75K-N160	ABB OT400U03
D5h/D6h	N200-N400	ABB OT600U03
F3	P630-P710	Merlin Gerin NPJF36000S12AAYP
F3	P800	Merlin Gerin NRKF36000S20AAYP
F4	P900-P1M2	Merlin Gerin NRKF36000S20AAYP

Table 5.20 Line Power Disconnects, D, E and F frame Adjustable Frequency Drives

Frame size	Power	Type
380–500 V		
F9	P250	ABB OETL-NF600A
F9	P315	ABB OETL-NF600A
F9	P355	ABB OETL-NF600A
F9	P400	ABB OETL-NF600A
F11	P450	ABB OETL-NF800A
F11	P500	ABB OETL-NF800A
F11	P560	ABB OETL-NF800A
F11	P630	ABB OT800U21
F13	P710	Merlin Gerin NPJF36000S12AAYP
F13	P800	Merlin Gerin NPJF36000S12AAYP
525–690 V		
F9	P355	ABB OT400U12-121
F9	P400	ABB OT400U12-121
F9	P500	ABB OT400U12-121
F9	P560	ABB OT400U12-121
F11	P630	ABB OETL-NF600A
F11	P710	ABB OETL-NF600A
F11	P800	ABB OT800U21
F13	P900	ABB OT800U21
F13	P1M0	Merlin Gerin NPJF36000S12AAYP
F13	P1M2	Merlin Gerin NPJF36000S12AAYP

Table 5.21 Line Power Disconnects, 12-Pulse Adjustable Frequency Drives

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				Default breaker settings (Trip level - Amps)	
Frame Size	Voltage [V]	Drive Model	Circuit Breaker Type	I1 (Overload)	I3/Ith (Instantaneous)
D6h	380-480	N110 - N132	ABB T5L400TW	400	4000
D6h	380-480	N160	ABB T5LQ400TW	400	4000
D8h	380-480	N200	ABB T6L600TW	600	6000
D8h	380-480	N250	ABB T6LQ600TW	600	6000
D8h	380-480	N315	ABB T6LQ800TW	800	8000
D6h	525-690	N75K - N160	ABB T5L400TW	400	4000
D8h	525-690	N200 - N315	ABB T6L600TW	600	6000
D8h	525-690	N400	ABB T6LQ600TW	600	6000

Table 5.22 D-frame Circuit Breakers

Frame size	Power & Voltage	Type	Default breaker settings	
			Trip level [A]	Time [s]
F3	P450 380–500 V & P630-P710 525–690 V	Merlin Gerin NPJF36120U31AABSCYP	1200	0.5
F3	P500-P630 380–500 V & P800 525–690 V	Merlin Gerin NRJF36200U31AABSCYP	2000	0.5
F4	P710 380–500 V & P900-P1M2 525–690 V	Merlin Gerin NRJF36200U31AABSCYP	2000	0.5
F4	P800 380–500 V	Merlin Gerin NRJF36250U31AABSCYP	2500	0.5

Table 5.23 F-frame Circuit Breakers

5.5.2 Line Power Contactors

Frame size	Power & Voltage	Type
D6h	N110-N160 380–480 V	CK95BE311N
	N75-N160 525–690 V	
D8h	N200-N315 380–480 V	CK11CE311N
	N200-N400 525–690 V	

Table 5.24 D-Frame 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	P630 380–500 V	Eaton XTCEC14P22B
F4	P900 525–690 V	Eaton XTCE820N22A
F4	P710-P800 380–500 V & P1M2 525–690 V	Eaton XTCEC14P22B

Table 5.25 F-Frame Contactors

NOTICE!

Customer supplied 230 V supply is required for line power contactors.

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5.5.3 Relay Output D frame

Relay 1

- Terminal 01: common
- Terminal 02: normal open 400 V AC
- Terminal 03: normal closed 240 V AC

Relay 2

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

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

Additional relay outputs by using option module MCB 105.

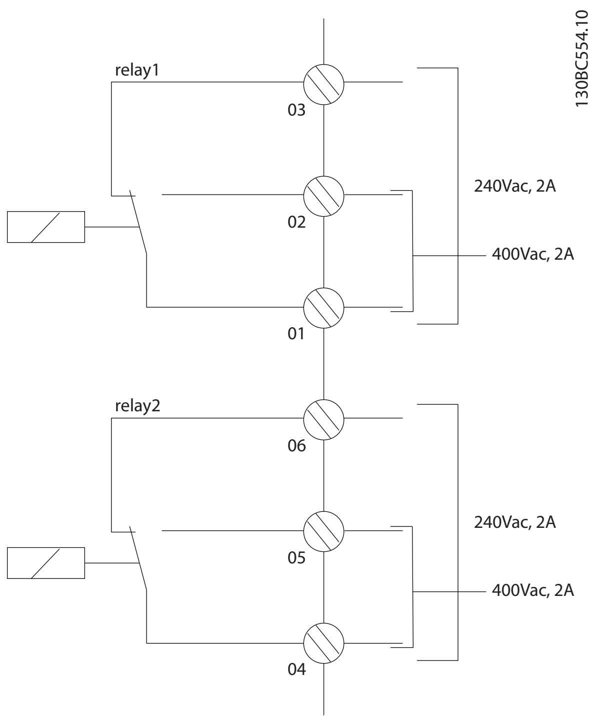

Figure 5.100 D-frame Additional Relay Outputs

5.5.4 Relay Output E & F-Frame

Relay 1

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

Relay 2

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

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

Additional relay outputs by using option module MCB 105.

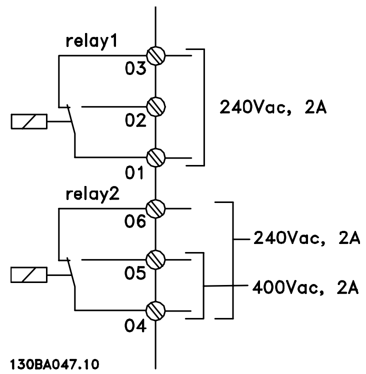

Figure 5.101 E- and F-frame Additional Relay Outputs

5.6 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.

NOTICE!

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

Step 2. Enter the motor nameplate data in this parameter list.
To access this list, first press [Quick Menu], then select "Q2 Quick Set-up".

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

Step 3. Activate the Automatic Motor Adaptation (AMA).

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Performing an AMA ensures optimum performance. The AMA measures the values from the motor model equivalent diagram.

1. Connect terminal 27 to terminal 12 or set *5-12 Terminal 27 Digital Input* to *[0] No function*
2. Activate the AMA *1-29 Automatic Motor Adaptation (AMA)*.
3. Choose between complete or reduced AMA. If an LC filter is mounted, run only the reduced AMA, or remove the LC filter during the AMA procedure.
4. Press [OK]. The display shows “Press [Hand On] to start”.
5. Press [Hand On]. A progress bar indicates whether the AMA is in progress.

Stop the AMA during operation

1. Press [Off] - the adjustable frequency drive enters into alarm mode and the display shows that the AMA was terminated.

Successful AMA

1. The display shows “Press [OK] to finish AMA”.
2. Press [OK] 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 *chapter 8 Troubleshooting*.
2. "Report Value” in the [Alarm Log] shows that 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 helps with trouble-shooting. If contacting Danfoss Service, make sure to mention the number and alarm description.

NOTICE!

AMA often fails because of incorrectly registered motor nameplate data or too great a difference between the motor power size and the adjustable frequency drive power size.

Step 4. Set speed limit and ramp time.

Set up the desired limits for speed and ramp time.

1. 3-02 Minimum Reference
2. 3-03 Maximum Reference

1. 4-11 Motor Speed Low Limit [RPM] or 4-12 Motor Speed Low Limit [Hz]
2. 4-13 Motor Speed High Limit [RPM] or 4-14 Motor Speed High Limit [Hz]

1. 3-41 Ramp 1 Ramp-up Time
2. 3-42 Ramp 1 Ramp-down Time

5.7 Safe Stop Installation

To carry out an installation of a Category 0 Stop (EN60204) in conformance with Safety Category 3 (EN954-1), follow these instructions:

1. The bridge (jumper) between Terminal 37 and 24 V DC of the FC 202 must be removed. Cutting or breaking the jumper is not sufficient. Remove it entirely to avoid short-circuiting. See jumper on *Figure 5.102*.
2. Connect terminal 37 to 24 V DC by a short circuit-protected cable. The 24 V DC voltage supply must be interruptible by an EN954-1 category 3 circuit interrupt device. If the interrupt device and the adjustable frequency drive are placed in the same installation panel, use a regular cable instead of a protected one.

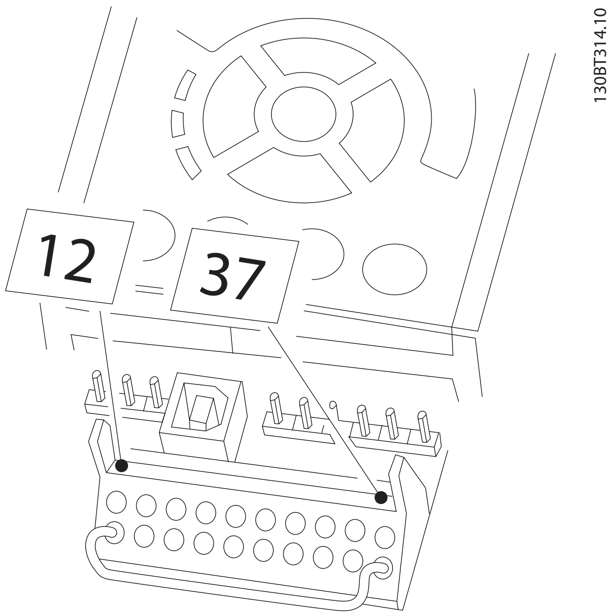

Figure 5.102 Bridge Jumper between Terminal 37 and 24 V DC

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Figure 5.103 shows a Stopping Category 0 (EN 60204-1) with safety Cat. 3 (EN 954-1). An opening door contact causes the circuit interrupt. The figure also shows how to connect a non-safety related hardware coast.

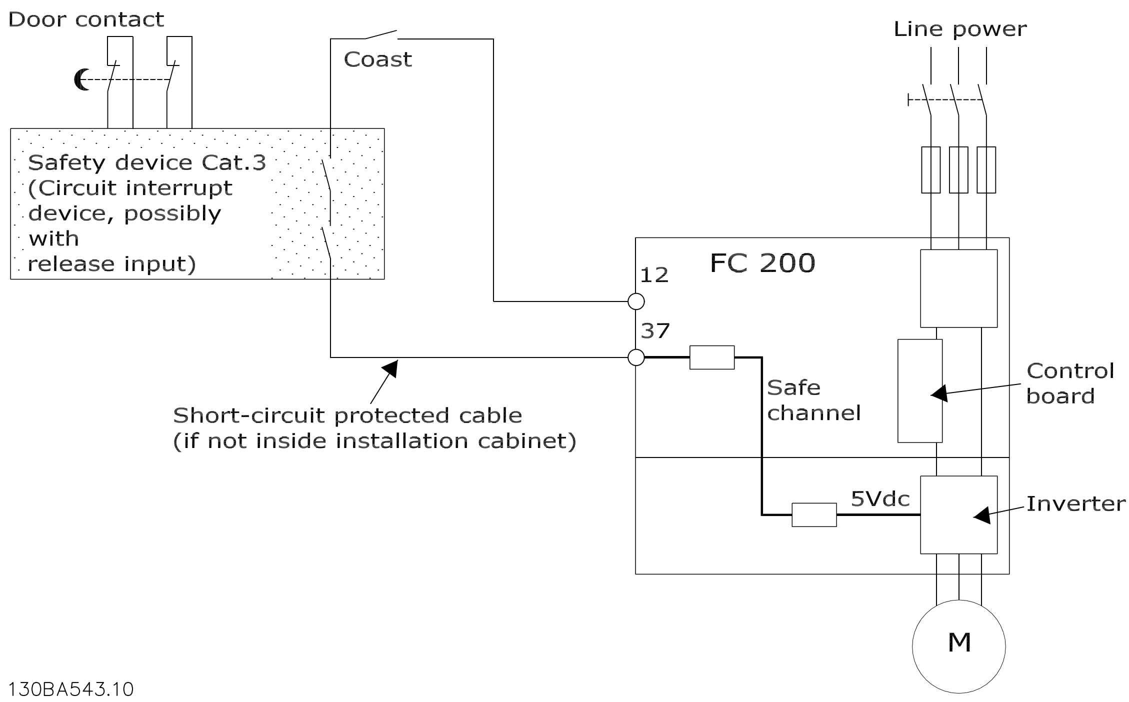

Figure 5.103 Essential Aspects of an Installation to Achieve a Stopping Category 0 (EN 60204-1) with Safety Cat. 3 (EN 954-1)

5.7.1 Safe Stop Commissioning Test

After installation and before first operation, perform a commissioning test of an installation or application using FC 200 Safe Stop.
Perform the test after each modification of the installation or application of which the FC 200 Safe Stop is part.

The commissioning test:

1. Remove the 24 V DC voltage supply to terminal 37 by the interrupt device while the adjustable frequency drive drives the motor (line power supply is not interrupted). The test step is successful if the motor reacts with a coast and the mechanical brake (if connected) is activated.
2. Send a 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.
4. Send a Reset signal (via bus, digital I/O, or [Reset] key). If the motor becomes operational again, this step is not necessary.
5. If all four test steps are completed successfully, the commissioning test is complete.

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5.8 Installation of Miscellaneous Connections

5.8.1 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.

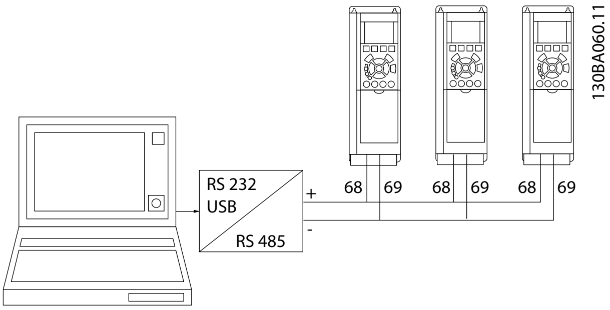

Figure 5.104 Parallel Connections

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

For EMC-compliant installation, refer to *chapter 5.10 EMC-compatible Installation*.

Bus termination
Terminate the RS-485 bus using a resistor network at both ends. For this purpose, set switch S801 on the control card to "ON".
For more information, see *chapter 5.3.16 Switches S201, S202 and S801*.

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

5.8.2 How to Connect a PC to the Unit

To control or program 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.

NOTICE!

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

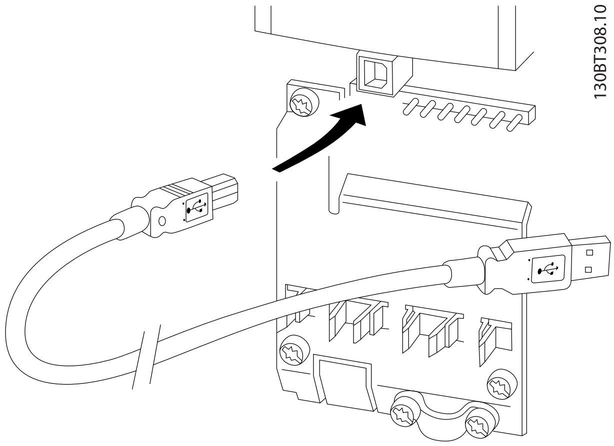

Figure 5.105 Connection of PC to Adjustable Frequency Drive

5.8.3 PC Software Tools

All adjustable frequency drives are equipped with a serial communication port. A PC tool for communication between PC and adjustable frequency drive is available.

5.8.3.1 MCT 10

MCT 10 has been designed as an easy-to-use interactive tool for setting parameters in our adjustable frequency drives.

The MCT 10 Set-up Software is useful for:

- Planning a communication network offline. MCT 10 contains a complete adjustable frequency drive database
- Commissioning adjustable frequency drives online.
- Saving settings for all adjustable frequency drives.
- Replacing an adjustable frequency drive in a network.
- Expanding an existing network
- Adjustable frequency drives developed in the future will be fully supported.

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MCT 10
Set-up Software support Profibus DP-V1 via a Master class 2 connection, which makes it possible to on line read/write parameters in an adjustable frequency drive via the Profibus network, eliminating the need for an extra communication network.

Save drive settings:

1. Connect a PC to the unit via the USB com port.
2. Open MCT 10 Set-up Software
3. Choose “Read from drive”
4. Choose “Save as”

All parameters are now stored on the PC.

Load drive settings:

1. Connect a PC to the unit via the USB com port.
2. Open MCT 10 Set-up software
3. Choose “Open” to view stored files
4. Open the appropriate file
5. Choose “Write to drive”

All parameter settings are now transferred to the adjustable frequency drive.

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

The MCT 10 Set-up Software Modules
The following modules are included in the software package:

MCT 10 Set-up Software

- Setting parameters
- Copy to and from adjustable frequency drives
- Documentation and print out of parameter settings incl. diagrams

Ext. User Interface

- Preventive Maintenance Schedule
- Clock settings
- Timed Action Programming
- Smart Logic Controller Set-up
- Cascade Control Config. Tool

Ordering number:
Order the CD containing MCT 10 Set-up Software using code number 130B1000.

MCT 10 can also be downloaded from *www.danfoss.com/BusinessAreas/DrivesSolutions/Softwaredownload/*.

5.8.3.2 MCT 31

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

Ordering number:
Order the CD containing the MCT 31 PC tool using code number 130B1031.

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

5.9 Safety

5.9.1 High Voltage Test

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

⚠WARNING

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

5.9.2 Safety Ground Connection

The adjustable frequency drive has a high leakage current and must be grounded appropriately for safety reasons, in accordance with EN 50178.

⚠WARNING

The ground leakage current from the adjustable frequency drive exceeds 3.5 mA. To ensure a good mechanical connection from the ground cable to the ground connection (terminal 95), the cable cross-section must be at least 0.016 in² [10 mm²] or two rated ground wires terminated separately.

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5.10 EMC-compatible Installation

5.10.1 Electrical Installation - EMC Precautions

The following is a guideline for good engineering practice when installing adjustable frequency drives. Follow these guidelines in compliance with EN 61800-3 *First environment*. If the installation is in EN 61800-3 *Second environment,* industrial networks, or in an installation with its own transformer, deviation from these guidelines is allowed but not recommended. See also *chapter 2.3.3 Danfoss Adjustable frequency drive and CE Labeling*, *chapter 2.9.3 EMC Test Results (Emission)* and *chapter 5.10.3 Grounding of Shielded/Armored Control Cables*.

Good engineering practice to ensure EMC-compatible electrical installation:

- Use only braided shielded/armored motor cables and braided shielded control cables. The shield provides 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 a conduit separate from the control and line cables. Full connection of the conduit from the adjustable frequency drive to the motor is required. The EMC performance of flexible conduits varies a lot and information from the manufacturer must be obtained.
- Connect the shield 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 *chapter 5.3.3 Connection to Line and Grounding*.
- Avoid terminating the shield 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 non-shielded motor or control cables inside cabinets housing the adjustable frequency drive, whenever possible.

Leave the shield as close to the connectors as possible.

Figure 5.106 shows an example of an EMC-compatible 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 doing the installation could have just as good an EMC performance, provided the guidelines to 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 *chapter 2.9.3 EMC Test Results (Emission)*.

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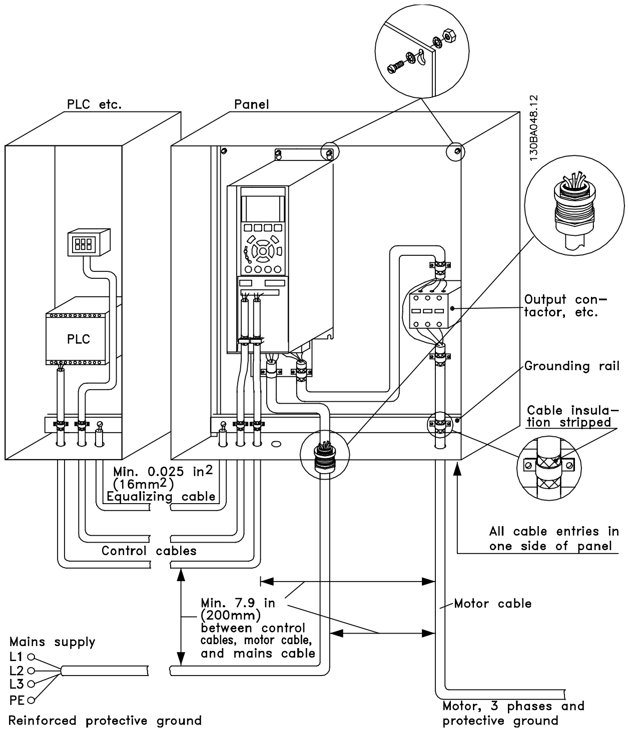

Figure 5.106 EMC-compatible Electrical Installation of an Adjustable Frequency Drive in Cabinet

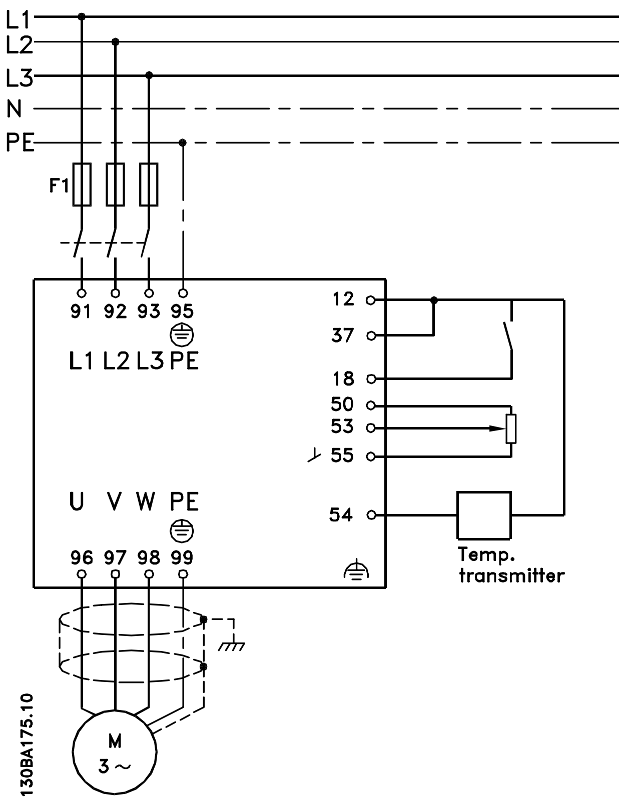

Figure 5.107 Electrical Connection Diagram (6-pulse example shown)

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5.10.2 Use of EMC-Compatible 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 incoming 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).

Cable manufacturers rare state transfer impedance (Z_T) but it is often possible to estimate transfer impedance (Z_T) by assessing the physical design of the cable.

Transfer impedance (Z_T) can be assessed based on the following factors:

- The conductibility of the shield material
- The contact resistance between the individual shield conductors
- The shield coverage which consists of the physical area of the cable covered by the shield - often stated as a percentage value
- Shield type–braided or twisted pattern
- Aluminum-clad with copper wire
- Twisted copper wire or shielded steel wire cable
- Single-layer braided copper wire with varying percentage shield coverage
- Double-layer braided copper wire
- Twin layer of braided copper wire with a magnetic, shielded/armored intermediate layer
- Cable that runs in copper tube or steel tube
- Lead cable with 0.043 in [1.1 mm] wall thickness

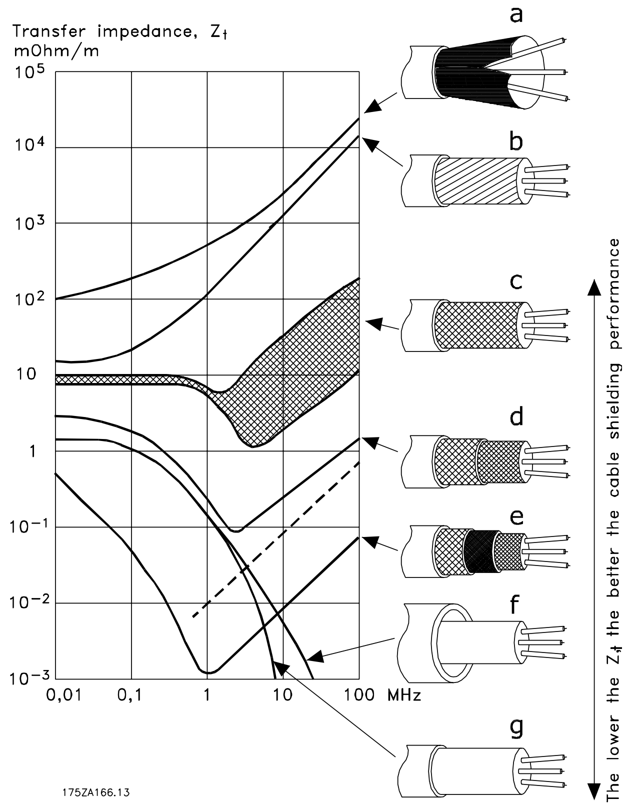

Figure 5.108 Transfer Impedance Z_T

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5.10.3 Grounding of Shielded/Armored Control Cables

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

Figure 5.109 indicates how correct grounding is carried out and what to do when 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 regarding ground potential between PLC and adjustable frequency drive**
If the ground potential between the adjustable frequency drive and the PLC is different, electric noise can occur that disturbs the entire system. Solve this problem by fitting an equalizing cable next to the control cable. Minimum cable cross-section: 16 mm^2.

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

e. **Cables for serial communication**
Eliminate low-frequency noise currents between 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 for reducing the differential mode interference between the conductors.

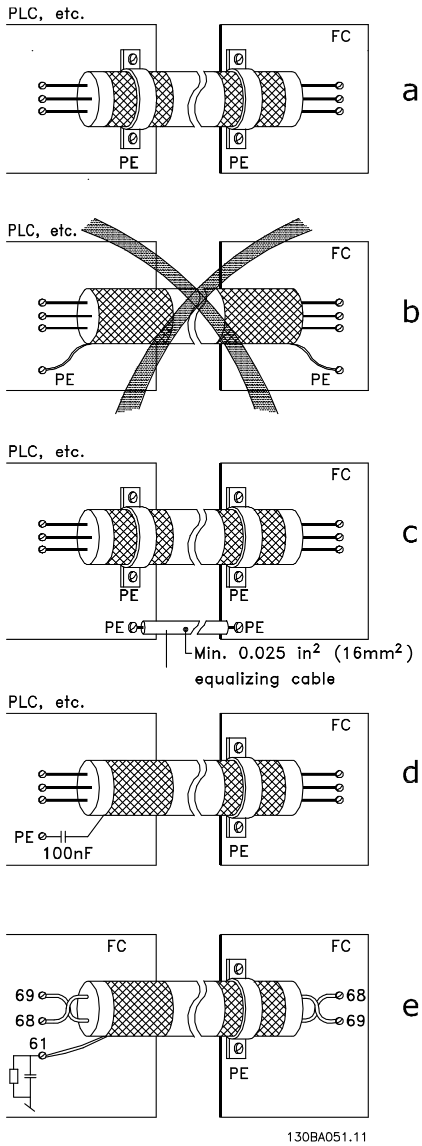

Figure 5.109 Grounding

5.11 Residual Current Device

Use RCD relays, multiple protective grounding, or grounding as extra protection to comply with local safety regulations.
If a ground fault appears, a DC content could develop in the faulty current.
If RCD relays are used, local regulations must be observed. Relays must be suitable for protection of 3-phase equipment with a bridge rectifier and for a brief discharge on power-up see *chapter 2.12 Ground Leakage Current* for further information.

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6 Application Examples

6.1 Typical Application Examples

6.1.1 Start/Stop

Terminal 18 = start/stop *5-10 Terminal 18 Digital Input [8] Start*
Terminal 27 = No operation *5-12 Terminal 27 Digital Input [0] No operation* (Default *coast inverse*

5-10 Terminal 18 Digital Input = *Start* (default)

5-12 Terminal 27 Digital Input = *coast inverse* (default)

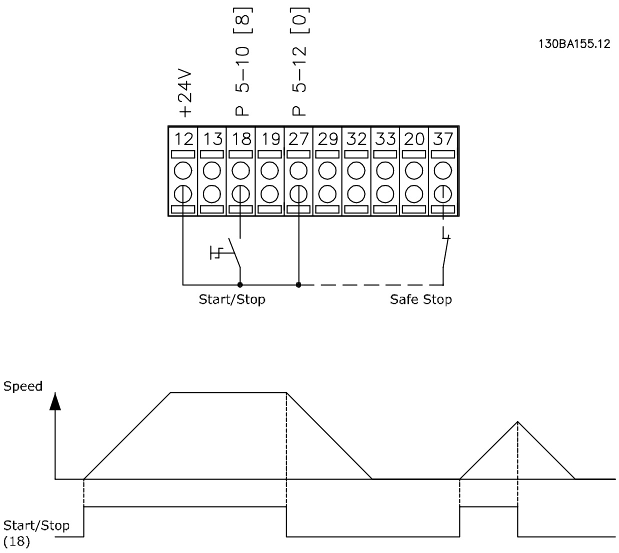

Figure 6.1 Terminal 37: Available only with Safe Stop Function!

6.1.2 Pulse Start/Stop

Terminal 18 = start/stop *5-10 Terminal 18 Digital Input [9] Latched start*
Terminal 27= Stop *5-12 Terminal 27 Digital Input [6] Stop inverse*

5-10 Terminal 18 Digital Input = *Latched start*

5-12 Terminal 27 Digital Input = *Stop inverse*

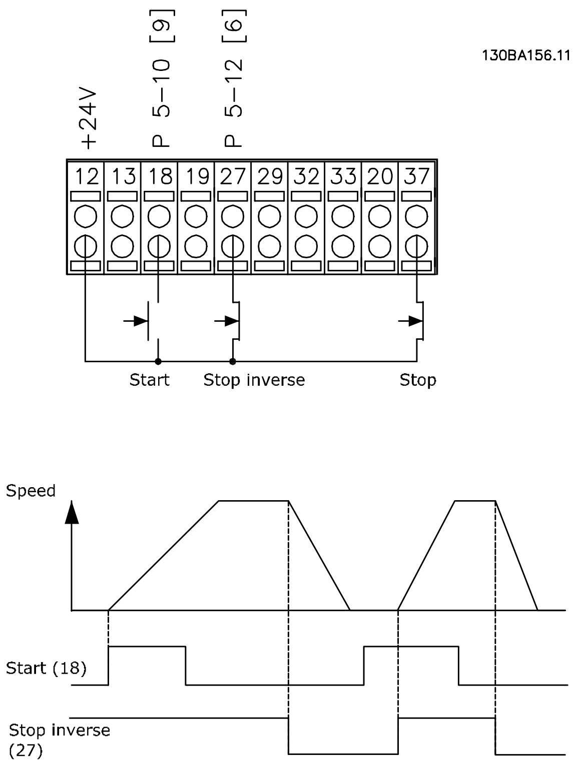

Figure 6.2 Terminal 37: Available only with Safe Stop Function!

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6.1.3 Potentiometer Reference

Voltage reference via a potentiometer.

3-15 Reference 1 Source [1] = *Analog Input 53*

6-10 Terminal 53 Low Voltage = 0 V

6-11 Terminal 53 High Voltage = 10 V

6-14 Terminal 53 Low Ref./Feedb. Value = 0 RPM

6-15 Terminal 53 High Ref./Feedb. Value = 1500 RPM

Switch S201 = OFF (U)

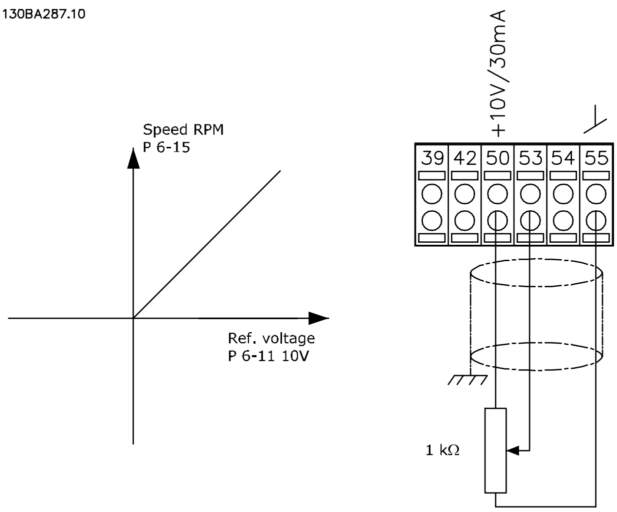

Figure 6.3 Potentiometer Reference

6.1.4 Automatic Motor Adaptation (AMA)

AMA is an algorithm to measure the electrical motor parameters on a motor at standstill, meaning that AMA 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. This feature is used where the default setting does not apply to the connected motor.
1-29 Automatic Motor Adaptation (AMA) allows a choice of complete AMA with determination of all electrical motor parameters or reduced AMA with determination of the stator resistance Rs only.
The duration of a total AMA varies from a few minutes on small motors to more than 15 minutes on large motors.

Limitations and preconditions:

- For the AMA to determine the motor parameters optimally, enter the correct motor nameplate data in *1-20 Motor Power [kW]* to *1-28 Motor Rotation Check*.
- For the best adjustment of the adjustable frequency drive, carry out an AMA on a cold motor. Repeated AMA runs could lead to a heating of the motor, which results in an increase of the stator resistance, Rs. Normally, this increase 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 a 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 wind milling in ventilation systems, for example. This disturbs the AMA function.
- AMA cannot be activated when running a PM motor (when *1-10 Motor Construction* is set to *[1] PM non-salient SPM*).

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6.1.5 Smart Logic Control

The Smart Logic Control (SLC) is essentially a sequence of user-defined actions (see *13-52 SL Controller Action*) executed by the SLC when the associated user-defined *event* (see *13-51 SL Controller Event*) is evaluated as TRUE by the SLC.
Events and *actions* are each numbered and are linked in pairs called states, which means that when *event [1]* is fulfilled (attains the value TRUE), *action [1]* is executed. After this sequence, 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* is 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* are evaluated, so that when the SLC starts, it evaluates *event [1]* (and only *event [1]*) each scan interval. Only when *event [1]* is evaluated TRUE does the SLC execute *action [1]* and start 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*:

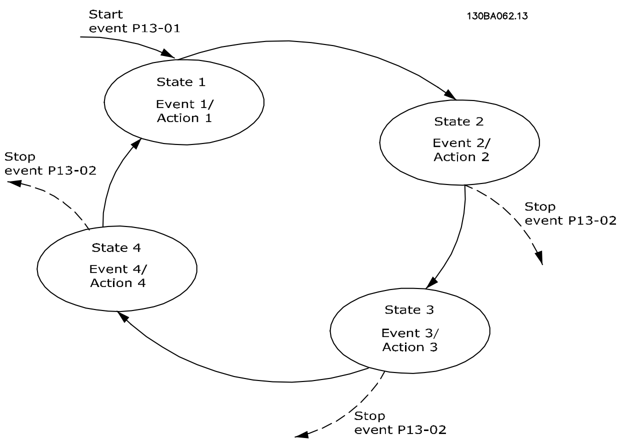

Figure 6.4 Events and Actions

6.1.6 Smart Logic Control Programming

In applications where a PLC is generating a simple sequence, the SLC takes over elementary tasks from the main control.
SLC is designed to act from event send to or generated in the adjustable frequency drive. The adjustable frequency drive then performs the pre-programmed action.

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6.1.7 SLC Application Example

One sequence 1:
Start – ramp up – run at reference speed two seconds – ramp down and hold shaft until stop.

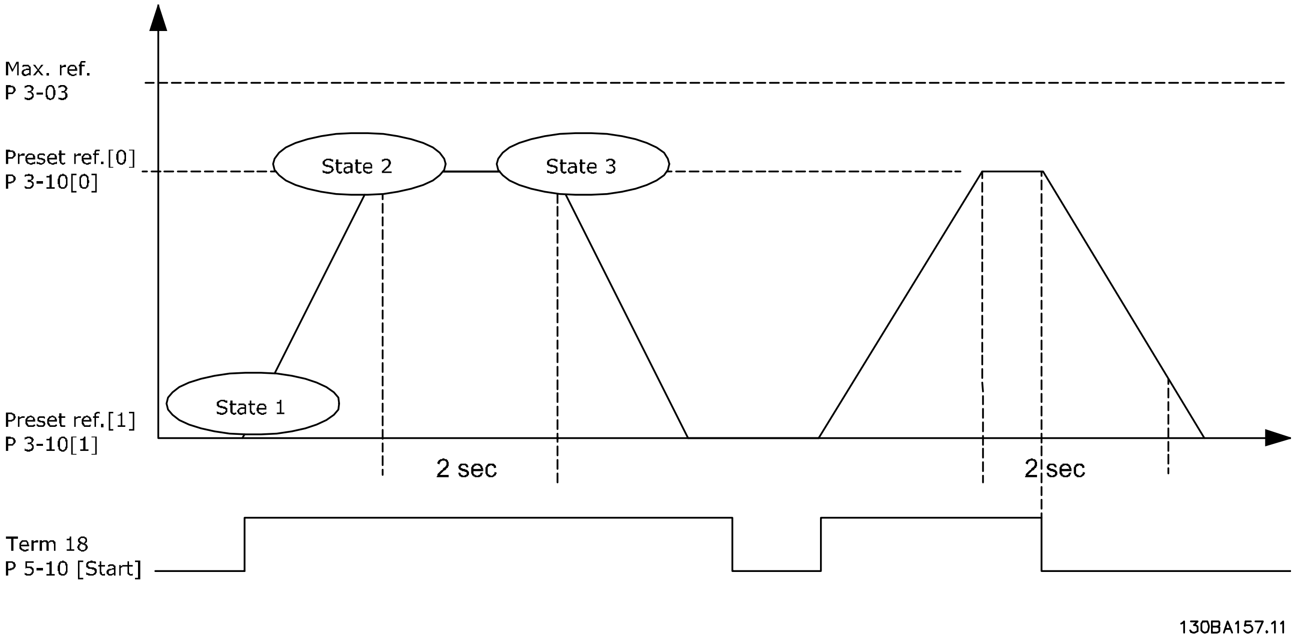

Figure 6.5 Ramp-up/Ramp-down

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

$$tramp = \frac{tacc \times nnorm\,(par.\ 1\ -\ 25)}{ref\,[RPM]}$$

Set term 27 to *No Operation* (*5-12 Terminal 27 Digital Input*)
Set Preset reference 0 to first preset speed (*3-10 Preset Reference* [0]) in percentage of Max reference speed (*3-03 Maximum Reference*). Ex.: 60%
Set preset reference 1 to second preset speed (*3-10 Preset Reference* [1] Ex.: 0% (zero).
Set the timer 0 for constant running speed in *13-20 SL Controller Timer* [0]. Ex.: 2 s

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

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

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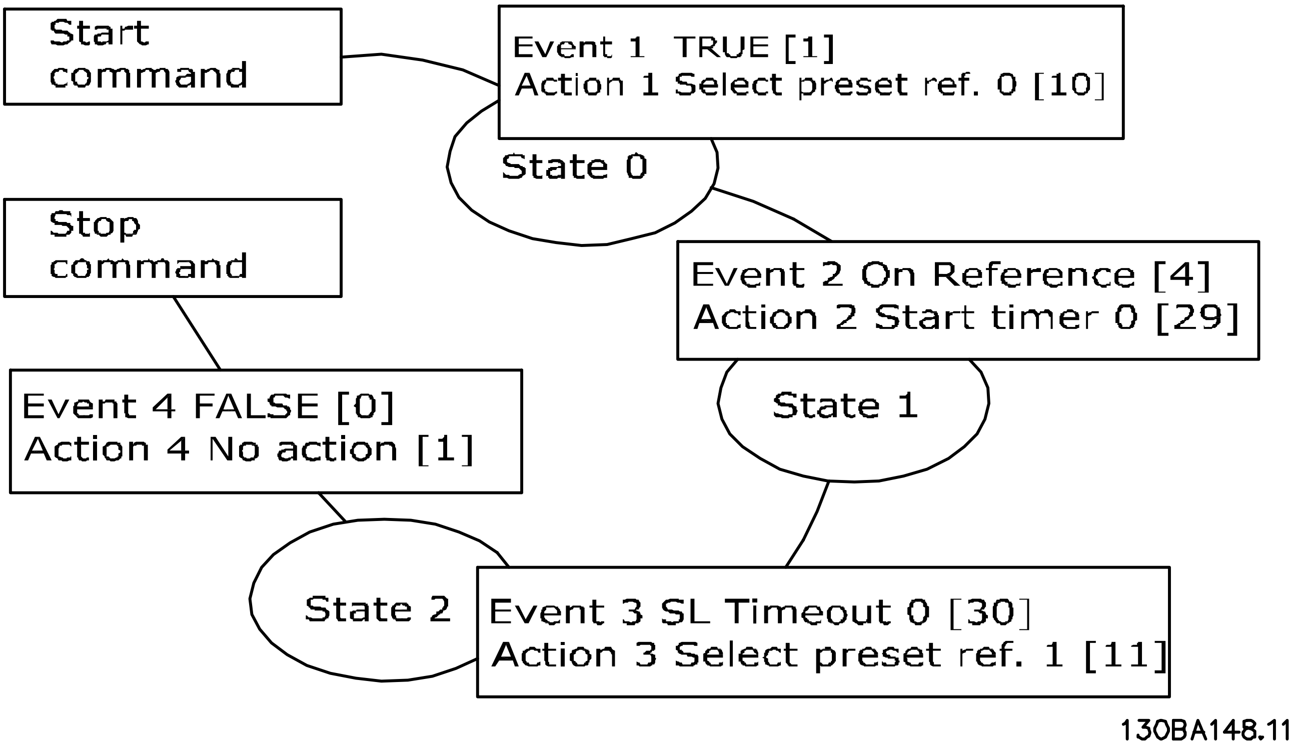

Figure 6.6 SLC Application Example

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

Start/stop command is applied on terminal 18. If the stop signal is applied, the adjustable frequency drive ramps down and goes into free mode.

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6.1.8 BASIC Cascade Controller

The BASIC Cascade Controller is used for pump applications where a certain pressure ("head") or level must be maintained over a wide dynamic range. Running a large pump at variable speeds over a wide range is not an ideal solution because of low pump efficiency at lower speeds. In a practical way, the limit is 25% of the rated full load speed for the pump.

In the BASIC Cascade Controller, the adjustable frequency drive controls a variable-speed (lead) motor as the variable-speed pump and can stage up to two additional constant-speed pumps on and off. By varying the speed of the initial pump, variable speed control of the entire system is provided, maintaining constant pressure while eliminating pressure surges, resulting in reduced system stress, and quieter operation in pumping systems.

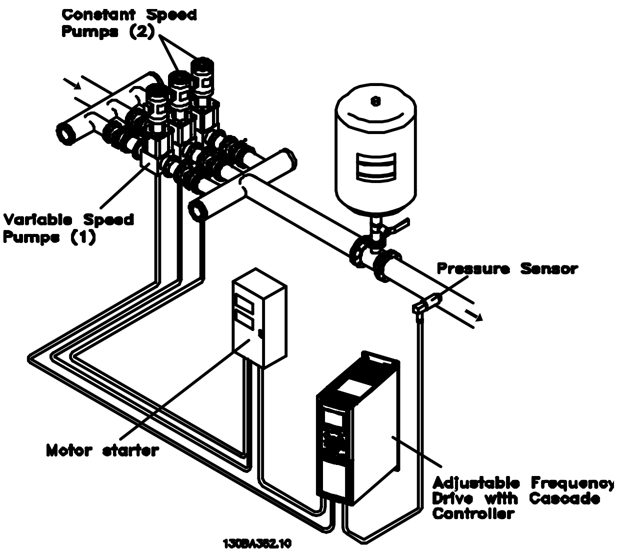

Figure 6.7 BASIC Cascade Controller

Fixed Lead Pump
The motors must be of equal size. The BASIC Cascade Controller allows the adjustable frequency drive to control up to three equal size pumps using the adjustable frequency drive's two built-in relays. When the variable pump (lead) is connected directly to the adjustable frequency drive, the two built-in relays control the other two pumps. When lead pump alternations are enabled, pumps are connected to the built-in relays and the adjustable frequency drive can operate two pumps.

Lead Pump Alternation
The motors must be of equal size. This function makes it possible to cycle the adjustable frequency drive between the pumps in the system (maximum of two pumps). In this operation, the run time between pumps is equalized reducing the required pump maintenance and increasing reliability and lifetime of the system. The alternation of the lead pump can take place at a command signal or at staging (adding another pump).

The command can be a manual alternation or an alternation event signal. If the alternation event is selected, the lead pump alternation takes place every time the event occurs. Selections include whenever an alternation timer expires, at a predefined time of day or when the lead pump goes into sleep mode. The actual system load determines staging.

A separate parameter limits alternation only to take place if total capacity required is > 50%. Total pump capacity is determined as lead pump plus fixed-speed pumps capacities.

Bandwidth Management
In cascade control systems, to avoid frequent switching of fixed-speed pumps, the desired system pressure is kept within a bandwidth rather than at a constant level. The staging bandwidth provides the required bandwidth for operation. When a large and quick change in system pressure occurs, the override bandwidth overrides the staging bandwidth to prevent immediate response to a short duration pressure change. An override bandwidth timer can be programmed to prevent staging until the system pressure has stabilized and normal control established.

When the cascade controller is enabled and the drive issues a trip alarm, the system head is maintained by staging and de-staging fixed-speed pumps. To prevent frequent staging and de-staging and minimize pressure fluctuations, a wider fixed-speed bandwidth is used instead of the staging bandwidth.

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6.1.9 Pump Staging with Lead Pump Alternation

With lead pump alternation enabled, a maximum of two pumps are controlled. At an alternation command, the PID stops, the lead pump ramps to minimum frequency (f_{min}) and after a delay, it ramps to maximum frequency (f_{max}). When the speed of the lead pump reaches the de-staging frequency, the fixed-speed pump is cut out (de-staged). The lead pump continues to ramp up, then ramps down to a stop, and the two relays are cut out.

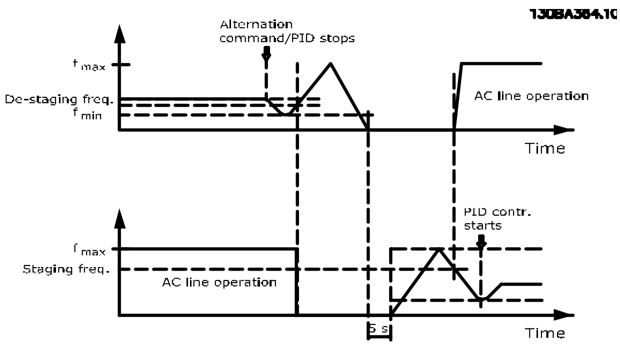

Figure 6.8 Lead Pump Alternation

After a time delay, the relay for the fixed-speed pump cuts in (staged) and this pump becomes the new lead pump. The new lead pump ramps up to maximum speed and then down to minimum speed. When ramping down and reaching the staging frequency, the old lead pump is now cut in (staged) on the line power as the new fixed-speed pump.

If the lead pump has been running at minimum frequency (f_{min}) for a programmed amount of time, with a fixed-speed pump running, the lead pump contributes little to the system. When the programmed value of the timer expires, the lead pump is removed to avoid water heating problems.

6.1.10 System Status and Operation

If the lead pump goes into sleep mode, the function is displayed on the LCP. It is possible to alternate the lead pump into a sleep mode condition.

When the cascade controller is enabled, the operation status for each pump and the cascade controller is displayed on the LCP. Information displayed includes:

- Pumps Status, is a readout of the status for the relays assigned to each pump. The display shows pumps that are disabled, off, running on the adjustable frequency drive, or running on the line power/motor starter.
- Cascade Status, a readout of the status for the cascade controller. The display shows that the Cascade Controller is disabled, all pumps are off, and emergency has stopped all pumps, all pumps are running, fixed-speed pumps are being staged/de-staged and lead pump alternation is occurring.
- De-stage at no-flow ensures that all fixed-speed pumps are stopped individually until the no-flow status disappears.

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6.1.11 Cascade Controller Wiring Diagram

The wiring diagram shows an example with the built-in BASIC Cascade Controller with one variable-speed pump (lead) and two fixed-speed pumps, a 4–20 mA transmitter and System Safety Interlock.

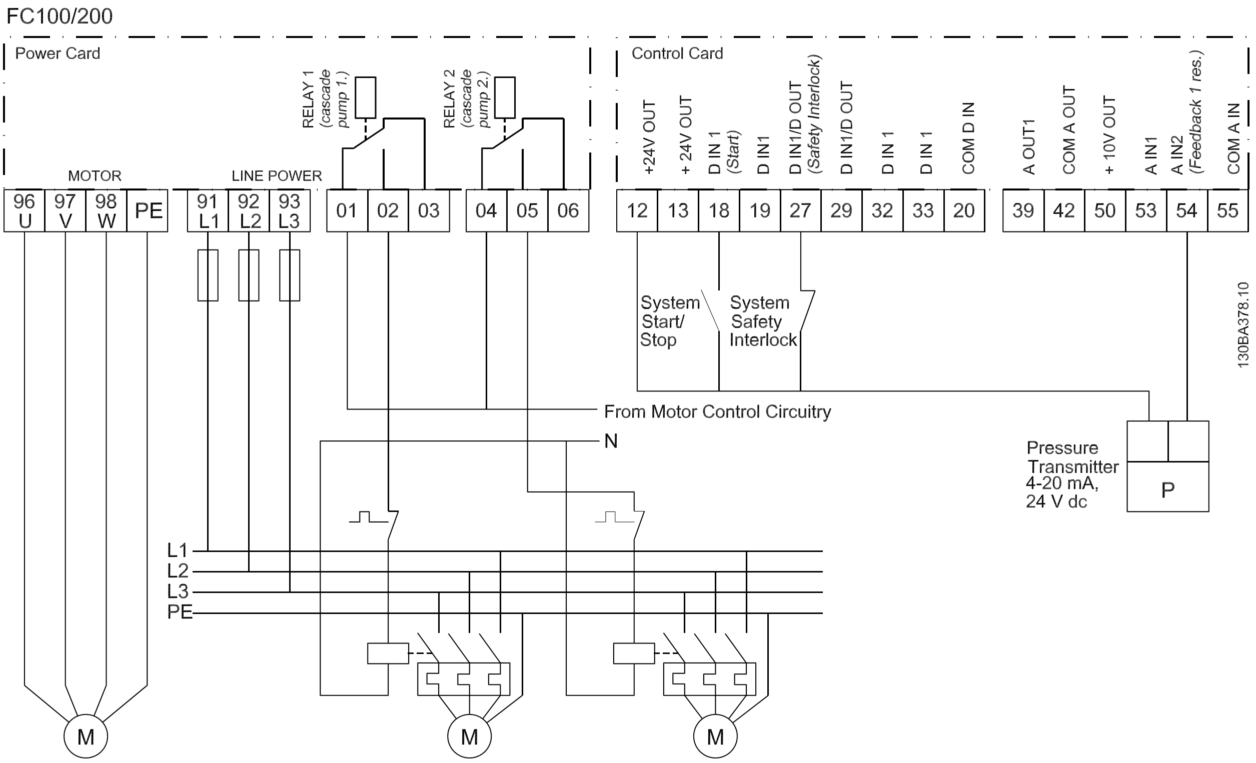

Figure 6.9 Cascade Controller Wiring Diagram

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6.1.12 Fixed Variable Speed Pump Wiring Diagram

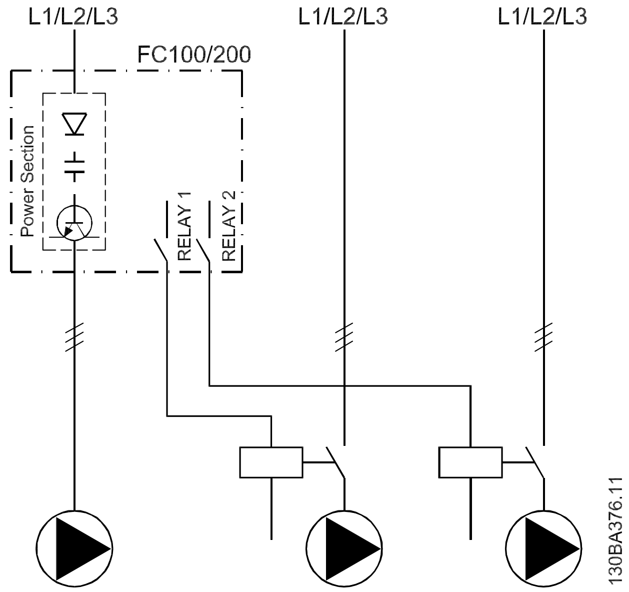

Figure 6.10 Fixed Variable Speed Pump Wiring Diagram

6.1.13 Lead Pump Alternation Wiring Diagram

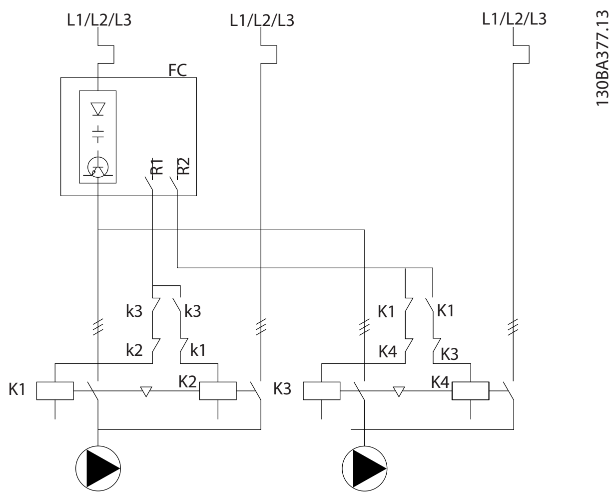

Figure 6.11 Lead Pump Alternation Wiring Diagram

Every pump must be connected to two contactors (K1/K2 and K3/K4) with a mechanical interlock. Thermal relays or other motor protection devices must be applied according to local regulation and/or individual demands.

- RELAY 1 (R1) and RELAY 2 (R2) are the built-in relays in the adjustable frequency drive.
- When all relays are de-energized, the first built-in relay that is energized cuts in the contactor corresponding to the pump controlled by the relay. For example, RELAY 1 cuts in contactor K1, which becomes the lead pump.
- K1 blocks K2 via the mechanical interlock, preventing line power to be connected to the output of the adjustable frequency drive (via K1).
- Auxiliary break contact on K1 prevents K3 from cutting in.
- RELAY 2 controls contactor K4 for on/off control of the fixed-speed pump.
- At alternation, both relays de-energize and now RELAY 2 are energized as the first relay.

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6.1.14 Start/Stop Conditions

Commands assigned to digital inputs. See parameter group *5-1* Digital Inputs*.

	Variable-speed pump (lead)	**Fixed-speed pumps**
Start (SYSTEM START /STOP)	Ramps up (if stopped and there is a demand)	Staging (if stopped and there is a demand)
Lead Pump Start	Ramps up if SYSTEM START is active	Not affected
Coast (EMERGENCY STOP)	Coast to stop	Cut out (built in relays are de-energized)
Safety Interlock	Coast to stop	Cut out (built in relays are de-energized)

Table 6.1 Commands Assigned to Digital Input

	Variable-speed pump (lead)	**Fixed-speed pumps**
Hand On	Ramps up (if stopped by a normal stop command) or stays in operation if already running.	De-staging (if running)
Off	Ramps down	Cut out
Auto On	Starts and stops according to commands sent via terminals or serial bus.	Staging/De-staging

Table 6.2 Function of LCP Keys

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7 RS-485 Installation and Set-up

7.1 Introduction

RS-485 is a two-wire bus interface compatible with multi-drop network topology. Nodes can be connected as a bus, or via drop cables from a common trunk line. A total of 32 nodes can be connected to one network segment.
Repeaters divide network segments. Note each repeater function as a node within the segment in which it is installed. Each node connected within a given network must have a unique node address across all segments.
Terminate each segment at both ends using either the termination switch (S801) of the adjustable frequency drives or a biased termination resistor network. Always use shielded twisted pair (STP) cable for bus cabling, and always follow good common installation practice.
Low-impedance ground connection of the shield at every node is important, including at high frequencies. Thus, connect a large surface of the shield to ground, with a cable clamp or a conductive cable connector, for example. If necessary, apply potential-equalizing cables to maintain the same ground potential throughout the network. Particularly in installations with long cables.
To prevent impedance mismatch, always use the same type of cable throughout the entire network. When connecting a motor to the adjustable frequency drive, always use shielded motor cable.

Cable	Shielded twisted pair (STP)
Impedance	120 Ω
Cable length	Max. 4000 ft [1200 m] (including drop lines)
Max. 1650 ft [500 m] station-to-station	

Table 7.1 Motor Cable

7.1.1 Hardware Set-up

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

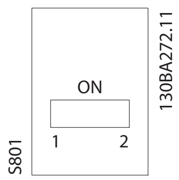

Figure 7.1 Terminator Switch Factory Setting

NOTICE!

The factory setting for the dip switch is OFF.

7.1.2 Parameter Settings for Modbus Communication

The parameters in *Table 7.2* apply to the RS-485 interface (FC port)

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

Table 7.2 Modbus Communication Parameters

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7.1.3 EMC Precautions

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

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

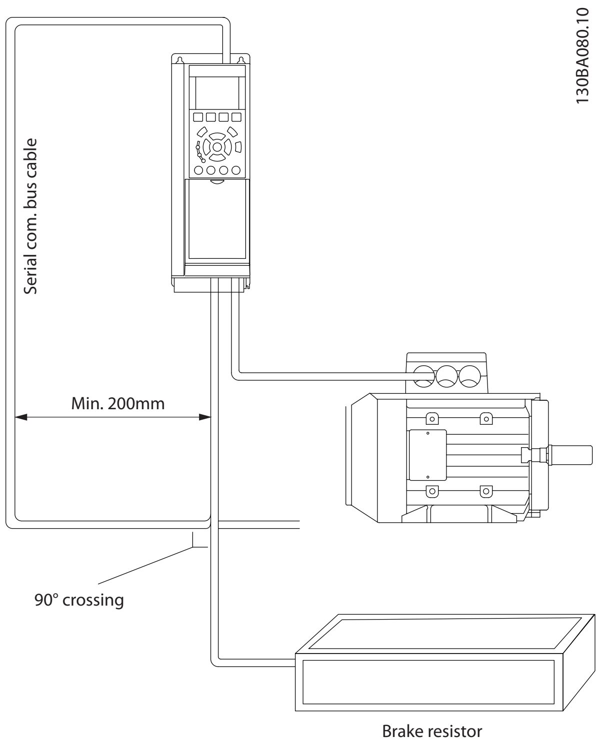

Figure 7.2 EMC Precautions

7.2 FC Protocol Overview

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

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

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

7.2.1 Modbus RTU

The FC protocol 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 various preset speeds
- Run in reverse
- Change of the active set-up
- Control of the two relays built into the adjustable frequency drive

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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, permitting a range of control options, including controlling the setpoint of the adjustable frequency drive when its internal PID controller is used.

7.3 Network Connection

One or more adjustable frequency drives can be connected to a control (or master) using the RS-485 standardized interface. Terminal 68 is connected to the P signal (TX+, RX+), while terminal 69 is connected to the N signal (TX-, RX-). See drawings in *chapter 5.10.3 Grounding of Shielded/ Armored Control Cables*

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

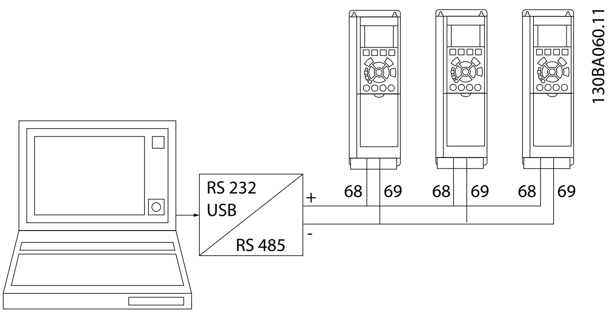

Figure 7.3 Parallel Connections

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

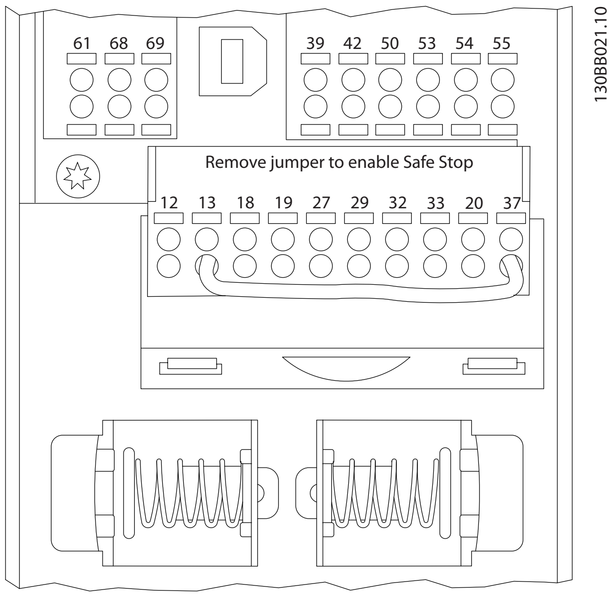

Figure 7.4 Control Card Terminals

7.4 FC Protocol Message Framing Structure

7.4.1 Content of a Character (byte)

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

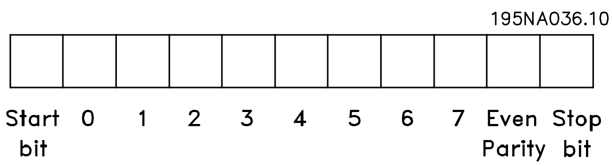

Figure 7.5 Character (Byte)

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7.4.2 Message Structure

Each message has the following structure:

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

A number of data bytes (variable, depending on the type of message) follows. A data control byte (BCC) completes the message.

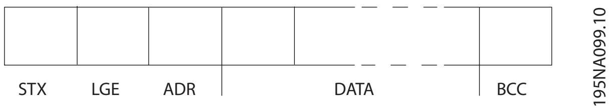

Figure 7.6 Message Structure

7.4.3 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).

7.4.4 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 message.

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7.4.5 Data Control Byte (BCC)

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

7.4.6 The Data Field

The structure of data blocks depends on the type of message. There are three 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 4 bytes (two words) and contains:

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

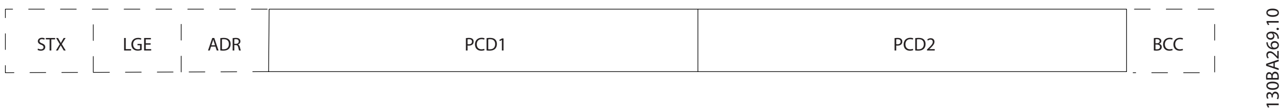

Figure 7.7 PCD

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

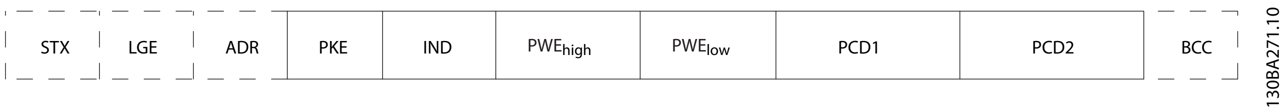

Figure 7.8 Parameter Block

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

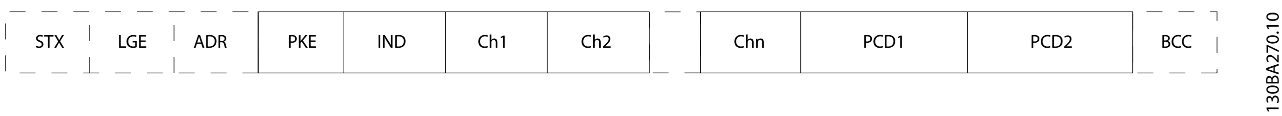

Figure 7.9 Text Block

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7.4.7 The PKE Field

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

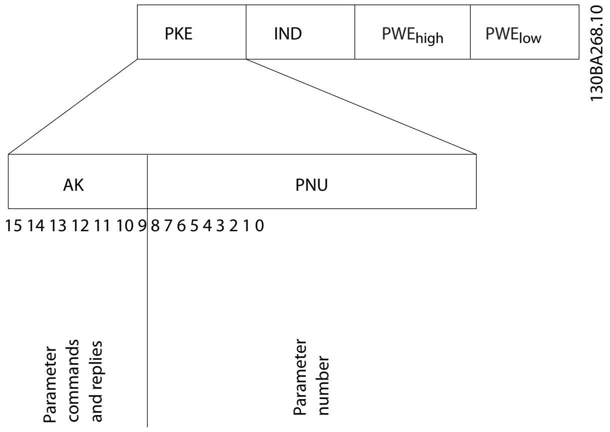

Figure 7.10

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

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

Table 7.3 Parameter Commands Master⇒Slave

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

Table 7.4 Response Slave⇒Master

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

PWE low (Hex)	Fault report
0	The parameter number used does not exist
1	There is no write access to the defined parameter
2	Data value exceeds the parameter limits
3	The sub index used does not exist
4	The parameter is not the array type.
5	The data type does not match the defined parameter
11	Data change in the defined parameter is not possible in the present mode of the adjustable frequency drive. Certain parameters can only be changed when the motor is turned off
82	There is no bus access to the defined parameter
83	Data change is not possible because the factory set-up is selected.

Table 7.5 Fault Report

7.4.8 Parameter Number (PNU)

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

7.4.9 Index (IND)

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

Only the low byte is used as an index.

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7.4.10 Parameter Value (PWE)

The parameter value block consists of two 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, for example, *0-01 Language [0] English*, and *[4] Danish*, select the data value by entering the value in the PWE block. See example - selecting a data value. Serial communication is only capable of reading parameters containing data type 9 (text string).

15-40 FC Type to *15-53 Power Card Serial Number* contain data type 9.
For example, read the unit size and AC line voltage range in *15-40 FC Type*. When a text string is transferred (read), the length of the telegram 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 via the serial bus. To write a text via the PWE block, set the parameter command (AK) to ’F’ Hex. The index characters high-byte must be “5.”

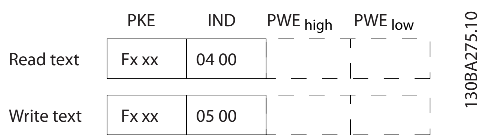

Figure 7.11 PWE

7.4.11 Data Types Supported

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

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

Table 7.6 Data Types Supported

7.4.12 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.

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

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

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

Table 7.7 Conversion Table

7.4.13 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

Table 7.8 PCD

7.5 Examples

7.5.1 Writing a Parameter Value

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

PKE=E19E Hex - Write single word in *4-14 Motor Speed High Limit [Hz]*
IND=0000 Hex
PWE$_{high}$=0000 Hex
PWE$_{low}$=03E8 Hex - Data value 1,000, corresponding to 100 Hz, see *chapter 7.4.12 Conversion*.

E19E H	0000 H	0000 H	03E8 H
PKE	IND	PWE $_{high}$	PWE $_{low}$

130BA092.10

Figure 7.12 Message

NOTICE!

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

119E H	0000 H	0000 H	03E8 H
PKE	IND	PWE $_{high}$	PWE $_{low}$

130BA093.10

Figure 7.13 Response from Master to Slave

7.5.2 Reading a Parameter Value

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

PKE=1,155 Hex - Read parameter value in *3-41 Ramp 1 Ramp-up Time*
IND=0000 Hex
PWE$_{high}$=0000 Hex
PWE$_{low}$=0000 Hex

1155 H	0000 H	0000 H	0000 H
PKE	IND	PWE $_{high}$	PWE $_{low}$

130BA094.10

Figure 7.14 Parameter Value

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

130BA267.10

1155 H	0000 H	0000 H	03E8 H
PKE	IND	PWE $_{high}$	PWE $_{low}$

Figure 7.15 Response from Slave to Master

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

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7.6 Modbus RTU Overview

7.6.1 Assumptions

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

7.6.2 Prerequisite Knowledge

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 reader has full knowledge of the capabilities and limitations of the controller.

7.6.3 Modbus RTU Overview

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

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

If a reply is required, the controller constructs the reply message and sends it.
Controllers communicate using a master-slave technique in which only one device (the master) can initiate transactions (called queries). The other devices (slaves) respond by supplying the requested data to the master, or by responding to 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 query by placing into it the device (or broadcast) address, a function code defining the requested action, any data to send, and an error-checking field.
The slave response message is also constructed using Modbus protocol. It contains fields confirming the action taken, any data to return, and an error-checking field. If an error occurs in receipt of the message, or if the slave is unable to perform the requested action, the slave constructs an error message and sends it in response or a timeout occurs.

7.6.4 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 various preset speeds
- Run in reverse
- Change the active set-up
- Control the built-in relay of the adjustable frequency drive

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, permitting a range of control options, including controlling the setpoint of the adjustable frequency drive when its internal PI controller is used.

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7.7 Network Configuration

7.7.1 Adjustable Frequency Drive with Modbus RTU

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

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

7

7.8 Modbus RTU Message Framing Structure

7.8.1 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 in *Table 7.9*.

Start bit	Data byte								Stop/ parity	Stop

Table 7.9 Example Format

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)

Table 7.10 Bit Detail

7.8.2 Modbus RTU Message Structure

The transmitting device places a Modbus RTU message into a frame with a known beginning and ending point. Receiving devices are able to begin at the start of the message, read the address portion, determine which device is addressed (or all devices, if the message is broadcast), and to recognize when the message is completed. Partial messages are detected, and errors are set as a result. Characters for transmission must be in hexadecimal 00 to FF format in each field. The adjustable frequency drive continuously monitors the network bus, also during 'silent' intervals. When the first field (the address field) is received, each adjustable frequency drive or device decodes it to determine which device is being addressed. Modbus RTU messages addressed to zero are broadcast messages. No response is permitted for broadcast messages. A typical message frame is shown in *Table 7.11*.

Start	Address	Function	Data	CRC check	End
T1-T2-T3-T4	8 bits	8 bits	N x 8 bits	16 bits	T1-T2-T3-T4

Table 7.11 Typical Modbus RTU Message Structure

7.8.3 Start/Stop Field

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

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7.8.4 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.

7.8.5 Function Field

The function field of a message frame contains 8 bits. Valid codes are in the range of 1-FF. Function fields are used to send messages between master and slave. When a message is sent from a master to a slave device, the function code field tells the slave what 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 an error has 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 code tells the master what error occurred, or the reason for the exception. See *chapter 7.8.9 Function Codes Supported by Modbus RTU*.

7.8.6 Data Field

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

7.8.7 CRC Check Field

Messages include an error-checking field, operating based on a Cyclical Redundancy Check (CRC) method. The CRC field checks the contents of the entire message. It is applied regardless of any parity check method used for the individual characters of the message. The transmitting device calculates the CRC value then 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. After error-checking, the low-order byte of the field is appended first, followed by the high-order byte. The CRC high-order byte is the last byte sent in the message.

7.8.8 Coil Register Addressing

In Modbus, all data are organized in coils and holding registers. Coils hold a single bit, whereas holding registers hold a 2-byte word (16 bits). All data addresses in Modbus messages are referenced to zero. The first occurrence of a data item is addressed as item number 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).

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Coil number	Description	Signal direction
1–16	Adjustable frequency drive control word (see *Table 7.13*)	Master to slave
17–32	Adjustable frequency drive speed or setpoint reference Range 0x0–0xFFFF (-200%... ~200%)	Master to slave
33–48	Adjustable frequency drive status word (see *Table 7.13*)	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)	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.	
66-65536	Reserved	

Table 7.12 Coils and Holding Registers

Coil	0	1
01	Preset reference LSB	
02	Preset reference MSB	
03	DC brake	No DC brake
04	Coast stop	No coast stop
05	Quick stop	No quick stop
06	Freeze freq.	No freeze freq.
07	Ramp stop	Start
08	No reset	Reset
09	No jog	Jog
10	Ramp 1	Ramp 2
11	Data not valid	Data valid
12	Relay 1 off	Relay 1 on
13	Relay 2 off	Relay 2 on
14	Set up LSB	
15	Set up MSB	
16	No reversing	Reversing

Table 7.13 Adjustable Frequency Drive Control Word (FC Profile)

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

Table 7.14 Adjustable Frequency Drive Status Word (FC Profile)

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

Table 7.15 Holding Registers

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

7.8.9 Function Codes Supported by Modbus RTU

Modbus RTU supports use of the function codes in *Table 7.16* in the function field of a message.

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

Table 7.16 Function Codes

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

Table 7.17 Function Codes

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7.8.10 Database Error Codes

In the event of an error, the following error codes may appear in the data field of a response message. For a full explanation of the structure of an exception (error) response, refer to *chapter 7.8.5 Function Field*.

Error Code in data field (decimal)	**Database Error Code description**
00	The parameter number does not exit.
01	There is no write access to the parameter.
02	The data value exceeds the parameter limits.
03	The sub-index in use does not exit.
04	The parameter is not of the array type.
05	The data type does not match the parameter called
06	Only reset
07	Not changeable
11	No write access
17	Data change in the parameter called is not possible in the present mode.
18	Other error
64	Invalid data address
65	Invalid message length
66	Invalid data length or value
67	Invalid function code
130	There is no bus access to the parameter called
131	Data change is not possible because factory set-up is selected

Table 7.18 Error Codes

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7.9 How to Access Parameters

7.9.1 Parameter Handling

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

7.9.2 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).

7.9.3 IND

The array index is set in holding register 9 and used when accessing array parameters.

7.9.4 Text Blocks

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

7.9.5 Conversion Factor

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

7.9.6 Parameter Values

Standard Data Types
Standard data types are int16, int32, uint8, uint16 and uint32. They are stored as 4x registers (40001–4FFFF). The parameters are read using function 03HEX "Read Holding Registers." Parameters are written using the function 6HEX "Preset Single Register" for 1 register (16 bits), and the function 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 and are stored as 4x registers (40001–4FFFF). The parameters are read using function 03HEX "Read Holding Registers" and written using function 10HEX "Preset Multiple Registers." Readable sizes range from 1 register (2 characters) up to 10 registers (20 characters).

7.10 Examples

7.10.1 Read Coil Status (01 HEX)

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

Query
The query message specifies the starting coil and quantity of coils to read. Coil addresses start at zero.

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

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

Table 7.19 Query

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

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

Table 7.20 Response

NOTICE!

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

7

7.10.2 Force/Write Single Coil (05 HEX)

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

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

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

Table 7.21 Query

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

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

Table 7.22 Response

7.10.3 Force/Write Multiple Coils (0F HEX)

This function forces each coil in a sequence of coils to either ON or OFF. When broadcast, the function forces the same coil references in all attached slaves.

The query message specifies the coils 17–32 (speed setpoint) to be forced.

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

Table 7.23 Query

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

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

Table 7.24 Response

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7.10.4 Read Holding Registers (03 HEX)

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

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

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

Field Name	Example (HEX)
Slave Address	01
Function	03 (read holding registers)
Starting Address HI	0B (Register address 3029)
Starting Address LO	D5 (Register address 3029)
No. of Points HI	00
No. of Points LO	02 - (Par. 3–03 is 32 bits long, that is, two registers)
Error Check (CRC)	-

Table 7.25 Query

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

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

Table 7.26 Response

7.10.5 Preset Single Register (06 HEX)

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

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

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

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

Table 7.27 Query

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

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

Table 7.28 Response

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7.11 Danfoss FC Control Profile

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

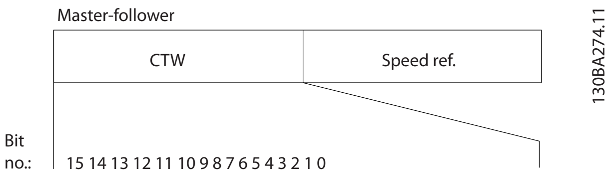

Figure 7.16 CW Master to Slave

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 *3-10 Preset Reference* according to *Table 7.29*.

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

Table 7.29 Control Bits

NOTICE!

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

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

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

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

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

Bit 05, Hold output frequency
Bit 05='0': The present output frequency (in Hz) freezes. Change the frozen output frequency only with the digital inputs (*5-10 Terminal 18 Digital Input* to *5-15 Terminal 33 Digital Input*) programmed to *Speed up* and *Slow-down*.

NOTICE!

If freeze output is active, only the following conditions can stop the adjustable frequency drive:

- **Bit 03 Coasting stop**
- **Bit 02 DC braking**
- **Digital input (*5-10 Terminal 18 Digital Input* to *5-15 Terminal 33 Digital Input*) programmed to *DC braking*, *Coasting stop*, or *Reset* and *coasting stop*.**

Bit 06, Ramp stop/start
Bit 06='0': Causes a stop and makes the motor speed ramp down to stop via the selected ramp-down parameter.
Bit 06='1': Permits the adjustable frequency drive to start the motor if the other starting conditions are met.

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Make a selection in *8-53 Start Select* to define how Bit 06 Ramp stop/start gates with the corresponding function on a digital input.

Bit 07, Reset:
Bit 07='0': No reset.
Bit 07='1': Resets a trip. Reset is activated on the leading edge of the signal, that is, when changing from logic '0' to logic '1'.

Bit 08, Jog
Bit 08='1': The output frequency depends on*3-19 Jog Speed [RPM]*.

Bit 09, Selection of ramp 1/2
Bit 09="0": Ramp 1 is active (*3-41 Ramp 1 Ramp-up Time* to *3-42 Ramp 1 Ramp-down Time*).
Bit 09="1": Ramp 2 (*3-51 Ramp 2 Ramp-up Time* to *3-52 Ramp 2 Ramp-down Time*) is active.

Bit 10, Data not valid/Data valid
Tell the adjustable frequency drive whether to use or ignore the control word. Bit 10='0': The control word is ignored.
Bit 10='1': The control word is used. This function is relevant because the message always contains the control word, regardless of the message type. Thus, it is possible to turn off the control word if not in use when updating or reading parameters.

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

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

Bit 13/14, Selection of set-up
Use bits 13 and 14 to choose from the four menu set-ups according to *Table 7.30*:

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

Table 7.30 Selection of Set-up

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

Make a selection in *8-55 Set-up Select* to define how Bit 13/14 gates with the corresponding function on the digital inputs.

Bit 15 Reverse
Bit 15='0': No reversing.
Bit 15='1': Reversing. In the default setting, reversing is set to digital in *8-54 Reverse Select*. Bit 15 causes reversing only when Ser. communication, Logic, or Logic and is selected.

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

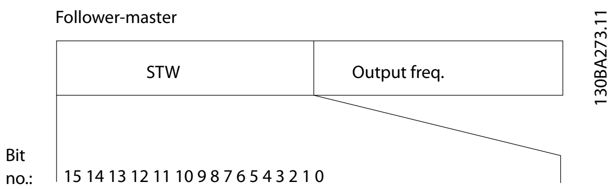

Figure 7.17 STW Slave to Master

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

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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. It could be the case when the speed ramps up/down during start/stop.
Bit 08='1': The motor speed matches the preset speed reference.

Bit 09, Local operation/bus control
Bit 09='0': [Stop/Reset] is activated on the control unit or *Local control* in *3-13 Reference Site* is selected. The adjustable frequency drive cannot be controlled via serial communication.
Bit 09='1' It is possible to control the adjustable frequency drive via the serial communication bus/serial communication.

Bit 10, Out of frequency limit
Bit 10='0': The output frequency has reached the value in *4-11 Motor Speed Low Limit [RPM]* or *4-13 Motor Speed High Limit [RPM]*.
Bit 10="1": The output frequency is within the defined limits.

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

Bit 12, Drive OK/stopped, autostart
Bit 12='0': There is no temporary overtemperature on the inverter.
Bit 12='1': The inverter stops because of overtemperature but the unit does not trip and resumes operation once the overtemperature stops.

Bit 13, Voltage OK/limit exceeded
Bit 13='0': There are no voltage warnings.
Bit 13='1': The DC voltage in the intermediate circuit is too low or too high.

Bit 14, Torque OK/limit exceeded
Bit 14='0': The motor current is lower than the torque limit selected in *4-18 Current Limit*.
Bit 14='1': The torque limit in *4-18 Current Limit* is exceeded.

Bit 15, Timer OK/limit exceeded
Bit 15='0': The timers for motor thermal protection and thermal protection are not exceeded 100%.
Bit 15='1': One of the timers exceeds 100%.

If the connection between the Interbus option and the adjustable frequency drive is lost, or an internal communication problem has occurred, all bits in the STW are set to '0.'

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

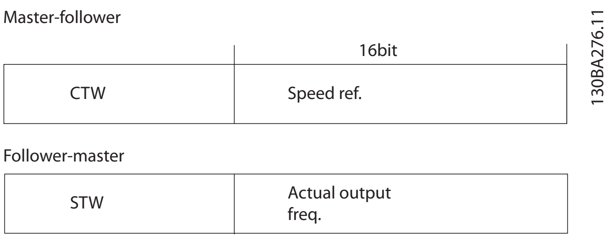

Figure 7.18 Bus Speed Reference Value

The reference and MAV are scaled as showed in *Figure 7.19*.

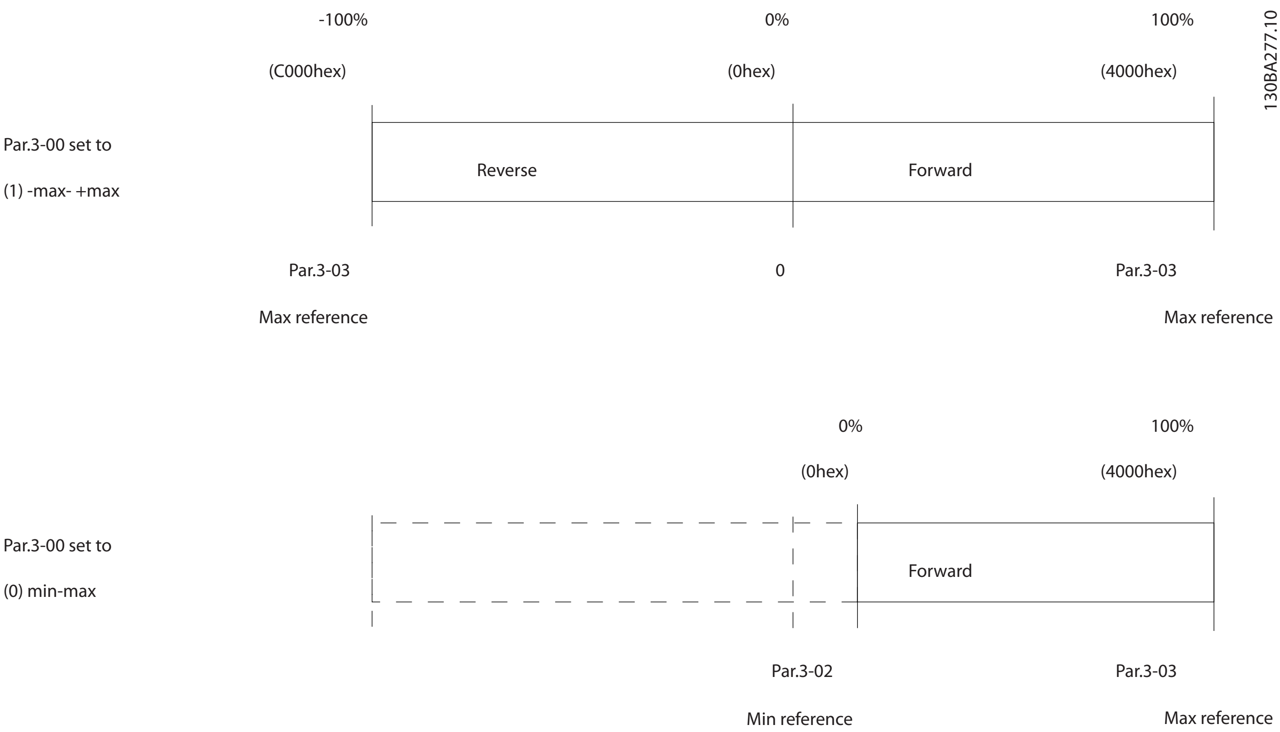

Figure 7.19 Reference and MAV

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8 Troubleshooting

8.1 Status Messages

A warning or an alarm is signaled by the relevant LED on the front of the adjustable frequency drive and indicated by a code on the display.

A warning remains active until its cause is no longer present. Under certain circumstances, operation of the motor can continue. Warning messages are sometimes critical, but are not always so.

In case of an alarm, the adjustable frequency drive has tripped. Alarms must be reset to restart operation once their cause has been rectified.

There are four ways to restart:

1. By pressing [Reset].
2. Via a digital input with the “Reset” function.
3. Via serial communication/optional serial communication bus.
4. By resetting automatically using the [Auto Reset] function, which is a default setting for VLT® AQUA Drive FC 202 Drive. See *14-20 Reset Mode* in *VLT® AQUA Drive FC 202 Programming Guide*

NOTICE!

After a manual reset pressing [Reset], [Auto On] or [Hand On] must be pressed to restart the motor.

If an alarm cannot be reset, the possible reason is that its cause has not been rectified, or the alarm is trip-locked (see also *Table 8.1*).

Alarms that are trip-locked offer more protection, meaning that the line power supply must be switched off before the alarm can be reset. After being switched back on, the adjustable frequency drive is no longer blocked and can be reset once the cause has been rectified.

Alarms that are not trip-locked can also be reset using the automatic reset function in *14-20 Reset Mode*

NOTICE!

Automatic wake-up is possible!

If a warning and alarm are marked against a code in *Table 8.1*, this means that either a warning occurs before an alarm, or it can be specified whether it is a warning or an alarm that is displayed for a given fault.

This is possible, for instance, in *1-90 Motor Thermal Protection*. After an alarm or trip, the motor carries on coasting, and the alarm and warning flash on the adjustable frequency drive. Once the problem has been rectified, only the alarm continues flashing.

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No.	Description	Warning	Alarm/ Trip	Alarm/ Trip Lock	Parameter Reference
1	10 Volts low	X			
2	Live zero error	(X)	(X)		6-01 Live Zero Timeout Function
3	No motor	(X)			1-80 Function at Stop
4	Mains phase loss	(X)	(X)	(X)	14-12 Function at Mains Imbalance
5	DC link voltage high	X			
6	DC link voltage low	X			
7	DC overvoltage	X	X		
8	DC undervoltage	X	X		
9	Inverter overloaded	X	X		
10	Motor ETR overtemperature	(X)	(X)		1-90 Motor Thermal Protection
11	Motor thermistor overtemp.	(X)	(X)		1-90 Motor Thermal Protection
12	Torque limit	X	X		
13	Overcurrent	X	X	X	
14	Ground fault	X	X	X	
15	Hardware mismatch		X	X	
16	Short Circuit		X	X	
17	Ctrl. word TO	(X)	(X)		8-04 Control Timeout Function
23	Internal Fan Fault	X			
24	External Fan Fault	X			14-53 Fan Monitor
25	Brake resistor short-circuited	X			
26	Brake resistor power limit	(X)	(X)		2-13 Brake Power Monitoring
27	Brake chopper short-circuited	X	X		
28	Brake check	(X)	(X)		2-15 Brake Check
29	Drive over temperature	X	X	X	
30	Motor phase U missing	(X)	(X)	(X)	4-58 Missing Motor Phase Function
31	Motor phase V missing	(X)	(X)	(X)	4-58 Missing Motor Phase Function
32	Motor phase W missing	(X)	(X)	(X)	4-58 Missing Motor Phase Function
33	Inrush fault		X	X	
34	Fieldbus communication fault	X	X		
35	Out of frequency range	X	X		
36	Mains failure	X	X		
37	Imb of sup volt	X	X		
39	Heatsink sensor		X	X	
40	Overload of Digital Output Term. 27	(X)			5-00 Digital I/O Mode, 5-01 Terminal 27 Mode
41	Overload of Digital Output Term. 29	(X)			5-00 Digital I/O Mode, 5-02 Terminal 29 Mode
42	Overload of Digital Output On X30/6	(X)			5-32 Term X30/6 Digi Out (MCB 101)
42	Overload of Digital Output On X30/7	(X)			5-33 Term X30/7 Digi Out (MCB 101)

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No.	Description	Warning	Alarm/ Trip	Alarm/ Trip Lock	Parameter Reference
46	Pwr. card sup		X	X	
47	24V supply low	X	X	X	
48	1.8V supply low		X	X	
49	Speed limit	X			
50	AMA calibration failed		X		
51	AMA check U_{nom} and I_{nom}		X		
52	AMA low I_{nom}		X		
53	AMA motor too big		X		
54	AMA motor too small		X		
55	AMA par. out of range		X		
56	AMA interrupted by user		X		
57	AMA timeout		X		
58	AMA internal fault	X	X		
59	Current limit	X			
60	Ext. interlock	X			
62	Output Frequency at Maximum Limit	X			
64	Voltage Limit	X			
65	Control Board Over temperature	X	X	X	
66	Heatsink Temperature Low	X			
67	Option Configuration has Changed		X		
68	Safe Stop Activated		X[1)]		
69	Pwr. Card Temp (E- and F-frames only)		X	X	
70	Illegal FC config			X	
71	PTC 1 Sf. Stop	X	X[1)]		
72	Dang. failure			X[1)]	
73	Sf stp aut rest				
76	Pwr Unit Set-up	X			
79	Illegal PS config		X	X	
80	Drive Initialized to Default Value		X		
91	Analog input 54 wrong settings			X	
92	No-Flow	X	X		*22-2* No-Flow Detection*
93	Dry Pump	X	X		*22-2* No-Flow Detection*
94	End of Curve	X	X		*22-5* End of Curve*
95	Broken Belt	X	X		*22-6* Broken Belt Detection*
96	Start Delayed	X			*22-7* Short Cycle Protection*
97	Stop Delayed	X			*22-7* Short Cycle Protection*
98	Clock Fault	X			*0-7* Clock Settings*
104	Mixing Fan Fault (D-frame only)	X	X		14-53 Fan Monitor
220	Overload Trip		X		
243	Brake IGBT	X	X		
244	Heatsink temp	X	X	X	
245	Heatsink sensor		X	X	
246	Pwr.card sup		X	X	
247	Pwr.card temp		X	X	

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No.	Description	Warning	Alarm/ Trip	Alarm/ Trip Lock	Parameter Reference
248	Illegal PS config		X	X	
250	New spare part			X	
251	New Type Code		X	X	

Table 8.1 Alarm/Warning Code List

(X) Dependent on parameter

1) Cannot be Auto reset via 14-20 Reset Mode

A trip is the action when an alarm has appeared. The trip coasts the motor and can be reset by pressing [Reset] or make a reset by a digital input in parameter group *5–1* Digital Inputs [1] Reset*). The original event that caused an alarm cannot damage the adjustable frequency drive or cause dangerous conditions. A trip lock is an action when an alarm occurs that can damage the adjustable frequency drive or connected parts. A trip lock situation can only be reset by power cycling.

Warning	yellow
Alarm	flashing red
Trip locked	yellow and red

Table 8.2 LED Indication

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Alarm Word and Extended Status Word					
Bit	Hex	Dec	Alarm Word	Warning Word	Extended Status Word
0	00000001	1	Brake Check	Brake Check	Ramping
1	00000002	2	Pwr. Card Temp	Pwr. Card Temp	AMA Running
2	00000004	4	Ground Fault	Ground Fault	Start CW/CCW
3	00000008	8	Ctrl. Card Temp	Ctrl. Card Temp	Slow-down
4	00000010	16	Ctrl. Word TO	Ctrl. Word TO	Catch Up
5	00000020	32	Overcurrent	Overcurrent	Feedback High
6	00000040	64	Torque Limit	Torque Limit	Feedback Low
7	00000080	128	Motor Th Over	Motor Th Over	Output Current High
8	00000100	256	Motor ETR Over	Motor ETR Over	Output Current Low
9	00000200	512	Inverter Overld.	Inverter Overld.	Output Freq High
10	00000400	1024	DC undervolt	DC undervolt	Output Freq Low
11	00000800	2048	DC overvolt	DC overvolt	Brake Check OK
12	00001000	4096	Short Circuit	DC Voltage Low	Braking Max
13	00002000	8192	Inrush Fault	DC Voltage High	Braking
14	00004000	16384	Mains ph. Loss	Mains ph. Loss	Out of Speed Range
15	00008000	32768	AMA Not OK	No Motor	OVC Active
16	00010000	65536	Live Zero Error	Live Zero Error	
17	00020000	131072	Internal Fault	10V low	
18	00040000	262144	Brake Overload	Brake Overload	
19	00080000	524288	U phase Loss	Brake Resistor	
20	00100000	1048576	V phase Loss	Brake IGBT	
21	00200000	2097152	W phase Loss	Speed Limit	
22	00400000	4194304	Fieldbus Fault	Fieldbus Fault	
23	00800000	8388608	24V Supply Low	24V Supply Low	
24	01000000	16777216	Mains Failure	Mains Failure	
25	02000000	33554432	1.8V supply low	Current Limit	
26	04000000	67108864	Brake Resistor	Low Temp	
27	08000000	134217728	Brake IGBT	Voltage Limit	
28	10000000	268435456	Option Change	Unused	
29	20000000	536870912	Drive initialized	Unused	
30	40000000	1073741824	Safe Stop	Unused	

Table 8.3 Description of Alarm Word, Warning Word, and Extended Status Word

The alarm words, warning words and extended status words can be read out via serial bus or optional serial communication bus for diagnosis. See also *16-90 Alarm Word*, *16-92 Warning Word* and *16-94 Ext. Status Word*.

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