Design Guide
VLT® HVAC Drive FC 102
110–1400 kW

www.danfoss.com/drives

VLT®
THE REAL DRIVE

Contents

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1 How to Read this Design Guide

1.1 How to Read this Design Guide

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VLT® HVAC Drive

CE c(UL)us C

This guide can be used with all
VLT® HVAC Drive adjustable
frequency drives with software
version 3.9x.
The full software version number
can be read from
15-43 Software Version.

</div>

Table 1.1 Software Version Information

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Danfoss reserves the right to revise this publication at any time and to change its contents without prior notice or any obligation to notify former or present users of such revisions or changes.

1.1.1 Available Literature

- The *VLT® HVAC Drive Instruction Manual* is shipped with the unit and includes information on installation and startup.

- The *VLT® HVAC Drive Design Guide* includes all technical information about the adjustable frequency drive, frames D, E, and F, and customer design and applications.

- The *VLT® HVAC Drive Programming Guide* provides information on how to program and includes complete parameter descriptions.

- Application Note, Temperature Derating Guide.

- PC-based configuration tool MCT 10, enables configuration of the adjustable frequency drive from a Windows™-based PC environment.

- Danfoss VLT® Energy Box software at *www.danfoss.com/BusinessAreas/DrivesSolutions/Softwaredownload/*

- Instruction Manual VLT® HVAC Drive BACnet.

- Instruction Manual VLT® HVAC Drive Metasys.

- Instruction Manual VLT® HVAC Drive FLN.

Danfoss technical literature is available in print from local Danfoss sales offices or online at: *www.danfoss.com/BusinessAreas/DrivesSolutions/Documentations/VLT+Technical+Documentation.htm*

1.1.2 Approvals
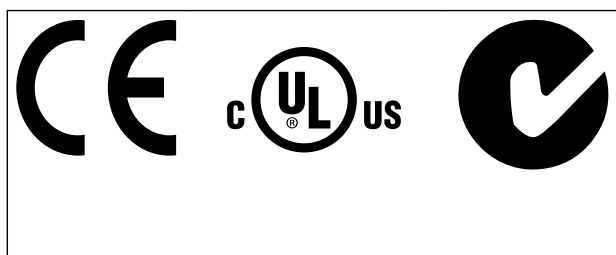
Table 1.2 Compliance Marks: CE, UL, and C-Tick

The adjustable frequency drive complies with UL508C thermal memory retention requirements. For more information, refer to *chapter 2.13.1 Motor Thermal Protection* .

The following symbols are used in this document.

⚠WARNING

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

⚠CAUTION

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

NOTICE!

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

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 1.3 Abbreviations used in this Manual

Drive:

IDRIVE,MAX
The maximum output current.

IDRIVE,N
The rated output current supplied by the adjustable
frequency drive.

UDRIVE, MAX
The maximum output voltage.

Input:

Control command	Group 1	Reset, coasting stop,
Start and stop the connected motor with the LCP or the digital inputs. Functions are divided into two groups. Functions in group 1 have higher priority than functions in group 2.		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 1.4 Input Functions

Motor:

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

fM
The motor frequency.

fMAX
The maximum motor frequency.

fMIN
The minimum motor frequency.

fM,N
The rated motor frequency (nameplate data).

IM
The motor current.

IM,N
The rated motor current (nameplate data).

nM,N
The rated motor speed (nameplate data).

PM,N
The rated motor power (nameplate data).

TM,N
The rated torque (motor).

UM
The instantaneous motor voltage.

UM,N
The rated motor voltage (nameplate data).

Break-away torque:

ns
Synchronous motor speed.

$$n_S = \frac{2 \times par. \ 1-23 \times 60 \ s}{par. \ 1-39}$$
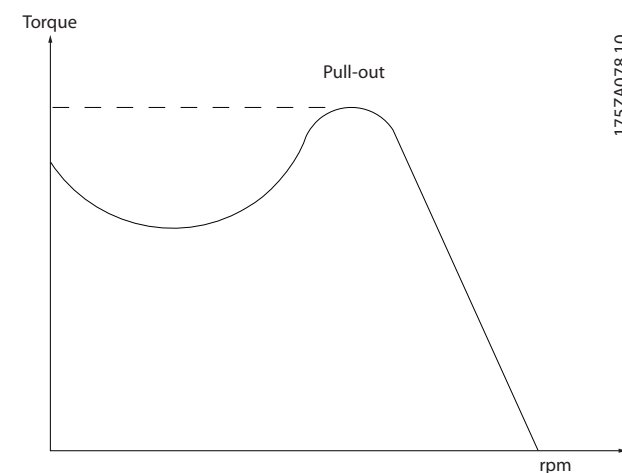
Figure 1.1 Break-Away Torque Chart

ηDRIVE
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.

Stop command
See control commands parameter group.

References:

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

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

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

Preset Reference
A defined preset reference set 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).

RefMAX
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 is set in *3-03 Maximum Reference*.

RefMIN
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 is 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 energy increases the intermediate circuit voltage and a brake chopper ensures that the power is transmitted to the brake resistor.

CT Characteristics
Constant torque characteristics used for screw and scroll refrigeration compressors.

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

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

DSP
Digital Signal Processor.

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 (LCP102)

Hiperface®
Hiperface® is a registered trademark by Stegmann.

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 LCP is detachable and can be installed up to 10 ft [3 m] from the adjustable frequency drive, in a front panel with the installation kit option. The LCP is available in two versions:

- Numerical LCP101 (NLCP)

- Graphical LCP102 (GLCP)

lsb

Least significant bit.

MCM

Short for mille circular mil, an American measuring unit for cable cross-section. 1 MCM ≡ 0.5067 mm^2.

msb

Most significant bit.

NLCP

Numerical local control panel LCP101.

Online/Offline Parameters

Changes to online parameters are activated immediately after the data value is changed. Changes to offline parameters are not activated until [OK] is entered on the LCP.

PID Controller

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

PCD

Process Data.

Pulse input/incremental encoder

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

RCD

Residual Current Device. A device that disconnects a circuit in case of an imbalance between an energized conductor and ground. Also known as a ground fault circuit interrupter (GFCI).

Set-up

Parameter settings can be saved 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 <u>S</u>tator <u>F</u>lux oriented <u>A</u>synchronous <u>V</u>ector <u>M</u>odulation (*14-00 Switching Pattern*).

Slip Compensation

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

Smart Logic Control (SLC)

The SLC is a sequence of user-defined actions executed when the associated user-defined events are evaluated as true by the SLC.

STW

Status word.

Thermistor:

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

THD

Total Harmonic Distortion. A state of full harmonic distortion.

Trip

A state entered in fault situations. For example, if the adjustable frequency drive is subject to an overtemperature or when it 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 requires physical intervention. For example, if the adjustable frequency drive is subject to a short circuit on the output, it will enter trip lock. A locked trip can only be canceled by cutting off line power, removing the cause of the fault, and reconnecting the adjustable frequency drive.

VT Characteristics

Variable torque characteristics used for pumps and fans.

VVC^{plus}

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

60° AVM

Switching pattern called 60°<u>A</u>synchronous <u>V</u>ector <u>M</u>odulation (See *14-00 Switching Pattern*).

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

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

The power factor for 3-phase control:

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

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

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

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 minimizes the imposed load on the line power supply.

2

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 units 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. 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. Do not use [Stop/Reset] as a safety switch. It does not disconnect the unit from line power.

3. In accordance with applicable national and local regulations:

    - Establish correct protective ground of the unit

    - Protect the operator against supply voltage

    - Protect the motor against overload

4. Ensure that 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 are present. 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 stopped while connected to line power in the following ways:

    - digital commands

    - bus commands

    - references

    - local stop

    Unintended start can still occur.

2. While parameters are being changed, the motor could start. Always activate [Stop/Reset] before modifying data.

3. A stopped motor can restart if the following conditions occur:

    - A fault in the electronics of the adjustable frequency drive

    - A temporary overload

    - A fault in the supply line power

    - A disruption in the motor connection

Refer to the instruction manual for further safety guidelines.

⚠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, take the following precautions:

- **Disconnect AC line power**

- **Disconnect any permanent magnet motors**

- **Disconnect any remote DC link power supplies, including battery backups, UPS, and DC link connections to other units**

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. See *Table 2.1* for discharge times.

Rating (hp [kW])	380–480 V	525–690 V
150–450 [110–315]	20 minutes	
60–550 [45–400]		20 minutes
450–1350 [315–1000]	40 minutes	
600–1600 [450–1200]		30 minutes

Table 2.1 DC Capacitor Discharge Times

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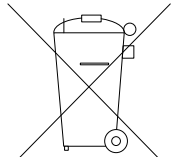
	Do not dispose of equipment containing electrical components together with domestic waste. Collect it separately in accordance with local and currently valid legislation.

Table 2.2 Disposal Instructions

2.2 CE Labeling

2.2.1 CE Conformity and Labeling

What is CE conformity and labeling?
The purpose of CE labeling is to avoid technical trade obstacles within the EFTA and the EU. The EU has introduced the CE label as a simple way of showing whether a product complies with the relevant EU directives. The CE label says nothing about the specifications or quality of the product. Adjustable frequency drives follow three EU directives:

The machinery directive (2006/42/EC)
Adjustable frequency drives with 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.

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 *chapter 5.7 EMC-compatible Installation*. In addition, we specify which standards our products comply with. We offer the filters presented in the specifications and provide other types of assistance to ensure the optimum EMC result.

Trade professionals use the adjustable frequency drive 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.

2

2.2.2 What Is Covered

The EU "*Guidelines on the Application of Council Directive 2004/108/EC*" outline three typical situations for using an adjustable frequency drive. See *chapter 2.2.3 Danfoss Adjustable frequency drive and CE Labeling* and *chapter 2.2.4 Compliance with EMC Directive 2004/108/EC* for CE labeling and EMC coverage.

1.   The adjustable frequency drive is sold directly to the end-consumer. The adjustable frequency drive is, for example, sold to a DIY market. The end-consumer is a layman who uses the adjustable frequency drive with a hobby machine, or 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, such as a production plant or a heating/ventilation plant designed and installed by trade professionals. 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. Use 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, such as an air-conditioning system. The system is marketed as complete. 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. The entire system need not be tested when only CE-labeled components are used.

2.2.3 Danfoss Adjustable frequency drive and CE Labeling

CE labeling is a positive feature when used for its original purpose: To facilitate trade within the EU and EFTA.

However, CE labeling could cover many different specifications, so check the specifics of each CE label.

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

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

For more on EMC, refer to *chapter 5.7 EMC-compatible Installation*.

Danfoss provides other types of assistance to obtain the best EMC result.

2.2.4 Compliance with EMC Directive 2004/108/EC

Trade professionals use the adjustable frequency drive 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. Following EMC-compatible installation instructions ensures compliance with standards and test levels stated for power drive systems. See *chapter 2.9 General aspects of EMC*.

2.3 Air Humidity

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

2.4 Aggressive Environments

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

⚠CAUTION

Do not install the adjustable frequency drive 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
Install the safe torque off function only in an enclosure with an IP54 or higher rating (or equivalent environment). Doing so will avoid cross faults and short circuits between terminals, connectors, tracks, and safety-related circuitry caused by foreign objects.

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

Airborne particles such as dust 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 IP 54/55 (NEMA 12) or an enclosure for IP 00/IP 20 (NEMA 1) equipment.

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

Such chemical reactions rapidly damage the electronic components. In such environments, mount the unit in an enclosure with fresh air ventilation, keeping aggressive gases away from the adjustable frequency drive. Optional coating of printed circuit boards provides extra protection in such areas.

NOTICE!

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

Before installing the adjustable frequency drive, observe existing installations in the environment to check the ambient air for liquids, particles, and gases. Typical indicators of harmful airborne liquids are water, oil, or corrosion on metal parts.

Excessive dust particle levels are often found on installation enclosures 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 drive. Contact Danfoss for more information.

2.5 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 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

2.6 Safe Torque Off

2.6.1 Electrical Terminals

The adjustable frequency drive can perform the safety function *Safe Torque Off* (As defined by draft CD 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. Before integration and use of safe torque off in an installation, perform a thorough risk analysis on the installation to determine whether the safe torque off functionality and safety category are sufficient.

Typical reaction time for terminal 37 is <10 ms.

2

2.6.2 Safe Torque Off Installation

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

1. Remove the bridge (jumper) between terminal 37 and 24 V DC. Cutting or breaking the jumper is not sufficient. Remove it entirely to avoid short-circuiting. See jumper in *Figure 2.1*.

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 an non-shielded cable instead of a shielded one.
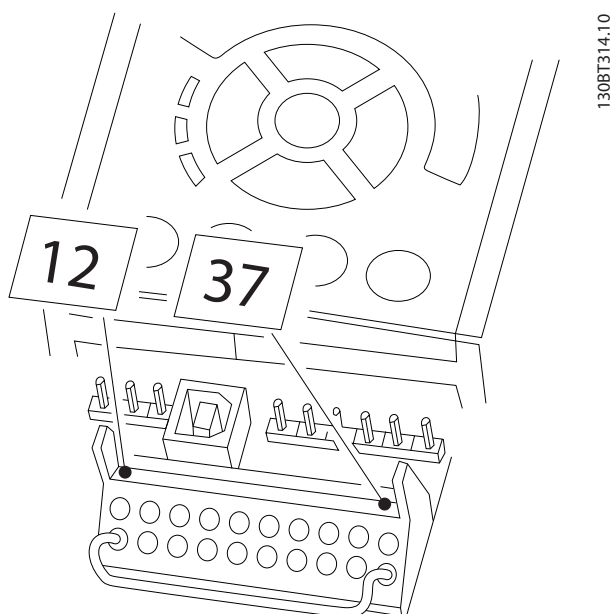
Figure 2.1 Bridge Jumper Between Terminal 37 and 24 V DC

2

Figure 2.2 shows a stopping category 0 (EN 60204-1) with safety Category 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.
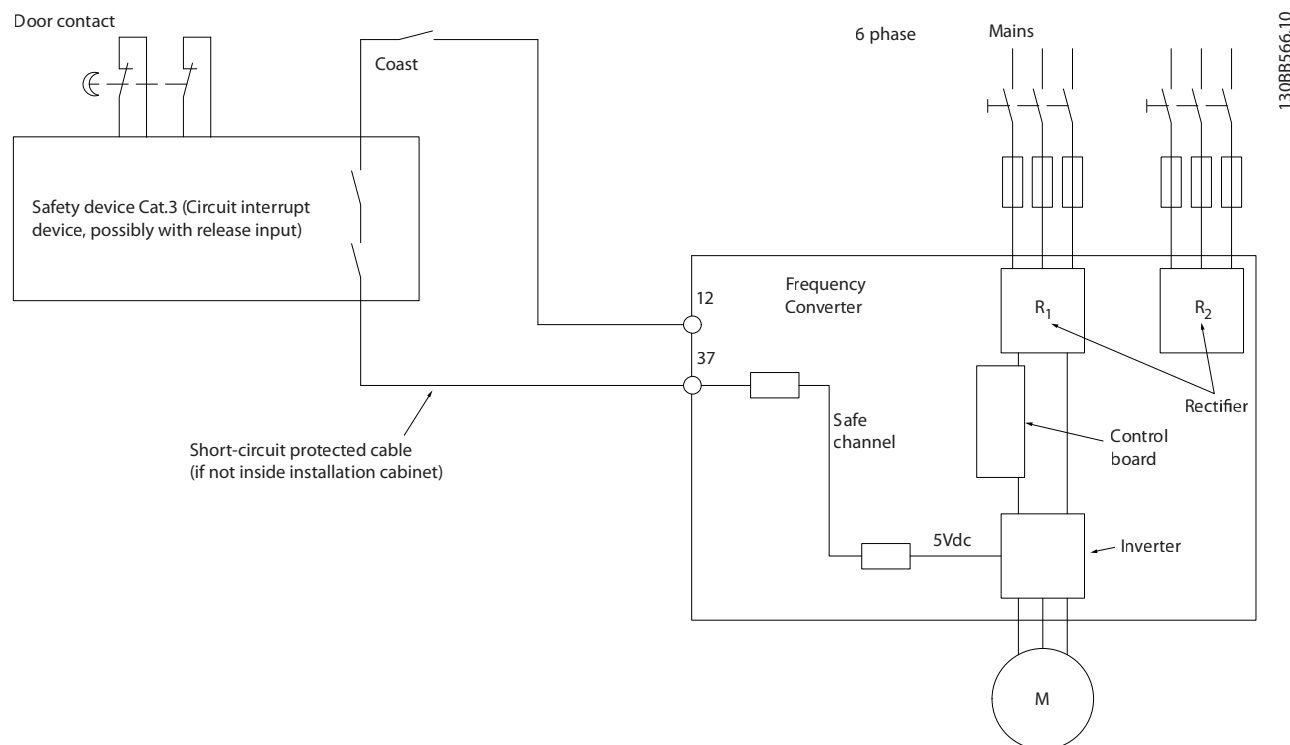
Figure 2.2 Installation with Stopping Category 0 and Safety Category 3

⚠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 grounded leg, AC line voltage can exceed 440 V between phase and ground.

2.6.3 Approvals & Certificates

The latest certificates and approvals are available on the Internet, see
www.danfoss.com/BusinessAreas/DrivesSolutions/Documentations

2.7 Advantages

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 applications. For further information, see *chapter 2.7.3 Example of Energy Savings*.

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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.
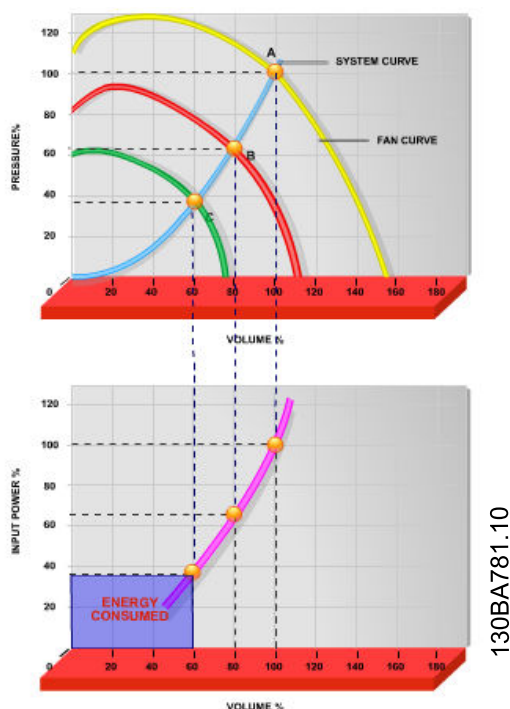
130BA781.10

Figure 2.3 Energy Saved with Reduced Fan Capacity
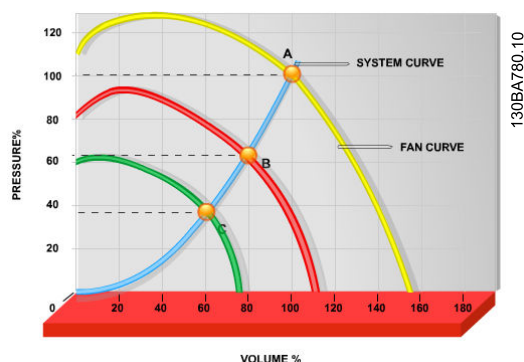
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Figure 2.4 Fan Curves for Reduced Fan Volumes.

2.7.3 Example of Energy Savings

As seen in *Figure 2.5*, the flow is controlled by changing the RPM. Reducing the speed only 20% from the rated speed also reduces the flow by 20%. The flow is directly proportional to the RPM. The consumption of electricity, however, is reduced by 50%.

If the system only runs at 100% flow a few days per year, while the average is below 80% of the rated flow, the amount of energy saved is even more than 50%.

Figure 2.5 describes the dependence of flow, pressure, and power consumption on RPM.	
Q = Flow	P = Power
Q_1 = Rated flow	P_1 = Rated power
Q_2 = Reduced flow	P_2 = Reduced power
H = Pressure	n = speed control
H_1 = Rated pressure	n_1 = Rated speed
H_2 = Reduced pressure	n_2 = Reduced speed

Table 2.3 Laws of Proportionality

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

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

Power: $\dfrac{P1}{P2} = \left(\dfrac{n1}{n2}\right)^3$
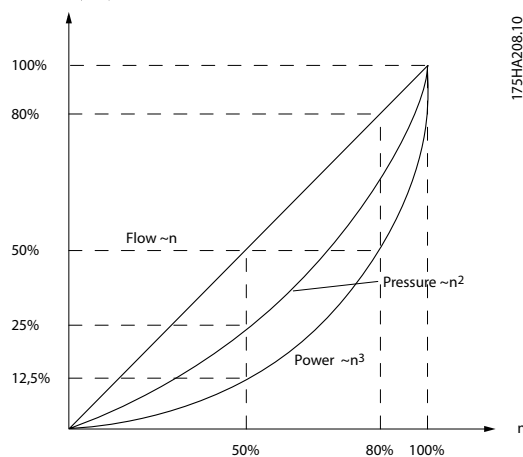
175HA208.10

Figure 2.5 Laws of Proportionality

Danfoss

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2.7.4 Comparison of Energy Savings

The Danfoss adjustable frequency drive solution offers major savings compared with traditional energy saving solutions. The adjustable frequency drive is able to control fan speed according to thermal load on the system and it has the ability to function as a Building Management System (BMS).

The graph (*Figure 2.6*) shows typical energy savings obtainable with three well-known solutions when fan volume is reduced to 60%.
As the graph shows, more than 50% energy savings can be achieved in typical applications.
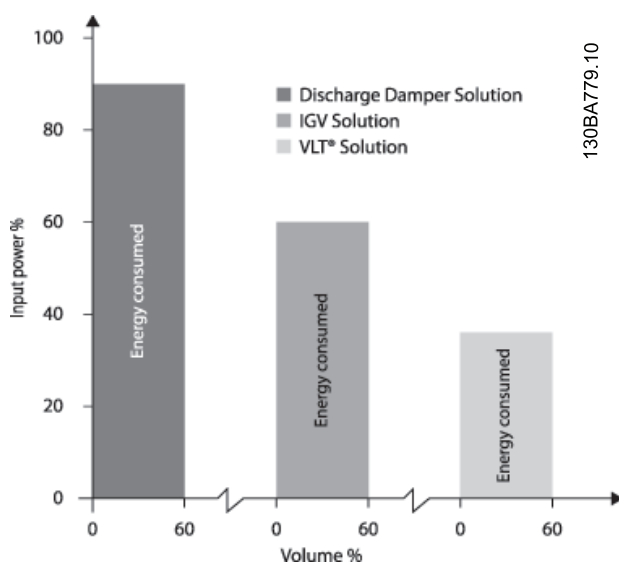
Figure 2.6 Three Common Energy Saving Systems

Discharge dampers reduce power consumption. Inlet guide vanes offer a 40% reduction but are expensive to install. The Danfoss adjustable frequency drive solution reduces energy consumption by more than 50% and is easy to install.

2.7.5 Example with Varying Flow over 1 Year

Table 2.4 is 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 adjustable frequency drive. In this example, it is less than a year when compared with valves and constant speed.
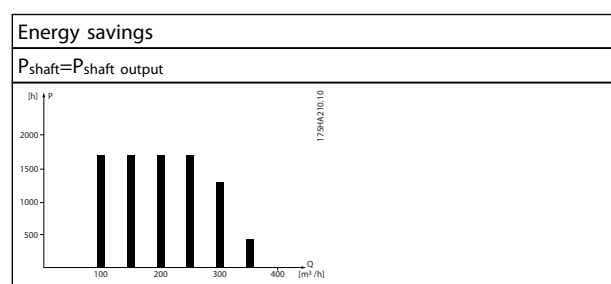
Table 2.4 Flow Distribution Over One Year

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m³/h	Distribution		Valve regulation		Control	
	%	Hours	Power	Consumption	Power	Consumption
			$A_1 - B_1$	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
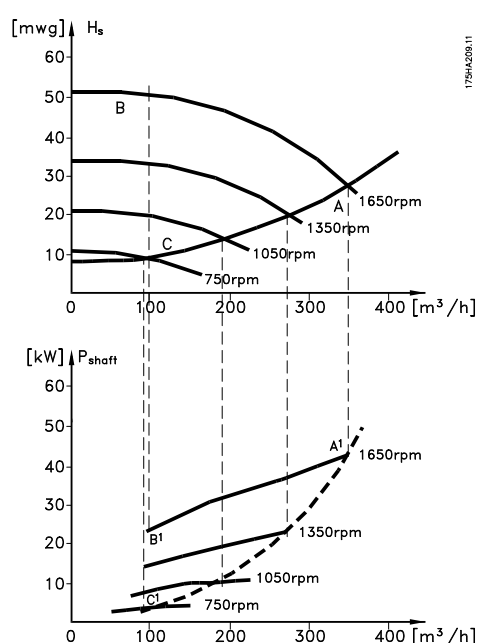
Figure 2.7 Energy Savings in a Pump Application

2.7.6 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

2.7.7 Cos φ Compensation

Typically, the VLT® HVAC Drive has a cos φ of 1 and provides power factor correction for the cos φ of the motor, which means there is no need to make allowance for the cos φ of the motor when sizing the power factor correction unit.

2.7.8 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 illustrated in *Figure 2.8*, an adjustable frequency drive does not consume more than rated current.
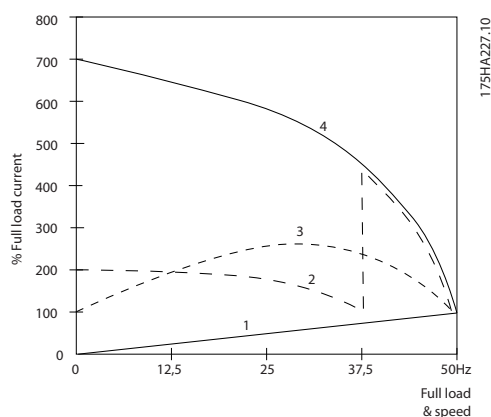
Figure 2.8 Current Consumption with an Adjustable Frequency Drive

1 = VLT® HVAC Drive
2 = Star/delta starter
3 = Soft-starter
4 = Start directly on line power

Table 2.6 Legend to *Figure 2.8*

2.7.9 Using an Adjustable Frequency Drive Saves Money

The adjustable frequency drive eliminates the need for some equipment that would normally be used. It is possible to calculate the cost of installing the two different systems. The two systems shown in *Figure 2.9* and *Figure 2.10* can be established at roughly the same price.

2

2.7.10 Without an Adjustable Frequency Drive
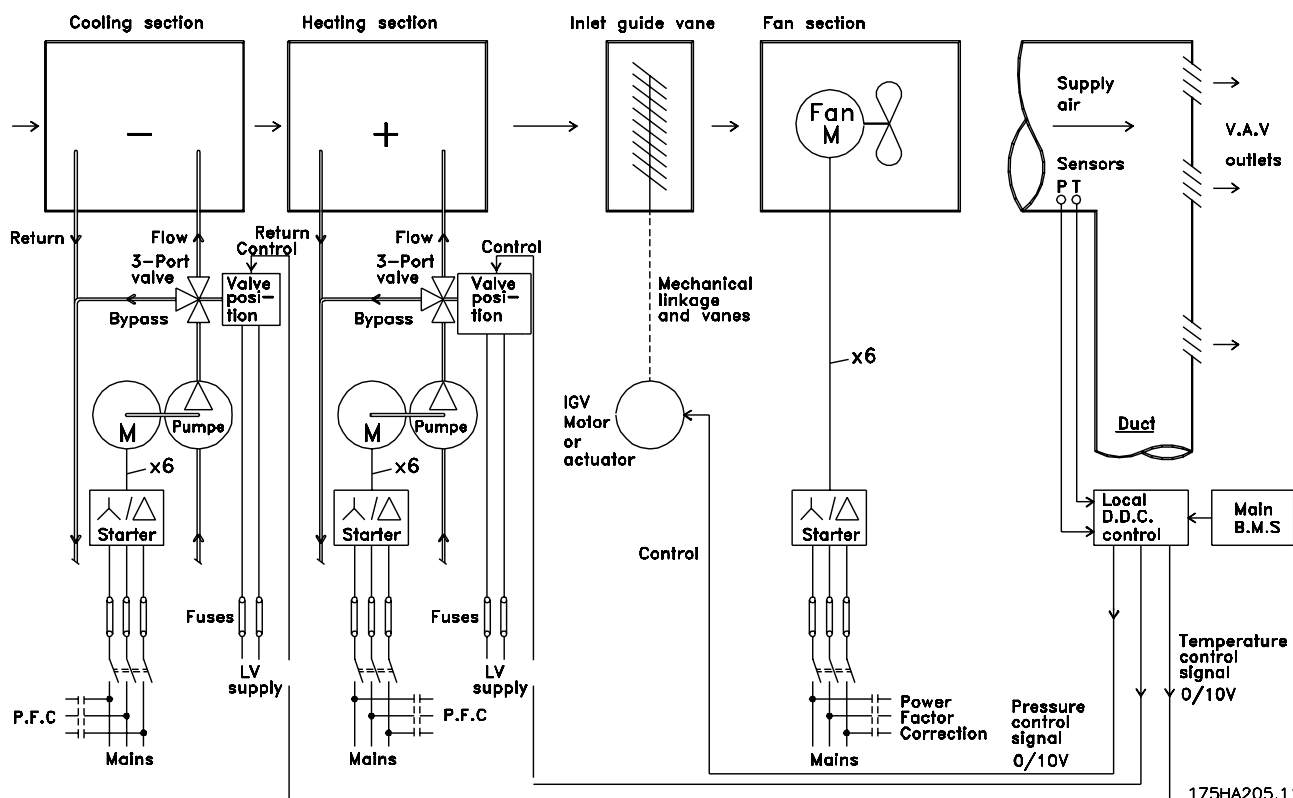
Figure 2.9 Traditional Fan System

DDC	Direct Digital Control
VAV	Variable Air Volume
Sensor P	Pressure
EMS	Energy Management System
Sensor T	Temperature

Table 2.7 Legend to *Figure 2.9*

2

2.7.11 With an Adjustable Frequency Drive

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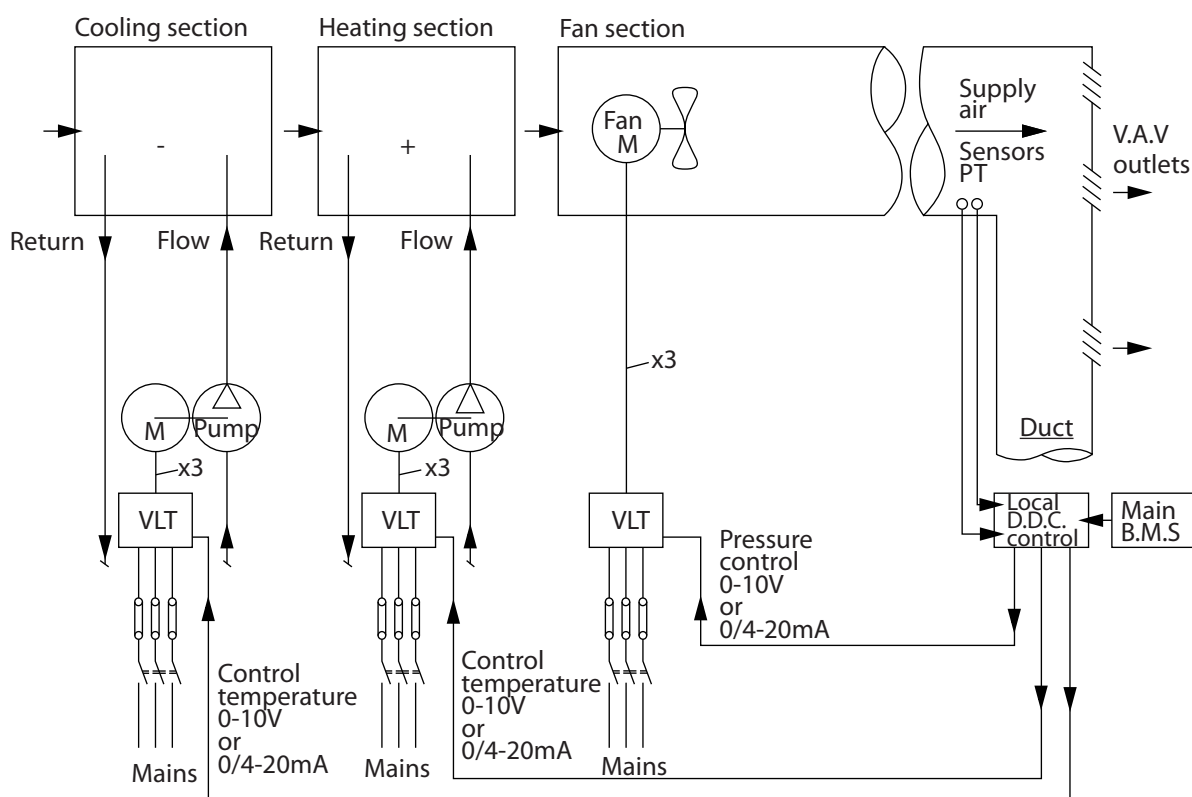
Figure 2.10 Fan System Controlled by Adjustable Frequency Drives

2.7.12 Application Examples

The next few pages give typical examples of applications within HVAC.
For further information about a given application, consult the Danfoss supplier for an application note that gives a full description of the application.

- Variable Air Volume: Improving VAV Ventilation Systems

- Constant Air Volume: Improving CAV Ventilation Systems

- Cooling Tower Fan: Improving Fan Control on Cooling Towers

- Condenser Pumps: Improving Condenser Water Pumping Systems

- Primary Pumps: Improving Primary Pumping in Pri/Sec System

- Secondary Pumps: Improving Secondary Pumping in Pri/Sec System

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2.7.13 Variable Air Volume

VAV or variable air volume systems, are used to control both the ventilation and temperature to satisfy the requirements of a building. Central VAV systems are considered to be the most energy efficient method to air condition buildings. Central systems are more efficient than distributed systems.

The efficiency comes from using larger fans and chillers, which have higher efficiencies than small motors and distributed air-cooled chillers. Savings are also realized from the decreased maintenance requirements.

2.7.14 The VLT Solution

While dampers and IGVs work to maintain a constant pressure in the ductwork, an adjustable frequency drive solution saves more energy and reduces the complexity of the installation. Instead of creating an artificial pressure drop or a decrease in fan efficiency, the adjustable frequency drive decreases the speed of the fan to provide the flow and pressure required by the system.

Centrifugal devices such as fans decrease the pressure and flow they produce as their speed is reduced. Their power consumption is reduced.

The return fan is frequently controlled to maintain a fixed difference in airflow between the supply and return. The advanced PID controller of the HVAC adjustable frequency drive can be used to eliminate the need for more controllers.
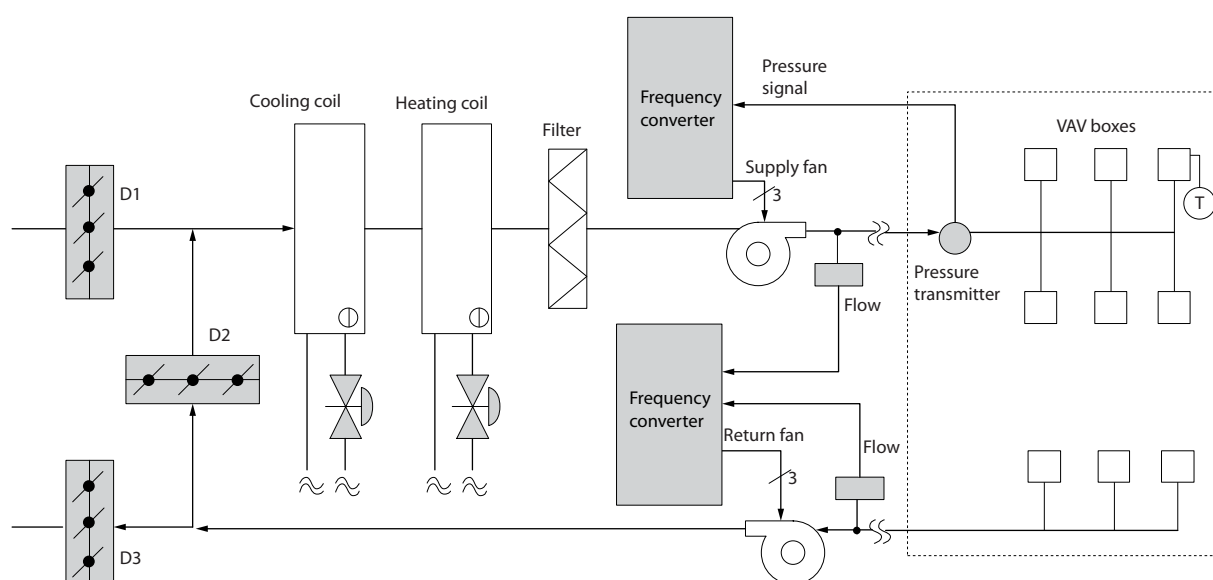
Figure 2.11 Adjustable Frequency Drives Used in a VAV System

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2

2.7.15 Constant Air Volume

CAV or constant air volume systems are central ventilation systems used to supply large common zones with the minimum amounts of fresh tempered air. They preceded VAV systems and are found in older multi-zoned commercial buildings as well. These systems preheat fresh air with air handling units (AHUs) that have heating coils. Many are also used for air conditioning buildings and have a cooling coil. Fan coil units are often used to help with the heating and cooling requirements in the individual zones.

2.7.16 The VLT Solution

With an adjustable frequency drive, significant energy savings can be obtained while maintaining decent control of the building. Temperature sensors or CO_2 sensors can be used as feedback signals to adjustable frequency drives. Whether controlling temperature, air quality, or both, a CAV system can be controlled to operate based on actual building conditions. As the number of people in the controlled area decreases, the need for fresh air decreases. The CO_2 sensor detects lower levels and decreases the supply fan speed. The return fan modulates to maintain a static pressure setpoint or fixed difference between the supply and return air flows.

Temperature control needs vary based on outside temperature and number of people in the controlled zone. As the temperature decreases below the setpoint, the supply fan can decrease its speed. The return fan modulates to maintain a static pressure setpoint. Decreasing the air flow, reduces the energy used to heat or cool the fresh air, resulting in further savings.

Several features of the Danfoss dedicated adjustable frequency drive can be used to improve the performance of a CAV system. One concern of controlling a ventilation system is poor air quality. The programmable minimum frequency can be set to maintain a minimum amount of supply air, regardless of the feedback or reference signal. The adjustable frequency drive also includes a 3-zone, 3-setpoint PID controller which allows monitoring both temperature and air quality. Even if the temperature requirement is satisfied, the adjustable frequency drive maintains enough supply air to satisfy the air quality sensor. The controller can monitor and compare two feedback signals to control the return fan by maintaining a fixed differential air flow between the supply and return ducts.
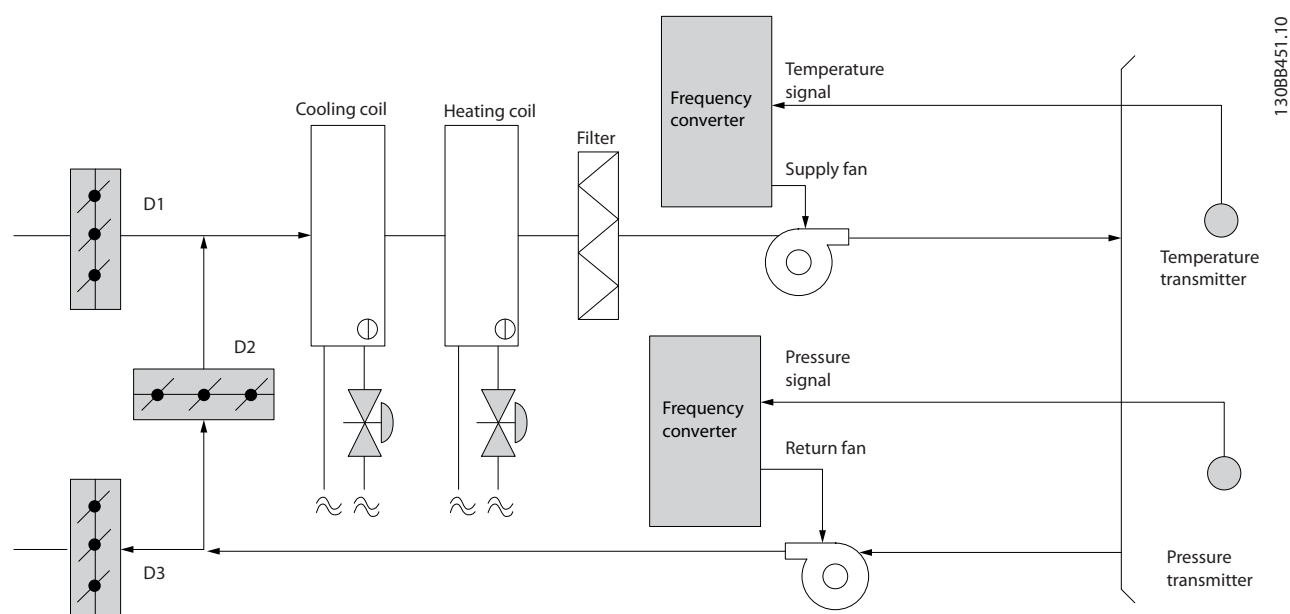
Figure 2.12 Adjustable Frequency Drive used in a CAV System

2

2.7.17 Cooling Tower Fan

Cooling tower fans are used to cool condenser water in water-cooled chiller systems. Water-cooled chillers provide the most efficient means of creating chilled water. They are as much as 20% more efficient than air-cooled chillers. Depending on climate, cooling towers are often the most energy efficient method of cooling the condenser water from chillers.
Cooling towers cool the condenser water by evaporation.
The condenser water is sprayed into the cooling tower onto the fill to increase its surface area. The tower fan blows air through the fill and sprayed water to aid in the evaporation. Evaporation removes energy from the water, thus dropping its temperature. The cooled water collects in the basin of the cooling tower where it is pumped back into the chiller condenser and the cycle is repeated.

2.7.18 The VLT Solution

With an adjustable frequency drive, the cooling towers fans can be set to the speed required to maintain the condenser water temperature. The adjustable frequency drives can also be used to turn the fan on and off as needed.

With the Danfoss HVAC adjustable frequency drive, as the cooling tower fans drop below a certain speed, the cooling effect decreases. When using a gear box to frequency control the tower fan, a minimum speed of 40–50% could be required. The customer programmable minimum frequency setting is available to maintain this minimum frequency even as the feedback or speed reference calls for lower speeds.

The adjustable frequency drive can be programmed to enter a "sleep" mode and stop the fan until a higher speed is required. Additionally, some cooling tower fans have undesirable frequencies that can cause vibrations. These frequencies can easily be avoided by programming the bypass frequency ranges in the adjustable frequency drive.

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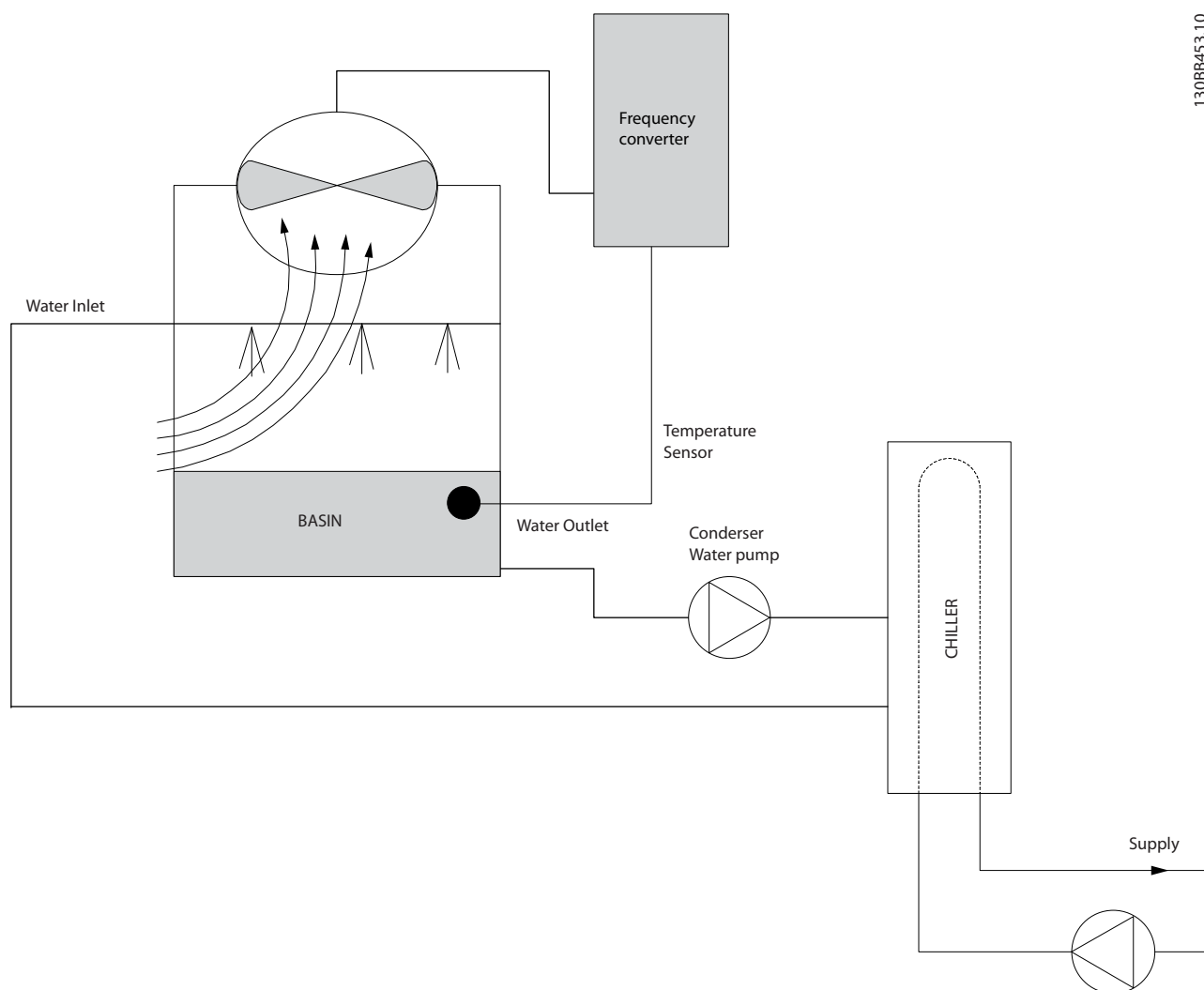
Figure 2.13 Adjustable Frequency Drives Used with a Cooling Tower Fan

2

2.7.19 Condenser Pumps

Condenser water pumps are primarily used to circulate water through the condenser section of water-cooled chillers and their associated cooling tower. The condenser water absorbs the heat from the condenser section and releases it into the atmosphere in the cooling tower. These systems provide the most efficient means of creating chilled water. They are as much as 20% more efficient than air-cooled chillers.

2.7.20 The VLT Solution

Adjustable frequency drives can be added to condenser water pumps instead of balancing the pumps with a throttling valve or trimming the pump impeller.

Using an adjustable frequency drive instead of a throttling valve saves the energy that the valve would otherwise have absorbed. This change can amount to savings of 15–20% or more. Trimming the pump impeller is irreversible, so if the conditions change and higher flow is required the impeller must be replaced.
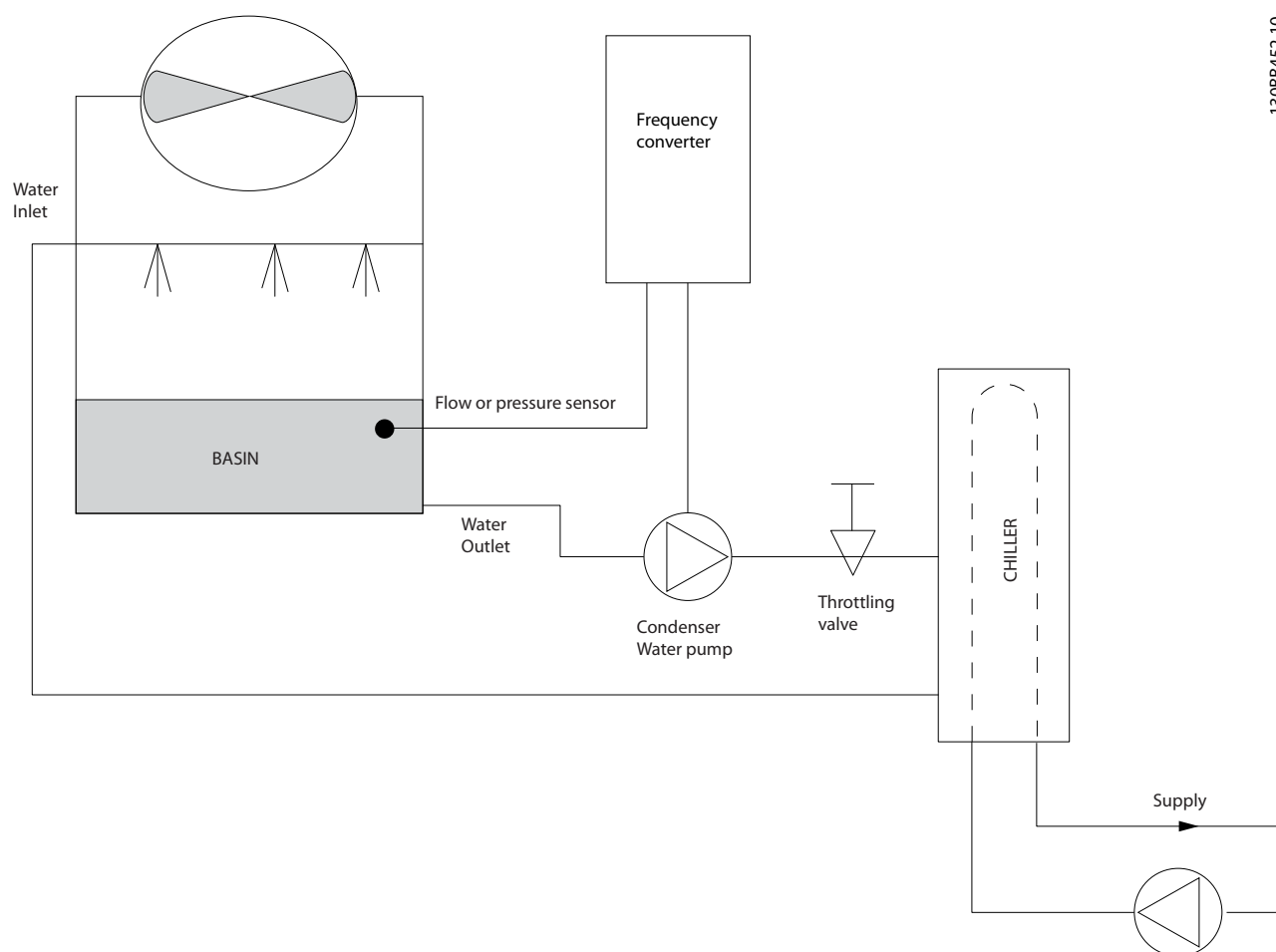
Figure 2.14 Adjustable Frequency Drive used with a Condenser Pump

2

2.7.21 Primary Pumps

Primary pumps in a primary/secondary pumping system can maintain a constant flow through devices that encounter operation or control difficulties when exposed to variable flow. The primary/secondary pumping technique decouples the "primary" production loop from the "secondary" distribution loop. Decoupling allows devices such as chillers to obtain constant design flow and operate properly while allowing the rest of the system to vary in flow.

As the evaporator flow rate decreases in a chiller, the chilled water begins to become overly chilled. As this happens, the chiller attempts to decrease its cooling capacity. If the flow rate drops far enough, or too quickly, the chiller cannot shed its load sufficiently and the low evaporator temperature safety trips the chiller, requiring a manual reset. This situation is common in large installations, especially when two or more chillers in parallel are installed if primary/secondary pumping is not used.

2.7.22 The VLT Solution

Depending on the size of the system and the size of the primary loop, the energy consumption of the primary loop can become substantial.

An adjustable frequency drive can be added to the primary system to replace the throttling valve and/or trimming of the impellers, leading to reduced operating expenses. Two control methods are common:

The first method uses a flow meter. Because the desired flow rate is known and constant, a flow meter installed at the discharge of each chiller can control the pump directly. Using the PID controller, the adjustable frequency drive always maintains the appropriate flow rate, even compensating for the changing resistance in the primary piping loop as chillers and their pumps are staged on and off.

The other method is local speed determination. The operator simply decreases the output frequency until the design flow rate is achieved.
Using an adjustable frequency drive to decrease the pump speed is similar to trimming the pump impeller, but more efficient. The balancing contractor simply decreases the speed of the pump until the proper flow rate is achieved and leaves the speed fixed. The pump operates at this speed any time the chiller is staged on. Because the primary loop lacks control valves or other devices that can change the system curve and the variance due to staging pumps and chillers on and off is small, this fixed speed remains appropriate. If the flow rate must be increased later in the life of the system, the adjustable frequency drive can simply increase the pump speed instead of requiring a new pump impeller.

2
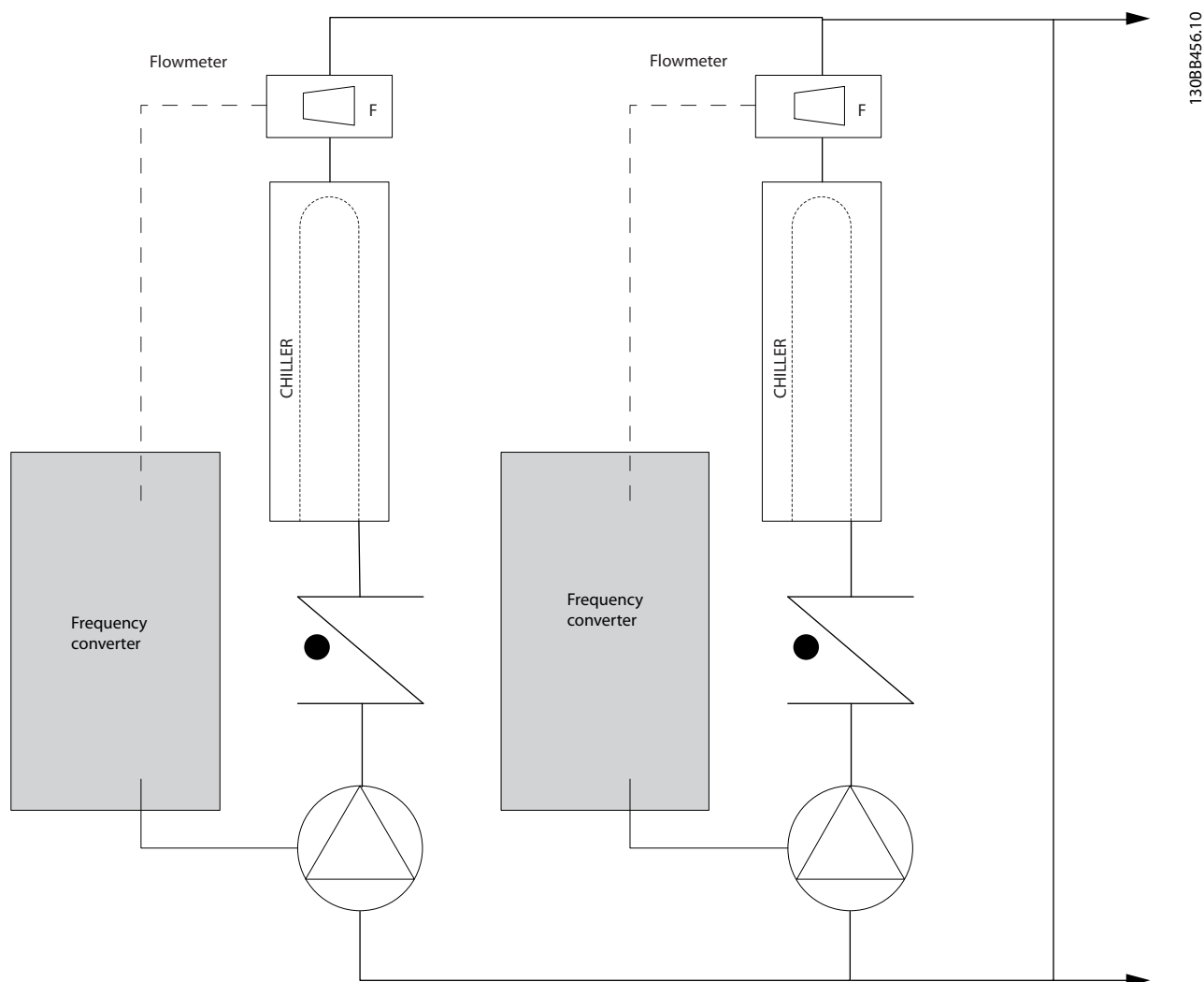
Figure 2.15 Adjustable Frequency Drives used with Primary Pumps in a Primary/Secondary Pump System

2

2.7.23 Secondary Pumps

Secondary pumps in a primary/secondary chilled water pumping system are used to distribute the chilled water to the loads from the primary production loop. The primary/secondary pumping system is used to decouple one piping loop from another hydronically. In this case, the primary pump maintains a constant flow through the chillers, allowing the secondary pumps to vary flow, increase control and save energy.

If the primary/secondary design concept is not used and a variable volume system is designed, the chiller cannot shed its load properly when the flow rate drops far enough or too quickly. The low evaporator temperature safety then trips the chiller, requiring a manual reset. This situation is common in large installations, especially when two or more chillers are installed in parallel.

2.7.24 The VLT Solution

While the primary/secondary system with 2-way valves improves energy and system control, using adjustable frequency drives increases the energy savings and control potential further.

With the proper sensor location, the addition of adjustable frequency drives allows the pumps to match their speed to the system curve instead of the pump curve.

This eliminates wasted energy and most of the over-pressurization, two-way valves can be subjected to.

As the monitored loads are reached, the two-way valves close down, increasing the differential pressure measured across the load and two-way valve. As this differential pressure starts to rise, the pump is slowed to maintain the control head also called setpoint value. This setpoint value is calculated by adding the pressure drop of the load and the two-way valve under design conditions.

NOTICE!

When running multiple pumps in parallel, they must run at the same speed to increase energy savings, either with individual dedicated adjustable frequency drives, or one adjustable frequency drive running multiple pumps in parallel.
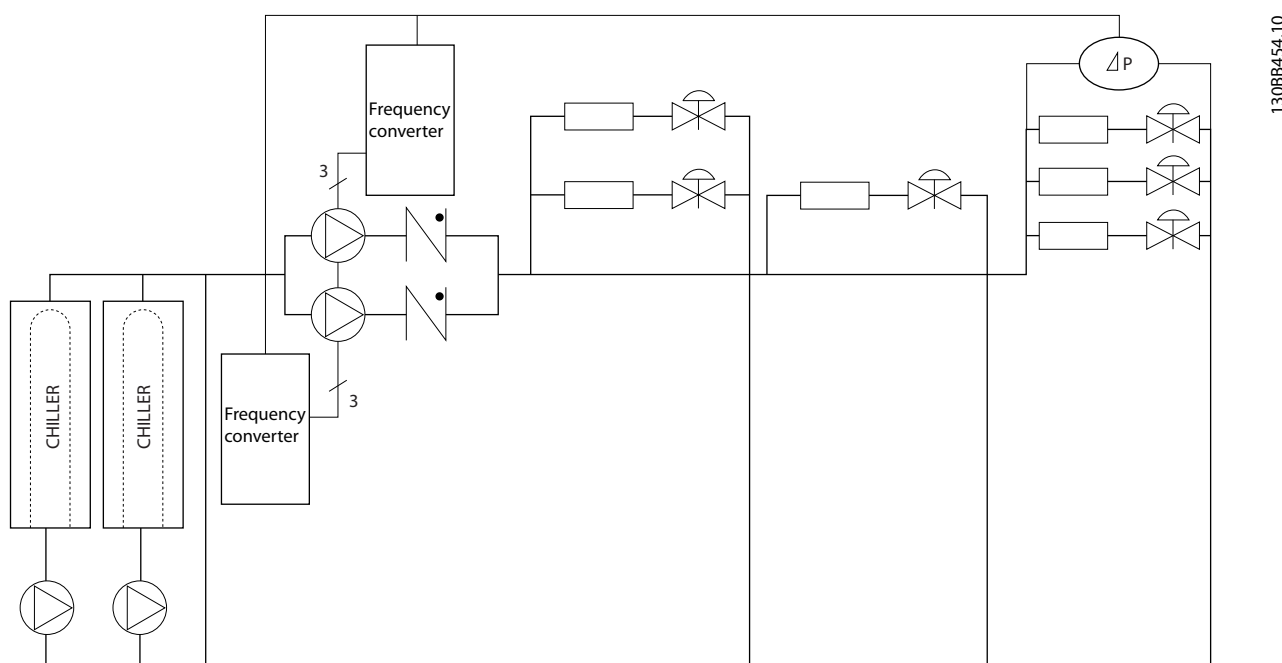
Figure 2.16 Adjustable Frequency Drives used with Secondary Pumps in a Primary/Secondary Pump System

2

2.8 Control Structures

2.8.1 Control Principle
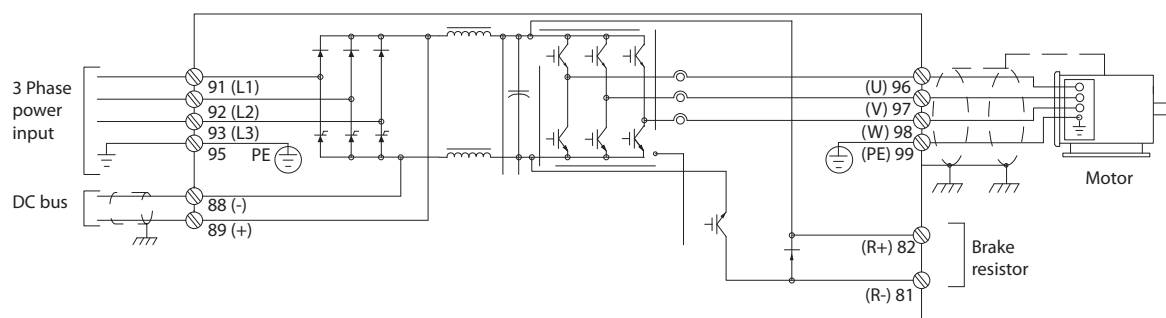
Figure 2.17 Control Structure, 6-pulse
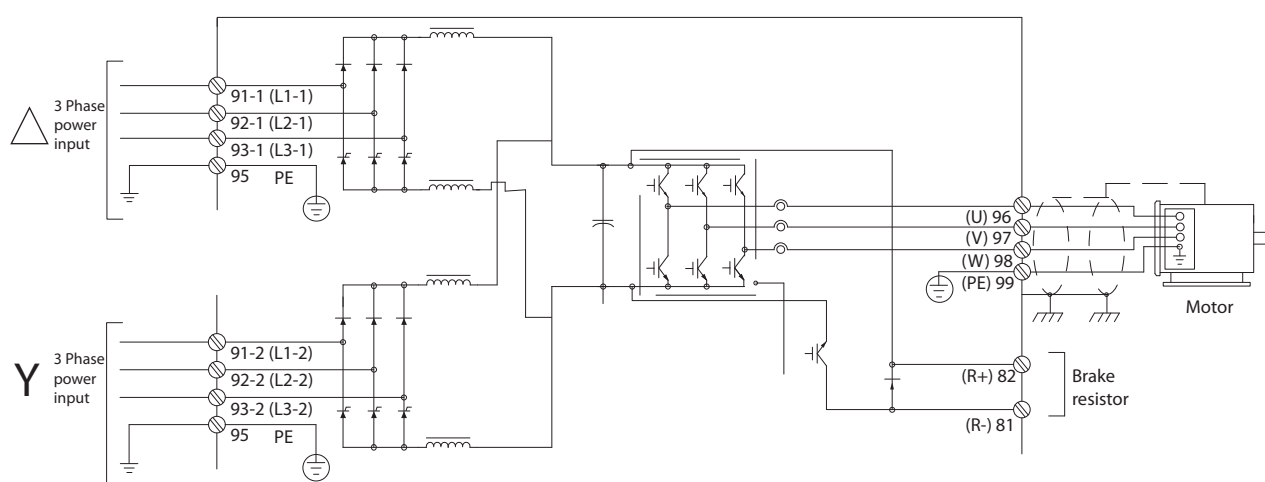
Figure 2.18 Control Structure, 12-pulse

The adjustable frequency drive is a high-performance unit for demanding applications. It can handle various motor control principles including:

- U/f special motor mode

- VVC^{plus}

- Squirrel cage asynchronous motors

Short circuit behavior on this adjustable frequency drive depends on the three current transducers in the motor phases.

In *1-00 Configuration Mode*, it can be selected if using open or closed-loop.

2.8.2 Control Structure Open-loop
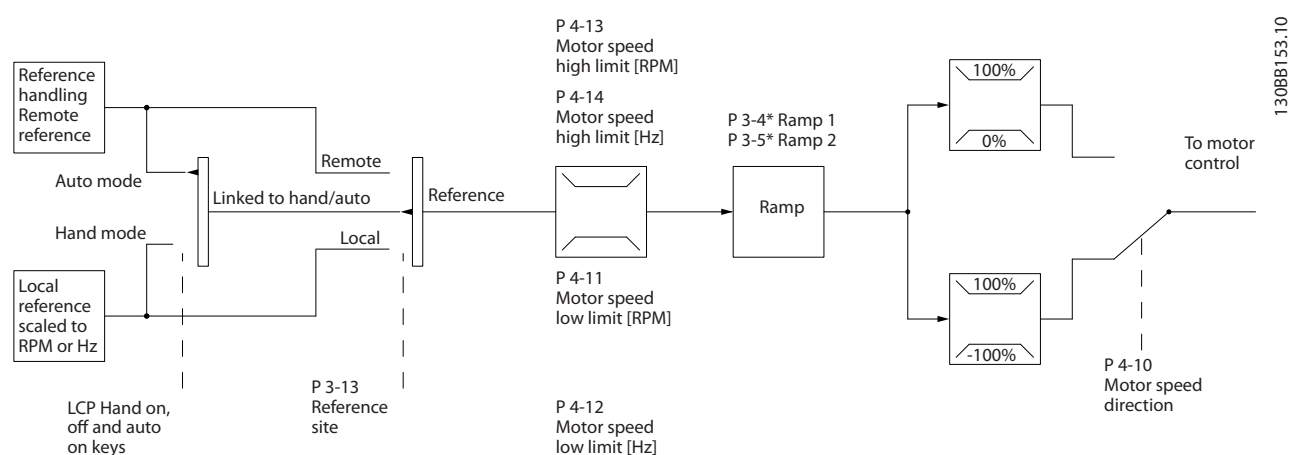
Figure 2.19 Open-loop Structure

In the configuration shown in *Figure 2.19, 1-00 Configuration Mode* is set to *[0] open-loop*. The resulting reference comes from the reference handling system or the local reference and is fed through the ramp and speed limitations before proceeding to the motor control.
The maximum frequency limit curbs output from the motor control.

2

2.8.3 PM/EC+ Motor Control

The Danfoss EC+ concept provides the possibility for using high efficiency PM motors in IEC standard frame size operated by Danfoss adjustable frequency drives. The commissioning procedure is comparable to the existing one for asynchronous (induction) motors by utilizing the Danfoss VVC^{plus} PM control strategy.

Customer advantages:

- Option of motor technology (permanent magnet or induction motor)

- Installation and operation as on induction motors

- Manufacturer independent when choosing system components such as motors

- Best system efficiency by choosing best components

- Possible retrofit of existing installations

- High power range: 1.5–1875 hp [1.1–1400 kW] for induction motors and 1.5–30 hp [1.1–22 kW] for PM motors

Current limitations:

- Currently only supported up to 30 hp [22 kW]

- Currently limited to non-salient type PM motors

- LC filters not supported with PM motors

- Overvoltage control algorithm is not supported with PM motors

- Kinetic backup algorithm is not supported with PM motors

- AMA algorithm is not supported with PM motors

- No missing motor phase detection

- No stall detection

- No ETR function

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

The adjustable frequency drive can be operated manually via the local control panel (LCP) or remotely via analog/digital inputs or serial bus.
It is possible to start and stop the adjustable frequency drive by LCP using the [Hand On] and [Off] keys if allowed in the following parameters:

- *0-40 [Hand on] Key on LCP*

- *0-41 [Off] Key on LCP*

- *0-42 [Auto on] Key on LCP*

- *0-43 [Reset] Key on LCP*

Alarms can be reset via the [Reset] key. After pressing [Hand On], the adjustable frequency drive goes into Hand mode and follows (as default) the local reference set by pressing [▲] and [▼].

After pressing [Auto On], 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* Digital/Bus*.
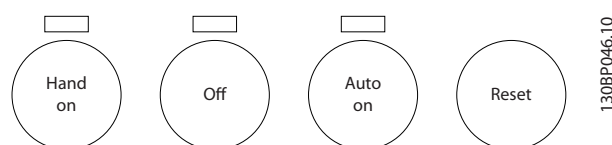
Figure 2.20 LCP Keys

Hand Off Auto LCP 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 Local or Remote Reference

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Table 2.8 shows which conditions activate the local or remote reference. 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.

2.8.5 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 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 where 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 value to the adjustable frequency drive as a feedback signal. If the feedback signal is greater than the setpoint reference, the adjustable frequency drive slows down to reduce the pressure. Likewise, if the pipe pressure is lower than the setpoint reference, the adjustable frequency drive speeds up to increase the pump pressure.

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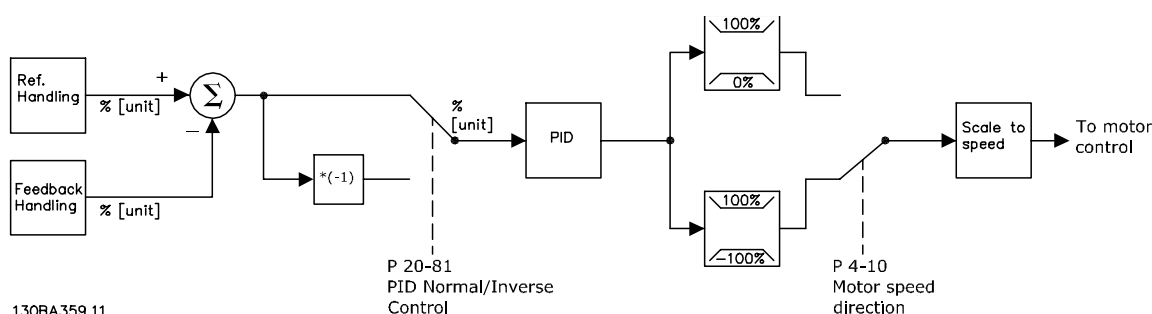
Figure 2.21 Block Diagram of Closed-loop Controller

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

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2.8.6 Feedback Handling

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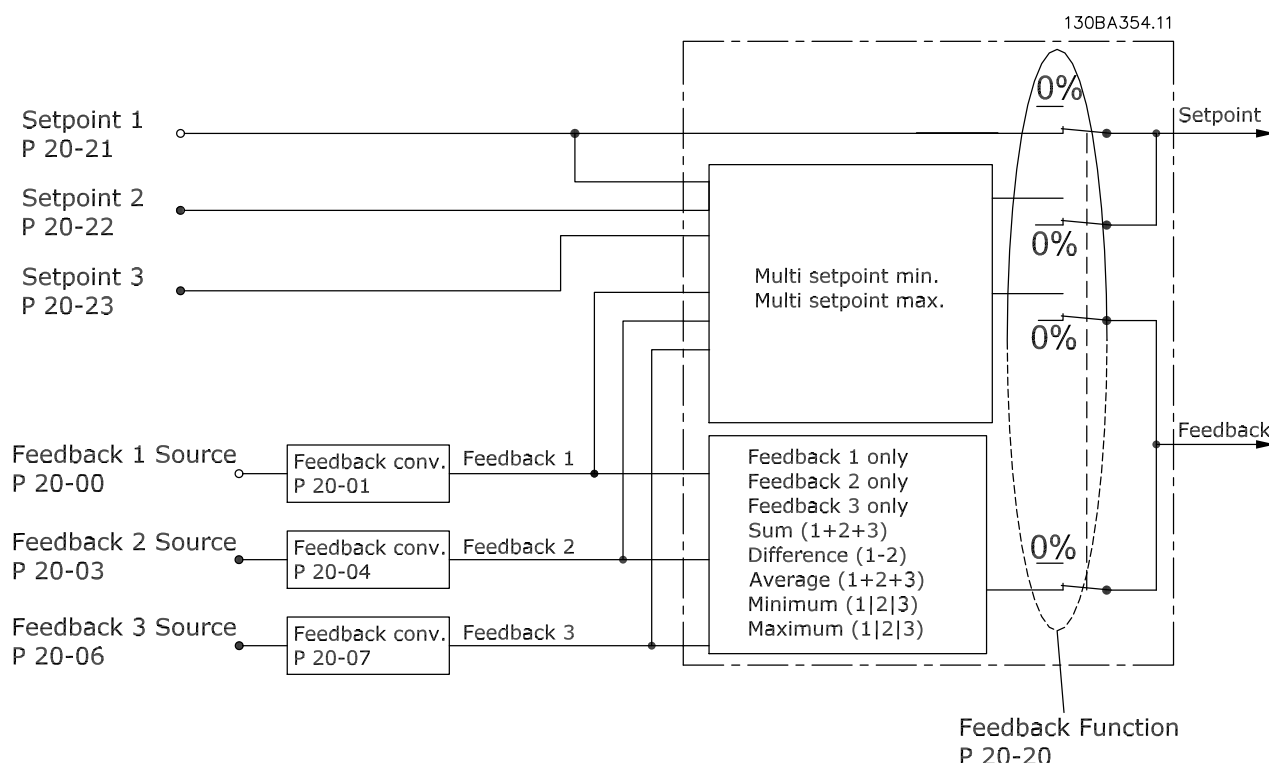
Figure 2.22 Block Diagram of Feedback Signal Processing

Feedback handling can be configured to work with applications requiring advanced control, such as multiple setpoints and multiple feedbacks. 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 *chapter 2.8.8 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 feedbacks can be added, subtracted (only feedback 1 and 2) or averaged. In addition, the maximum or minimum value could be used. Setpoint 1 is used exclusively in this configuration.

If *[5] Multi Setpoint Min* is selected, the setpoint/feedback pair with the largest difference controls the speed of the adjustable frequency drive. *[6] Multi Setpoint Max* attempts to keep all zones at or below their respective setpoints, while *[5] Multi Setpoint Min* attempts to keep all zones at or above their respective setpoints.

Example:

A 2-zone, 2-setpoint application in which the Zone 1 setpoint is 15 bar and the feedback is 5.5 bar. Zone 2 setpoint is 4.4 bar and the feedback is 4.6 bar. If *[6] Multi Setpoint Max* is selected, the setpoint and feedback of Zone 2 are sent to the PID controller, since this has the smaller difference (feedback is higher than setpoint, resulting in a negative difference). If *[5] Multi Setpoint Min* is selected, the setpoint and feedback of Zone 1 are sent to the PID controller, since this has the larger difference (feedback is lower than setpoint, resulting in a positive difference).

2

2.8.7 Feedback Conversion

In some applications, it may be useful to convert the feedback signal. One example of this 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. This is shown in *Figure 2.23*.
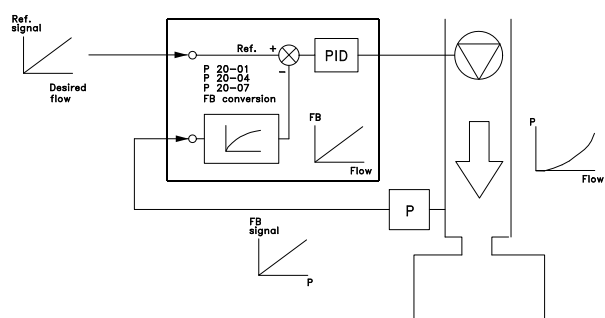
Figure 2.23 Feedback Conversion

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2.8.8 Reference Handling

Details for Open-loop and Closed-loop Operation
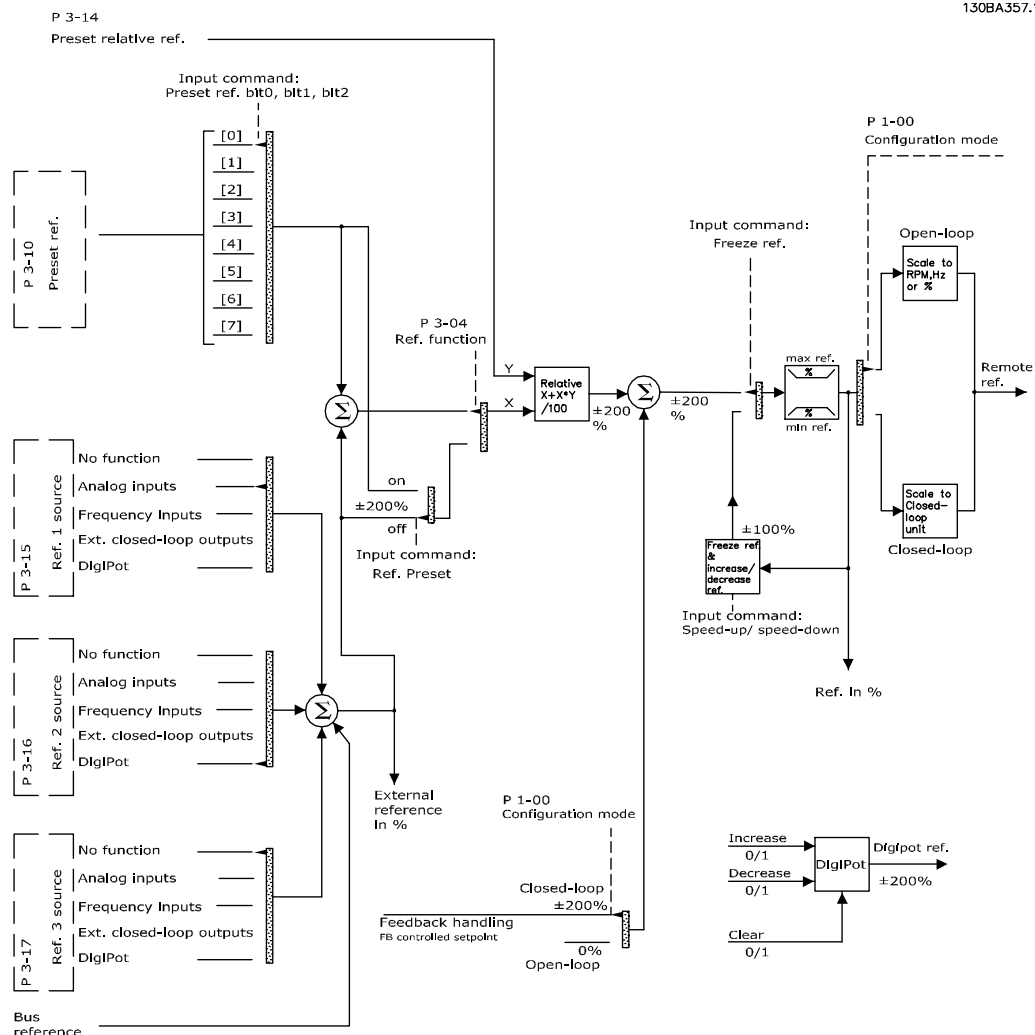
Figure 2.24 Remote Reference

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. This external source is selected by 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. This is also commonly called a Speed up/Slow control or a floating point control. To set it up, program one digital input 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 reference will not be affected by the scaling.

2.8.9 Example of Closed-loop PID Control
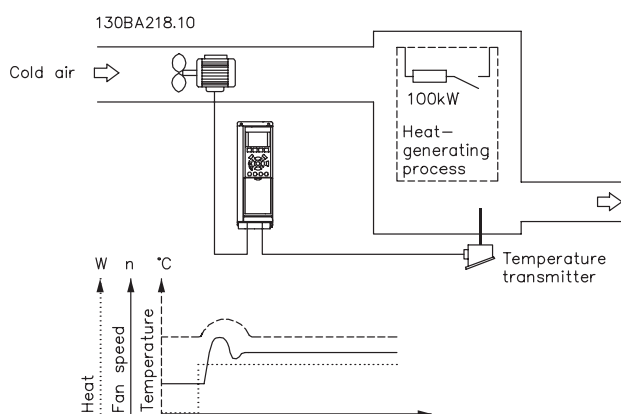
Figure 2.25 Closed-loop Control for a Ventilation System

In a ventilation system, maintain the temperature at a constant value. The desired temperature is set between 23°F and 95°F [-5–+35°C] using a 0–10 volt potentiometer. Because this is a cooling application, if the temperature is above the setpoint value, increase the speed of the fan to provide more cooling air flow. The temperature sensor has a range of 14–104°F [-10–+40°C] and uses a two-wire transmitter to provide a 4–20 mA signal. The output frequency range of the adjustable frequency drive is 10 to 50 Hz.

1. Start/Stop via the switch connected between terminals 12 (+24 V) and 18.

2. Temperature reference via a potentiometer (23–95°F [-5–+35 °C], 0–10 V) connected to the following terminals:

    - 50 (+10 V)

    - 53 (input)

    - 55 (common)

3. Temperature feedback via transmitter (14–104°F [-10–40 °C], 4–20 mA) connected to terminal 54. Switch S202 behind the LCP set to ON (current input).

2.8.10 Programming Order

NOTICE!

This example assumes an induction motor is used, so *1-10 Motor Construction* = [0] **Asynchron.**

2

Function	Parameter no.	Setting
1) Make sure the motor runs properly. Do the following:		
Set the motor parameters using nameplate data.	1-2*	As specified by motor nameplate
Run Automatic Motor Adaptation (AMA).	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 the adjustable frequency drive limits are set to safe values		
Check that the ramp settings are within capabilities of the adjustable frequency drive and 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.	20-13 20-14	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 (0–10 Bar, 0–10 V).	6-10 6-11 6-14 6-15	0 V 10 V (default) 0 Bar 10 Bar
Scale analog input 54 for pressure sensor (0–10 Bar, 4–20 mA)	6-22 6-23 6-24 6-25	4 mA 20 mA (default) 0 Bar 10 Bar
7) Tune the PID controller parameters.		
Adjust the closed-loop controller, if needed.	20-93 20-94	See Optimization of the PID Controller below.
8) Finished		
Save the parameter setting to the LCP	0-50	*[1] All to LCP*

Table 2.9 Programming Order

2

2.8.11 Tuning the Closed-loop Controller

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

2.8.12 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.

3. Reduce the PID proportional gain until the feedback signal stabilizes. Reduce the proportional gain by 40–60%.

4. Set *20-94 PID Integral Time* to 20 sec. 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.

5. Increase the PID integral time until the feedback signal stabilizes. Increase the integral time by 15–50%.

6. *20-95 PID Differentiation Time* should only be used for fast-acting systems. The typical value is 25% of *20-94 PID Integral Time*. The differential function should only be used 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 (parameters 6-16, 6-26, 5-54 or 5-59 as required).

2.9 General aspects of EMC

2.9.1 General Aspects of EMC Emissions

Electrical interference is usually conducted at frequencies in the range 150 kHz to 30 MHz. Airborne interference from the adjustable frequency drive system in the range 30 MHz to 1 GHz is generated from the inverter, motor cable, and motor. 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 2.26*) because shielded cables have higher capacitance to ground than non-shielded cables. If the leakage current is not filtered, it will cause greater interference on the line power in the radio frequency range below approximately 5 MHz. Since the leakage current (I_1) is carried back to the unit through the shield (I_3), there is only a small electromagnetic field (I_4) from the shielded motor cable.

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. This is best done by using integrated shield clamps so as to avoid twisted shield ends (pigtails) These increase the shield impedance at higher frequencies, which reduces the shield effect and increases the leakage current (I_4).
If a shielded cable is used for serial communication bus, relay, control cable, signal interface and brake, the shield must be mounted on the enclosure at both ends. In some situations, however, it will be necessary to break the shield to avoid current loops.
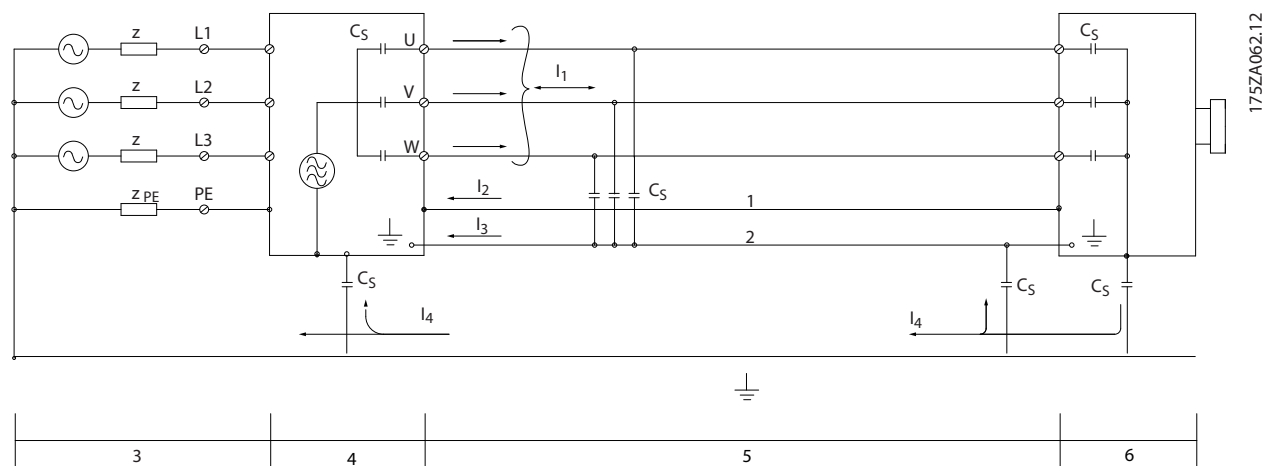
Figure 2.26 Leakage Currents Cause

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

Table 2.10 Legend to *Figure 2.26*

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

Use of non-shielded cables does not comply with all emission requirements, although the immunity requirements are observed.

To reduce the interference level from the entire system (unit + installation), make motor and brake cables as short as possible. Avoid placing cables with a sensitive signal level alongside motor and brake cables. Radio interference higher than 50 MHz (airborne) is generated by the control electronics. See *chapter 5.7 EMC-compatible Installation* for more information on EMC.

2

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 intended use of the adjustable frequency drive. Four categories are defined in the EMC product standard. The definitions of the four categories and the requirements for line power supply voltage conducted emissions are given in *Table 2.11*.

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

Table 2.11 Emission Requirements

When using generic emission standards, the adjustable frequency drives must comply with the limits in *Table 2.12*.

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 2.12 Emission Requirements, Generic Standards

MG16C122   45

2

2.9.3 EMC Test Results (Emission)

The test results in *Table 2.13* 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)		meter	meter	meter		
110–1000 kW 380–480 V	T4	50	No	No	No	No
45–1200 kW 525–690 V	T7	150	No	No	No	No
H4 (6-pulse)						
110–1000 kW 380–480 V	T4	150	150	No	Yes	No
110–400 kW 525–690 V	T7	150	30	No	No	No
B2 (12-pulse)						
250–800 kW 380–480 V	T4	150	No	No	No	No
355–1200 kW 525–690 V	T7	150	No	No	No	No
B4 (12-pulse)						
250–800 kW 380–480 V	T4	150	150	No	Yes	No
355–1200 kW 525–690 V	T7	150	25	No	No	No

Table 2.13 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.

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 by means of a Fourier analysis and split up into sine-wave currents with different frequencies with 50 Hz as the basic frequency:

Harmonic currents	I_1	I_5	I_7
Hz	50	250	350

Table 2.14 Harmonic Currents

The harmonics do not affect the power consumption directly but increase the heat losses in the installation (transformer, cables). Consequently, in plants with a high percentage of rectifier load, maintain harmonic currents at a low level to prevent an overload of the transformer and high temperature in the cables.
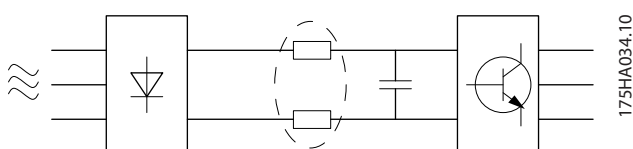
Figure 2.27 Harmonics Diagram

NOTICE!

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

To ensure low harmonic currents, the adjustable frequency drive is equipped with intermediate circuit coils as standard. This normally reduces 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 total voltage distortion THD is calculated on the basis of the individual voltage harmonics using this formula:

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

(U_N% of U)

2.9.5 Harmonics Emission Requirements

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 2.15 Equipment Connected to the Public Supply Network

2.9.6 Harmonics Test Results (Emission)

Power sizes up to PK75 in T2 and T4 complies with IEC/EN 61000-3-2 Class A. Power sizes from P1K1 and up to P18K in T2 and up to P90K in T4 complies with IEC/EN 61000-3-12, Table 4. Power sizes P110–P450 in T4 also complies with IEC/EN 61000-3-12 even though not required because currents are above 75 A.

Provided that 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 user's 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 that specified in the equation. 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 with reference to the power drive systems product standard. They may be used as the basis for calculation of the influence harmonic currents have on the power supply system and for the documentation of compliance with relevant regional guidelines: IEEE 519 -1992; G5/4.

2.9.7 Immunity Requirements

The immunity requirements for adjustable frequency drives depend on the environment in which they are installed. The requirements for the industrial environment are higher than the requirements for the home and office environments. All Danfoss adjustable frequency drives comply with the requirements for the industrial environment and consequently comply with the lower requirements for home and office environment with a large safety margin.

2

To document immunity against electrical interference from electrical phenomena, the following immunity tests have been performed on a system consisting of an adjustable frequency drive (with options if relevant), a shielded control cable and a control box with potentiometer, motor cable and motor.

The tests were performed in accordance with the following basic standards:

- **EN 61000-4-2 (IEC 61000-4-2):** Electrostatic discharges (ESD): Simulation of electrostatic discharges from human beings.

- **EN 61000-4-3 (IEC 61000-4-3):** Incoming electromagnetic field radiation, amplitude modulated simulation of the effects of radar and radio communication equipment as well as mobile communications equipment.

- **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 2.16*.

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 criteria	**B**	**B**	**B**	**A**	**A**
Line	4 kV CM	2 kV/2 Ω DM 4 kV/12 Ω CM	—	—	10 V$_{RMS}$
Motor	4 kV CM	4 kV/2 Ω 1)	—	—	10 V$_{RMS}$
Brake	4 kV CM	4 kV/2 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 24 V DC	2 V CM	0.5 kV/2 Ω DM2) 1 kV/12 Ω CM3)	—	—	10 V$_{RMS}$
Enclosure	—	—	8 kV AD4) 6 kV CD5)	10 V/m	—

Table 2.16 EMC Immunity Form

1) Injection on cable shield

2) AD–Air discharge

3) CD–Contact discharge

4) CM–Common mode

5) DM–Differential mode

2.10 Galvanic Isolation (PELV)

2.10.1 PELV - Protective Extra Low Voltage

PELV (Protective Extra Low Voltage) offers protection through extra low voltage. To ensure protection against electric shock, use a PELV electrical supply and install 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 providing the relevant creepage/clearance distances. These requirements are described in the EN 61800-5-1 standard.

The components that make up the electrical isolation, as described below, also comply with the requirements for higher isolation and the relevant test as described in EN 61800-5-1.
The PELV galvanic isolation is shown in six locations. See *Figure 2.28*:

To maintain PELV, all connections made to the control terminals must be PELV.
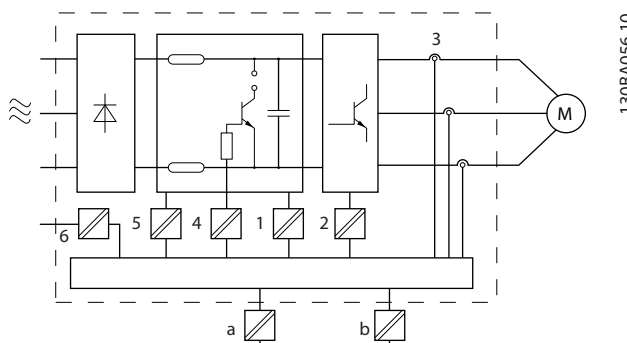
Figure 2.28 Galvanic Isolation

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	Opto-coupler, brake module
5	Internal soft-charge, RFI and temperature measurement circuits.
6	Custom relays
a	Functional Galvanic Isolation
b	Functional Galvanic Isolation

Table 2.17 Legend to *Figure 2.28*

The functional galvanic isolation is for the 24 V backup option and for the standard bus interface.

⚠WARNING

Installation at high altitude:
380–480 V, enclosure A, B and C: At altitudes above 6,600 ft [2 km], contact Danfoss regarding PELV.
380–480 V, enclosure D, E and F: At altitudes above 10,000 ft [3 km], contact Danfoss regarding PELV.

2

⚠WARNING

Touching the electrical parts could be fatal, even after the equipment has been disconnected from line power. Ensure that other voltage inputs, such as load sharing (linkage of DC intermediate circuit) as well as the motor connection for kinetic backup, have been disconnected. 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.

2.11 Ground Leakage Current

Follow national and local codes regarding protective grounding of equipment with a leakage current > 3.5 mA. Adjustable frequency drive technology implies high frequency switching at high power. This will generate a leakage current in the ground connection. A fault current in the adjustable frequency drive at the output power terminals may 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.
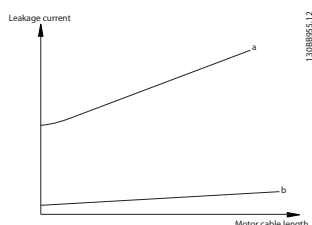
Figure 2.29 Cable Length and Power Size Influence on Leakage Current. Pa > Pb.
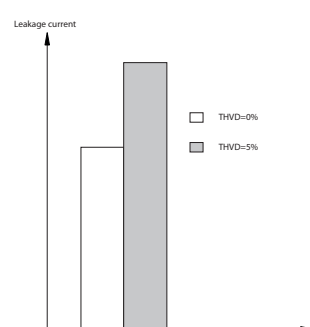
Figure 2.30 Line Distortion Influences Leakage Current.

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.

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

- Ground wire (terminal 95) of at least 0.016 in^2 [10 mm^2]

- Two separate ground wires both complying with the dimensioning rules

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

Using RCDs

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

- Use only RCDs of type B, which are 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

                    MG16C122
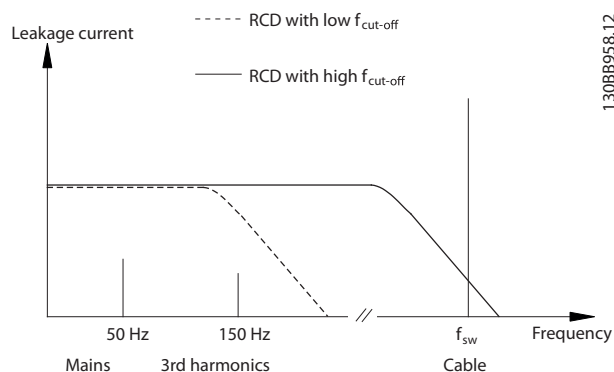
Figure 2.31 Main Contributions to Leakage Current.
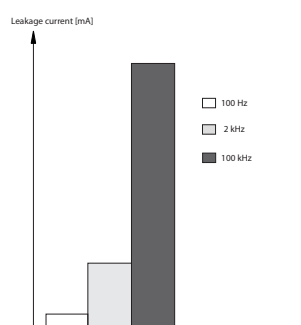
Figure 2.32 Effect of the RCD frequency

See the RCD Application Note for more information.

2.12 Brake Function

2.12.1 Brake Resistor Selection

In certain applications (in a tunnel or underground railway station ventilation system, for example), it is desirable to bring the motor to a stop faster than can be achieved through controlling via ramp-down or by free-wheeling. In such applications, use dynamic braking with a brake resistor to ensure 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, calculate the average power on the basis of the cycle time and braking time (intermittent duty cycle). The resistor intermittent duty cycle is an indication of the duty cycle at which the resistor is active. *Figure 2.33* shows a typical braking cycle.

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

Duty Cycle = t_b / T

T = cycle time in seconds
t_b is the braking time in seconds (as part of the total cycle time)
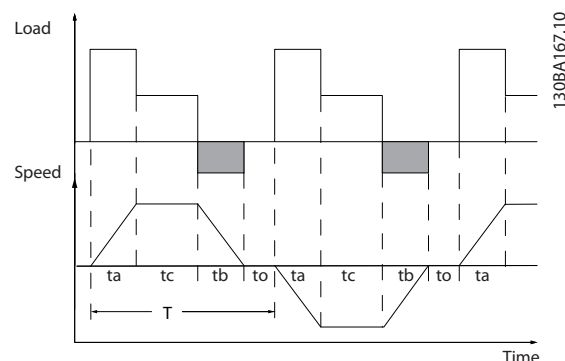
Figure 2.33 Typical Braking Cycle

Danfoss offers brake resistors with duty cycle of 10% and 40% suitable for use with the VLT® HVAC Drive adjustable frequency drive series. If a 10% duty cycle resistor is applied, this is capable of absorbing braking energy up to 10% of the cycle time with the remaining 90% being used to dissipate heat from the resistor.

2.12.2 Brake Resistor Calculation

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

$P_{peak} = P_{motor}$ x M_{br} x η_{motor} x η[W]

The brake resistance depends on the intermediate circuit voltage (U_{DC}).
The brake function of the adjustable frequency drive is settled in three areas of the line power supply:

Size	Brake active	Warning before cut-out	Cut-out (trip)
3 x 380–480 V	778 V	810 V	820 V
3 x 525–690 V	1084 V	1109 V	1130 V

Table 2.18 Effect of Brake Function on Line Power Supply

2

NOTICE!

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

Danfoss recommends the brake resistance R_{rec}, which guarantees that the adjustable frequency drive is able to brake at the highest braking torque ($M_{br(\%)}$) of 110%. The formula can be written as:

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

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

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

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

NOTICE!

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

NOTICE!

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

NOTICE!

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

⚠WARNING

Do not touch the brake resistor as it can get very hot during braking.

2.12.3 Control with Brake Function

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

NOTICE!

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

Overvoltage control (OVC), for units without a brake resistor, can be selected as an alternative brake function in *2-17 Over-voltage Control*. This function is active for all units. The function ensures that a trip can be avoided if the DC link voltage increases. This is done by increasing the output frequency to limit the voltage from the DC link.

NOTICE!

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

2.12.4 Brake Resistor Cabling

EMC (twisted cables/shielding)
Twist the wires to reduce noise between the brake resistor and the adjustable frequency drive.

Use a metal shield for enhanced EMC performance

2.13 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).
See certificate in *chapter 2.6.3 Approvals & Certificates*.

Output Switching
Output switching between the motor and the adjustable frequency drive is permitted. Output switching does not damage the adjustable frequency drive in any way but may cause fault messages.

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

- The load drives the motor (at constant output frequency from the adjustable frequency drive), generating energy.

- During deceleration ("ramp-down") if the moment of inertia is high, the friction is low and the ramp-down time is too short for the energy to be dissipated as a loss in the adjustable frequency drive, the motor and the installation.

- Incorrect slip compensation setting may cause higher DC link voltage.

- Back EMF (electromotive force) from PM motor operation. If coasted at high rpm, the PM motor back EMF may potentially exceed the maximum voltage tolerance of the adjustable frequency drive and cause damage. To help prevent this, the value of *4-19 Max Output Frequency* is automatically limited based on an internal calculation based on the value of *1-40 Back EMF at 1000 RPM*, *1-25 Motor Nominal Speed* and *1-39 Motor Poles*.
  If it is possible that the motor may overspeed, a brake resistor is recommended.

⚠WARNING

The adjustable frequency drive must be equipped with a break chopper.

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

NOTICE!

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

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

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

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

2.13.1 Motor Thermal Protection

Motor thermal protection prevents the motor from overheating. It is an electronic feature that simulates a bimetal relay based on internal measurements. The characteristic is shown in *Figure 2.34*

In *Figure 2.34*, 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.

2

2
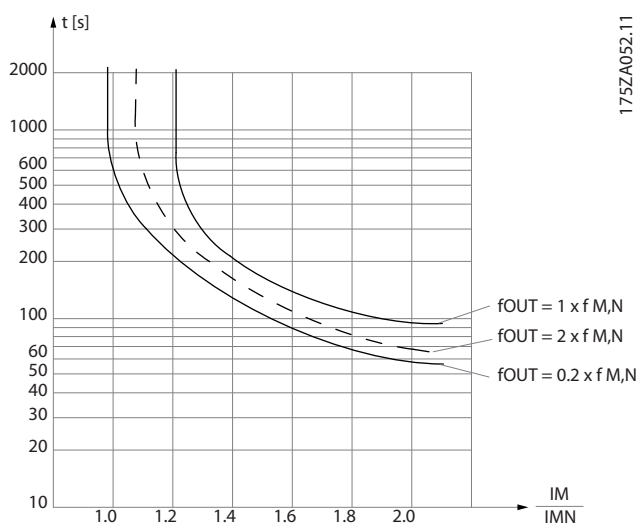
Figure 2.34 Nominal Speed

Figure 2.35 Trip

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 overheating 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.

The thermistor cut-out value is > 3 kΩ.

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).
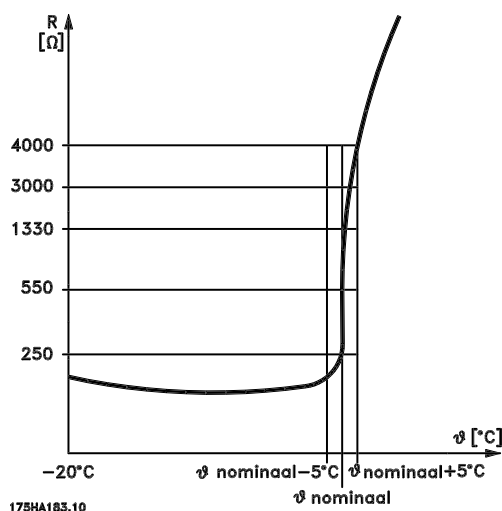
Example: Using a digital input and 24 V as power supply:
The adjustable frequency drive trips when the motor temperature is too high.
Parameter set-up:
Set *1-90 Motor Thermal Protection* to *Thermistor Trip* [2]
Set *1-93 Thermistor Source* to *Digital Input 33* [6]
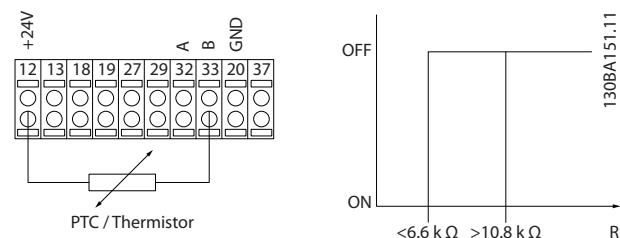
Figure 2.36 Digital Input and 24 V Power Supply

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

2
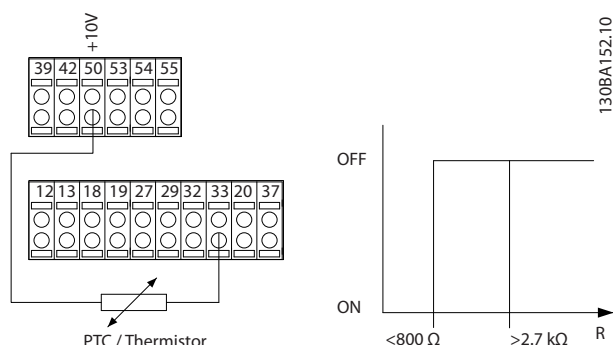
Figure 2.37 Digital Input and 10 V Power Supply

Example: Using an analog input and 10 V as power supply:
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.
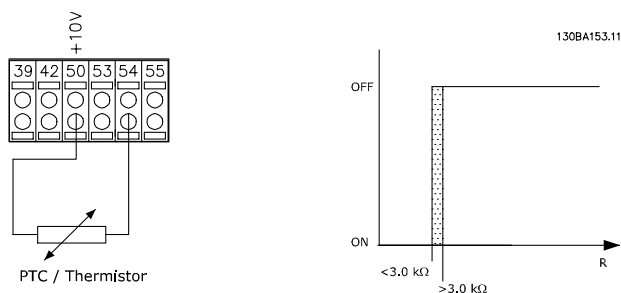
Figure 2.38 Analog Input and 10 V Power Supply

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

Table 2.19 Threshold Cut-out Values by Input and Voltage

NOTICE!

Check that the chosen supply voltage follows the specification of the thermistor element used.

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

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

3 Selection

3.1 Options and Accessories

Danfoss offers a wide range of options and accessories.

3.1.1 General Purpose Input Output Module MCB 101

MCB 101 is used for extending the number of digital and analog inputs and outputs.

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

- MCB 101 option module
- Extended LCP frame
- Terminal cover
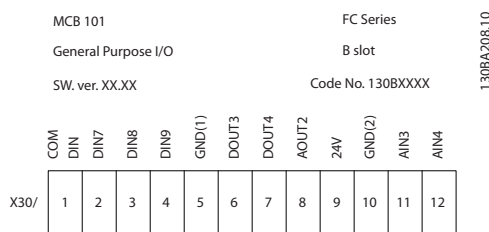
Figure 3.1 MCB 101

Galvanic isolation in the MCB 101
Digital/analog inputs are galvanically isolated from other inputs/outputs on the MCB 101 and in the control card of the adjustable frequency drive. Digital/analog outputs in the MCB 101 are galvanically isolated from other inputs/outputs on the MCB 101, but not from those on the control card.

If the digital inputs 7, 8 or 9 are to be switched using the internal 24 V power supply (terminal 9), the connection between terminals 1 and 5, which is shown in *Figure 3.2* has to be established.
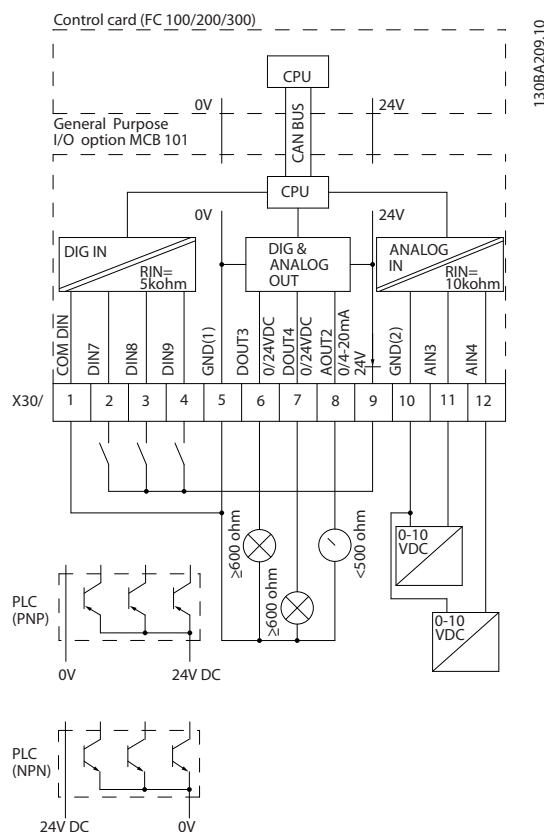
Figure 3.2 Principle Diagram

3.1.2 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 = 0 V 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 3.1 Digital Inputs - Terminal X30/1-4

3.1.3 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 3.2 Analog Voltage Inputs - Terminal X30/10-12

3.1.4 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 or 2 V DC	± 4 V	≥ 600 Ω

Table 3.3 Digital Outputs - Terminal X30/5-7

3.1.5 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 3.4 Analog Outputs - Terminal X30/5+8

3

3.1.6 Relay Option MCB 105

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

Electrical Data:

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

1) IEC 947 part 4 and 5

When the relay option kit is ordered separately, it 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

Adding the MCB 105 option:
1. Disconnect the power to the live part connections on relay terminals.

2. Do not mix live parts with control signals (PELV).

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

NOTICE!

(Index [6] is relay 7, index [7] is relay 8, and index [8] is relay 9)
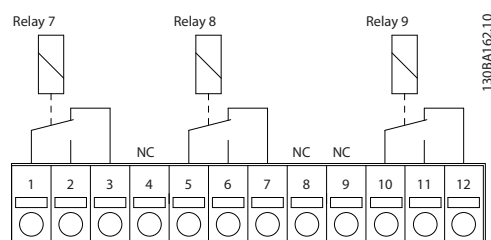
Figure 3.3 Relay Locations
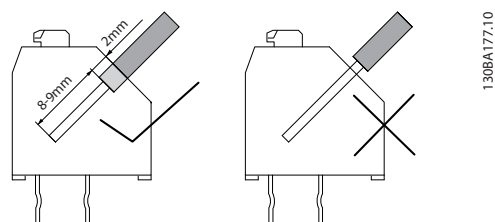
Figure 3.4 Correct Installation
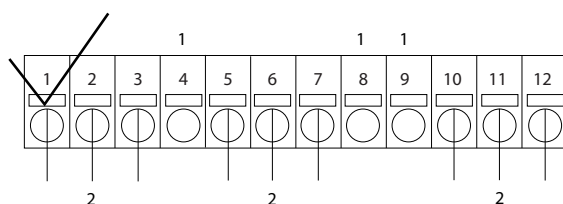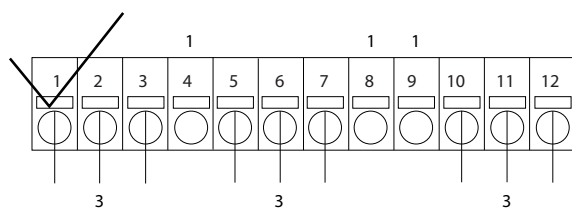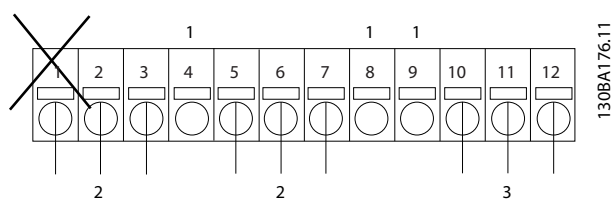
Figure 3.5 Location of NC, PELV and Live Parts

1	NC
2	Live part
3	PELV

Table 3.5 Legend to

⚠ WARNING

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

3

3.1.7 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. This enables full operation of the LCP (including the parameter setting) and serial communication buses without line power supplied to the power section.

External 24 V DC supply specification:

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

The inputs are protected.

Terminal numbers:

Terminal 35: (-) external 24 V DC supply.

Terminal 36: (+) external 24 V DC supply.

Follow these steps:

1. Remove the LCP or blind cover

2. Remove the terminal cover

3. Remove the cable decoupling plate and the plastic cover underneath

4. Insert the 24 V DC backup external supply option in the option slot

5. Mount the cable decoupling plate

6. Attach the terminal cover and the LCP or blind cover

When MCB 107, 24 V backup option supplies the control circuit, the internal 24 V supply is automatically disconnected.
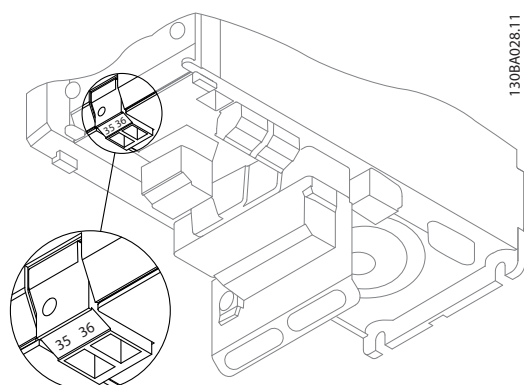
Figure 3.6 Connection to 24 V Backup Supplier (A2-A3).

3
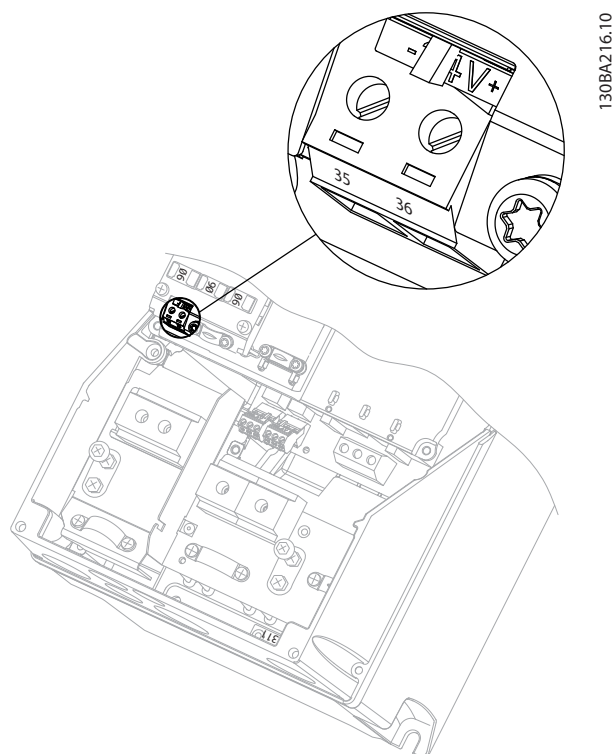
Figure 3.7 Connection to 24 V Backup Supplier (A5-C2).

Figure 3.8 Principle diagram for Analog I/O Mounted in an Adjustable Frequency Drive.

3.1.8 Analog I/O Option MCB 109

Use the Analog I/O card, e.g., in the following cases:

- Providing battery backup of clock function on the control card

- As a general extension of Analog I/O selection available on control card, for example, multi-zone control with three pressure transmitters

- Turning the adjustable frequency drive into decentral I/O block supporting building management system with inputs for sensors and outputs for operating dampers and valve servos

- Supporting extended PID controllers with I/Os for setpoint inputs, transmitter/sensor inputs and outputs for servos

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

- 4–20 mA (voltage input 2–10 V) by mounting a 510 Ω resistor across terminals

- Ni 1000 temperature sensor of 1000 Ω at 32°F [0°C]. Specifications according to DIN43760

- Pt 1000 temperature sensor of 1000 Ω at 32°F [0°C]. Specifications according to IEC 60751

3 x Analog outputs supplying 0–10 V DC.

NOTICE!

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*. See also *VLT® HVAC Drive FC 102 Programming Guide.*

Parameter groups for set-up: 26-0*, 26-1*, 26-2* and 26-3*. See also *VLT® HVAC Drive FC 102 Programming Guide.*

3 x analog inputs	Operating range	Resolution	Accuracy	Sampling	Max load	Impedance
Used as temperature sensor input	-58–+302°F [-50–+150°C]	11 bits	-58°F [-50°C] ±1 Kelvin 302°F [+150°C] ± 2 Kelvin	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 3.6 Analog Input Specifications

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

When used for temperature sensors, 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, the maximum cable length to connect sensors is 262 ft [80 m] with non-shielded/non-twisted wires.

Analog outputs - terminal X42/7-12
Parameter group for reading out and writing: 18-3*. See also *VLT® HVAC Drive FC 102 Programming Guide.*
Parameter groups for set-up: 26-4*, 26-5* and 26-6*. See also *VLT® HVAC Drive FC 102 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 3.7 Analog Output Specifications

Analog outputs are scalable by parameters for each output.

The function assigned is selectable via a parameter and has the same options as analog outputs on the control card.

For a more detailed description of parameters, refer to the *VLT® HVAC Drive FC 102 Programming Guide.*

Real time clock (RTC) with backup
The data format of RTC includes year, month, date, hour, minute and weekday.

The built-in lithium backup battery lasts for a minimum of 10 years, when the adjustable frequency drive is operating at 104°F [40 °C] ambient temperature. If battery pack backup fails, exchange the Analog I/O option.

3.1.9 MCB 112 VLT® PTC Thermistor Card

The MCB 112 option makes it possible to monitor the temperature of an electrical motor through a galvanically-isolated PTC thermistor input. It is a B-option for adjustable frequency drives with safe torque off.

For information on mounting and installation of the option, see *chapter 6 Application Examples* for different application possibilities.

X44/1 and X44/2 are the thermistor inputs, X44/12 enables safe torque off of the adjustable frequency drive (T-37) if the thermistor values make it necessary and X44/10 informs the adjustable frequency drive that a request for safe torque off came from the MCB 112 in order to ensure a suitable alarm handling. One of the digital inputs of the adjustable frequency drive (or a DI of a mounted option) must be set to PTC Card 1 [80] in order to use the information from X44/10. Configure *5-19 Terminal 37 Digital Input* to the desired STO functionality (default is safe torque off alarm).

ATEX Certification
The MCB 112 has been certified for ATEX which means that the adjustable frequency drive together with the MCB 112 can be used with motors in potentially explosive atmospheres. See the MCB 112 Instruction Manual for more information.

ATmosphère EXplosive (ATEX)

Table 3.8 ATEX Logo

3

Electrical Data

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

Testing conditions	
EN 60 947-8	
Measurement voltage surge resistance	6000 V
Overvoltage category	III
Pollution degree	2
Measurement isolation voltage Vbis	690 V
Reliable galvanic isolation until Vi	500 V
Perm. ambient temperature	-4°F ... +140°F [-20 °C ... +60 °C]
	EN 60068-2-1 Dry heat
Moisture	5–95%, no condensation permissible
EMC resistance	EN61000-6-2
EMC emissions	EN61000-6-4
Vibration resistance	10 ... 1000 Hz 1.14 g
Shock resistance	50 g

Safety system values	
EN 61508 for Tu = 167°F [75°C] ongoing	
SIL	2 for maintenance cycle of 2 years
	1 for maintenance cycle of 3 years
HFT	0
PFD (for yearly functional test)	4.10 *10^{-3}
SFF	78%
$\lambda_s + \lambda_{DD}$	8494 FIT
λ_{DU}	934 FIT

3

3.1.10 Sensor Input Option MCB 114

The sensor input option card MCB 114 can be used in the following cases:

- Sensor input for temperature transmitters PT100 and PT1000 for monitoring bearing temperatures

- As general extension of analogue inputs with one additional input for multi-zone control or differential pressure measurements

- Support extended PID controllers with I/Os for setpoint, transmitter/sensor inputs

Typical motors, designed with temperature sensors to protect bearings from being overloaded, are fitted with 3 PT100/1000 temperature sensors; one in front, one in the backend bearing, and one in the motor windings. The Danfoss Option MCB 114 supports 2- or 3-wire sensors with individual temperature limits for under/over temperature. An auto detection of sensor type, PT100 or PT1000 takes place at power up.

The option can generate an alarm if the measured temperature is either below the low limit or above the high limit specified by the user. The individual measured temperature on each sensor input can be read out in the display or by readout parameters. If an alarm occurs, the relays or digital outputs can be programmed to be active high by selecting *[21] Thermal Warning* in parameter group 5-**.

A fault condition has a common warning/alarm number associated with it, which is Alarm/Warning 20, Temp. input error. Any present output can be programmed to be active in case the warning or alarm appears.

3.1.10.1 Electrical and Mechanical Specifications

Analog Input

Number of analog inputs	1
Format	0–20 mA or 4–20 mA
Wires	2
Input impedance	<200 Ω
Sample rate	1 kHz
Third order filter	100 Hz at 3 dB

The option is able to supply the analog sensor with 24 V DC (terminal 1).

Temperature Sensor Input

Number of analog inputs supporting PT100/1000	3
Signal type	PT100/1000
Connection	PT 100 2 or 3 wire/PT1000 2 or 3 wire
Frequency PT100 and PT1000 input	1 Hz for each channel
Resolution	10 bit
Temperature range	-50–204 °C -58–399 °F

Galvanic Isolation

The sensors to be connected are expected to be galvanically isolated from the AC line voltage

level.	IEC 61800-5-1 and UL508C

Cabling

Maximum signal cable length	1640 ft [500 m]

3.1.10.2 Electrical Wiring
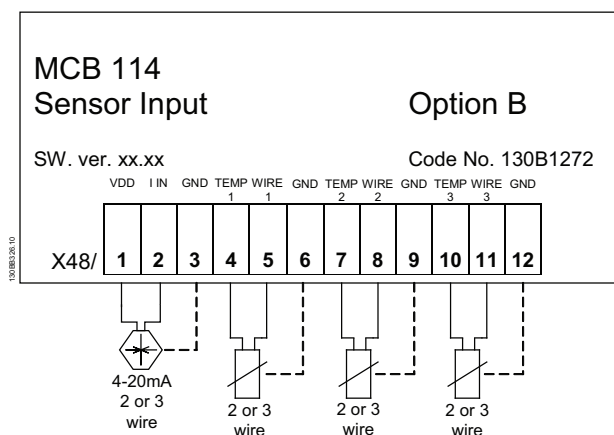
Figure 3.9 MCB 114

Terminal	Name	Function
1	VDD	24 V DC to supply 4–20 mA sensor
2	I in	4–20 mA input
3	GND	Analog input GND
4, 7, 10	Temp 1, 2, 3	Temperature input
5, 8, 11	Wire 1, 2, 3	Third wire input if three wire sensors are used
6, 9, 12	GND	Temp. input GND

Table 3.9 Legend to *Figure 3.9*

3.1.11 D-frame Options

3.1.11.1 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 unit. A terminal cover, supplied with the adjustable frequency drive, must be installed to maintain the IP20 rating of the enclosure. *Figure 3.10* shows both the covered and uncovered terminals.
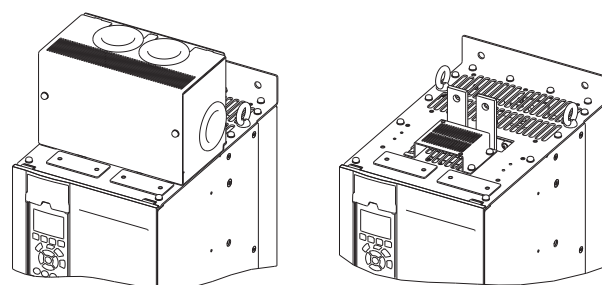
Figure 3.10 Load Share or Regeneration Terminal with Cover (Left) and without Cover (Right)

3.1.11.2 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 sent back onto line power, resulting in energy savings. Regen terminals are available in IP20 adjustable frequency drives and extend out the top of the unit. A terminal cover, supplied with the adjustable frequency drive, must be installed to maintain the IP20 rating of the enclosure. *Figure 3.10* shows both the covered and uncovered terminals.

3.1.11.3 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. The heater is controlled by customer-supplied 230 V AC. For best results, operate the heater only when the unit is not running.

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

3.1.11.4 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 and prevents 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.

3.1.11.5 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

3.1.11.6 Ruggedized Printed Circuit Boards

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

NOTICE!

Ruggedized boards are required to meet marine approval requirements.

3.1.11.7 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.

3.1.11.8 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 3.10* 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 3.10 Line Power Disconnect Information

3.1.11.9 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 3.11 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 5.2.9 Fuses chapter 5.2.10 Fuse Specifications* for fuse recommendations.

3.1.11.10 Circuit Breaker

Table 3.12 provides details on the type of circuit breaker provided as an option with the various units and power ranges.

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

Table 3.12 Circuit Breaker Information

3

3.1.12 F-frame Panel Options

Space Heaters and Thermostat
There are space heaters mounted on the cabinet interior of F-frame adjustable frequency drives. These heaters are controlled by an automatic thermostat and help control humidity inside the enclosure. 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 F-frame 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, 2.5 A, CE/ENEC

- 120 V, 60 Hz, 5 A, UL/cUL

Transformer Tap Set-up
If the cabinet light and outlet and/or the space heaters and thermostat are installed, transformer T1 requires its taps to be set to the proper input voltage. A 380–480/500 V drive will initially be set to the 525 V tap and a 525–690 V drive will be set to the 690 V tap to ensure no overvoltage of secondary equipment occurs if the tap is not changed before applying power. See *Table 3.13* to set the proper tap at terminal T1 located in the rectifier cabinet.

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

Table 3.13 Transformer Tap Set-up

NAMUR Terminals
NAMUR is an international association of automation technology users in process industries, primarily in the chemical and pharmaceutical industries, in Germany. Selecting this option provides terminals organized and labeled to the specifications of the NAMUR standard for drive input and output terminals. This requires MCB 112 PTC Thermistor Card and MCB 113 Extended Relay Card.

RCD (Residual Current Device)
Uses the core balance method to monitor ground fault currents in grounded and high-resistance grounded systems (TN and TT systems in IEC terminology). There is a pre-warning (50% of main alarm setpoint) and a main alarm setpoint. Associated with each setpoint is an SPDT alarm relay for external use. Requires an external "window-type" current transformer (supplied and installed by the customer).

- Integrated into the adjustable frequency drive safe torque off circuit

- IEC 60755 Type B device monitors AC, pulsed DC, and pure DC ground fault currents

- LED bar graph indicator of the ground fault current level from 10–100% of the setpoint

- Fault memory

- TEST / RESET button

Insulation Resistance Monitor (IRM)
Monitors the insulation resistance in ungrounded systems (IT systems in IEC terminology) between the system phase conductors and ground. There is an ohmic pre-warning and a main alarm setpoint for the insulation level. An SPDT alarm relay for external use is associated with each setpoint.

NOTICE!

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

- Integrated into the adjustable frequency drive safe torque off circuit

- LCD display of the ohmic value of the insulation resistance

- Fault memory

- INFO, TEST, and RESET buttons

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

Manual Motor Starters

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

In applications where the motor is used as a brake, energy is generated in the motor and sent back into the adjustable frequency drive. If the energy cannot be transported back to the motor, it increases the voltage in the adjustable frequency drive DC line. In applications with frequent braking and/or high inertia loads, this increase may lead to an overvoltage trip in the adjustable frequency drive and finally a shutdown. Brake resistors are used to dissipate the excess energy resulting from the regenerative braking. The resistor is selected based on its ohmic value, its power dissipation rate and its physical size. Danfoss offers a wide variety of different resistors that are specifically designed for Danfoss adjustable frequency drives.

3.1.13 Remote Mounting Kit for LCP

When the adjustable frequency drive is inside a larger enclosure, the LCP can be moved from an adjustable frequency drive inside to the front of a cabinet using the remote mounting kit. The LCP enclosure is IP66. Tighten fastening screws with a torque of 1 Nm, maximum.

Enclosure	IP66 front
	10 ft [3 m]
Max. cable length between LCP and unit	26 ft [8 m] for option 130B1129
Communication std	RS-485

Table 3.14 Technical Data
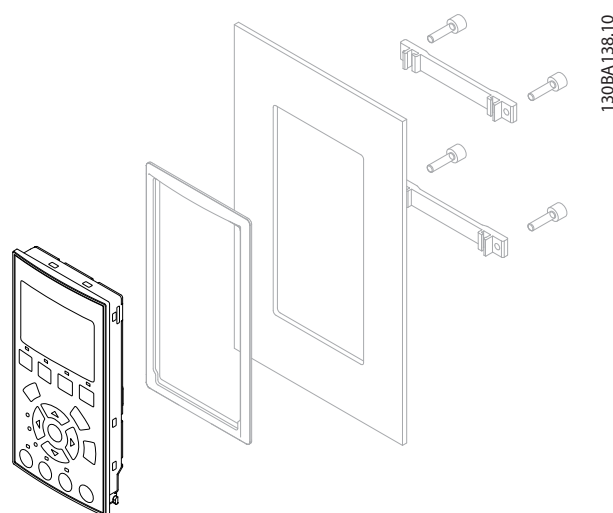
Figure 3.11 LCP Kit with Graphical LCP, Fasteners, 10 ft [3 m] Cable and Gasket
Ordering No. 130B1113
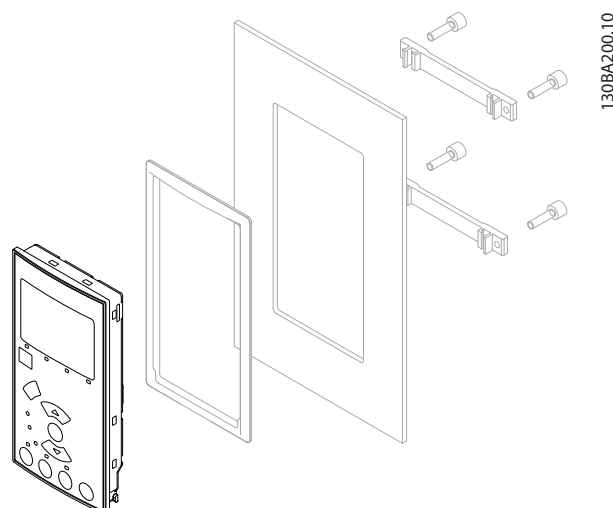
Figure 3.12 LCP Kit with Numerical LCP, Fasteners and Gasket
Ordering no. 130B1114

3

3.1.14 Output Filters

The high-speed switching of the adjustable frequency drive produces some secondary effects, which influence the motor and the enclosed environment. These side effects are addressed by two different filter types, the dU/dt and the sine-wave filter.

dU/dt filters
Motor insulation stresses are often caused by the combination of rapid voltage and current increase. 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 and rapid energy change in the motor. This reduction prevents 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 less than the installation without filter.

Sine-wave filters
Sine-wave filters are designed to let only low frequencies pass, resulting in a sinusoidal phase-to-phase voltage waveform and sinusoidal current waveforms.
With the sinusoidal waveforms, special adjustable frequency drive motors with reinforced insulation are no longer needed. The acoustic noise from the motor is also reduced 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 the use of longer motor cables in applications where the motor is installed far from the adjustable frequency drive. The length is limited because the filter does not reduce leakage currents in the cables.

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4 How to Order

4.1 Ordering Form

4.1.1 Drive Configurator

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

Order the adjustable frequency drive as either standard or with integral options by sending a type code string describing the product to the local Danfoss sales office.

The type code is a string of characters describing the configuration, for example:

-102N132KT4E21H1XGCXXXSXXXXAGBKCXXXXDX

From the online drive configurator, a customer can configure the right adjustable frequency drive for a given application and generate the type code string. The drive configurator automatically generates an 8-digit sales number to be delivered to the local sales office. Another option is to establish a project list with several products and send it to a Danfoss sales representative.

The tables of type codes and configuration options includes frame sizes A, B, and C. For detailed information on those frame sizes, see the relevant design guide.

Example of a Drive Configurator Interface Set-up:
The numbers shown in the boxes refer to the letter/figure position in the type code string, read from left to right.

Product groups	1-2
Adjustable frequency drive series	3-5
Power rating	8-10
Phases	6-9
AC line voltage	10-11
Enclosure	12-14
RFI filter	15-16
Brake	17
Display (LCP)	18
Coating PCB	19
Line power option	20
Adaptation A	22
Adaptation B	23
Software release	24-27
Software language	28
A options	29-30
B options	31-32
C0 options, MCO	33-34
C1 options	35
C option software	36-37
D options	38-39

Table 4.1 Type Code Character Positions

4.1.2 Type Code String

130BB565.10

Figure 4.1 Example Type Code

Description	Position	Possible Choice
Product Group	1–3	FC
Drive Series	4–6	102
Generation Code	7	N
Power Rating	8–10	75–400 kW
AC Line Voltage	11–12	T4: 380–480 V AC
		T7: 525–690 V AC
Enclosure	13–15	E20: IP20 (chassis - for installation in external enclosure)
		E2S: IP20/Chassis, D3h Frame
		C2S: IP20/Chassis, D3h Frame, stainless steel backchannel
		E21: IP21 (NEMA 1)
		E2D: IP 21 (NEMA 1), D1h Frame
		E5D: IP54 (NEMA 12), D1h Frame
		E54: IP54 (NEMA 12)
		E2M: IP21 (NEMA 1) with line power shield
		E5M: IP54 (NEMA 12) with line power shield
		C20: IP20 (chassis) + 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 torque off
		U: Brake chopper + safe torque off
		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

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Description	Position	Possible Choice
Software language	28	
1): Available for all D frames.		

Table 4.2 Ordering Type Code for D-frame Adjustable frequency drives

Description	Pos	Possible choice
Product group	1–3	FC
Drive series	4–6	102
Power rating	8–10	450–630 kW
Phases	11	Three phases (T)
AC line voltage	11- 12	T 4: 380–500 V AC T 7: 525–690 V AC
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

Description	Pos	Possible choice
D options	38–39	DX: No option
		D0: DC backup
1) Available for all E frames 380–480/500 V AC only		
2) Consult factory for applications requiring maritime certification		

Table 4.3 Ordering Type Code for E-Frame Adjustable Frequency Drives

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
Profibus top entry kit	Top entry kit for Profibus connection - D + E enclosures	176F1742
Terminal blocks	Screw terminal blocks for replacing spring loaded terminals. Connectors: • 1 pc 10 pin • 1 pc 6 pin • 1 pc 3 pin	130B1116
LCPs and kits		
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	Front mounting kit, IP55 enclosures	130B1129
LCP kit	Panel mounting kit for all LCPs including fasteners and gasket - without cable	130B1170

Table 4.4 Options can be ordered as factory built-in options

Type	Description	Comments
Options for Slot A		**Ordering no.**
		Coated
MCA 101	Profibus option DP V0/V1	130B1200
MCA 104	DeviceNet option	130B1202
MCA 108	Lonworks	130B1206
MCA 109	BACnet gateway for built-in. Do not use with relay option MCB 105 card	130B1244
MCA 120	Profinet	130B1135
MCA 121	Ethernet	130B1219
Options for Slot B		
MCB 101	General purpose input output option	
MCB 105	Relay option	
MCB 109	Analog I/O option and battery backup for real time clock	130B1243
MCB 112	ATEX PTC	130B1137
MCB 114	Sensor input - uncoated	130B1172
	Sensor input - coated	130B1272
Option for Slot D		
MCB 107	24 V DC backup	130B1208
External Options		
Ethernet IP	Ethernet master	

Table 4.5 A, B, D Slot & External Options

For information on serial communication bus and application option compatibility with older software versions, contact your Danfoss supplier.

Type	Description		
Spare Parts		**Ordering no.**	**Comments**
Control board FC	With STO function	130B1150	
Control board FC	Without STO function	130B1151	

Table 4.6 Control Board

4.2.2 Advanced Harmonic Filters

Harmonic filters are used to reduce line harmonics:

- AHF 010: 10% current distortion

- AHF 005: 5% current distortion

For detailed information on advanced harmonic filters, see the *Advanced Harmonic Filters Design Guide.*

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		AHF005	AHF010
		[A]	hp [kW]	hp [kW]	[A]	[W]	[W]	[dBA]	AHF005	AHF010
130B1446 130B1251	130B1295 130B1214	204	150 [110]	N150 [N110]	204	1080	742	<75	X6	X6
130B1447 130B1258	130B1369 130B1215	251	175 [132]	N175 [N132]	251	1195	864	<75	X7	X7
130B1448 130B1259	130B1370 130B1216	304	250 [160]	N250 [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]	N300 [N200]	381	1510	1175	<77	X8	X7
130B1469 130B1261	130B1391 130B1228	480	350 [250]	N350 [N250]	472	1852	1542	<77	X8	X8
2x130B1448 2x130B1259	2x130B1370 2x130B1216	608	450 [315]	N450 [N315]	590	2576	1810	<80		

Table 4.7 Advanced Harmonic Filters 380–415 V, 50 Hz, D-frame

4

Code number AHF005 IP00 IP20	Code number AHF010 IP00 IP20	Filter current rating [A]	Typical motor hp [kW]	VLT model and current ratings hp [kW]	[A]	Losses AHF005 [W]	AHF010 [W]	Acoustic noise [dBA]	Frame size AHF005	AHF010
2x130B3153 2x130B3152	2x130B3151 2x130B3136	650	475 [355]	P475 [P355]	647	2812	1904	<80		
130B1448+130B1449 130B1259+130B1260	130B1370+130B1389 130B1216+130B1217	685	550 [400]	P550 [P400]	684	2798	2080	<80		
2x130B1449 2x130B1260	2x130B1389 2x130B1217	762	600 [450]	P600 [P450]	779	3020	2350	<80		
130B1449+130B1469 130B1260+130B1261	130B1389+130B1391 130B1217+130B1228	861	650 [500]	P650 [P500]	857	3362	2717	<80		
2x130B1469 2x130B1261	2x130B1391 2x130B1228	960	750 [560]	P750 [P560]	964	3704	3084	<80		
3x130B1449 3x130B1260	3x130B1389 3x130B1217	1140	850 [630]	P850 [P630]	1090	4530	3525	<80		
2x130B1449+130B1469 2x130B1260+130B1261	2x130B1389+130B1391 2x130B1217+130B1228	1240	950 [710]	P950 [P710]	1227	4872	3892	<80		
3x130B1469 3x1301261	3x130B1391 3x130B1228	1440	1075 [800]	P1075 [P800]	1422	5556	4626	<80		
2x130B1449+2x130B1469 2x130B1260+2x130B1261	2x130B1389+2x130B1391 2x130B1217+2x130B1228	1720	1350 [1000]	P1350 [P1000]	1675	6724	5434	<80		

Table 4.8 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 [A]	Typical motor hp [kW]	VLT model and current ratings hp [kW]	[A]	Losses AHF005 [W]	AHF010 [W]	Acoustic noise [dBA]	Frame size AHF005	AHF010
130B3131 130B2869	130B3090 130B2500	204	150 [110]	N150 [N110]	204	1080	743	<75	X6	X6
130B3132 130B2870	130B3091 130B2700	251	175 [132]	N175 [N132]	251	1194	864	<75	X7	X7
130B3133 130B2871	130B3092 130B2819	304	250 [160]	N250 [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]	N300 [N200]	381	1510	1175	<77	X8	X7
130B3135 130B2873	130B3094 130B2856	480	350 [250]	N350 [N250]	472	1850	1542	<77	X8	X8
2x130B3133 2x130B2871	2x130B3092 2x130B2819	608	450 [315]	N450 [N315]	590	2576	1810	<80		

Table 4.9 Advanced Harmonic Filters, 380–415 V, 60 Hz, D-frame

4

Code number AHF005 IP00 IP20	Code number AHF010 IP00 IP20	Filter current rating [A]	Typical motor hp [kW]	VLT model/ current ratings hp [kW]	[A]	Losses AHF005 [W]	Losses AHF010 [W]	Acoustic noise [dBA]	Frame size AHF005	Frame size AHF010
2x130B3157 2x130B3156	2x130B3155 2x130B3154	650	450 [315]	P475 [P355]	647	2812	1904	<80		
130B3133+130B3134 130B2871+130B2872	130B3092+130B3093 130B2819+130B2855	685	475 [355]	P550 [P400]	684	2798	2080	<80		
2x130B3134 2x130B2872	2x130B3093 2x130B2855	762	550 [400]	P600 [P450]	779	3020	2350	<80		
130B3134+130B3135 130B2872+130B3135	130B3093+130B3094 130B2855+130B2856	861	600 [450]	P650 [P500]	857	3362	2717	<80		
2x130B3135 2x130B2873	2x130B3094 2x130B2856	960	650 [500]	P750 [P560]	964	3704	3084	<80		
3x130B3134 3x130B2872	3x130B3093 3x130B2855	1140	750 [560]	P850 [P630]	1090	4530	3525	<80		
2x130B3134+130B3135 2x130B2872+130B2873	2x130B3093+130B3094 2x130B2855+130B2856	1240	850 [630]	P950 [P710]	1227	4872	3892	<80		
3x130B3135 3x130B2873	3x130B3094 3x130B2856	1440	950 [710]	P1075 [P800]	1422	5556	4626	<80		
2x130B3134+2x130B3135 2x130B2872+2x130B2873	2x130B3093+2x130B3094 2x130B2855+2x130B2856	1722	1075 [800]	P1M0	1675	6724	5434	<80		

Table 4.10 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 [A]	Typical motor [HP]	VLT model and current ratings [HP]	[A]	Losses AHF005 [W]	Losses AHF010 [W]	Acoustic noise [dBA]	Frame size AHF005	Frame size 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 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 4.11 Advanced Harmonic Filters 440–480 V, 60 Hz, D-frame

4

Code number AHF005 IP00/IP20	Code number AHF010 IP00/IP20	Filter current rating	Typical motor	VLT model/ current ratings		Losses		Acoustic noise	Frame size	
						AHF005	AHF010		AHF005	AHF010
		[A]	[HP]	[kW]	[A]	[W]	[W]	[dBA]		
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	2x130B17852x130B1785 +2x130B1786 2x130B1499+2x130B1751	1582	1350	P1M0	1490	6516	5988	<80		

Table 4.12 Advanced Harmonic Filters, 440–480 V, 60 Hz, E- and F-frames

Code number AHF005 IP00/ IP20	Code number AHF010 IP00/ IP20	Filter current rating 50 Hz	Typical motor	VLT model and current ratings		Losses		Acoustic noise	Frame size	
						AHF005	AHF010		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 4.13 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		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 4.14 Advanced Harmonic Filters, 600 V, 60 Hz

Code number AHF005 IP00/IP20	Code number AHF010 IP00/IP20	Filter current rating 50 Hz [A]	VLT model and current ratings						Losses		Acoustic noise [dBa]	Frame size	
			Typical motor size hp [kW]	500–550 V hp [kW]	[A]	Typical motor size hp [kW]	551–690 V hp [kW]	[A]	AHF005 [W]	AHF010 [W]		AHF005	AHF010
130B5024	130B5325	77	60 [45]	N75K [N55K]	71	100 [75]	N100K [N75K]	76	841	488	<72	X6	X6
130B5169	130B5287												
130B5025	130B5326	87	75 [55]	N100K [N75K]	89				962	692	<72	X6	X6
130B5170	130B5288												
130B5026	130B5327	109	100 [75]	N125K [N90K]	110	125 [90]	N125K [N90K]	104	1080	743	<72	X6	X6
130B5172	130B5289												
130B5028	130B5328	128	125 [90]	N150 [N110]	130	150 [110]	N150 [N110]	126	1194	864	<72	X6	X6
130B5195	130B5290												
130B5029	130B5329	155	150 [110]	N175 [N132]	158	175 [132]	N175 [N132]	150	1288	905	<72	X7	X7
130B5196	130B5291												
130B5042	130B5330	197	175 [132]	N250 [N160]	198	250 [160]	N250 [N160]	186	1406	952	<72	X7	X7
130B5197	130B5292												
130B5066	130B5331	240	250 [160]	N300 [N200]	245	300 [200]	N300 [N200]	234	1510	1175	<75	X8	X7
130B5198	130B5293												
130B5076	130B5332	296	300 [200]	N350 [N250]	299	350 [250]	N350 [N250]	280	1852	1288	<75	X8	X8
130B5199	130B5294												
2x130B5042	130B5333	366	350 [250]	N450 [N315]	355	450 [315]	N450 [N315]	333	2812	1542			X8
2x130B5197	130B5295												
2x130B5042	130B5334	395	450 [315]	N475 [N355]	381	550 [400]			2812	1852			X8
130B5042 +130B5066	130B5330 +130B5331	437	475 [355]	N550 [N400]	413	650 [500]	N550 [N400]	395	2916	2127			
130B5197 +130B5198	130B5292 +130B5293												

Table 4.15 Advanced Harmonic Filters, 500–690 V, 50 Hz

4

Code number AHF005 IP00/IP20	Code number AHF010 IP00/IP20	Filter current rating 50 Hz	VLT model and current ratings						Losses		Acoustic noise	Frame size	
			Typical motor size	500–550 V		Typical motor size	551–690 V		AHF005	AHF010		AHF005	AHF010
		[A]	hp [kW]	hp [kW]	[A]	hp [kW]	hp [kW]	[A]	[W]	[W]	[dBa]		
130B5066 +130B5076	130B5331 +130B5332	536	550 [400]	P600 [P450]	504	750 [560]	P650 [P500]	482	3362	2463			
130B5198 +130B5199	130B5292 +130B5294												
2 x130B5076	2x130B5332	592	600 [450]	P650 [P500]	574	850 [630]	P750 [P560]	549	3704	2576			
2 x130B5199	2x130B5294												
130B5076 +2x130B5042	130B5332 +130B5333	662	650 [500]	P750 [P560]	642	950 [710]	P850 [P630]	613	4664	2830			
130B5199 +2x130B5197	130B5294 +130B5295												
4x130B5042	2x130B5333	732	750 [560]	P850 [P630]	743	1075 [800]	P950 [P710]	711	5624	3084			
4x130B5197	2x130B5295												
3x130B5076	3x130B5332	888	950 [670]	P950 [P710]	866	1200 [900]	P1075 [P800]	828	5556	3864			
3x130B5199	3x130B5294												
2x130B5076 +2x130B5042	2x130B5332 +130B5333	958	1050 [750]	P1075 [P800]	962	1350 [1000]	P1200 [P900]	920	6516	4118			
2x130B5199 +2x130B5197	2x130B5294 +130B5295												
6x130B5042	3x130B5333	1098	1150 [850]	P1M0	1079		P1M0	1032	8436	4626			
6x130B5197	3x130B5295												

Table 4.16 Advanced Harmonic Filters, 500–690 V, 50 Hz

4.2.3 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/D5h/D6h	130B3182	130B3183
110	212	150	190	132	190	D1h/D3h/D5h/D6h	130B3184	130B3185
132	260	200	240	160	240	D1h/D3h/D5h/D6h, D13		
160	315	250	302	200	302	D2h/D4h, D7h/D8h, D13	130B3186	130B3187
200	395	300	361	250	361	D2h/D4h,D7h/D8h, D13		
250	480	350	443	315	443	D2h/D4h, D7h, D8h, D13, 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 4.17 Sine-Wave Filter Modules, 380–500 V

4

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
45	76	60	73	55	73	D1h/D3h/D5h/D6h	130B4116	130B4117
55	90	75	86	75	86	D1h/D3h/D5h/D6h	130B4118	130B4119
75	113	100	108	90	108	D1h/D3h/D5h/D6h	130B4118	130B4119
90	137	125	131	110	131	D1h/D3h/D5h/D6h	130B4121	130B4124
110	162	150	155	132	155	D1h/D3h/D5h/D6h		
132	201	200	192	160	192	D2h/D4h, D7h/D8h	130B4125	130B4126
160	253	250	242	200	242	D2h/D4h, D7h/D8h		
200	303	300	290	250	290	D2h/D4h, D7h/D8h	130B4129	130B4151
250	360	350	344	315	344	D2h/D4h, D7h/D8h, F8/F9		
		350	344	355	380	F8/F9	130B4152	130B4153
315	429	400	400	400	410	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 4.18 Sine-Wave Filter Modules 525–690 V

NOTICE!

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

See also *Advanced Harmonic Filters Design Guide.*

4.2.4 Ordering Numbers: dU/dt Filters

Typical application ratings										Frame Size	Filter ordering number	
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				
[kW]	[A]	[HP]	[A]	[kW]	[A]	[HP]	[A]	[kW]	[A]		IP00	IP23
90	177	125	160	90	137	125	131			D1h/D3h		
110	212	150	190	110	162	150	155	110	131	D1h/D3h	130B2847	130B2848
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		
250	480	350	443	250	360	350	344	250	290	D2h/D4h, D11 E1/E2, E9, F8/F9	130B2849	130B3850
315	588	450	535	315	429	400	410	315	344	D2h/D4h, E9, F8/F9		
355	658	500	590	355	470	450	450	355	380	E1/E2, E9, F8/F9	130B2851	130B2852
								400	410	E1/E2, F8/F9		
								450	450	E1/E2, F8/F9		
400	745	600	678	400	523	500	500	500	500	E1/E2, E9, F8/F9	130B2853	130B2854
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		
560	990	750	890	560	763	750	730	710	730	F1/F3, F10/F11, F18	2x130B2851	2x130B2852
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		
800	1460	1200	1380	850	1108	1150	1060	1000	1060	F2/F4, F12/F13	3x130B2851	3x130B2852
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 4.19 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.

4

380–480 V AC			
Drive data			
Aqua FC202 [T4]	Pm (NO) hp [kW]	Number of brake choppers [1]	R_{min}
N110	150 [110]	1	3.6
N132	175 [132]	1	3
N160	250 [160]	1	2.5
N200	300 [200]	1	2
N250	350 [250]	1	1.6
N315	315	1	1.2
P355	475 [355]	1	1.2
P400	550 [400]	1	1.2
P500	650 [500]	2	0.9
P560	750 [560]	2	0.9
P630	850 [630]	2	0.8
P710	950 [710]	2	0.7
P800	1075 [800]	3	0.6
P1M0	1350 [1000]	3	0.5

Table 4.20 Brake Chopper Data, 380–480 V

525–690 V AC			
Drive data			
Aqua FC202 [T7]	Pm (NO) hp [kW]	Number of brake choppers[1]	R_{min}
N75K	100 [75]	1	13.5
N90K	125 [90]	1	8.8
N110	150 [110]	1	8.2
N132	175 [132]	1	6.6
N160	250 [160]	1	4.2
N200	300 [200]	1	4.2
N250	350 [250]	1	3.4
N315	315	1	2.3
N400	550 [400]	1	2.3
P450	600 [450]	1	2.3
P500	650 [500]	1	2.1
P560	750 [560]	1	2
P630	850 [630]	1	2
P710	950 [710]	2	1.3
P800	1075 [800]	2	1.1
P900	1200 [900]	2	1.1
P1M0	1350 [1000]	3	1
P1M2	1600 [1200]	3	0.8
P1M4	1875 [1400]	3	0.7

Table 4.21 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.

Danfoss

5 How to Install

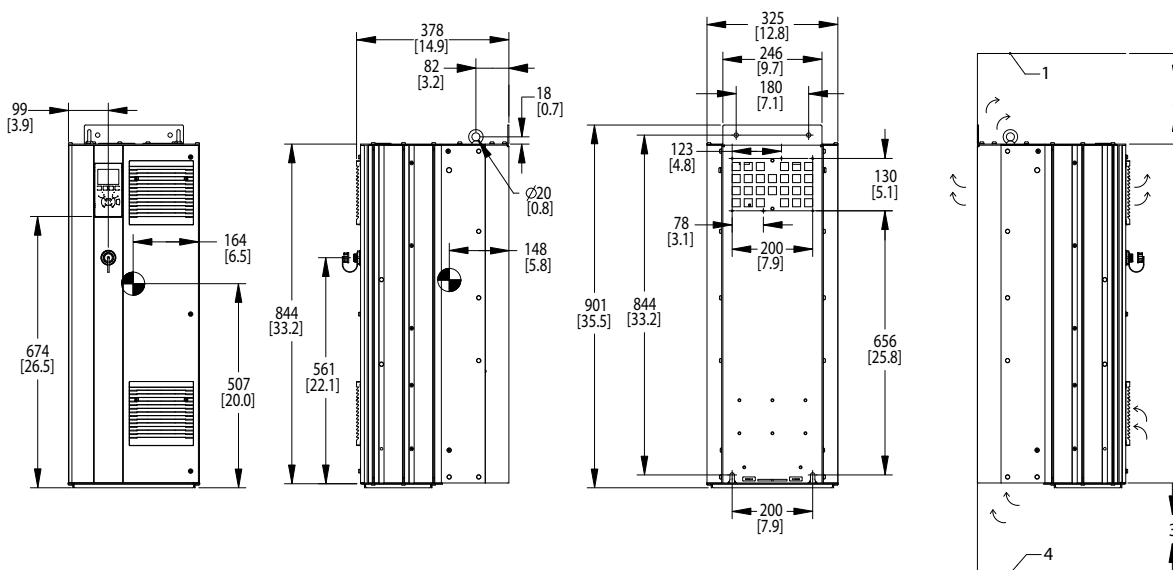## 5.1 Mechanical Installation

5.1.1 Mechanical Dimensions

Figure 5.1 Mechanical Dimensions, D1h

1	Ceiling
2	Air space outlet minimum 225 mm [8.9 in]
3	Air space inlet minimum 225 mm [8.9 in]
4	Floor

Table 5.1 Legend to *Figure 5.1*

NOTICE!

If using a kit to direct the airflow from the heatsink to the outside vent on the back of the adjustable frequency drive, the required ceiling clearance is 4 in [100 mm].
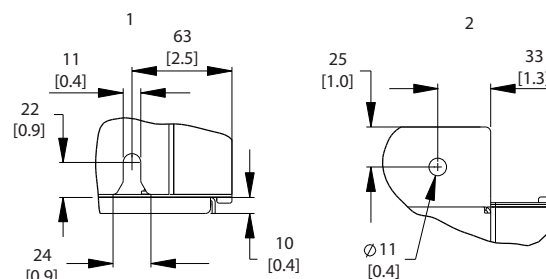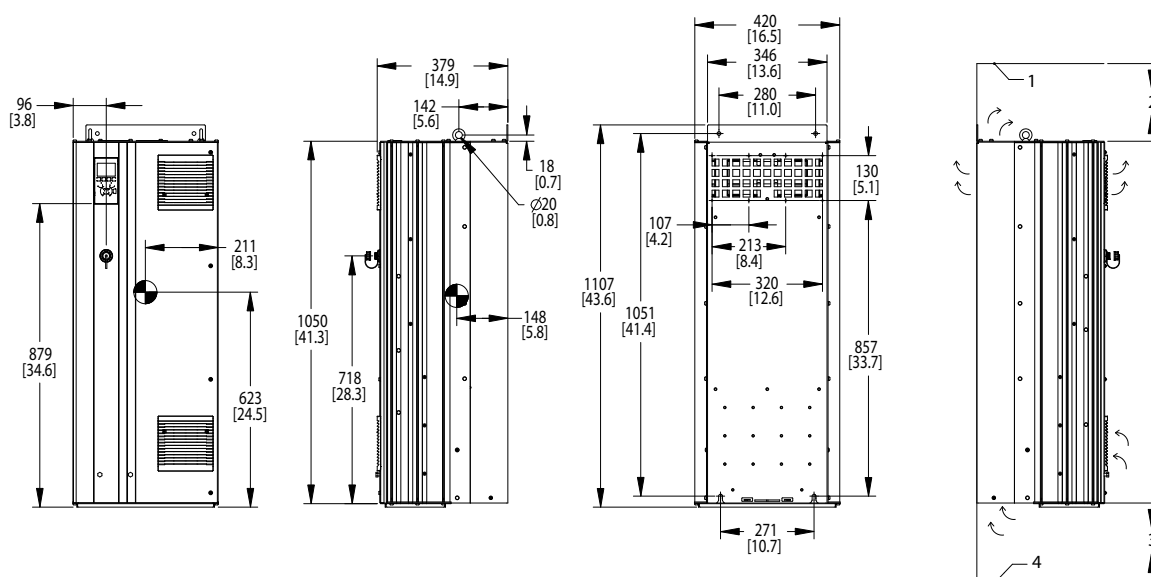

Figure 5.2 Detail Dimensions, D1h

1	Bottom mounting slot detail
2	Top mounting hole detail

Table 5.2 Legend to *Figure 5.2*

Figure 5.3 Mechanical Dimensions, D2h

1	Ceiling
2	Air space outlet minimum 225 mm [8.9 in]
3	Air space inlet minimum 225 mm [8.9 in]
4	Floor

Table 5.3 Legend to *Figure 5.3*

NOTICE!

If using a kit to direct the airflow from the heatsink to the outside vent on the back of the adjustable frequency drive, the required ceiling clearance is 4 in [100 mm].
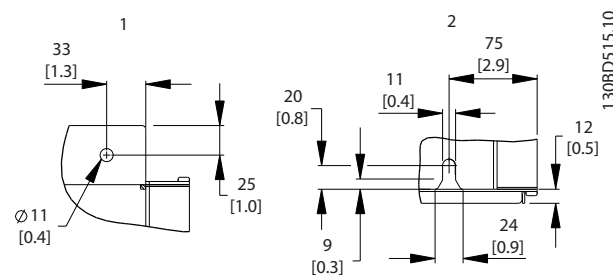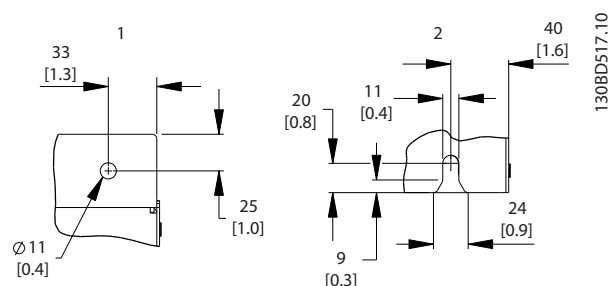

Figure 5.4 Detail Dimensions, D2h

1	Top mounting hole detail
2	Bottom mounting slot detail

Table 5.4 Legend to *Figure 5.4*
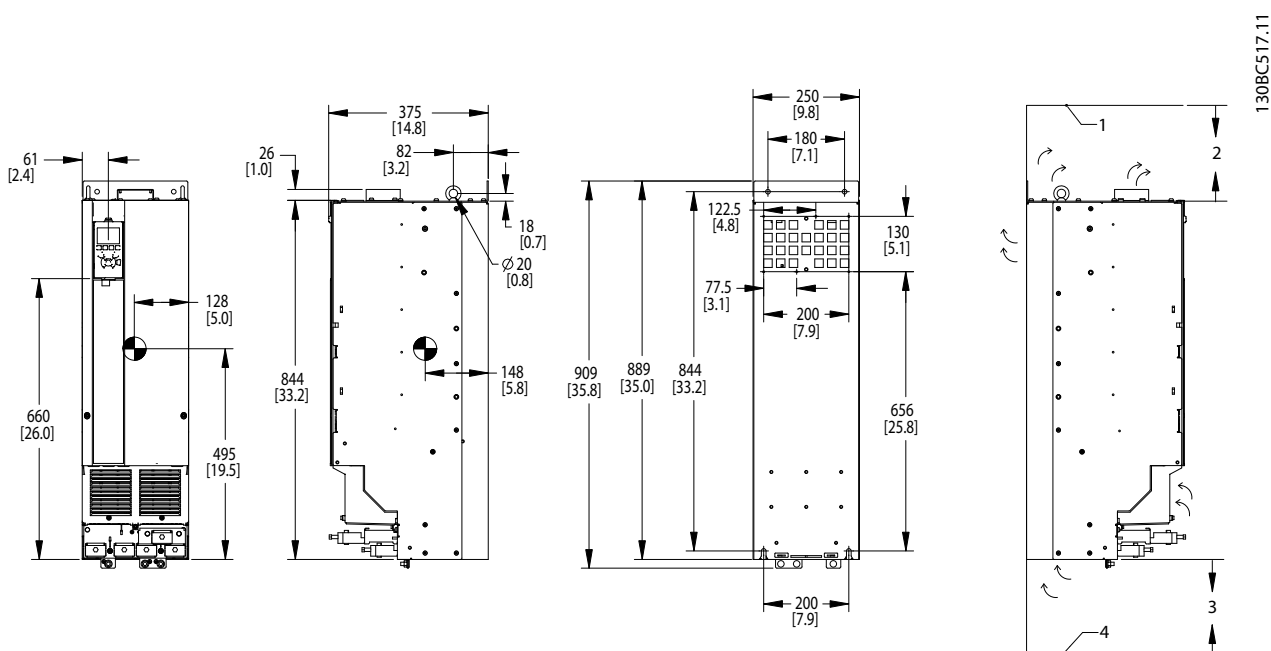
Figure 5.5 Mechanical Dimensions, D3h

1	Ceiling
2	Air space outlet minimum 225 mm [8.9 in]
3	Air space inlet minimum 225 mm [8.9 in]
4	Floor

Table 5.5 Legend to *Figure 5.5*

NOTICE!

If using a kit to direct the airflow from the heatsink to the outside vent on the back of the adjustable frequency drive, the required ceiling clearance is 4 in [100 mm].

Figure 5.6 Detail Dimensions, D3h

1	Top mounting hole detail
2	Bottom mounting slot detail

Table 5.6

5

Figure 5.7 Mechanical Dimensions, D4h

1	Ceiling
2	Air space outlet minimum 225 mm [8.9 in]
3	Air space inlet minimum 225 mm [8.9 in]
4	Floor

Table 5.7 Legend to *Figure 5.7*

NOTICE!

If using a kit to direct the airflow from the heatsink to the outside vent on the back of the adjustable frequency drive, the required ceiling clearance is 4 in [100 mm].

Figure 5.8 Detail Dimensions, D4h

1	Top mounting hole detail
2	Bottom mounting slot detail

Table 5.8 Legend to *Figure 5.8*

Figure 5.9 Mechanical Dimensions, D5h

1	Ceiling
2	Air space outlet minimum 225 mm [8.9 in]

Table 5.9 Legend to *Figure 5.9*

NOTICE!

If using a kit to direct the airflow from the heatsink to the outside vent on the back of the adjustable frequency drive, the required ceiling clearance is 4 in [100 mm].
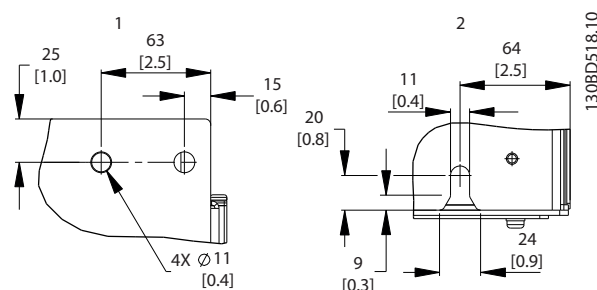
Figure 5.10 Detail Dimensions, D5h

1	Top mounting hole detail
2	Bottom mounting slot detail

Table 5.10 Legend to *Figure 5.10*

5
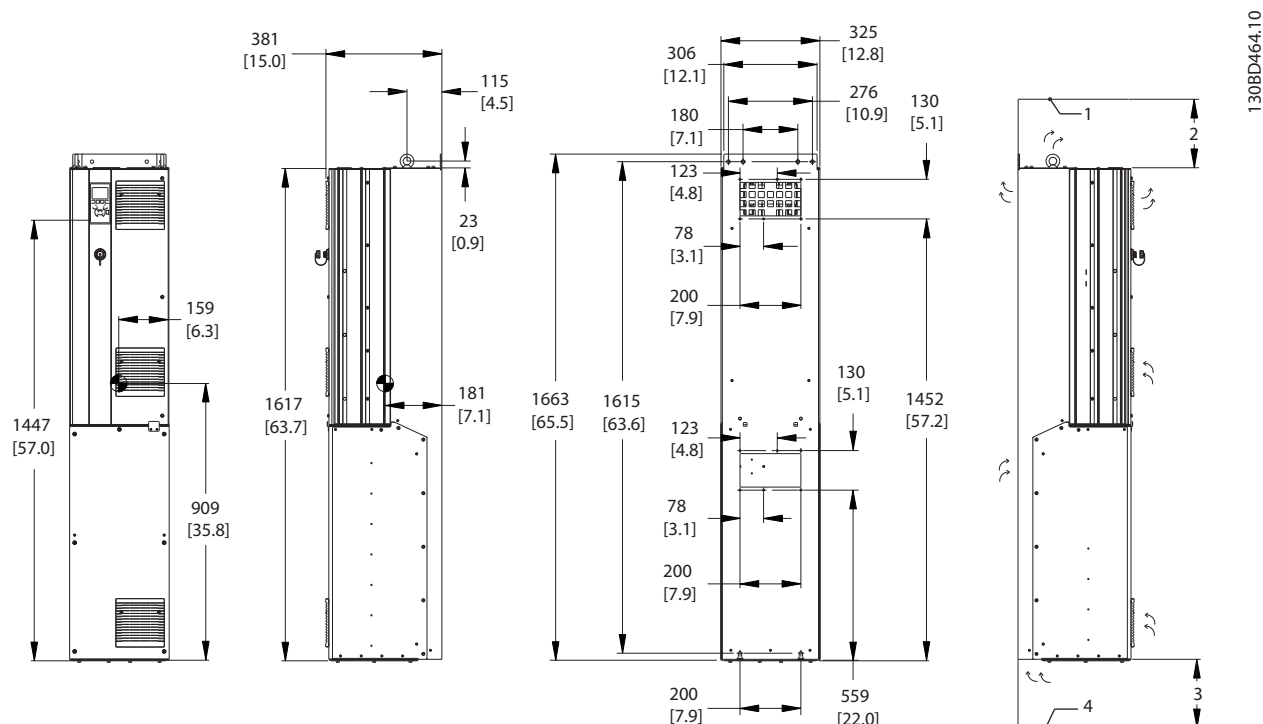
Figure 5.11 Mechanical Dimensions, D6h

1	Ceiling
2	Air space outlet minimum 225 mm [8.9 in]
3	Air space inlet minimum 225 mm [8.9 in]
4	Floor

Table 5.11 Legend to *Figure 5.11*

NOTICE!

If using a kit to direct the airflow from the heatsink to the outside vent on the back of the adjustable frequency drive, the required ceiling clearance is 4 in [100 mm].
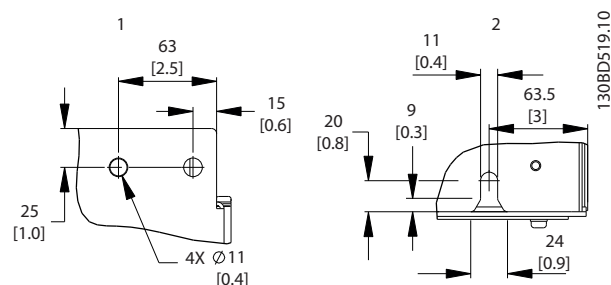

Figure 5.12 Detail Dimensions, D6h

1	Top mounting hole detail
2	Bottom mounting slot detail

Table 5.12 Legend to *Figure 5.12*
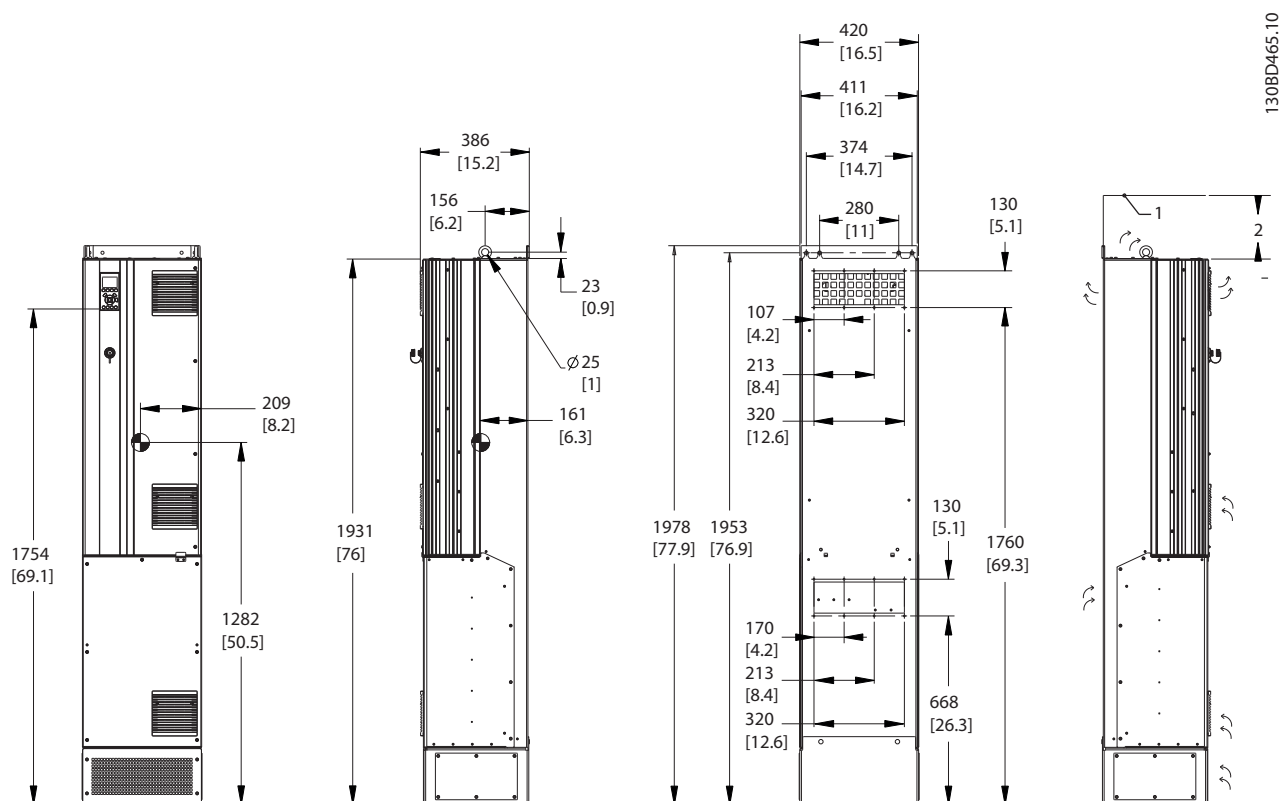
Figure 5.13 Mechanical Dimensions, D7h

1	Ceiling
2	Air space outlet minimum 225 mm [8.9 in]

Table 5.13 Legend to *Figure 5.13*

NOTICE!

If using a kit to direct the airflow from the heatsink to the outside vent on the back of the adjustable frequency drive, the required ceiling clearance is 4 in [100 mm].
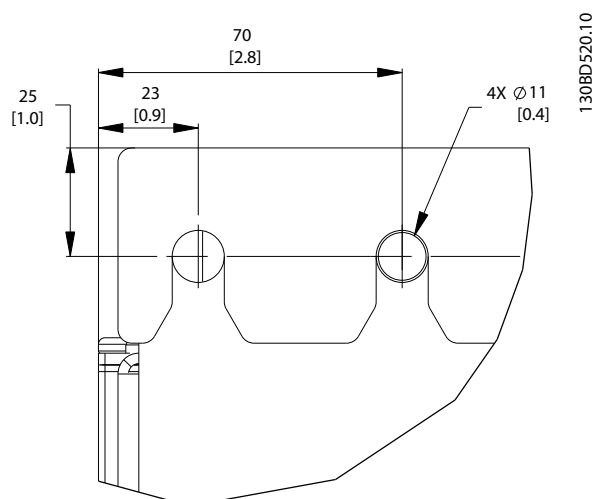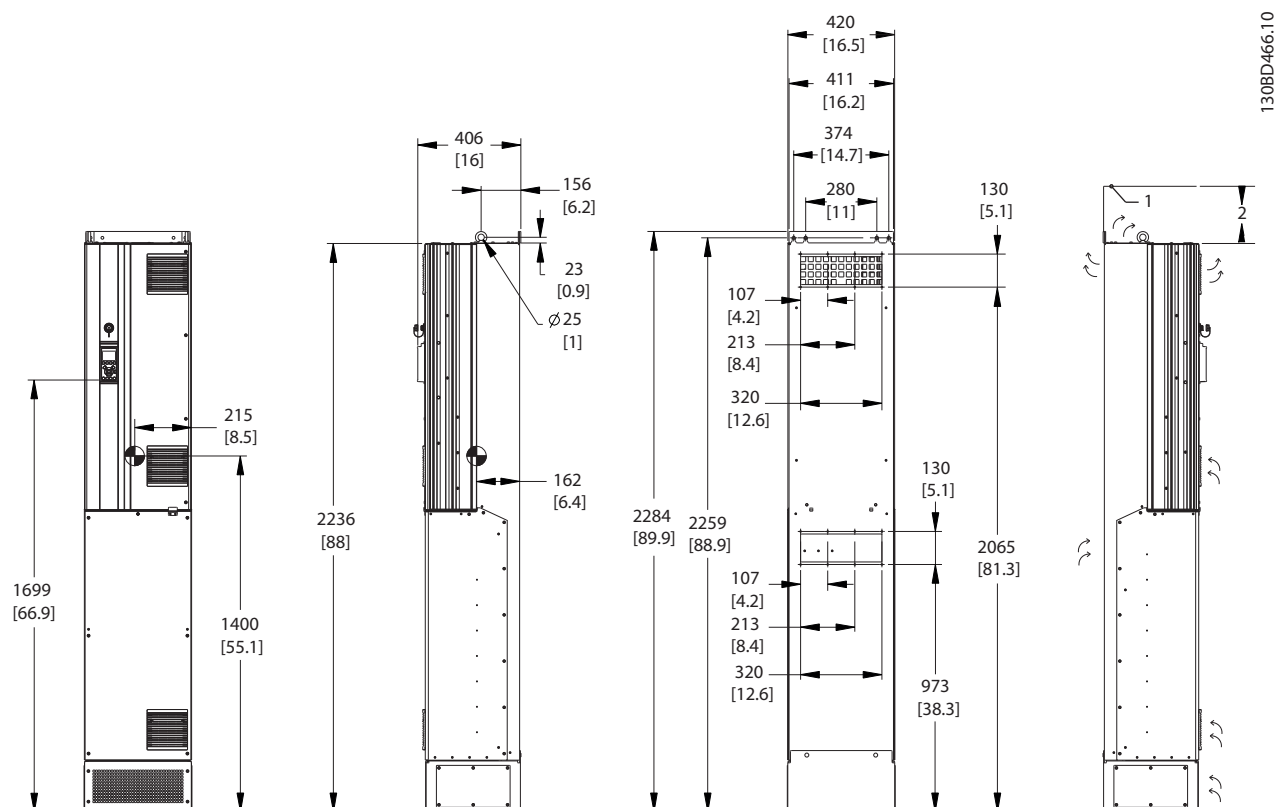

Figure 5.14 Top Mounting Hole Dimension Detail, D7h

Figure 5.15 Mechanical Dimensions, D8h

1	Ceiling
2	Air space outlet minimum 225 mm [8.9 in]

Table 5.14 Legend to *Figure 5.15*

NOTICE!

If using a kit to direct the airflow from the heatsink to the outside vent on the back of the adjustable frequency drive, the required ceiling clearance is 4 in [100 mm].
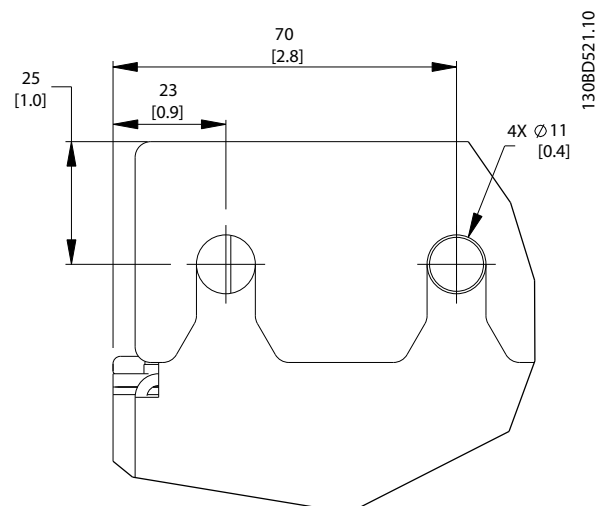

Figure 5.16 Top Mounting Hole Dimension Detail, D8h
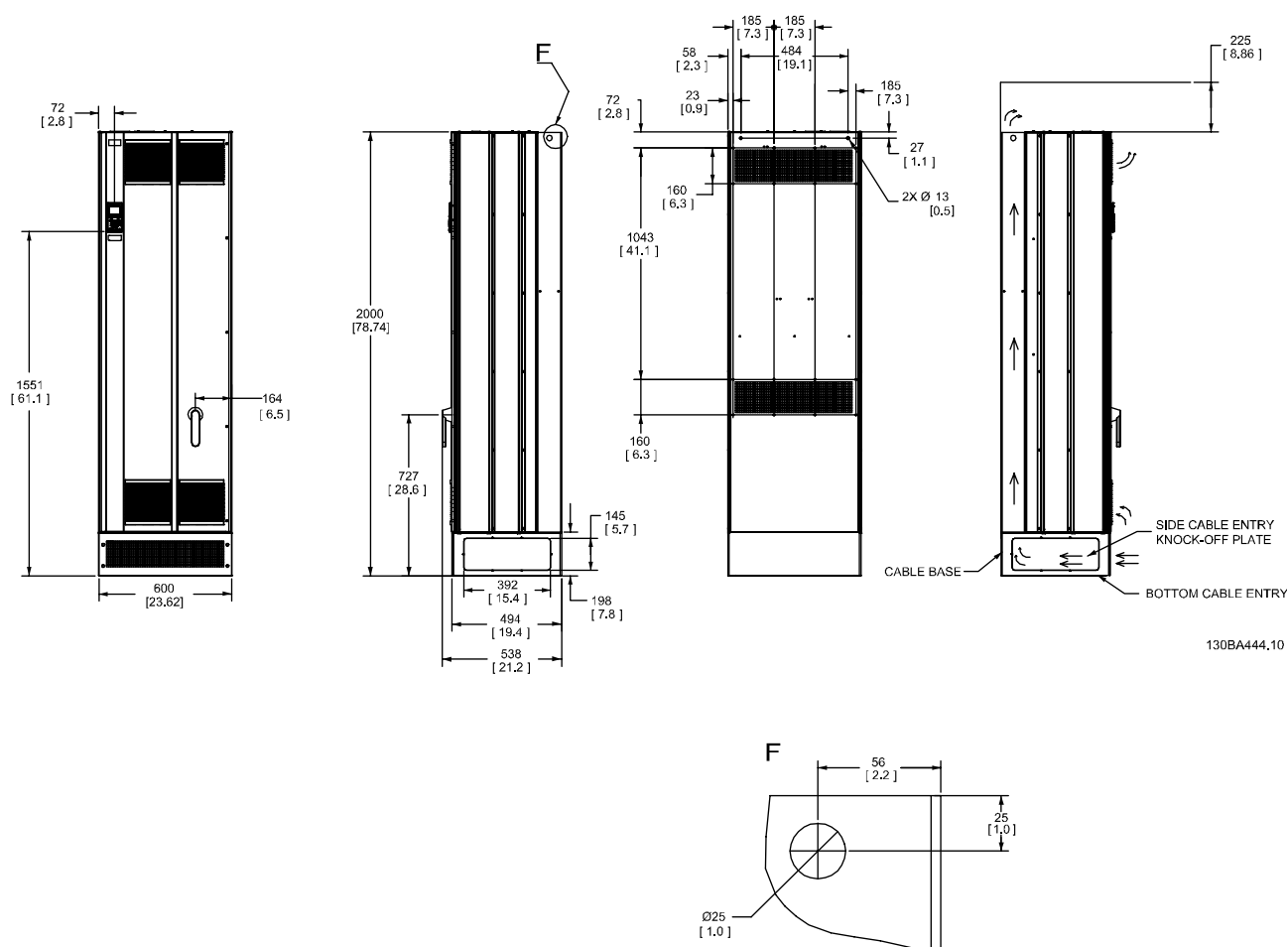
E1   IP21 AND IP54 / UL AND NEMA TYPE 1 AND 12

Figure 5.17 Mechanical Dimensions, E1

F	Lifting eye detail

Table 5.15 Legend to *Figure 5.17*

5

E2   IP00 / CHASSIS
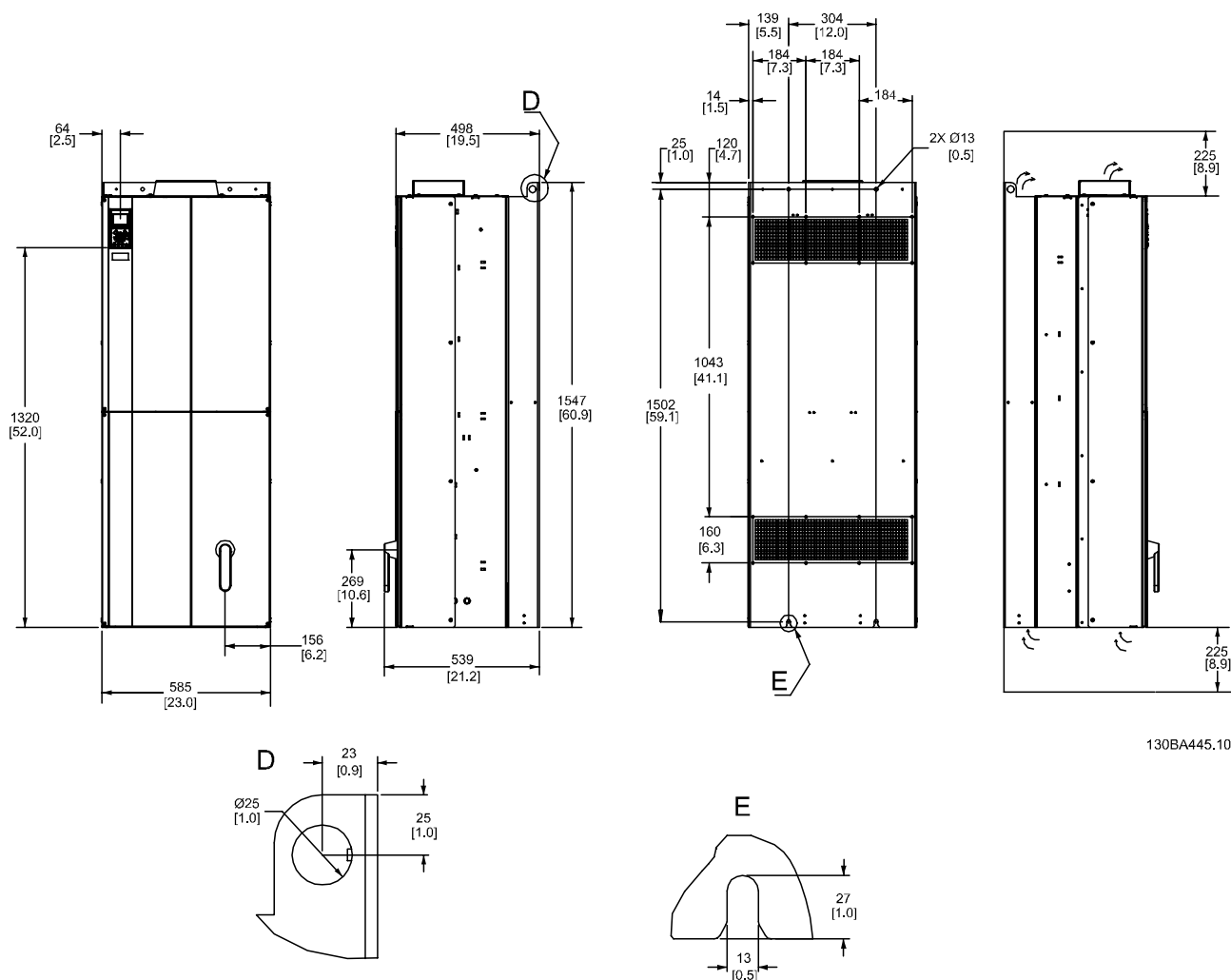
Figure 5.18 Mechanical Dimensions, E2

D	Lifting eye detail
E	Rear mounting slots

Table 5.16 Legend to *Figure 5.18*

130BA445.10

130BB028.10

1804
(71.0)

Ø29
(1.1)

1
225.0
(8.85)

2281
(89.8)

2206
(86.9)

1499
(59.0)

606
(23.8)
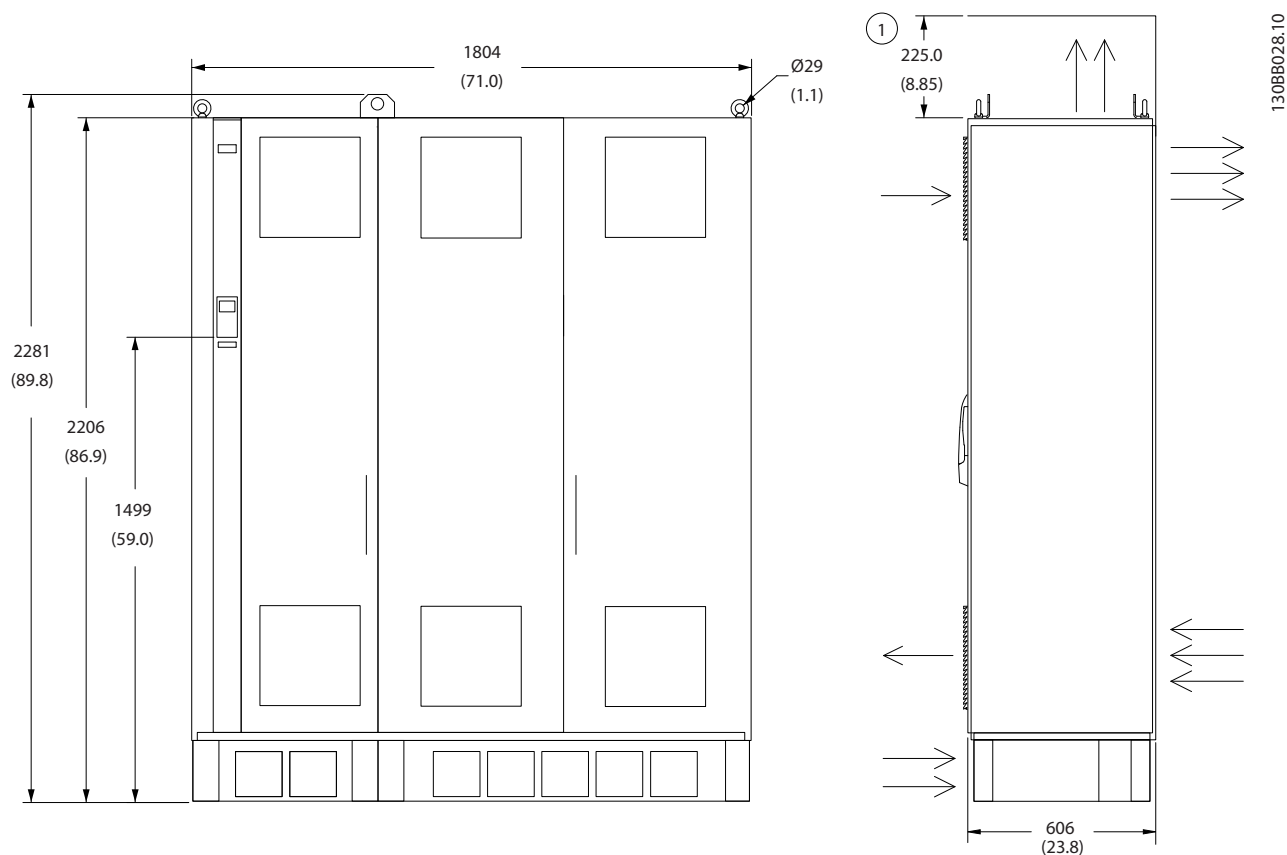
Figure 5.19 Mechanical Dimensions, F2

1	Minimum clearance from ceiling

Table 5.17 Legend to *Figure 5.19*

5

130BB030.10

2401
(94.5)

Ø29
(1.1)

225.0
(8.85)

2280
(89.7)

2205
(86.8)

1497
(58.9)

604
(23.8)
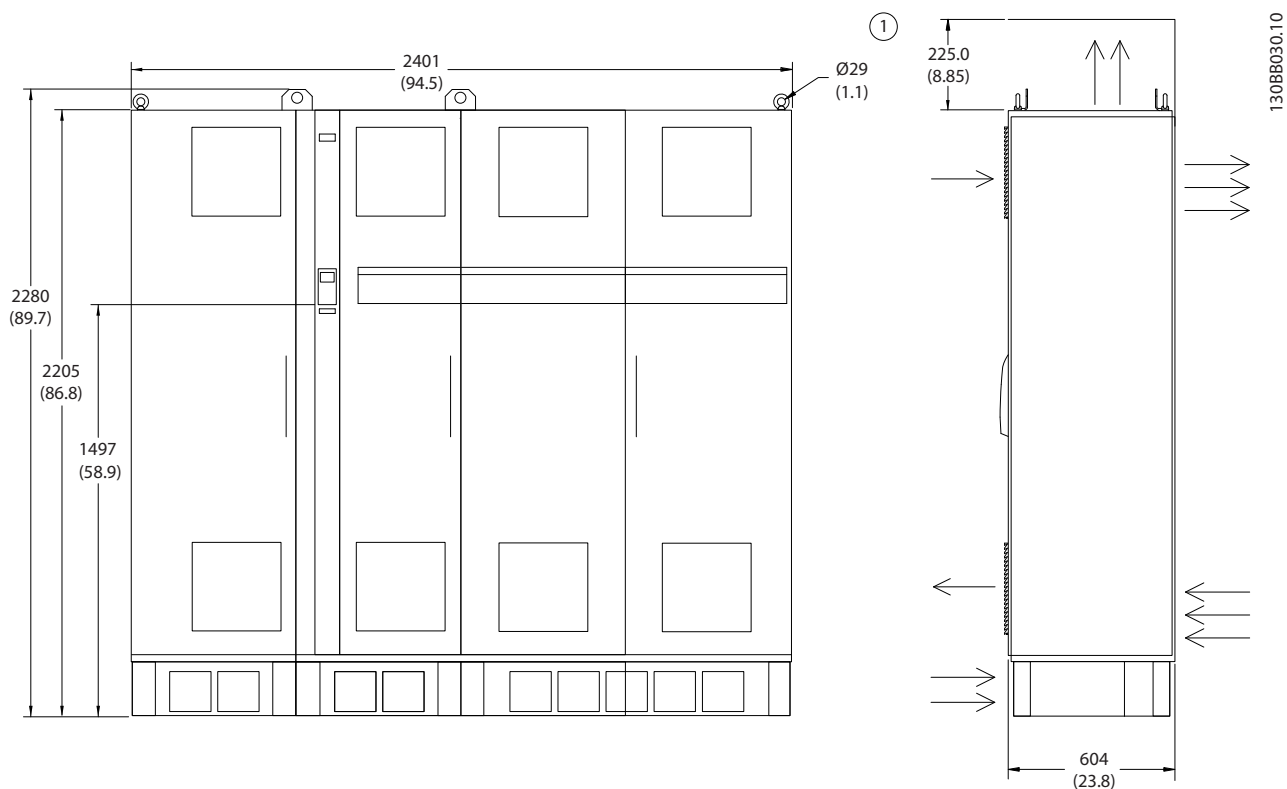
Figure 5.20 Mechanical Dimensions, F4

1	Minimum clearance from ceiling

Table 5.18 Legend to *Figure 5.20*

98   MG16C122

Frame size		D1h	D2h	D3h	D4h	D3h	D4h
		125–175 hp [90–132 kW] (380–500 V) 125–175 hp [90–132 kW] (525–690 V)	250–350 hp [160–250 kW] (380–500 V) 250–450 hp [160–315 kW] (525–690 V)	125–175 hp [90–132 kW] (380–500 V) 50–175 hp [37–132 kW] (525–690 V)	250–350 hp [160–250 kW] (380–500 V) 250–450 hp [160–315 kW] (525–690 V)	With Regeneration or Load Share Terminals	
IP		21/54	21/54	20	20	20	20
NEMA		Type 1/12	Type 1/12	Chassis	Chassis	Chassis	Chassis
Shipping dimensions (in [mm])	Height	23.11 [587]	23.11 [587]	23.11 [587]	23.11 [587]	23.11 [587]	23.11 [587]
	Width	39.25 [997]	46.06 [1170]	39.25 [997]	46.06 [1170]	48.43 [1230]	56.30 [1430]
	Depth	18.11 [460]	21.06 [535]	18.11 [460]	21.06 [535]	18.11 [460]	21.06 [535]
Drive dimensions (in [mm])	Height	35.47 [901]	41.73 [1060]	35.79 [909]	44.17 [1122]	39.53 [1004]	49.93 [1268]
	Width	12.80 [325]	16.54 [420]	9.84 [250]	13.78 [350]	9.84 [250]	13.78 [350]
	Depth	14.88 [378]	14.88 [378]	14.76 [375]	14.76 [375]	14.76 [375]	14.76 [375]
Max weight (lbs [kg])		216.05 [98]	361.56 [164]	216.05 [98]	361.56 [164]	238.10 [108]	394.63 [179]

Table 5.19 Mechanical Dimensions, Frame Size D1h-D4h

Frame size		D5h	D6h	D7h	D8h
		125–175 hp [90–132 kW] (380–500 V) 125–175 hp [90–132 kW] (525–690 V)	125–175 hp [90–132 kW] (380–500 V) 125–175 hp [90–132 kW] (525–690 V)	250–350 hp [160–250 kW] (380–500 V) 250–450 hp [160–315 kW] (525–690 V)	250–350 hp [160–250 kW] (380–500 V) 250–450 hp [160–315 kW] (525–690 V)
IP		21/54	21/54	21/54	21/54
NEMA		Type 1/12	Type 1/12	Type 1/12	Type 1/12
Shipping dimensions (in [mm])	Height	25.98 [660]	25.98 [660]	25.98 [660]	25.98 [660]
	Width	71.65 [1820]	71.65 [1820]	97.24 [2470]	97.24 [2470]
	Depth	20.08 [510]	20.08 [510]	23.23 [590]	23.23 [590]
Drive dimensions (in [mm])	Height	52.13 [1324]	65.47 [1663]	77.87 [1978]	89.92 [2284]
	Width	12.80 [325]	12.80 [325]	16.54 [420]	16.54 [420]
	Depth	15.0 [381]	15.0 [381]	15.20 [386]	15.98 [406]
Max weight (lbs [kg])		255.74 [116]	284.40 [129]	440.92 [200]	496.04 [225]

Table 5.20 Mechanical Dimensions, Frame Size D5h-D8h

5

Frame size		E1	E2	F1	F2	F3	F4
		350–550 hp	350–550 hp	600–850 hp	950–1075 hp	600–850 hp	950–1075 hp
		[250–400 kW]	[250–400 kW]	[450–630 kW]	[710–800 kW]	[450–630 kW]	[710–800 kW]
		(380–500 V)	(380–500 V)	(380–500 V)	(380–500 V)	(380–500 V)	(380–500 V)
		475–750 hp	475–750 hp	850–1075 hp	1200–1600 hp	850–1075 hp	1200–1600 hp
		[355–560 kW]	[355–560 kW]	[630–800 kW]	[900–1200 kW]	[630–800 kW]	[900–1200 kW]
		(525–690 V)	(525–690 V)	(525–690 V)	(525–690 V)	(525–690 V)	(525–690 V)
IP		21, 54	00	21, 54	21, 54	21, 54	21, 54
NEMA		Type 12	Chassis	Type 12	Type 12	Type 12	Type 12
Shipping	Height	33.07 [840]	32.72 [831]	91.50 [2324]	91.50 [2324]	91.50 [2324]	91.50 [2324]
dimensions	Width	86.50 [2197]	67.13 [1705]	61.77 [1569]	77.24 [1962]	85.0 [2159]	100.75 [2559]
(in [mm])	Depth	28.98 [736]	28.98 [736]	44.49 [1130]	44.49 [1130]	44.49 [1130]	44.49 [1130]
Drive	Height	78.74 [2000]	60.91 [1547]	86.77 [2204]	86.77 [2204]	86.77 [2204]	86.77 [2204]
dimensions	Width	23.62 [600]	23.03 [585]	55.12 [1400]	70.87 [1800]	78.74 [2000]	94.49 [2400]
(in [mm])	Depth	19.45 [494]	19.61 [498]	23.86 [606]	23.86 [606]	23.86 [606]	23.86 [606]
Max weight (lbs [kg])		690.05 [313]	610.68 [277]	2242.10 [1017]	2777.82 [1260]	2905.69 [1318]	3441.42 [1561]

Table 5.21 Mechanical Dimensions, Frame Size E1-E2, F1-F4
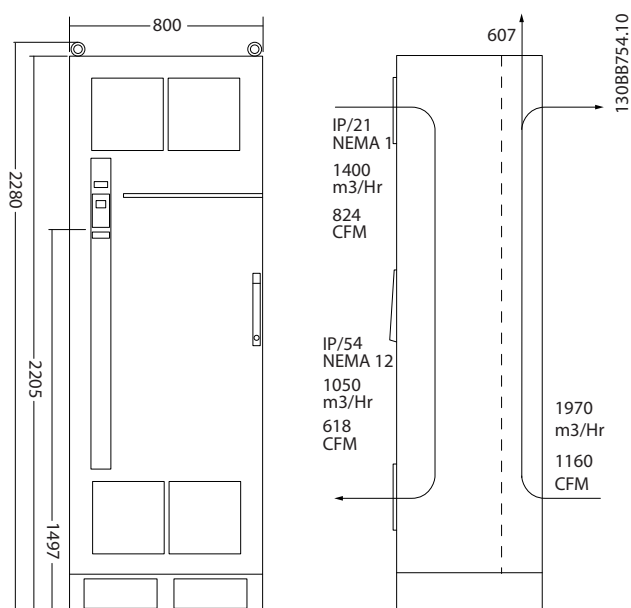
5.1.2 Mechanical Dimensions, 12-Pulse Units
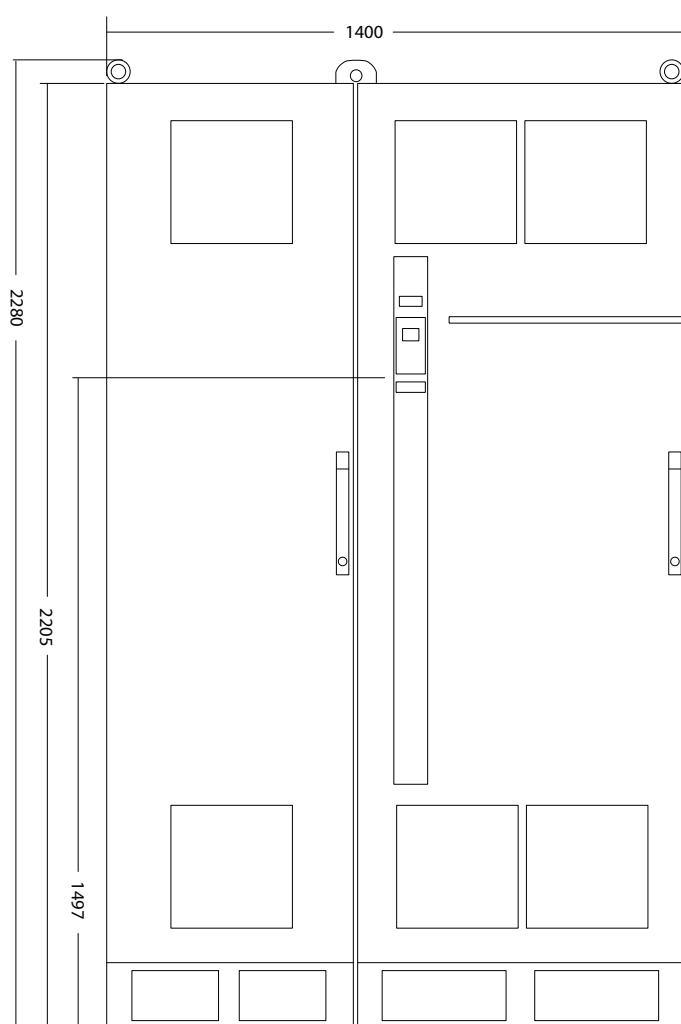

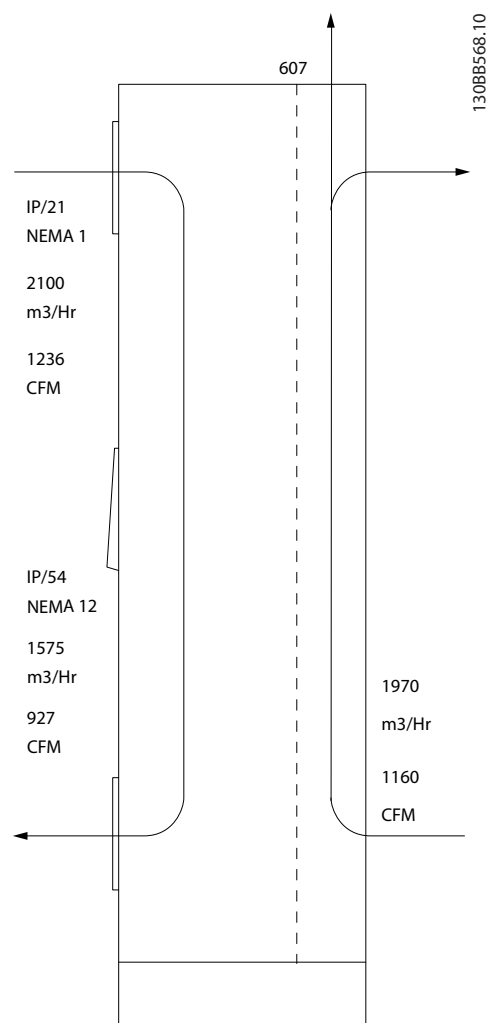**Figure 5.21 Mechanical Dimensions (mm), F8**

                        MG16C122

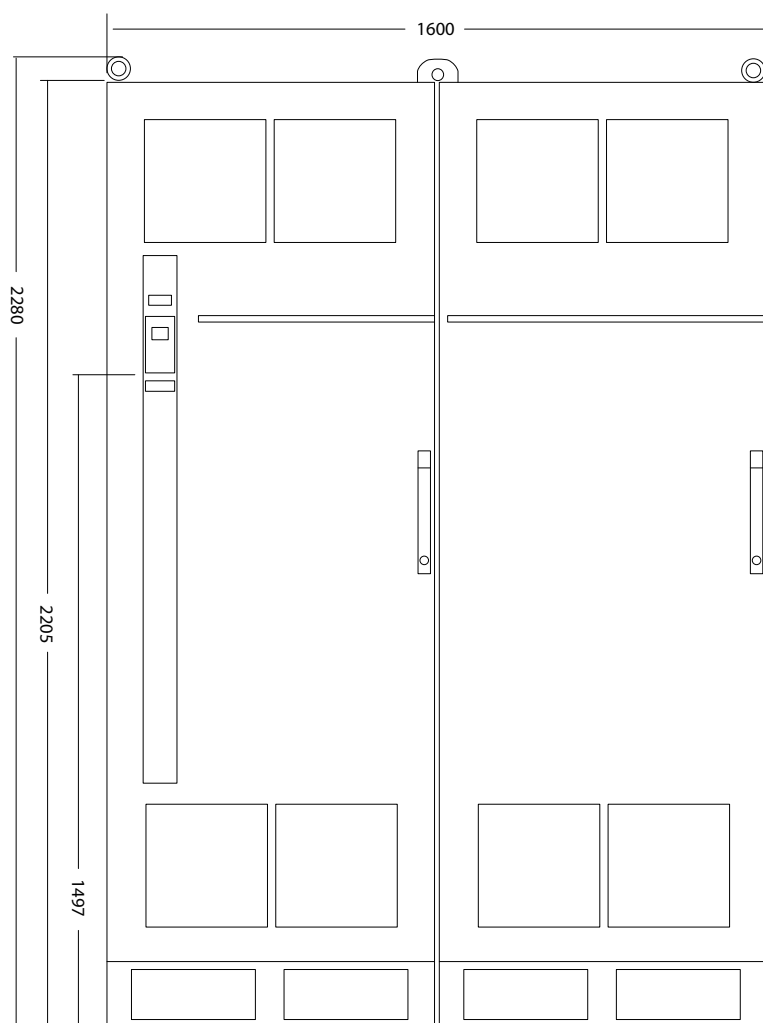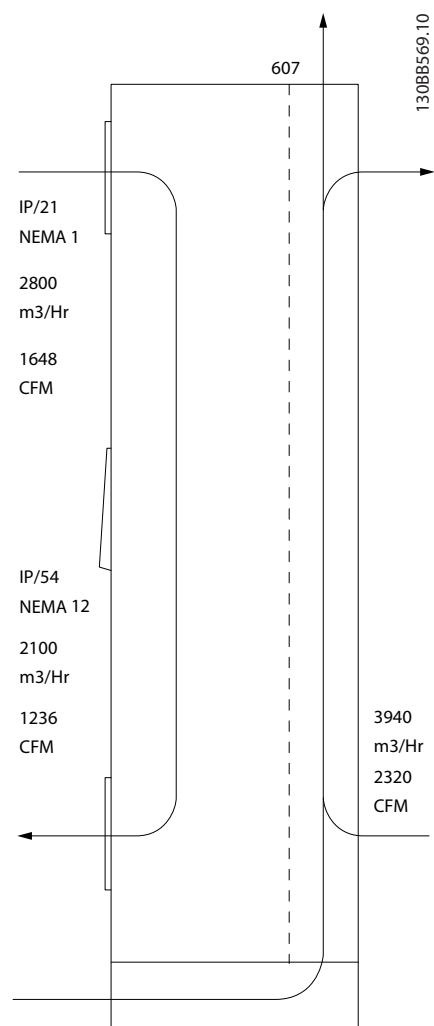**Figure 5.22 Mechanical Dimensions (mm), F9**

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130BB569.10

Figure 5.23 Mechanical Dimensions (mm), F10

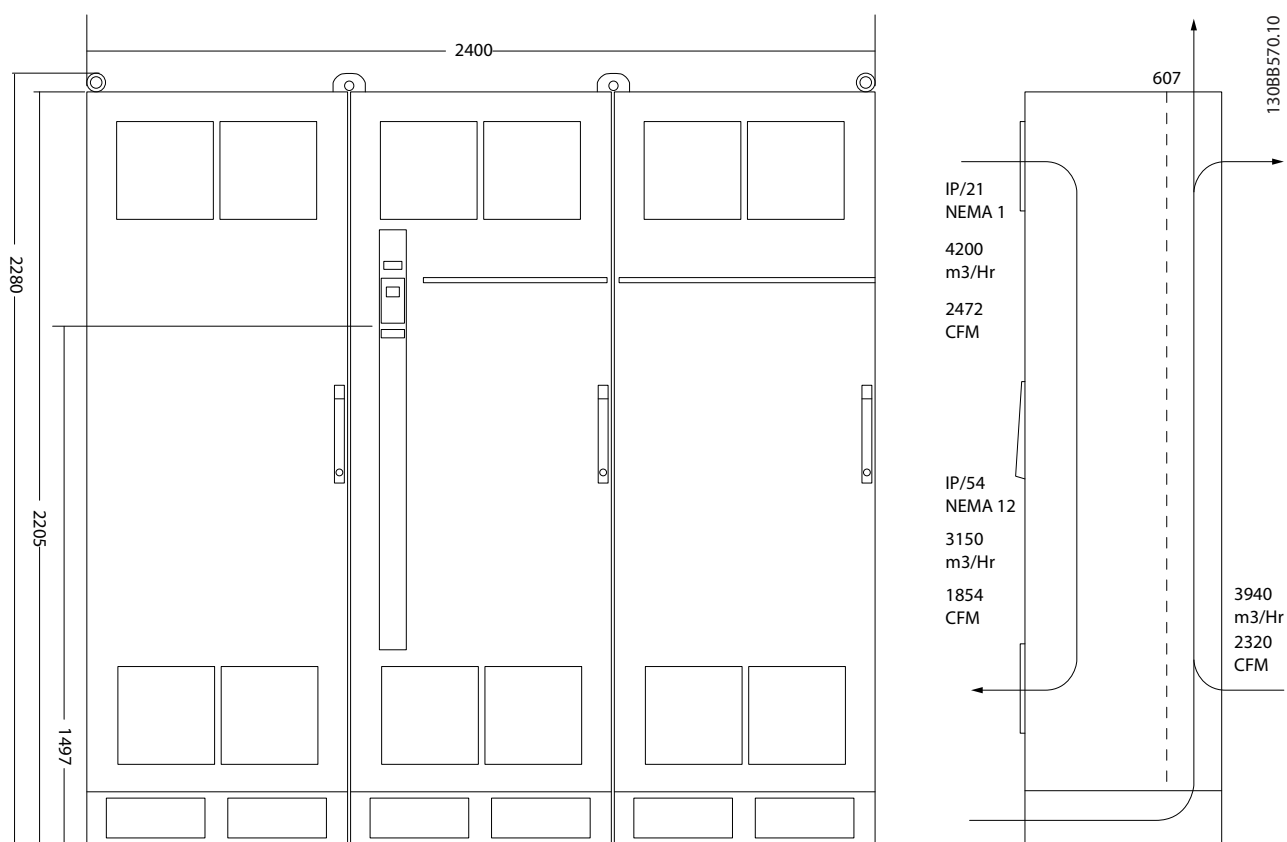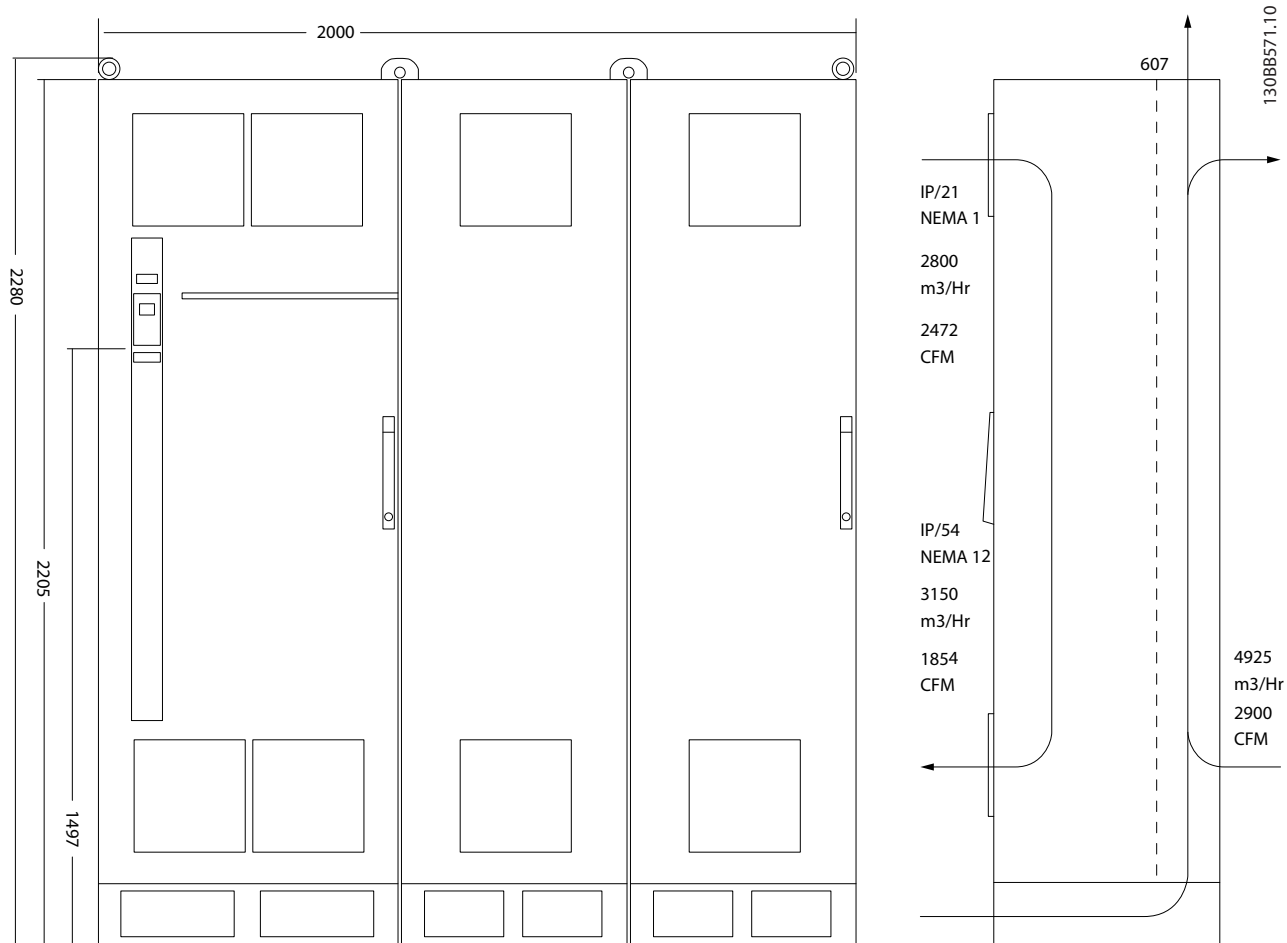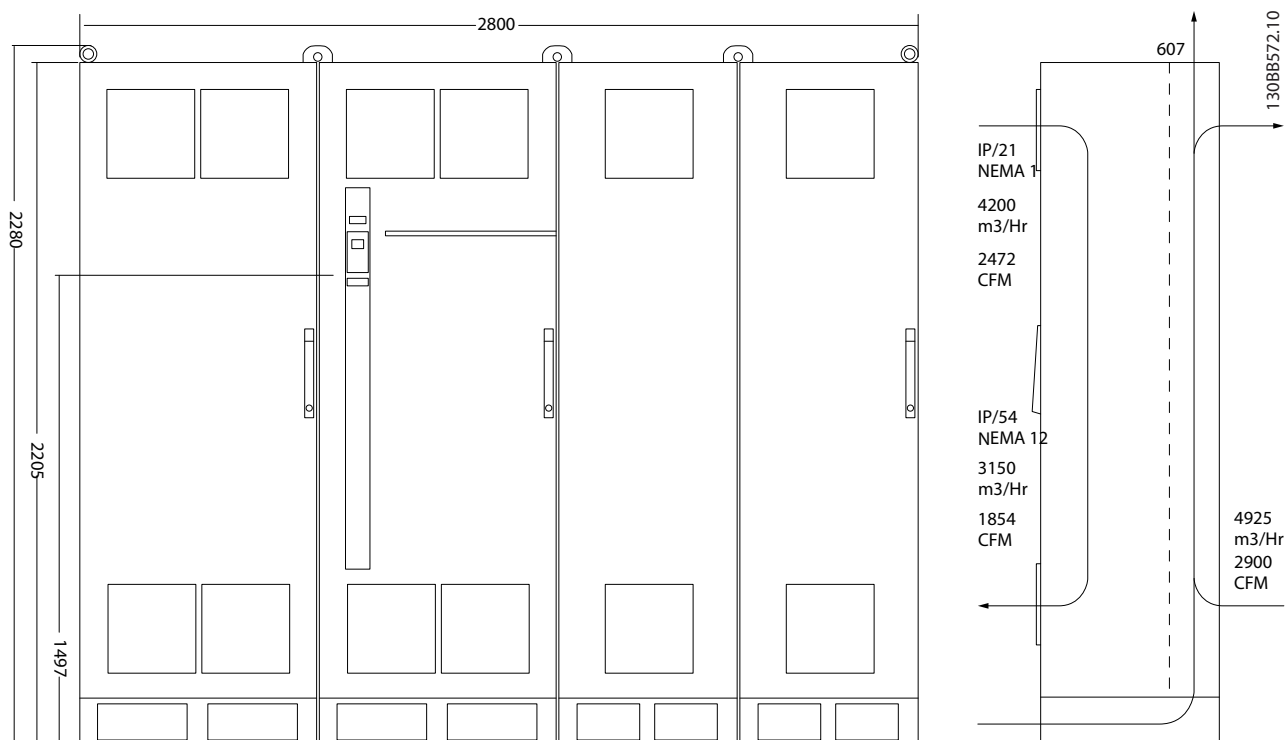**Figure 5.24 Mechanical Dimensions (mm), F11**

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Figure 5.25 Mechanical Dimensions (mm), F12

Figure 5.26 Mechanical Dimensions (mm), F13

Frame size		F8	F9	F10	F11	F12	F13
High overload rated power - 160% overload torque		**350–550 hp [250–400 kW] (380–500 V)**	**350–550 hp [250–400 kW] (380–500 V)**	**600–850 hp [450–630 kW] (380–500 V)**	**600–850 hp [450–630 kW] (380–500 V)**	**950–1075 hp [710–800 kW] (380–500 V)**	**950–1075 hp [710–800 kW] (380–500 V)**
		475–750 hp [355–560 kW] (525–690 V)	**475–750 hp [355–560 kW] (525–690 V)**	**850–1075 hp [630–800 kW] (525–690 V)**	**850–1075 hp [630–800 kW] (525–690 V)**	**1200–1600 hp [900–1200 kW] (525–690 V)**	**1200–1600 hp [900–1200 kW] (525–690 V)**
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
Shipping dimensions (in [mm])	Height	91.50 [2324]					
	Width	38.19 [970]	61.73 [1568]	69.29 [1760]	100.75 [2559]	85.04 [2160]	116.54 [2960]
	Depth	44.49 [1130]					
Drive dimensions (in [mm])	Height	86.77 [2204]					
	Width	31.50 [800]	55.12 [1400]	62.99 [1600]	86.61 [2200]	78.74 [2000]	102.36 [2600]
	Depth	23.86 [606]					
Max weight (lbs [kg])		985.47 [447]	1474.89 [669]	1968.73 [893]	2460.36 [1116]	2286.19 [1037]	2775.62 [1259]

Table 5.22 Mechanical Dimensions, 12-Pulse Units, Frame Sizes F8-F13

5.1.3 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 [mm]
D1h/D2h/D3h/D4h/D5h/D6h/D7h/D8h	225
E1/E2	225
F1/F2/F3/F4	225
F8/F9/F10/F11/F12/F13	225

Table 5.23 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].

5.1.4 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 5.27*.
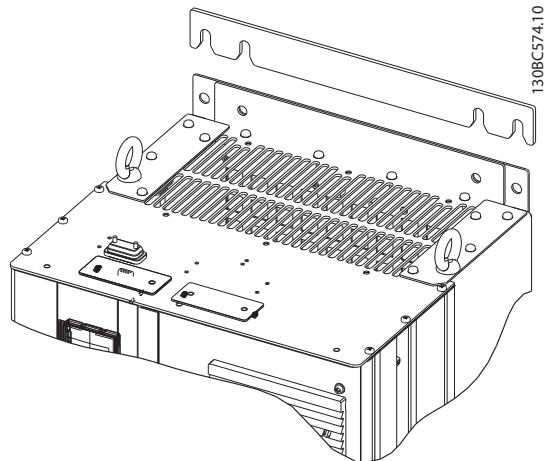

Figure 5.27 Wall Mounting Spacer

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To install a pedestal-mounted D-frame unit, perform the following steps as shown in *Figure 5.28*:

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

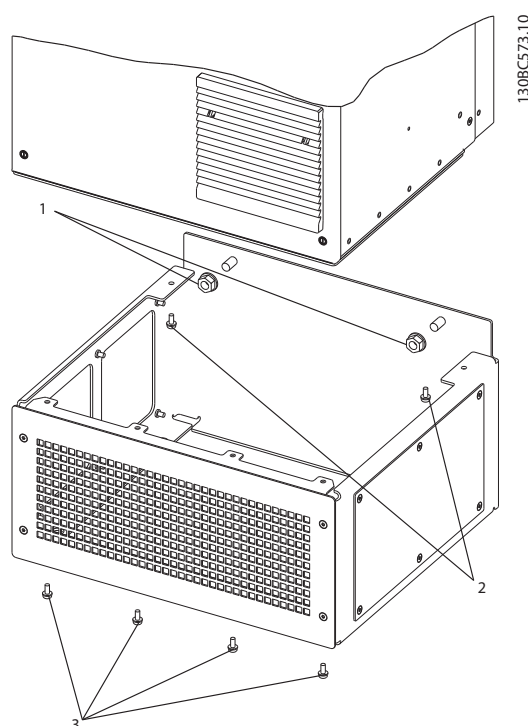3. Fasten four M5 screws through the front pedestal flange into the front connector plate mounting holes

Figure 5.28 Pedestal Hardware Installation

5.1.5 Pedestal Installation of F-frames

The F-frame adjustable frequency drives are shipped with a pedestal. The F-frame pedestals use eight bolts instead of four, as shown in *Figure 5.29*.
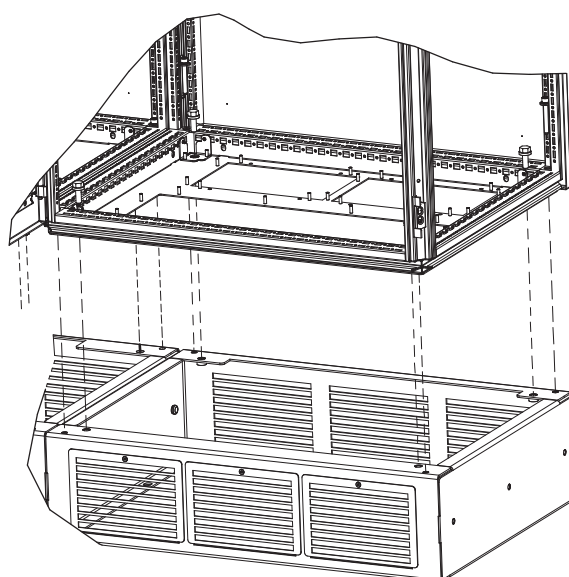

Figure 5.29 Pedestal Bolt Installation

To install a pedestal-mounted F-frame unit, perform the following steps:

1. If using a kit to direct the airflow from the heatsink to the outside vent on the back of the adjustable frequency drive, verify that there is a minimum of 4 in [100 mm] ceiling clearance.

2. 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. Refer to *Figure 5.30*

3. 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. Refer to *Figure 5.30*
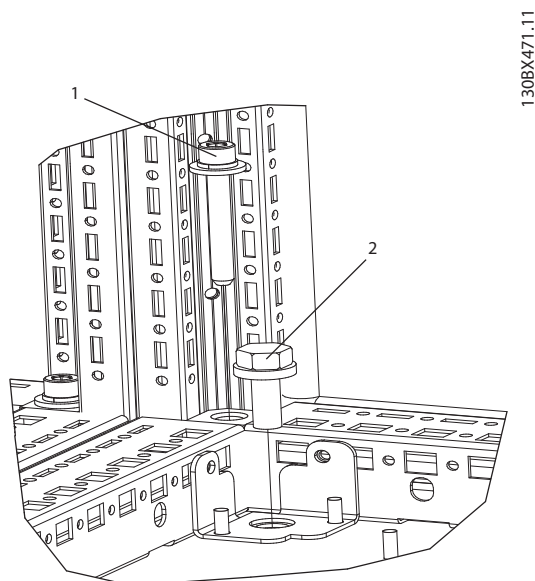
Figure 5.30 Fastener Location Detail

1	M8x60 mm bolt
2	M10x30 mm bolt

Table 5.24 Legend to *Figure 5.30*

5.1.6 Lifting

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

The following figures demonstrate the recommended lifting methods for the different frame sizes. In addition to *Figure 5.33*, *Figure 5.34*, and *Figure 5.35*, a spreader bar is an acceptable way to lift the F-frame.

⚠ WARNING

The lifting bar must be able to handle the weight of the adjustable frequency drive. See *chapter 5.1.1 Mechanical Dimensions* for the weight of each frame size. 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.
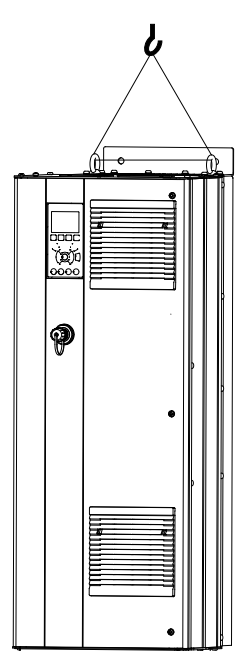

Figure 5.31 Recommended Lifting Method, D-frame Size
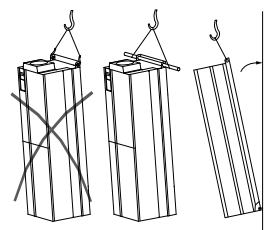
Figure 5.32 Recommended Lifting Method, E-frame Size
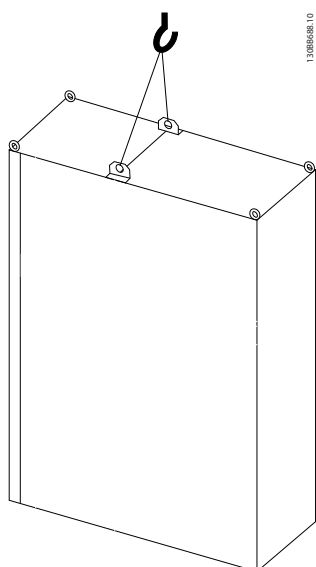
Figure 5.33 Recommended Lifting Method, Frame Sizes F1, F2, F9 and F10

Figure 5.34 Recommended Lifting Method, Frame Sizes F3, F4, F11, F12 and F13

Figure 5.35 Recommended Lifting Method, Frame Size F8

NOTICE!

The pedestal is packaged separately and included in the shipment. Mount the adjustable frequency drive on the pedestal in its final location. The pedestal allows proper airflow and cooling to the adjustable frequency drive. See *chapter 5.1.5 Pedestal Installation of F-frames*.

5.1.7 Safety Requirements of Mechanical Installation

⚠CAUTION

To avoid serious injury or equipment damage, observe the information in the field mounting and integration kits, 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 [45–55°C], derating of the adjustable frequency drive is relevant. See *chapter 8.5.2 Derating for Ambient Temperature*.
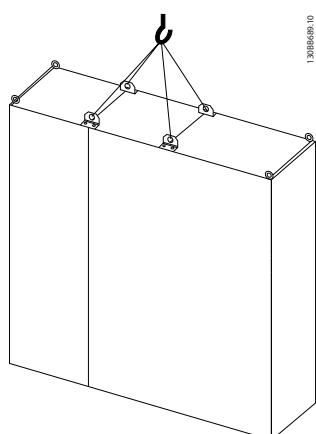**Failure to consider derating for ambient temperature can reduce the service life of the adjustable frequency drive.**

5.1.8 Field Mounting

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

5.2 Electrical Installation

5.2.1 Cables General

NOTICE!

For the VLT® HVAC Drive line power and motor connections, refer to the VLT® HVAC Drive High Power Instruction Manual.

NOTICE!

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

5

Frame size	Terminal		Size	Torque nominal [Nm (in-lbs)]	Torque range [Nm (in-lbs)]
D1h/D3h/D5h/D6h	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/D7h/D8h	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 5.25 Terminal Tightening Torques

5.2.2 Motor Cables

See *chapter 8 General Specifications and Troubleshooting* for maximum dimensioning of motor cable cross-section and length.

- Use a shielded/armored motor cable to comply with EMC emission specifications.

- 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 the metal cabinet of the motor.

- Make the shield connections with the largest possible surface area (cable clamp) using the installation devices in the adjustable frequency drive.

- Avoid mounting with twisted shield ends (pigtails), which will spoil 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 Requirements

F1/F3 requirements: Motor phase cable quantities must be multiples of 2, resulting in 2, 4, 6, or 8, to obtain an equal number 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, to obtain an equal number 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.

F8/F9 requirements: 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.

F10/F11 requirements: Motor phase cable quantities must be multiples of 2, resulting in 2, 4, 6, or 8, to obtain an equal number 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.

F12/F13 requirements: Motor phase cable quantities must be multiples of 3, resulting in 3, 6, 9, or 12, to obtain an equal number 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.

F14 requirements: Motor phase cable quantities must be multiples of 4, resulting in 4, 8, 12, or 16, to obtain an equal number 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.

NOTICE!

If a retrofit application requires an unequal number of wires per phase, consult the factory for requirements and documentation or use the top/bottom entry side cabinet busbar option.

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

Cable-length and cross-section: The adjustable frequency drive has been tested with a given length of cable and a given cross-section of that cable. If the cross-section is increased, the cable capacitance, and thus the leakage current, may increase. Reduce the cable length accordingly. Keep the motor cable as short as possible to reduce the noise level and leakage currents.

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

Aluminum conductors: Do not use aluminum conductors. Terminals can accept aluminum conductors but the conductor surface has to be clean and the oxidation removed and sealed by neutral, acid-free grease before the conductor is connected.
Additionally, the terminal screw must be retightened after two days due to the softness of the aluminum. Maintain a gas tight joint connection to prevent oxidation.

5.2.4 Preparing Connector Plates for Cables

1. Remove the connector plate from the adjustable frequency drive.

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.

5.2.5 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. The following figures show the cable entry points viewed from the bottom of various adjustable frequency drives.

NOTICE!

The connector plate must be fitted to the adjustable frequency drive to ensure the specified degree of protection.
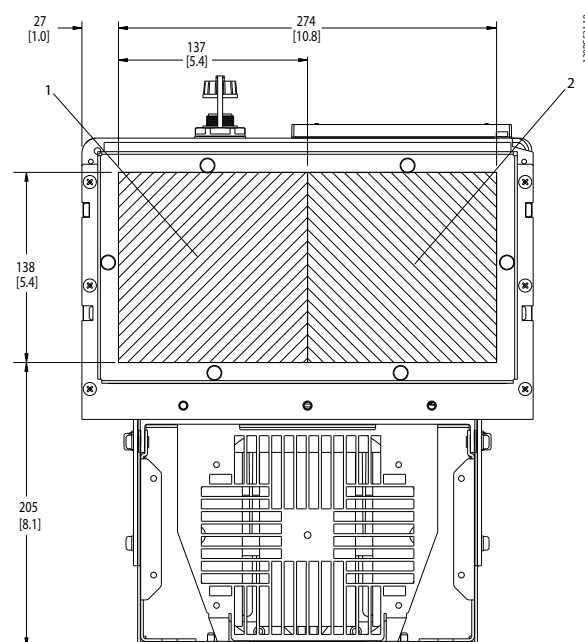
Figure 5.36 D1h, Bottom View 1) Line Power Side 2) Motor Side

1	Line Power Side
2	Motor Side

Table 5.26 Legend to *Figure 5.36*

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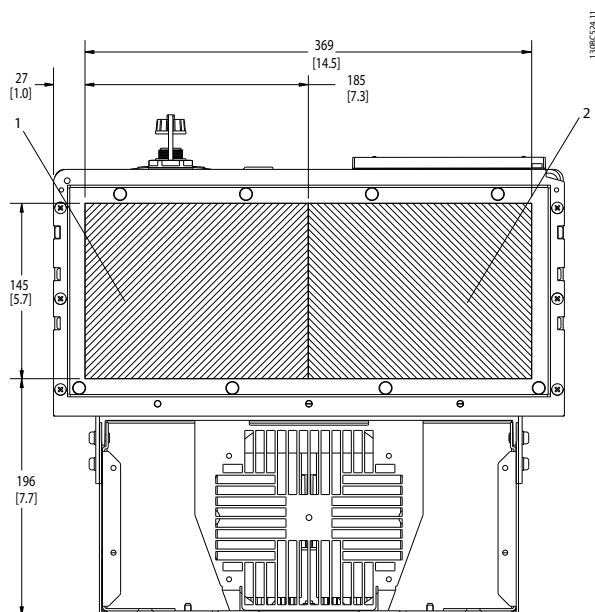
Figure 5.37 D2h, Bottom View

Figure 5.38 D5h & D6h, Bottom View

1	Line Power Side
2	Motor Side

Table 5.27 Legend to *Figure 5.37*

1	Line Power Side
2	Motor Side

Table 5.28 Legend to *Figure 5.38*
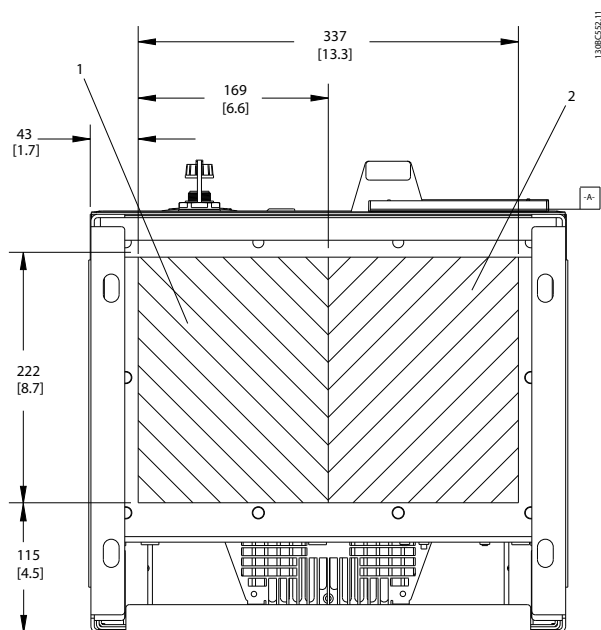
Figure 5.39 D7h & D8h, Bottom View

1	Line Power Side
2	Motor Side

Table 5.29 Legend to *Figure 5.39*
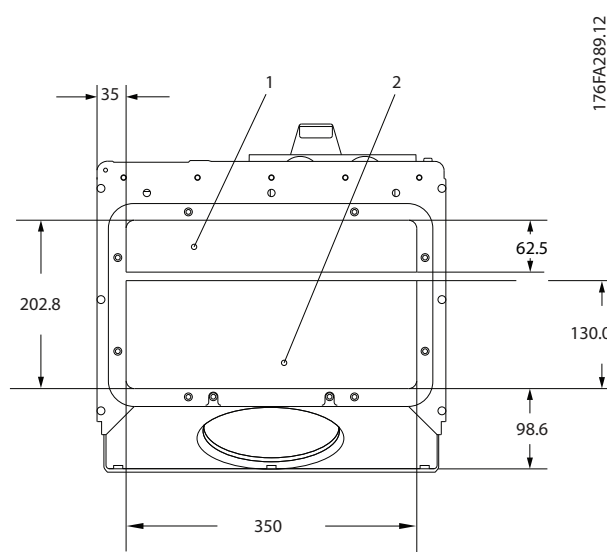
Figure 5.40 E1, Bottom View

1	Line Power Side
2	Motor Side

Table 5.30 Legend to *Figure 5.40*
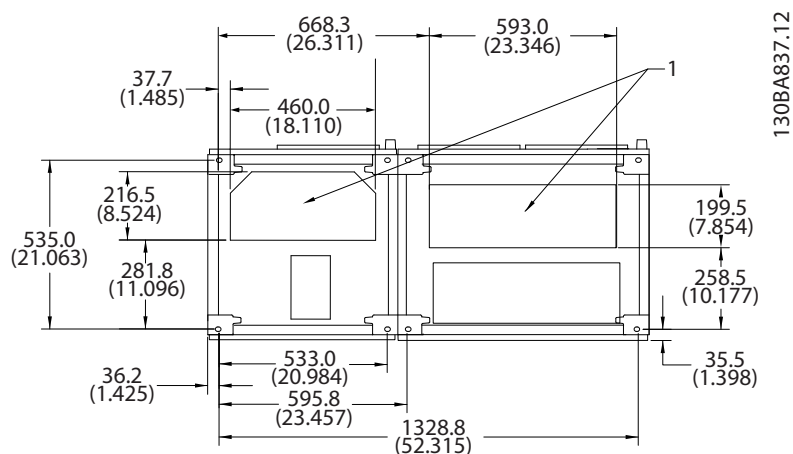
Figure 5.41 F1, Bottom View

1	Cable conduit entry

Table 5.31 Legend to *Figure 5.41*
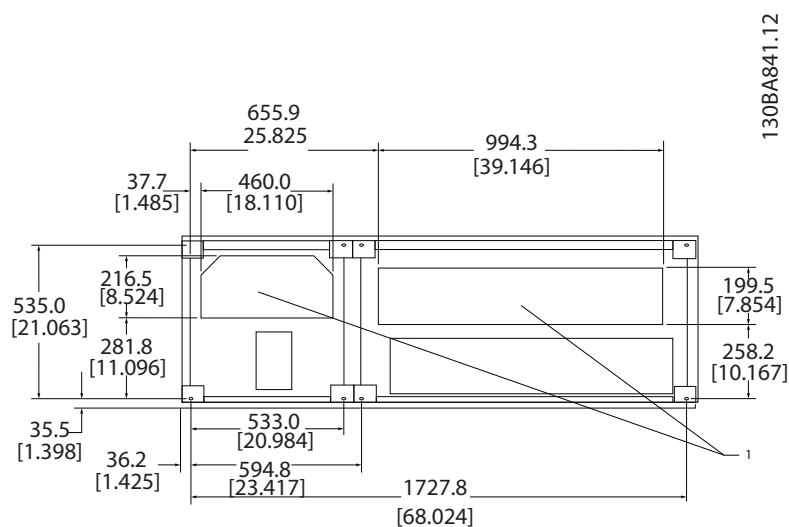
Figure 5.42 F2, Bottom View

1	Cable conduit entry

Table 5.32 Legend to *Figure 5.42*
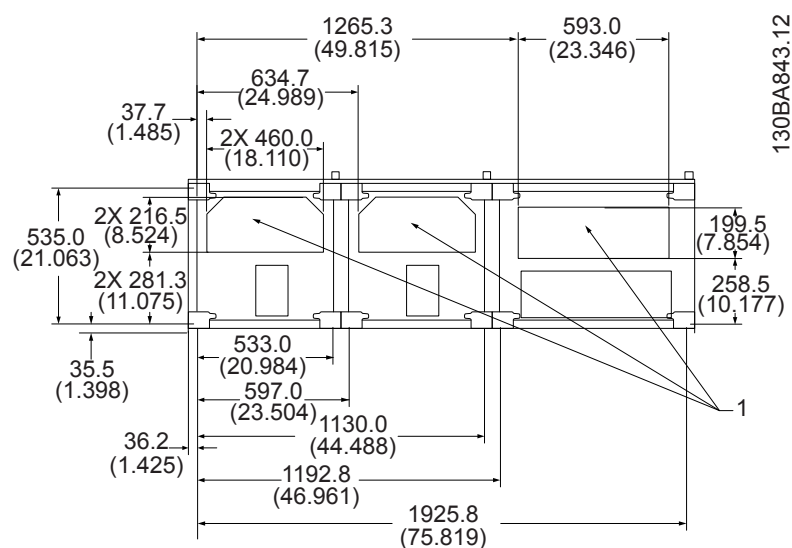
Figure 5.43 F3, Bottom View

| 1 | Cable conduit entry |

Table 5.33 Legend to *Figure 5.43*
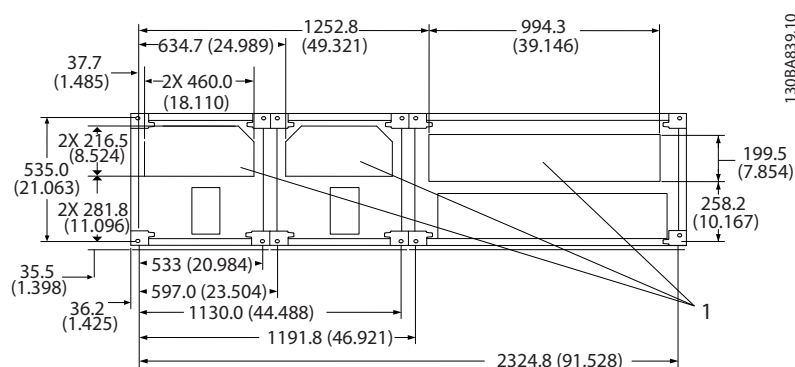
Figure 5.44 F4, Bottom View

| 1 | Cable conduit entry |

Table 5.34 Legend to *Figure 5.44*

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

The following figures show the cable entry points as viewed from the bottom of the adjustable frequency drive.
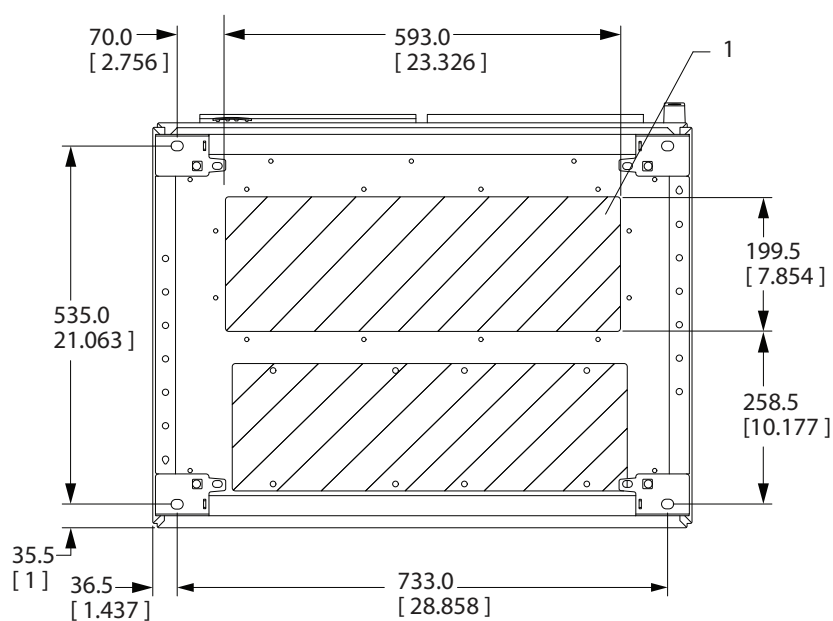
Figure 5.45 Frame Size F8

1	Place conduits in shaded areas

Table 5.35 Legend to *Figure 5.45*
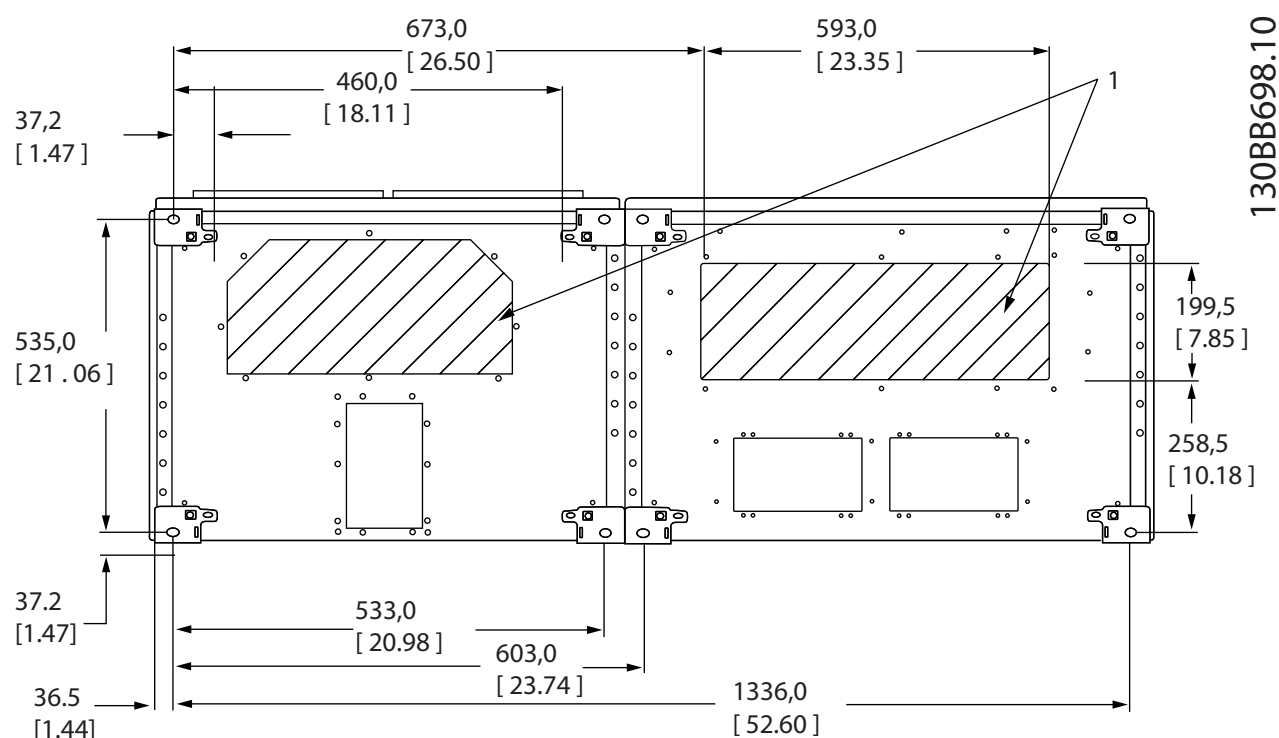
Figure 5.46 Frame Size F9

1	Place conduits in shaded areas

Table 5.36 Legend to *Figure 5.46*

Danfoss

5

130BB694.10
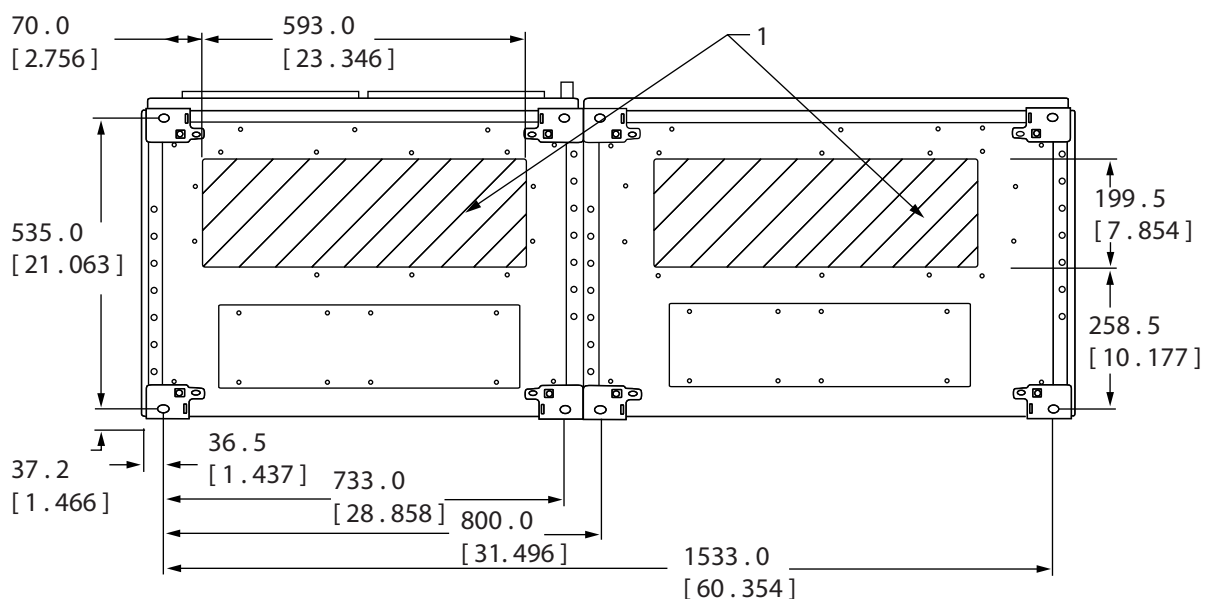
Figure 5.47 Frame Size F10

| 1 | Place conduits in shaded areas |

Table 5.37 Legend to *Figure 5.47*

130BB695.10
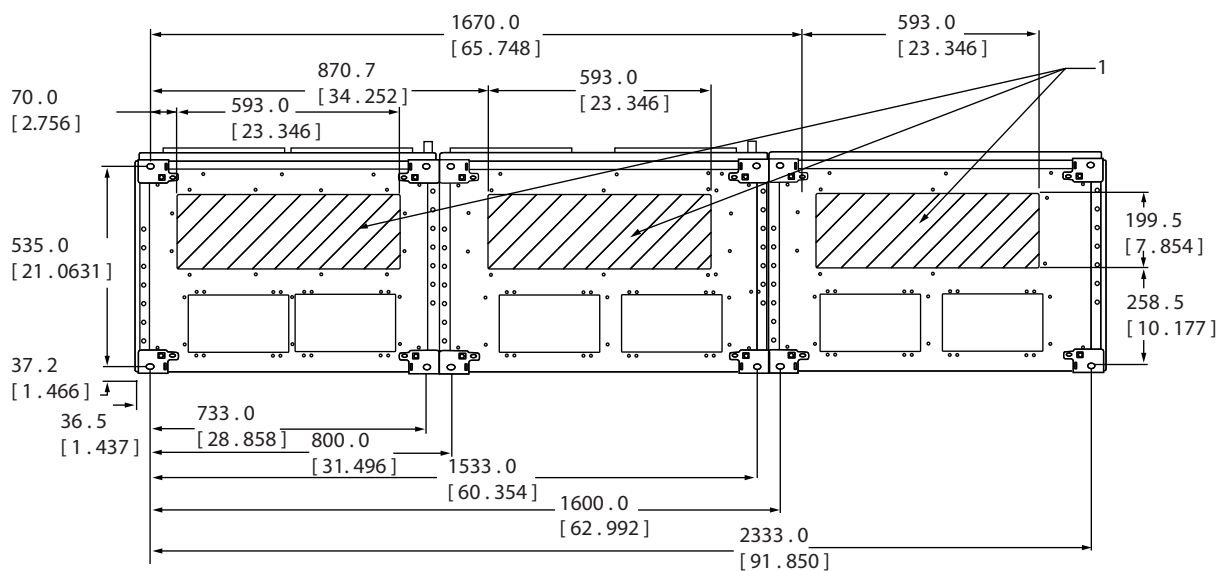
Figure 5.48 Frame Size F11

| 1 | Place conduits in shaded areas |

Table 5.38 Legend to *Figure 5.48*

                    MG16C122
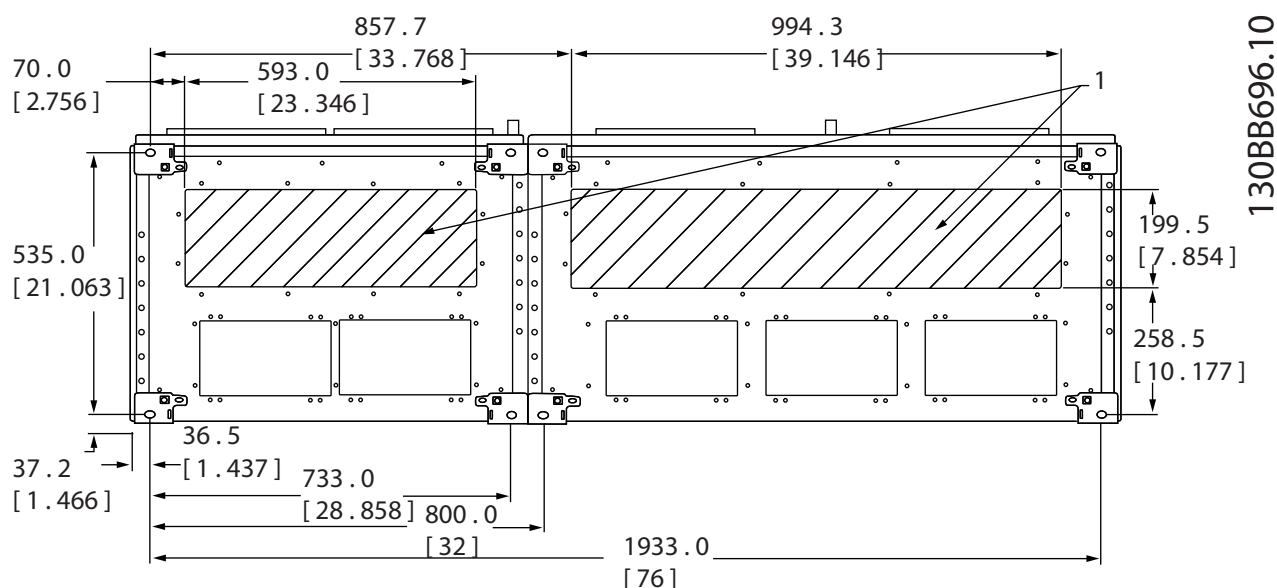
Figure 5.49 Frame Size F12

1	Place conduits in shaded areas

Table 5.39 Legend to *Figure 5.49*
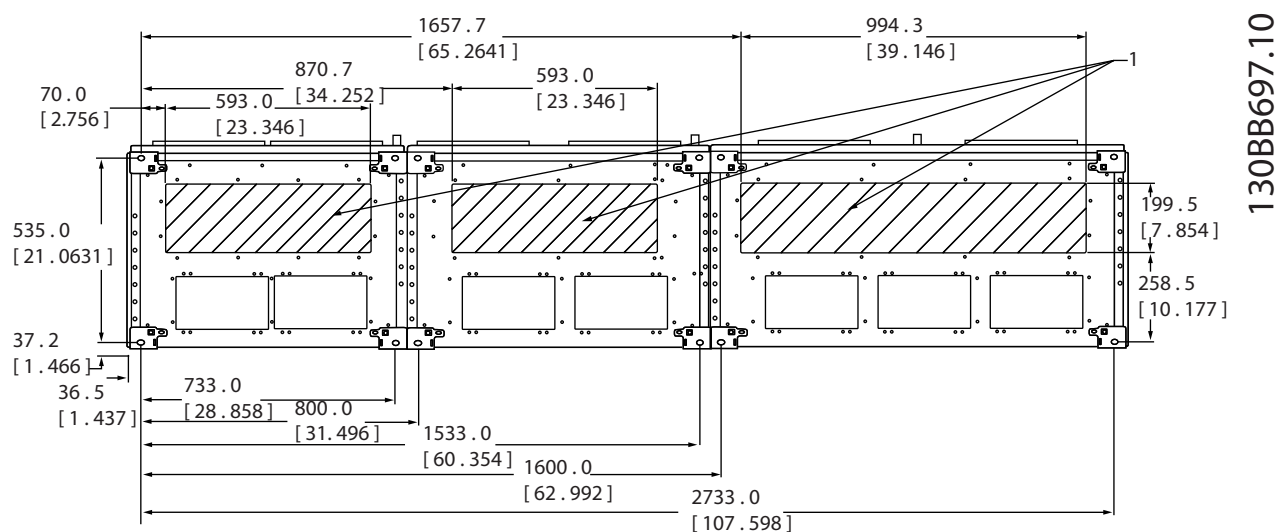
Figure 5.50 Frame Size F13

1	Place conduits in shaded areas

Table 5.40 Legend to *Figure 5.50*

5.2.7 Power Connections

NOTICE!

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. Non-UL applications can use 167°F [75°C] and 194°F [90°C] copper conductors.

The power cable connections are situated as shown in *Figure 5.51*. Dimensioning of cable cross-section must comply with the current ratings and local legislation. See *chapter 8.1 General Specifications* for correct dimensioning of motor cable cross-section and length.

For protection of the adjustable frequency drive, use the recommended fuses unless the unit has built-in fuses. Recommended fuses are listed in the Instruction Manual. Ensure that proper fusing complies with local regulations.

The AC line input connection is fitted to the line power switch if included.
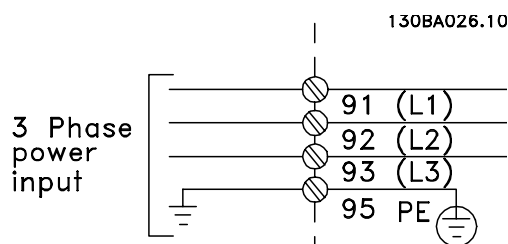
Figure 5.51 Power Cable Connections

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 5.7 EMC-compatible Installation*.

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 contactor, continue the shield at the lowest possible HF impedance.

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

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

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

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

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

Table 5.41 Motor Cable Connection

[1]*Protected Ground Connection*

NOTICE!

In motors without phase insulation, paper or other insulation reinforcement suitable for operation with voltage supply, fit a sine-wave filter on the output of the adjustable frequency drive.
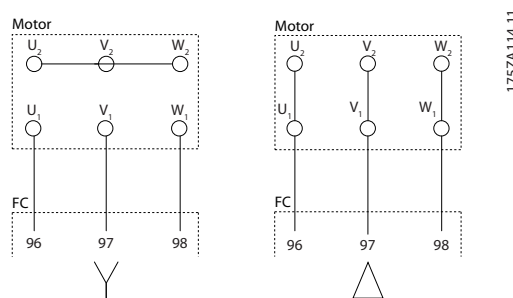
Figure 5.52 Motor Cable Connection

MG16C122

D-frame Interior Components
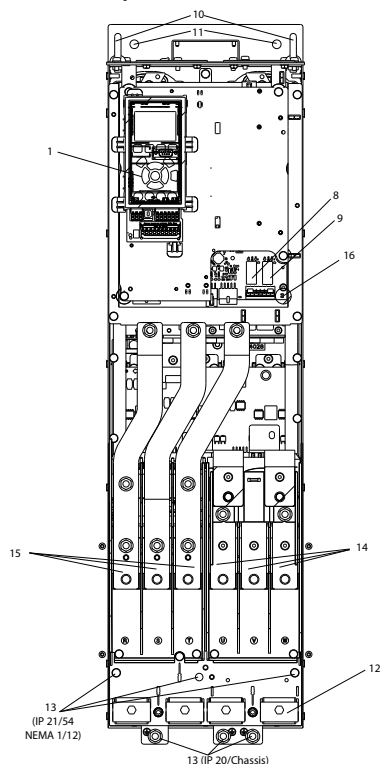
Figure 5.53 D-frame Interior Components
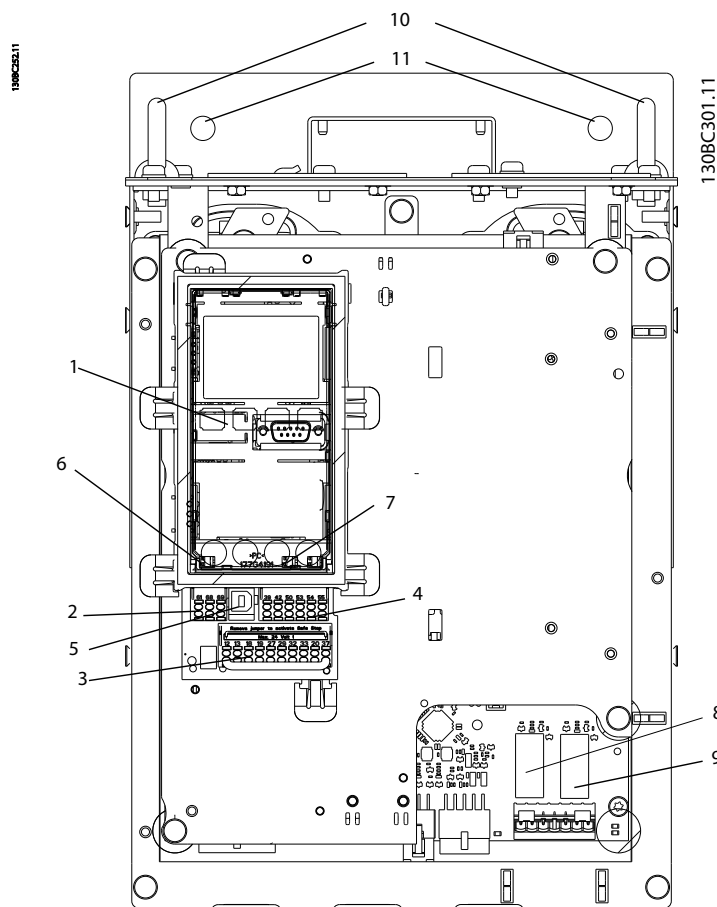
Figure 5.54 Close-up View: LCP and Control Functions

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 5.42 Legend to *Figure 5.53* and *Figure 5.54*

Terminal Locations - D1h/D2h

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

Figure 5.55 Position of Ground Terminals IP21 (NEMA Type 1) and IP54 (NEMA Type 12), D1h/D2h

Terminal Locations - D3h/D4h

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

Figure 5.56 Position of Ground Terminals IP20 (Chassis), D3h/D4h

1	Ground Terminals

Table 5.43 Legend to *Figure 5.55* and *Figure 5.56*

Terminal Locations - D5h

Take the following position of the terminals into consideration when designing the cable access.
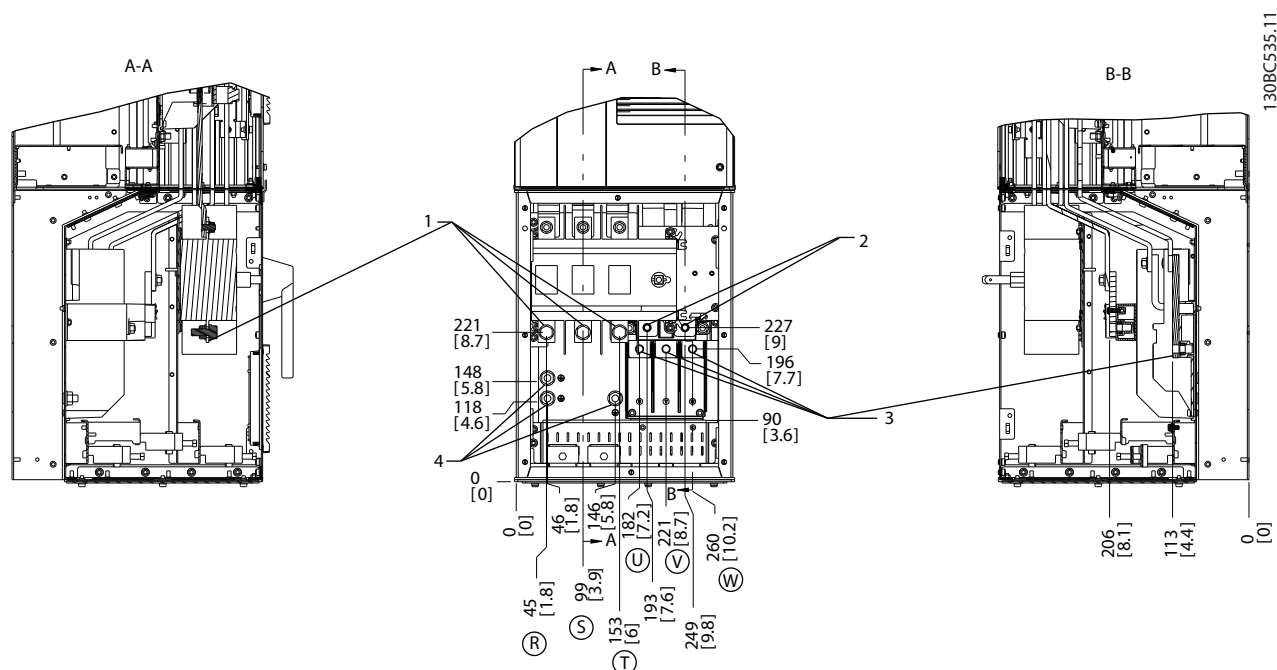
Figure 5.57 Terminal Locations, D5h with Disconnect Option

1	Line Power Terminals	3	Motor Terminals
2	Brake Terminals	4	Ground Terminals

Table 5.44 Legend to *Figure 5.57*

130BC536.11
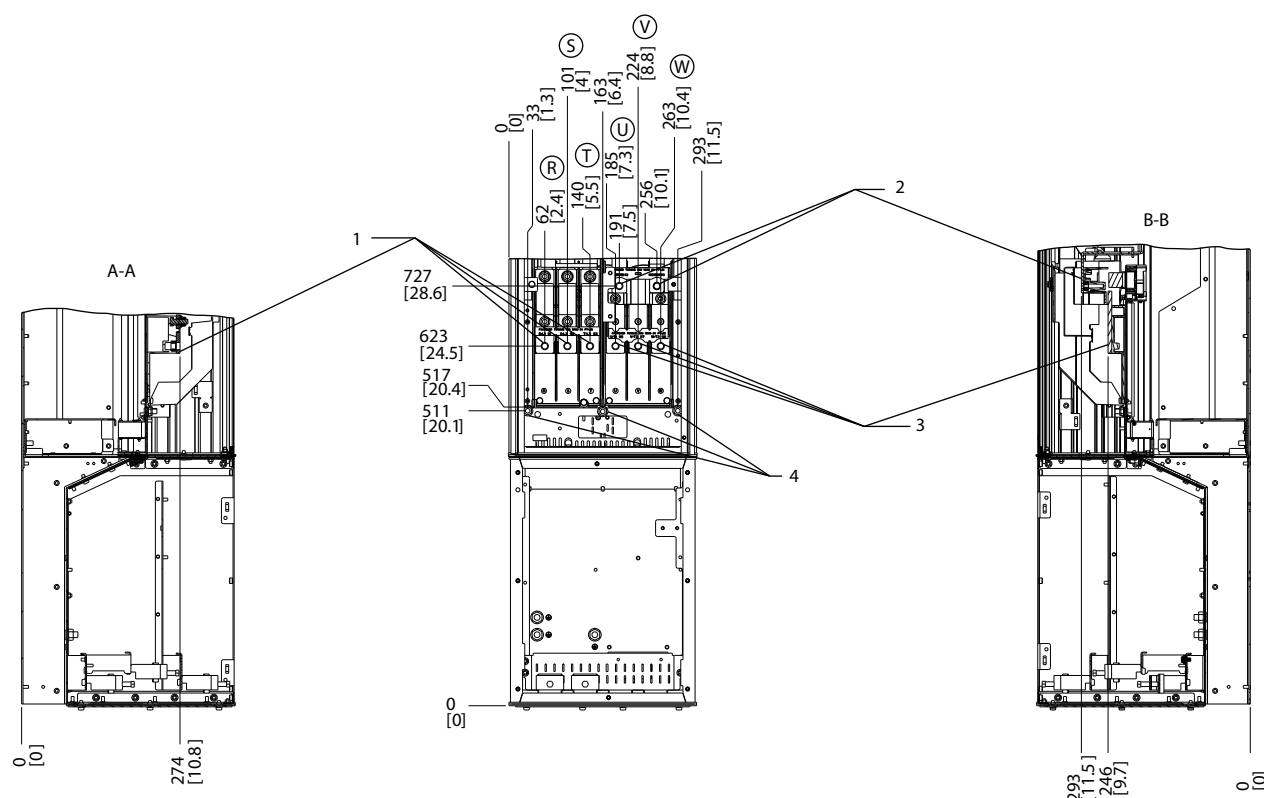
Figure 5.58 Terminal Locations, D5h with Brake Option

1	Line Power Terminals	3	Motor Terminals
2	Brake Terminals	4	Ground Terminals

Table 5.45 Legend to *Figure 5.58*

Terminal Locations - D6h

Take the following position of the terminals into consideration when designing the cable access.
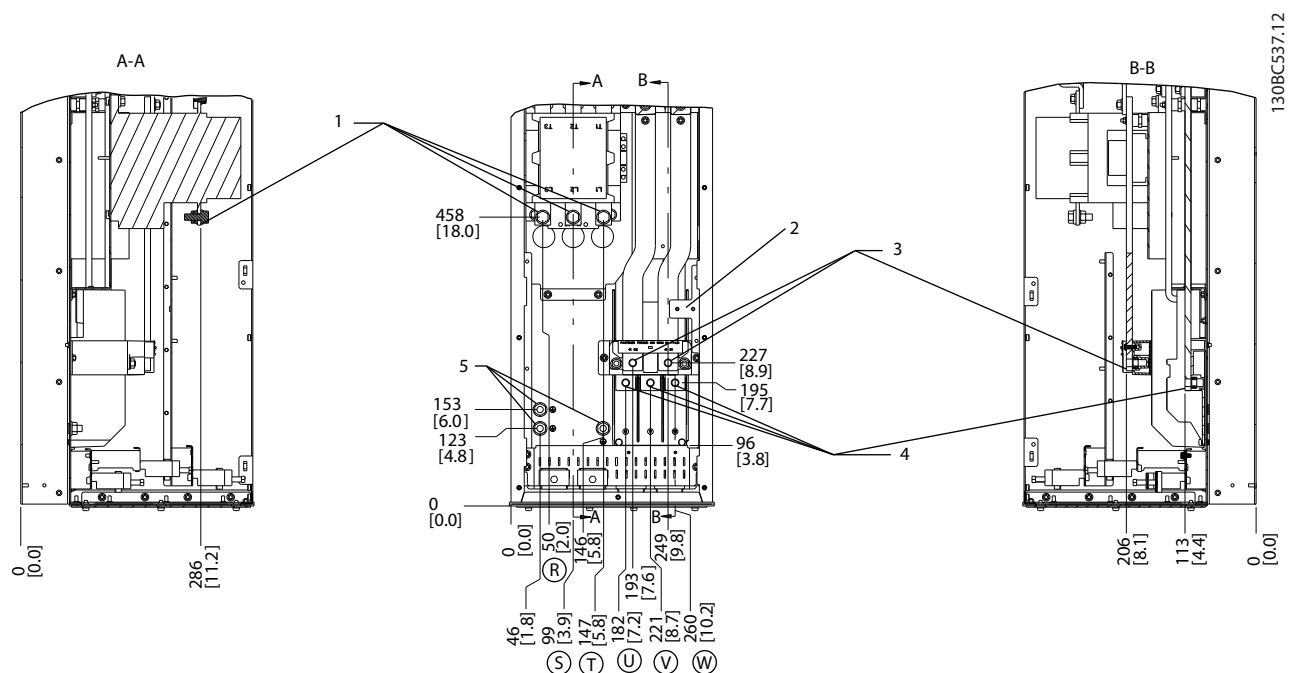
Figure 5.59 Terminal Locations, D6h with Contactor Option

1	Line Power Terminals	4	Motor Terminals
2	TB6 Terminal block for contactor	5	Ground Terminals
3	Brake Terminals		

Table 5.46 Legend to *Figure 5.59*

130BC538.12

5

A-A
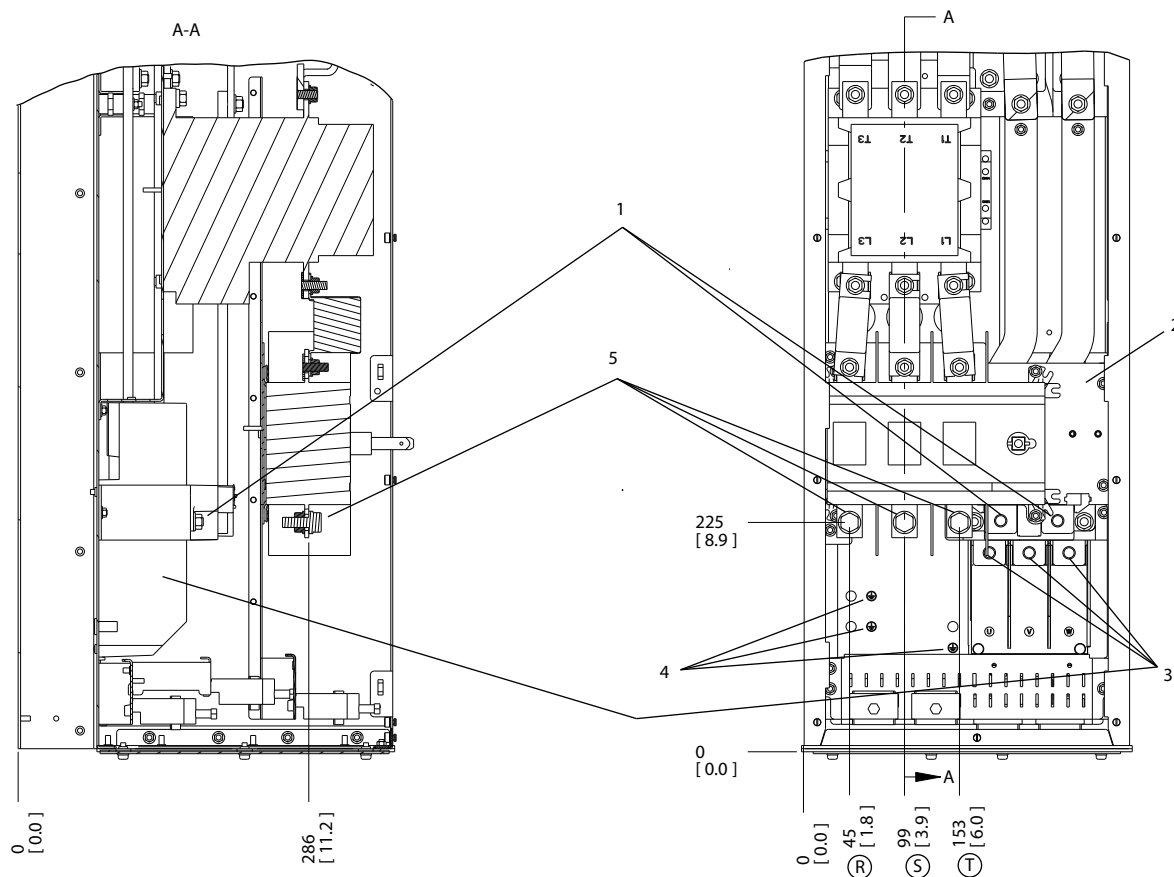
Figure 5.60 Terminal Locations, D6h with Contactor and Disconnect Options

1	Brake Terminals	4	Ground Terminals
2	TB6 Terminal block for contactor	5	Line Power Terminals
3	Motor Terminals		

Table 5.47 Legend to *Figure 5.60*

5

130BC541.11
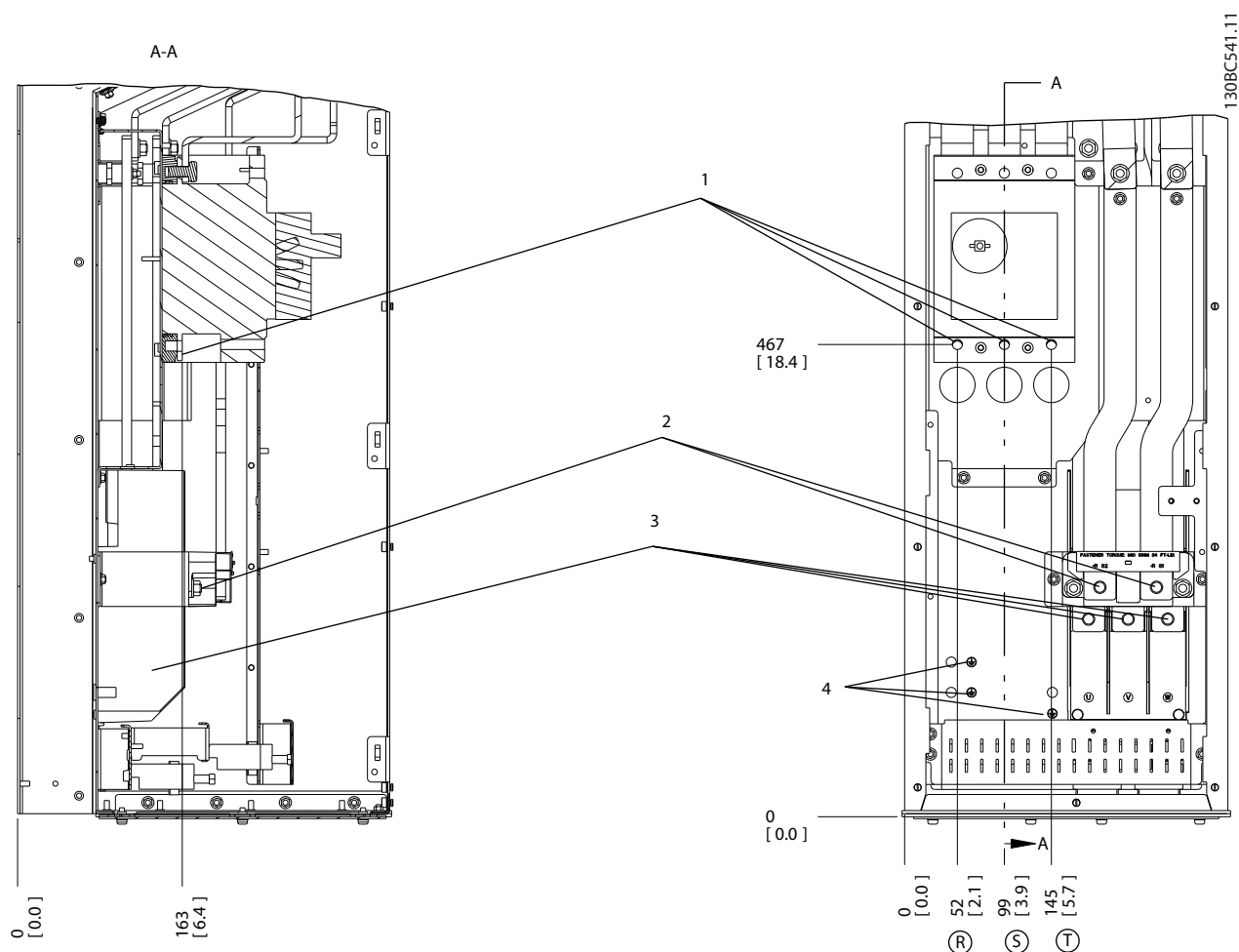
Figure 5.61 Terminal Locations, D6h with Circuit Breaker Option

1	Line Power Terminals	3	Motor Terminals
2	Brake Terminals	4	Ground Terminals

Table 5.48 Legend to *Figure 5.61*

Terminal Locations - D7h

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

130BC542.11
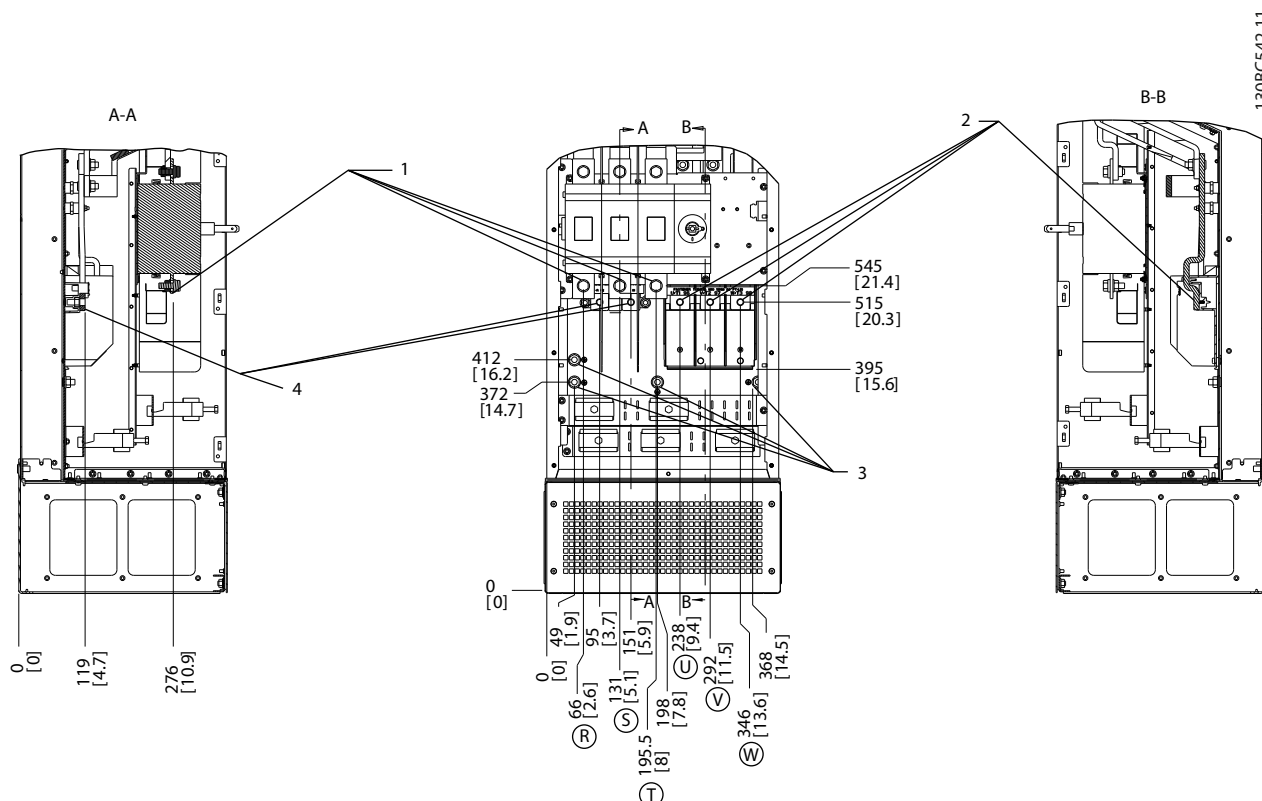
Figure 5.62 Terminal Locations, D7h with Disconnect Option

1	Line Power Terminals	3	Ground Terminals
2	Motor Terminals	4	Brake Terminals

Table 5.49 Legend to *Figure 5.62*

5
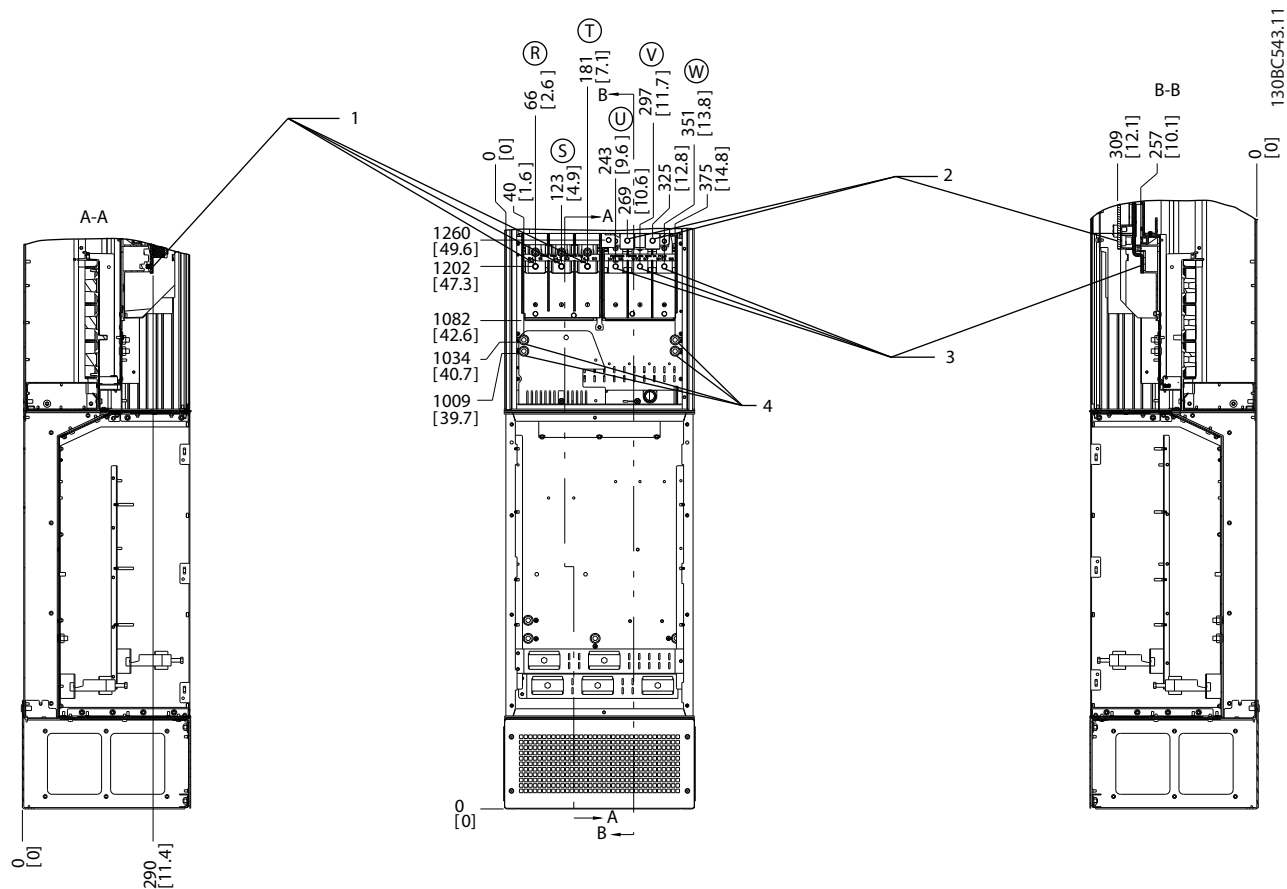
Figure 5.63 Terminal Locations, D7h with Brake Option

1	Line Power Terminals	3	Motor Terminals
2	Brake Terminals	4	Ground Terminals

Table 5.50 Legend to *Figure 5.63*

132   MG16C122

Terminal Locations - D8h

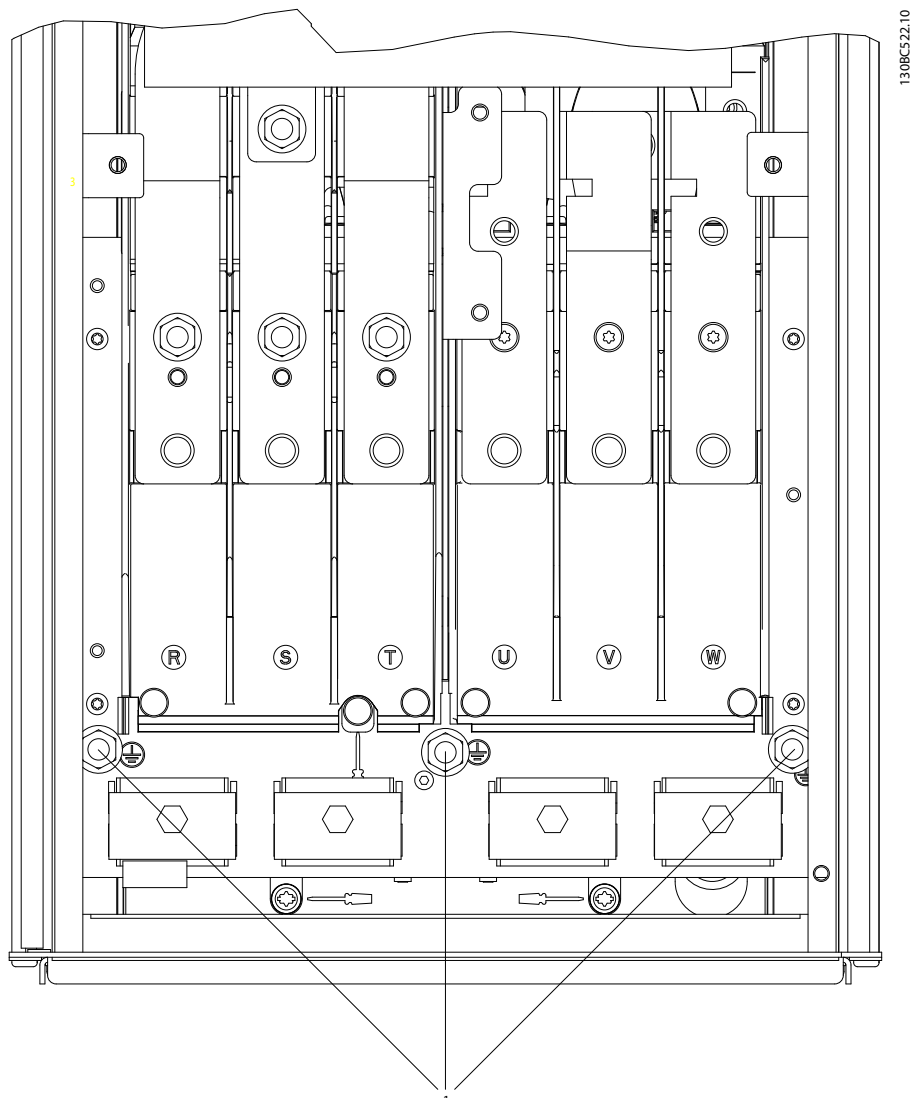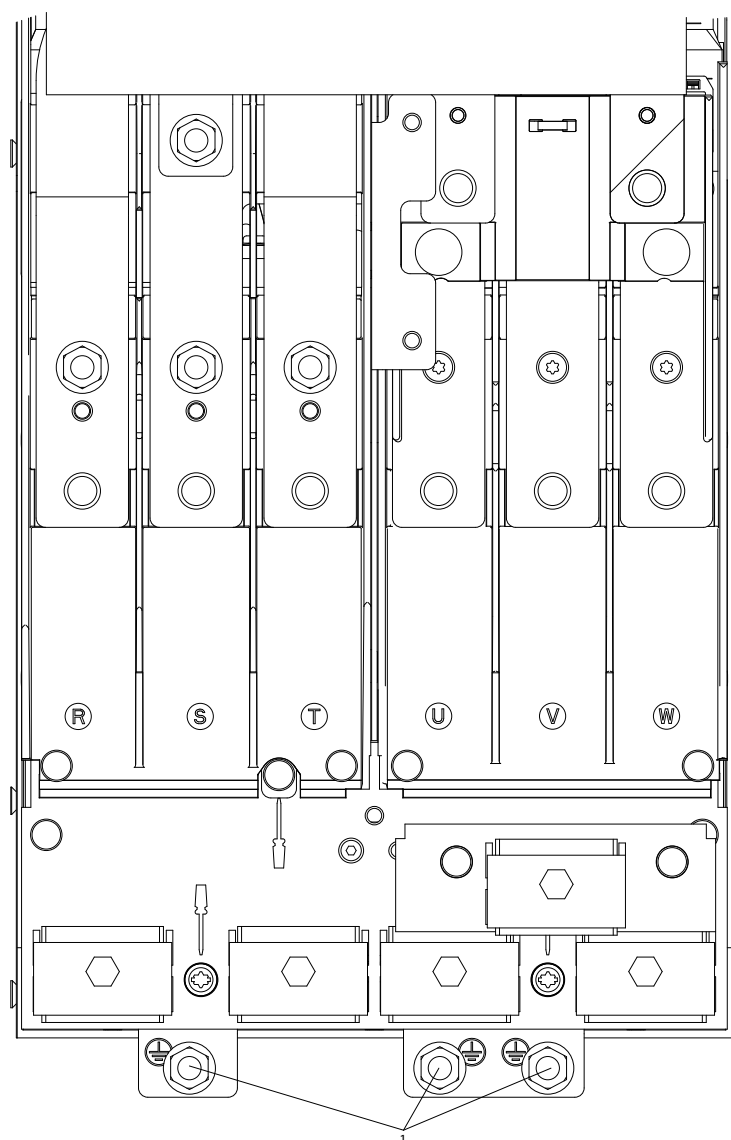Take the following position of the terminals into consideration when designing the cable access.
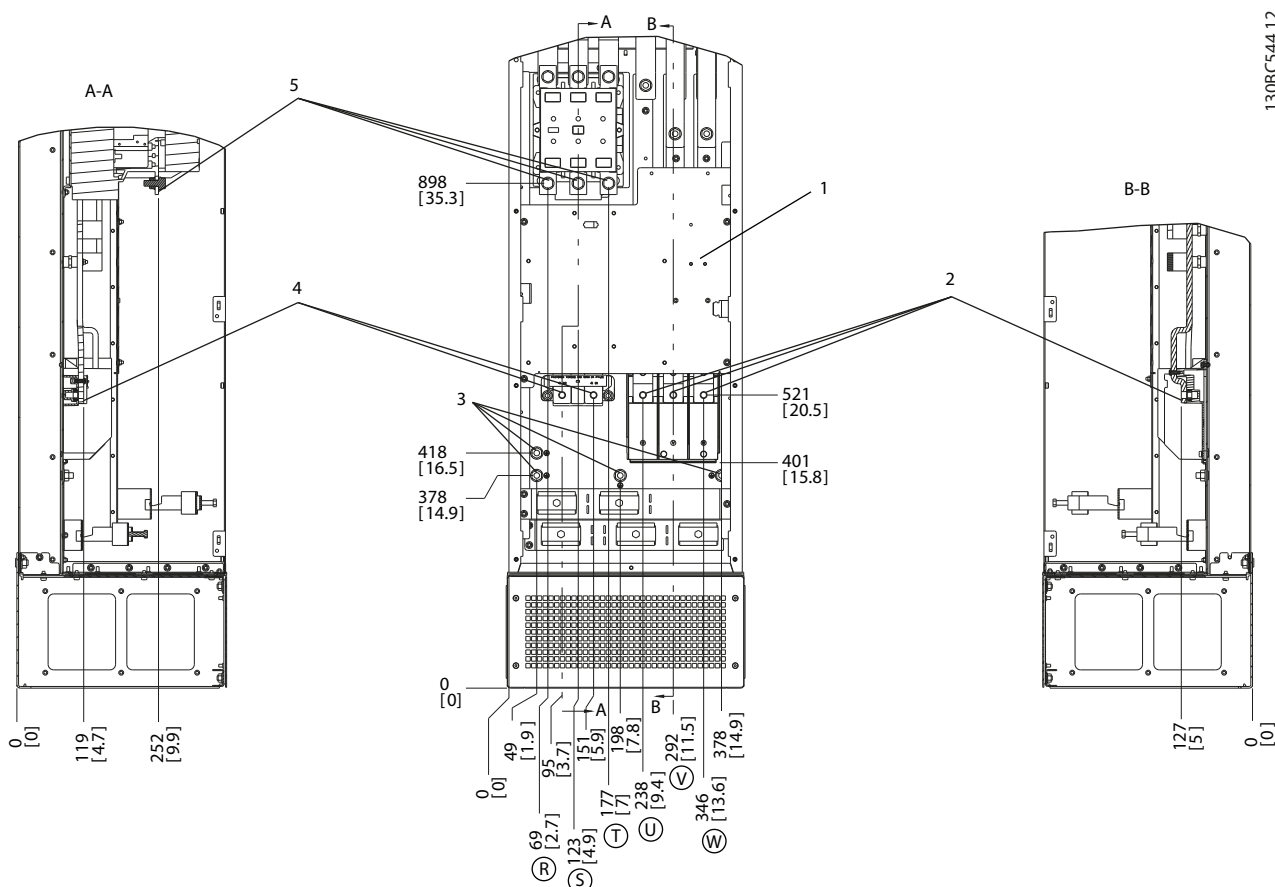
Figure 5.64 Terminal Locations, D8h with Contactor Option

1	TB6 Terminal block for contactor	4	Brake Terminals
2	Motor Terminals	5	Line Power Terminals
3	Ground Terminals		

Table 5.51 Legend to *Figure 5.64*

5
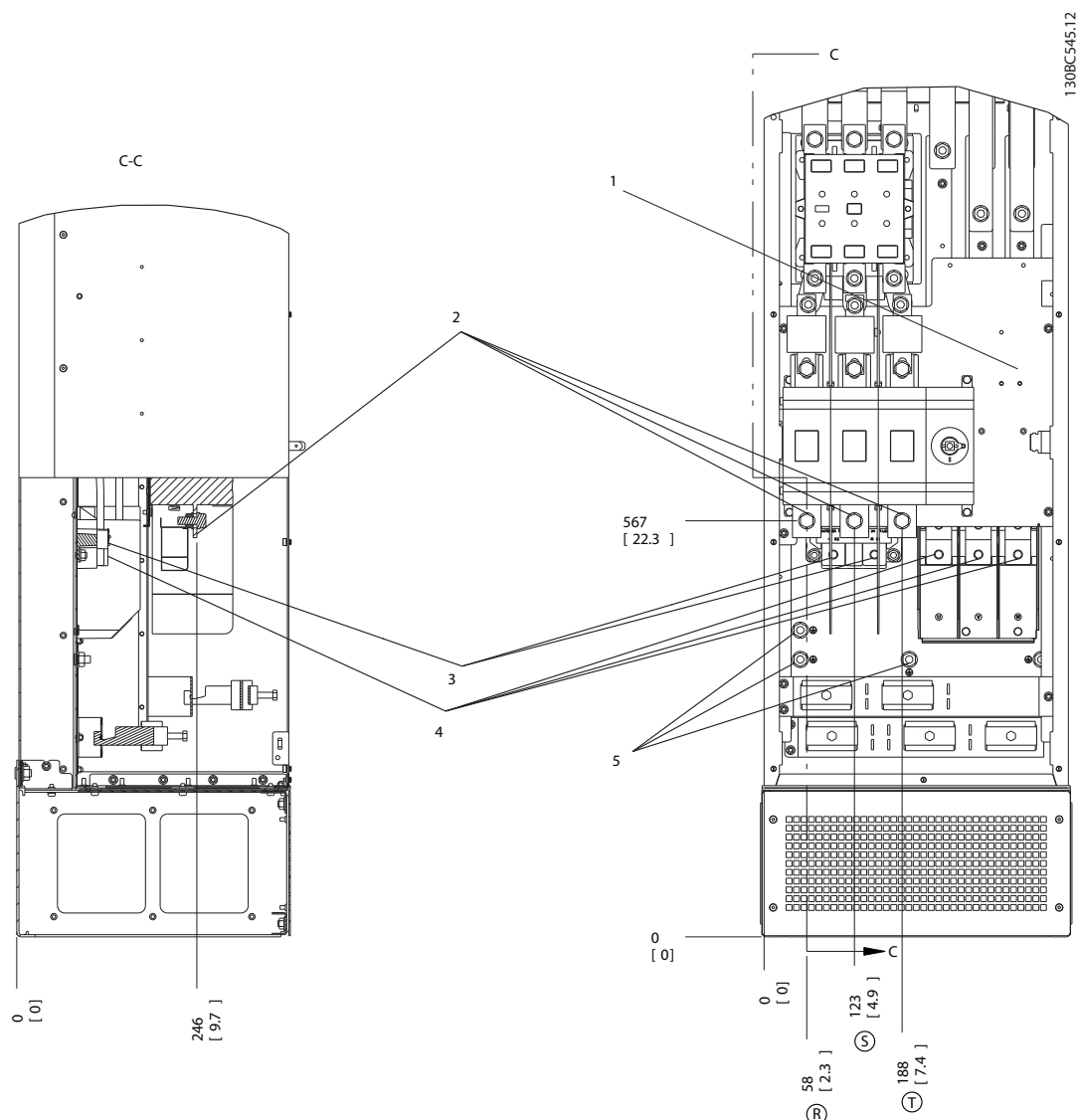
Figure 5.65 Terminal Locations, D8h with Contactor and Disconnect Options

1	TB6 Terminal block for contactor	4	Motor Terminals
2	Line Power Terminals	5	Ground Terminals
3	Brake Terminals		

Table 5.52 Legend to *Figure 5.65*

5
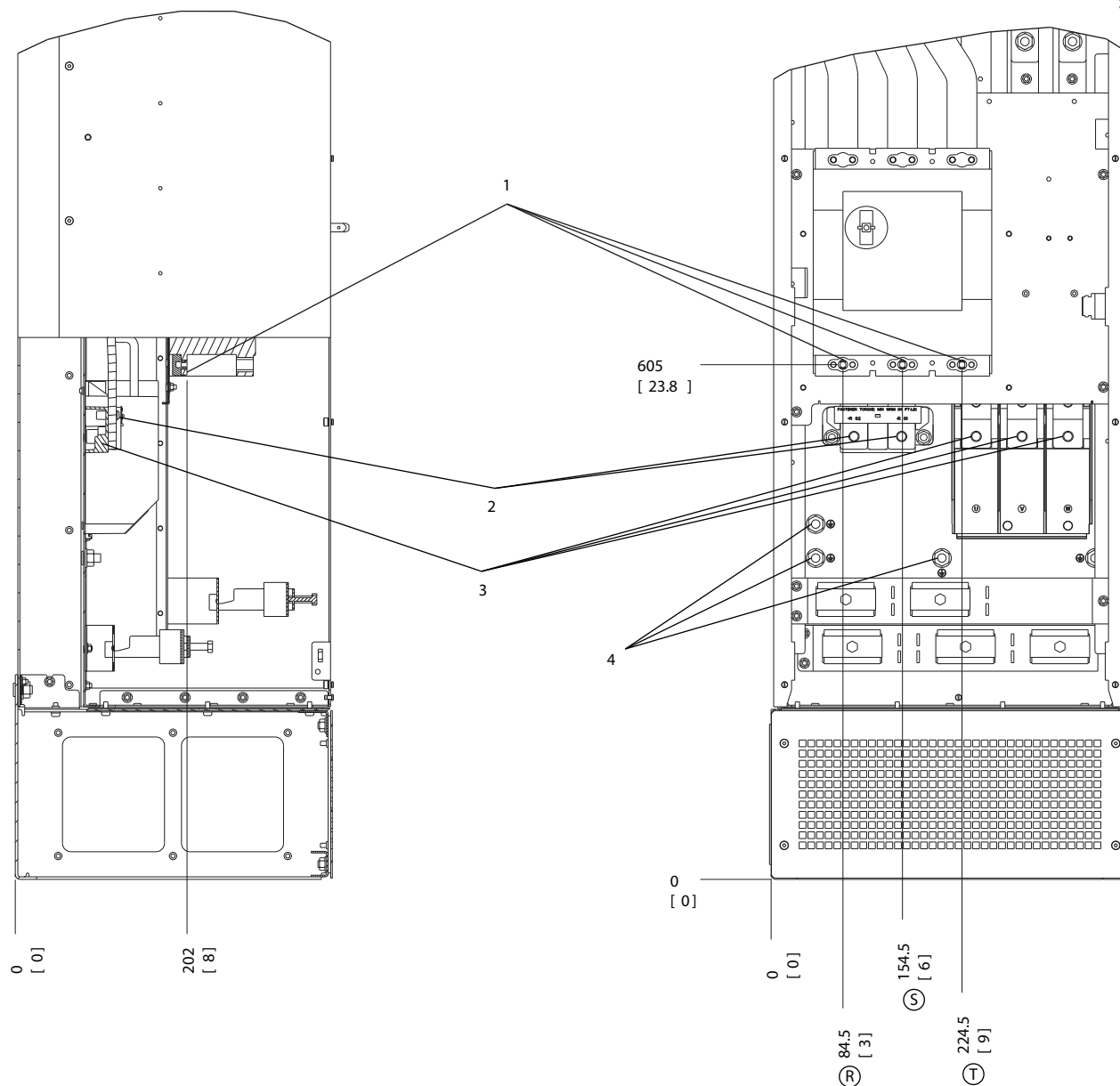
Figure 5.66 Terminal Locations, D8h with Circuit Breaker Option

1	Line Power Terminals	3	Motor Terminals
2	Brake Terminals	4	Ground Terminals

Table 5.53 Legend to *Figure 5.66*

Terminal Locations - E1

Take the following position of the terminals into consideration when designing the cable access.
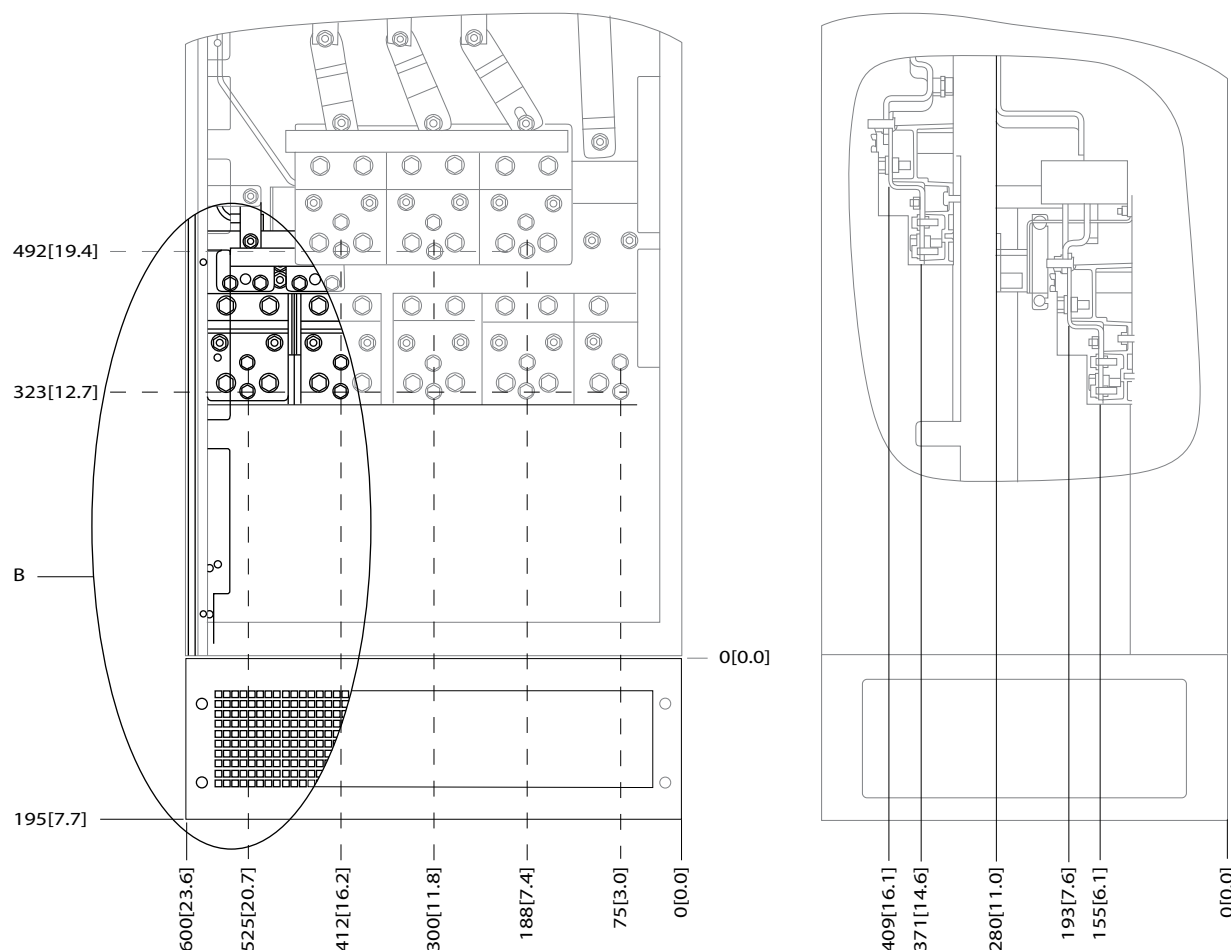
Figure 5.67 IP21 (NEMA Type 1) and IP54 (NEMA Type 12) Enclosure Power Connection Positions

B	Front View of Unit

Table 5.54 Legend to *Figure 5.67*
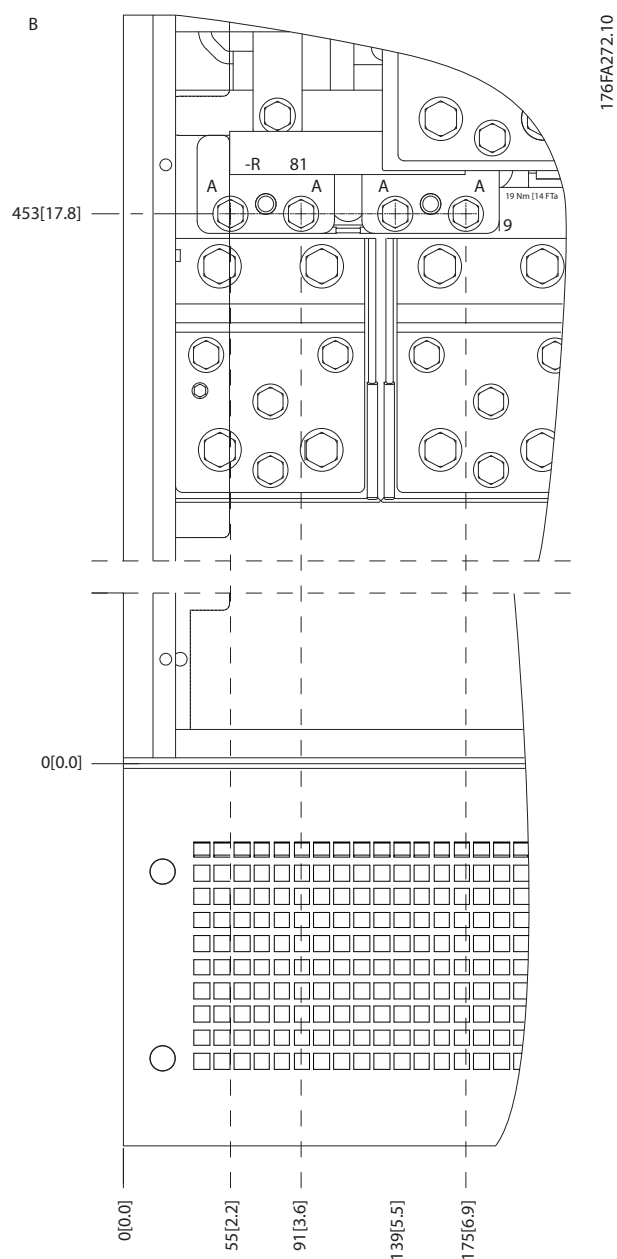
Figure 5.68 IP21 (NEMA Type 1) and IP54 (NEMA Type 12) Enclosure Power Connection Positions (Detail B)
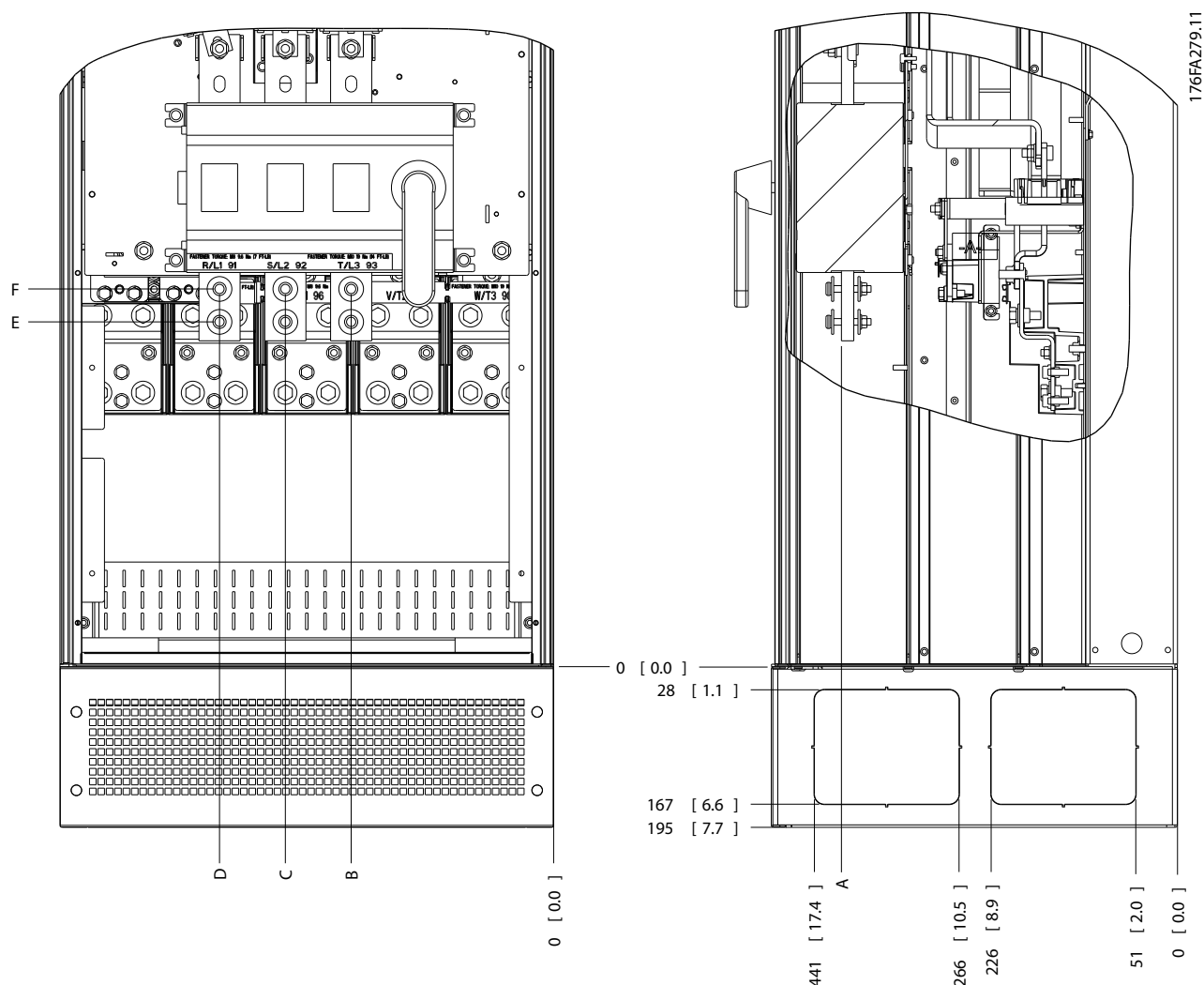
Figure 5.69 IP21 (NEMA Type 1) and IP54 (NEMA Type 12) Enclosure Power Connection Position of Disconnect Switch

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 5.55 Legend to *Figure 5.69*

Terminal Locations – Frame Size E2
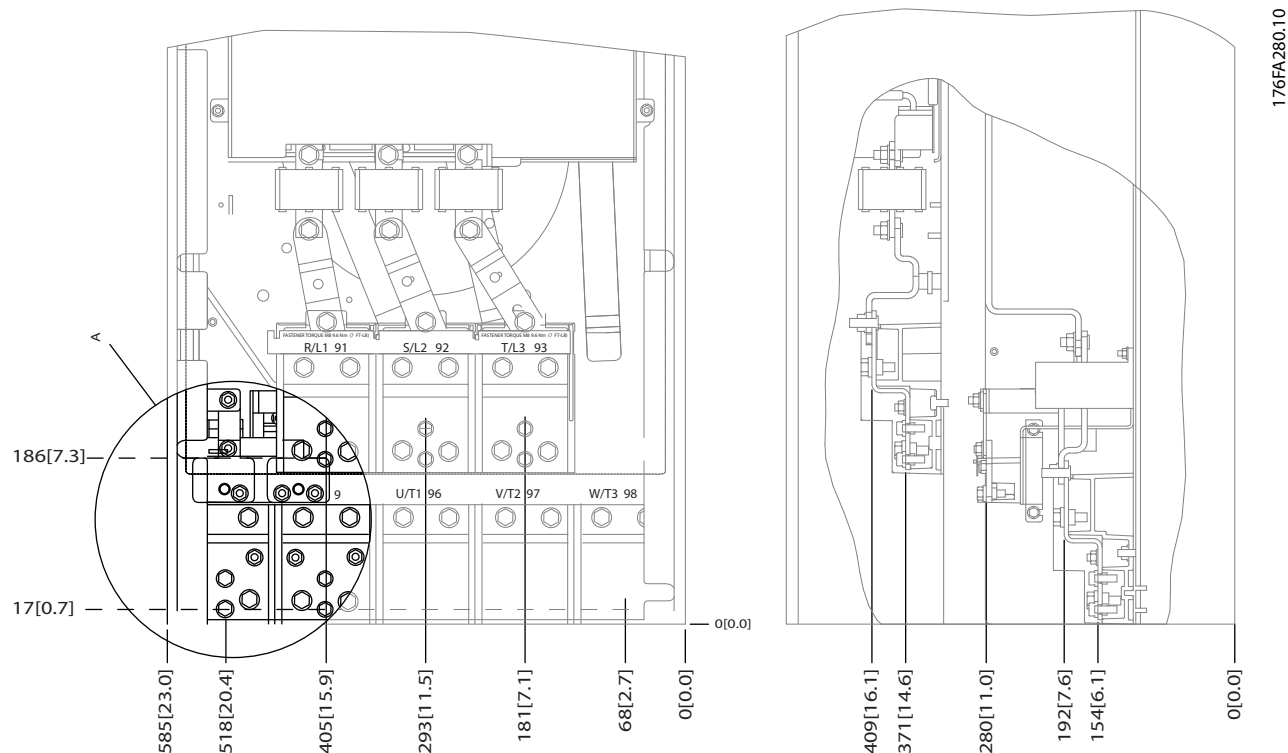
Figure 5.70 IP00 Enclosure Power Connection Positions

5

176FA282.10

A

147(5.8)

R 81

A   A   A   A

019Nm (14 F)

9

0(0.0)

0(0.0)   47(1.9)   83(3.3)   131(5.2)   167(6.6)
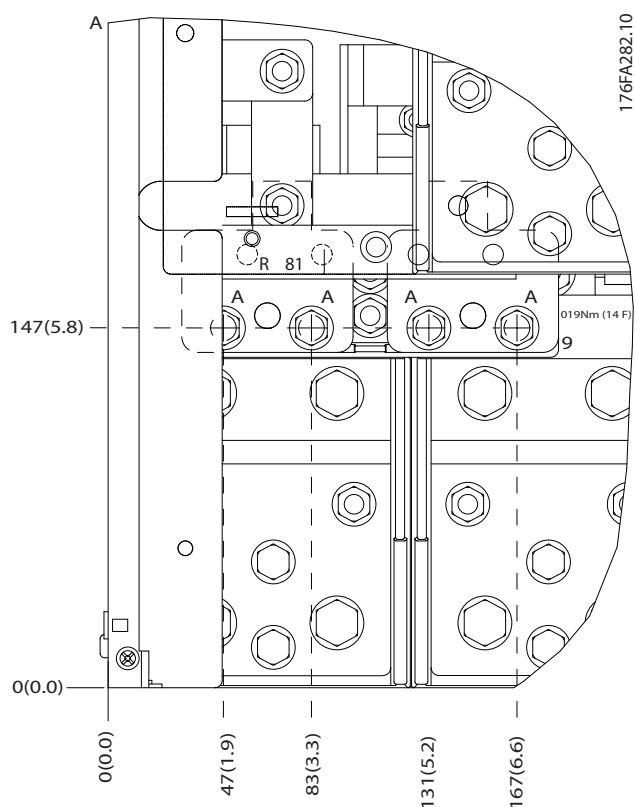
Figure 5.71 IP00 Enclosure Power Connection Positions

176FA281.11

F
E

R/L1 91   S/L2 92   T/L3 93

96

V/T   W/T3 9

D   C   B

0
[0.0]

0 [0.0]

A

0 [0.0]
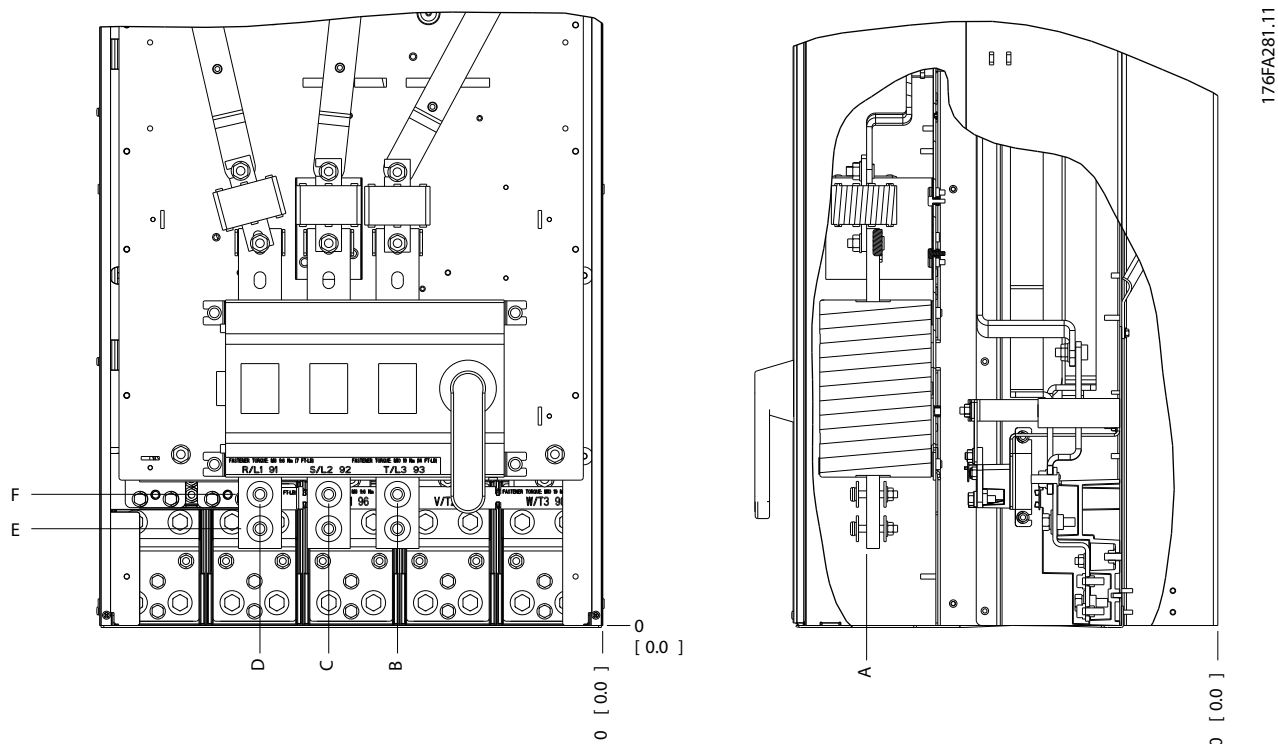
Figure 5.72 IP00 Enclosure Power Connections, Position of Disconnect Switch

5

NOTICE!

The power cables are heavy and difficult to bend. Consider the optimum position of the adjustable frequency drive to ensure easy cable installation. 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.
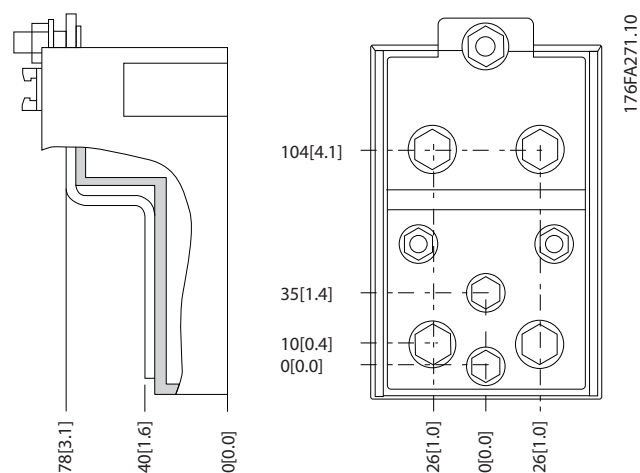
Figure 5.73 Terminal in Detail

NOTICE!

Power connections can be made to positions A or B.

Frame size	Unit type	Dimension for disconnect terminal					
		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 5.56 Power Connections, E2

Terminal Locations – Frame Sizes F1 and F3
Take the following position of the terminals into consideration when designing the cable access.
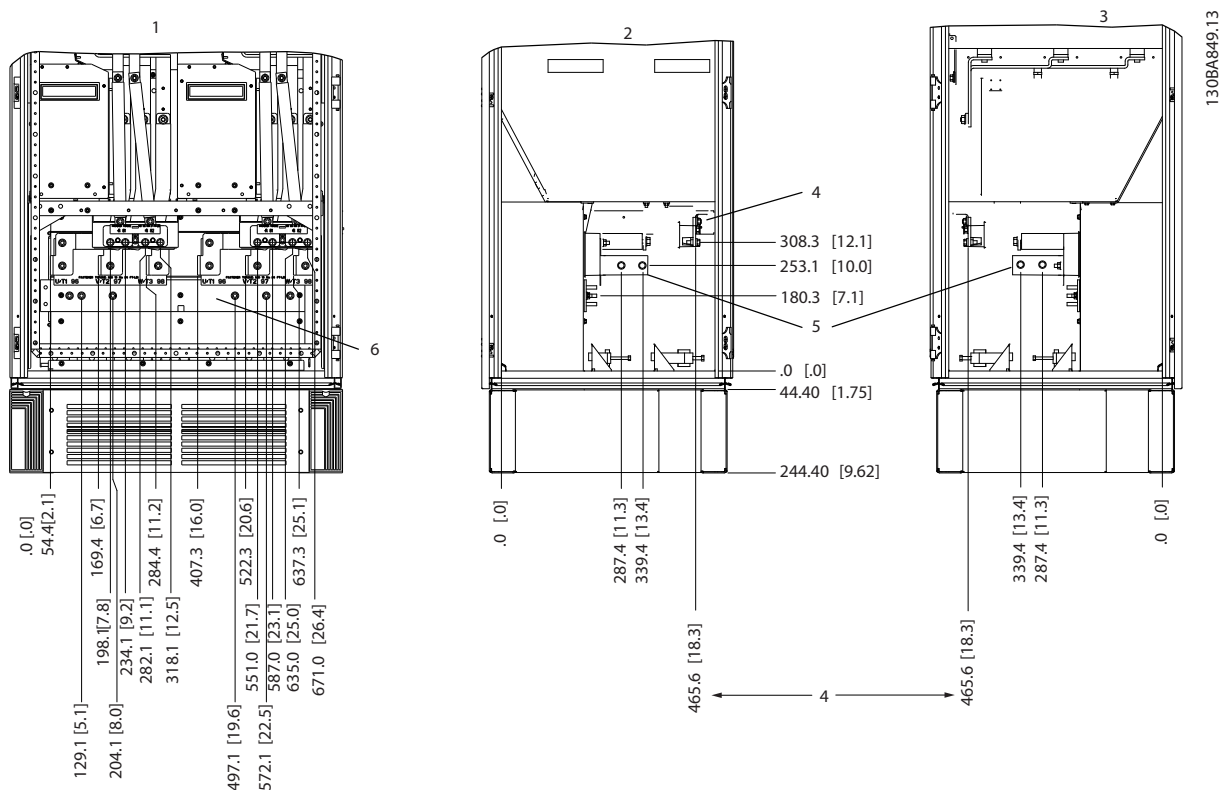
Figure 5.74 Terminal Locations – Inverter Cabinet – F1 and F3. Connector Plate is 1.65 in [42 mm] below .0 Level.

1	Front Side	4	Ground bar
2	Left Side	5	Motor Terminals
3	Right Side	6	Brake Terminals

Table 5.57 Legend to *Figure 5.74*
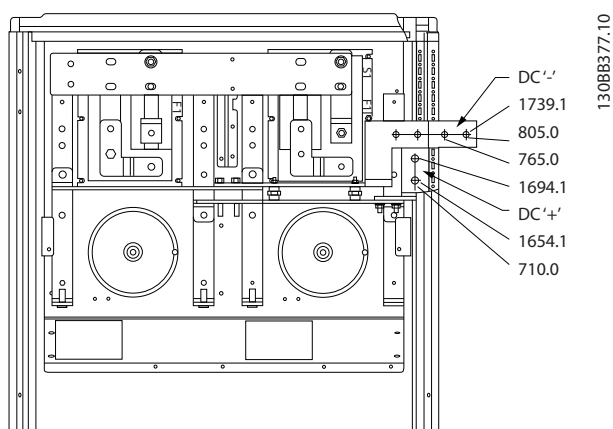
Figure 5.75 Regeneration Terminal Locations – F1 and F3

Terminal Locations - Frame Size F2 and F4
Take the following position of the terminals into consideration when designing the cable access.
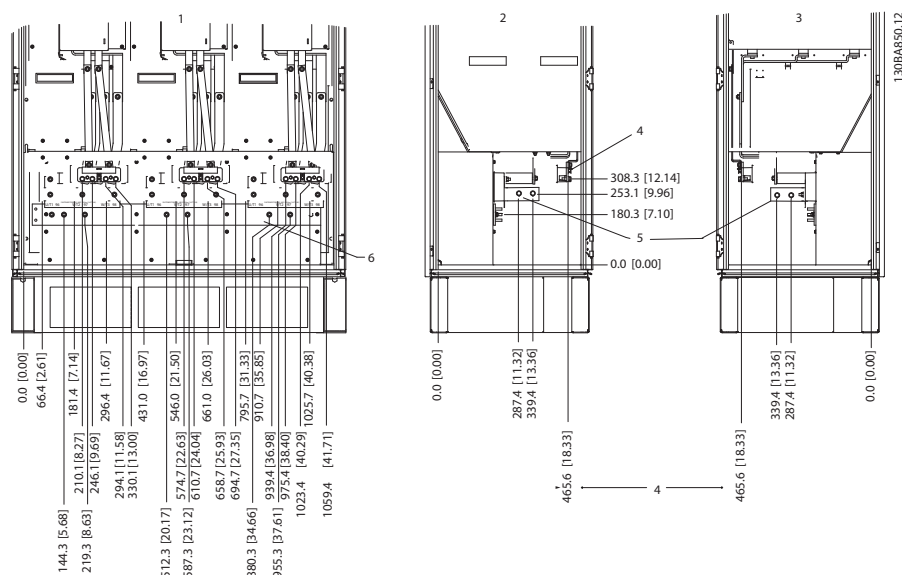
Figure 5.76 Terminal Locations - Inverter Cabinet - F2 and F4. Connector Plate is 1.65 in [42 mm] below .0 Level.

1	Front Side	3	Right Side
2	Left Side	4	Ground bar

Table 5.58 Legend to *Figure 5.76*
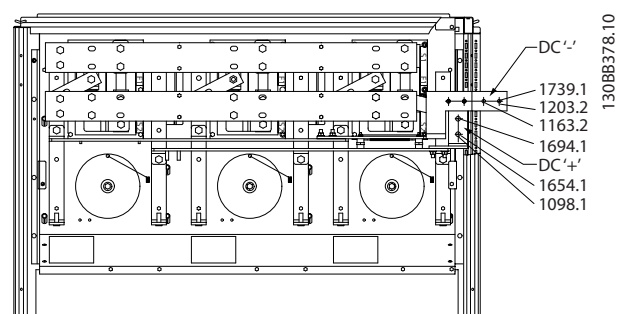
Figure 5.77 Regeneration Terminal Locations - F2 and F4

5

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

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

435.5 [17.15]
343.1 [13.51]
193.9 [7.64]
70.4 [2.77]
0.0 [0.00]

A B

188.6 [7.42]
136.6 [5.38]
90.1 [3.55]
38.1 [1.50]
0.0 [0.00]

0.0 [0.0]
74.6 [2.9]
125.8 [4.95]
149.6 [5.89]
183.4 [7.22]
218.6 [8.61]
293.6 [11.56]
362.6 [14.28]
373.4 [14.70]
437.6 [17.23]
486.6 [19.16]

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]
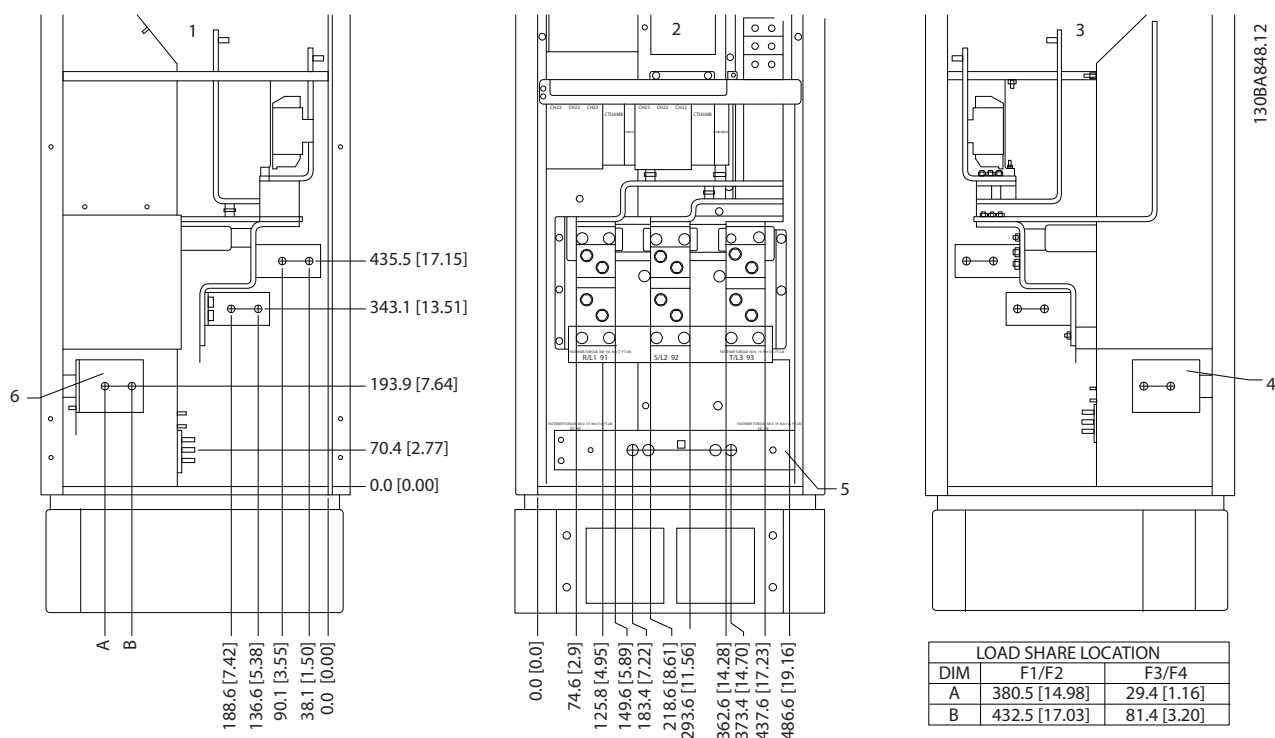
Figure 5.78 Terminal Locations - Rectifier. Connector Plate is 1.65 in [42 mm] below .0 Level.

1	Left Side	4	Load share Terminal (-)
2	Front Side	5	Ground bar
3	Right Side	6	Load share Terminal (+)

Table 5.59 Legend to *Figure 5.78*

Terminal Locations - Options Cabinet (F3 and F4)

Take the following position of the terminals into consideration when designing the cable access.
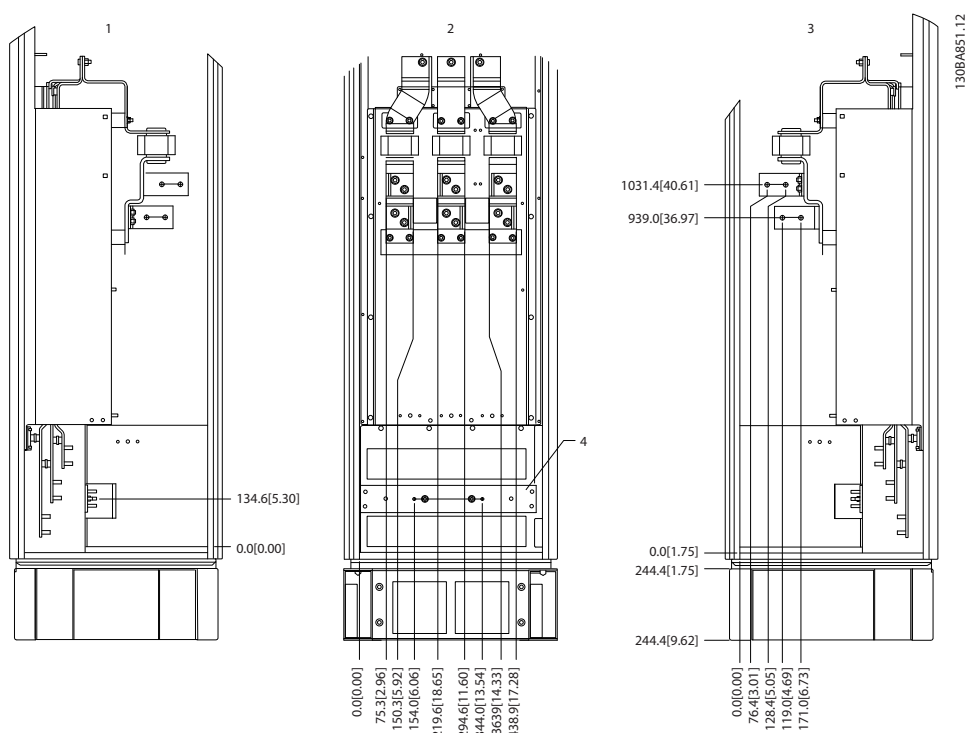
Figure 5.79 Terminal Locations - Options Cabinet. Connector Plate is 1.65 in [42 mm] below .0 Level.

1	Left Side	3	Right Side
2	Front Side	4	Ground bar

Table 5.60 Legend to *Figure 5.79*

Terminal Locations - Options Cabinet with Circuit Breaker/Molded Case Switch (F3 and F4)
Take the following position of the terminals into consideration when designing the cable access.
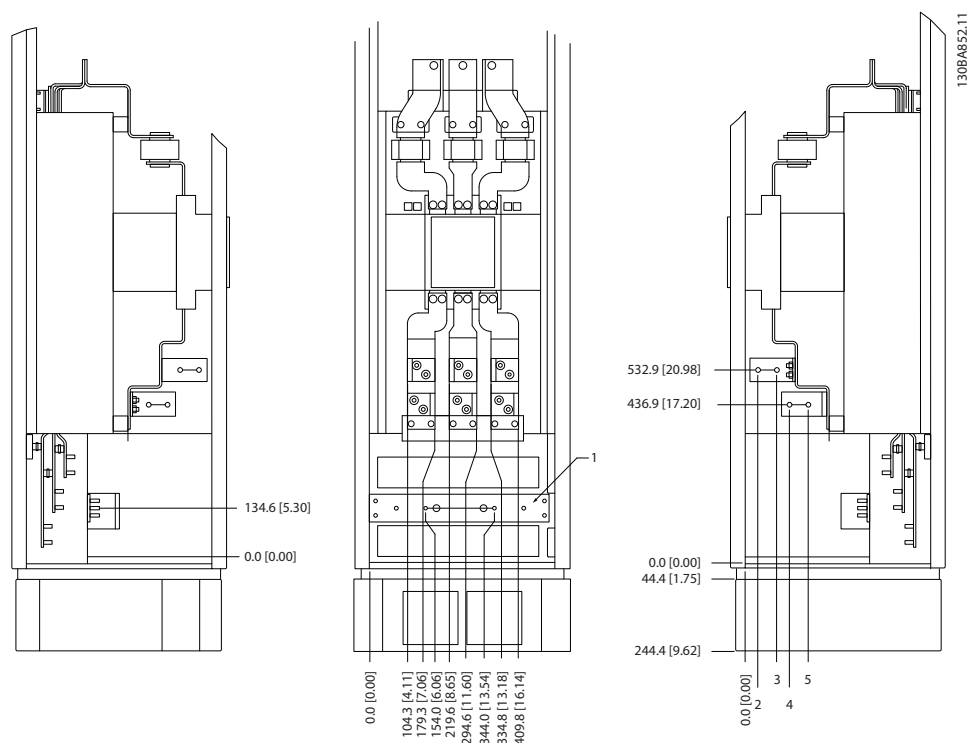
Figure 5.80 Terminal Locations - Options Cabinet with Circuit Breaker/Molded Case Switch. Connector Plate is 1.65 in [42 mm] below .0 Level.

1	Left Side	3	Right Side
2	Front Side	4	Ground bar

Table 5.61 Legend to *Figure 5.80*

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 5.62 Dimension for Terminal

5.2.8 Power Connections 12-Pulse Adjustable Frequency Drives

NOTICE!

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. Non-UL applications can use 167°F and 194°F [75 and 90°C] copper conductors.

The power cable connections are situated as shown in *Figure 5.81*. Dimensioning of cable cross-section must be done in accordance with the current ratings and local legislation. See *chapter 8.1 General Specifications* for correct dimensioning of motor cable cross-section and length.

For protection of the adjustable frequency drive, use the recommended fuses unless the unit is fitted with built-in fuses. Recommended fuses can be seen in *chapter 5.2.9 Fuses* . Always ensure that fusing complies with local regulations.

The AC line input connection is fitted to the line power switch if included.
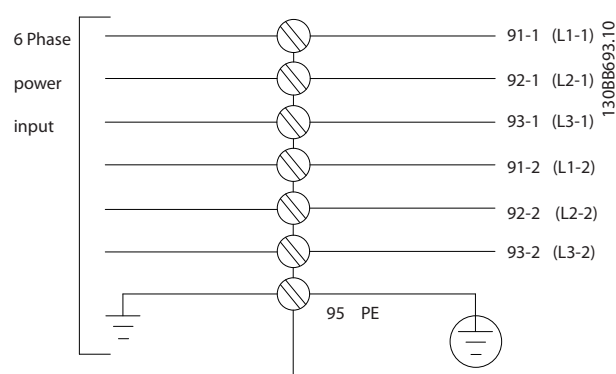
Figure 5.81 AC line input connections

NOTICE!

For more information, see *chapter 5.7 EMC-compatible Installation*.
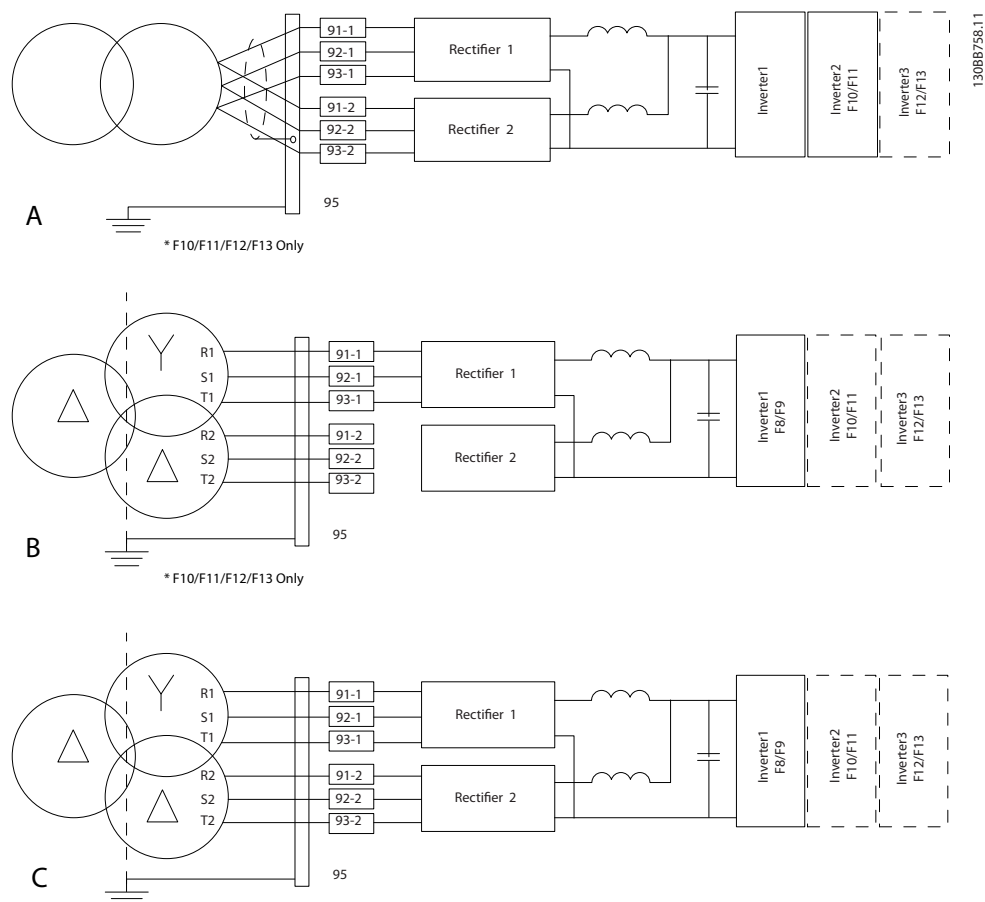
Figure 5.82 AC Line Input Connection Options for 12-Pulse Adjustable Frequency Drives

A	6-Pulse Connection[1), 2), 3)]
B	Modified 6-Pulse Connection[2), 3), 4)]
C	12-Pulse Connection[3), 5)]

Table 5.63 Legend to *Figure 5.82*

Notes:

[1)] Parallel connection shown. A single 3-phase cable may be used with sufficient carrying capability. Install shorting bus bars.

[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)] If 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 Danfoss for reconnection details.

[5)] No paralleling of line power cabling is shown here. A 12-pulse adjustable frequency drive used as a 6-pulse should have line cables of equal numbers and lengths.

5

NOTICE!

Use line cables of equal length (±10%) and the same wire size for all three phases on both rectifier sections.

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 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

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, set the switching frequency according to the instructions in *14-01 Switching Frequency*.

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

Table 5.64 Terminals

[1] *Protective Ground Connection*

NOTICE!

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

5.2.9 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 5.65* and *Table 5.66* to protect service personnel or other equipment in case of an internal failure. The adjustable frequency drive provides full short circuit protection in a short-circuit on the motor output.

Overcurrent protection:
To avoid fire hazard due to overheating of the cables, provide overcurrent protection 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.

5.2.10 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 5.65 380–480 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 5.66 525–690 V, Fuse Recommendations, Frame Sizes D, E and F

5.2.11 Control Terminals
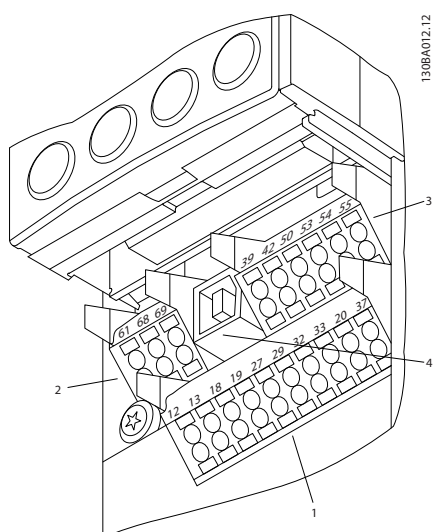
Figure 5.83 Control Terminals (all Enclosures)

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

Table 5.67 Legend to *Figure 5.83*

5.2.12 Control Cable Terminals

To mount the cable to the terminal:
1. Strip isolation of 0.35–0.39 in [9–10 mm].
2. Insert a screwdriver (Max. 0.4 x 2.5 mm) 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.

Control cable torque value is 0.5–0.6 Nm (5 in-lbs.)

To remove the cable from the terminal:
1. Insert a screwdriver[1] in the square hole.
2. Pull out the cable.

Wiring to Control Terminals
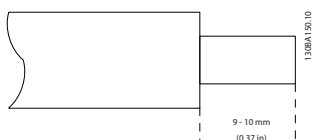
Figure 5.84 Strip Isolation
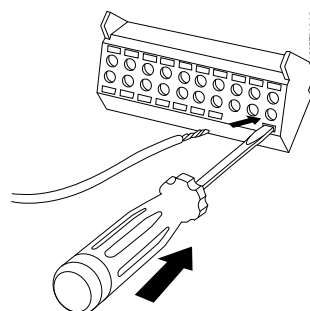
Figure 5.85 Insert Screwdriver and Cable
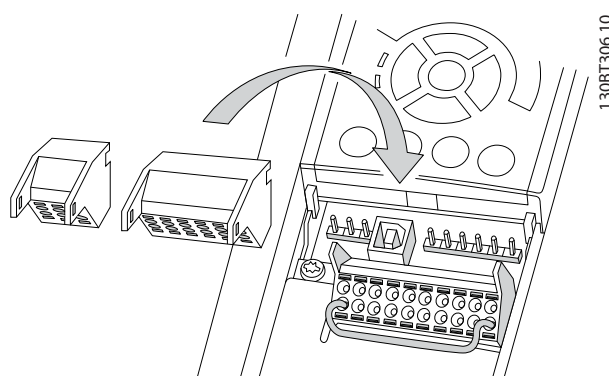
Figure 5.86 Control Cable Terminals

5.2.13 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 = latched start
27 = stop inverse

5

130BA156.11

Start   Stop inverse   Stop

Speed

Start (18)

Stop inverse
(27)
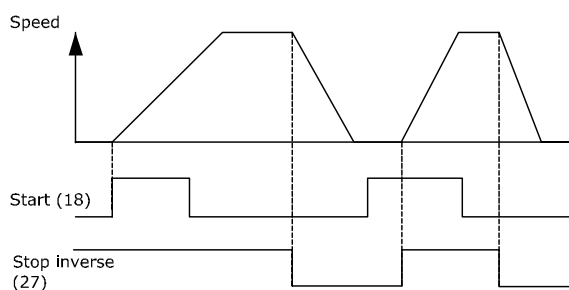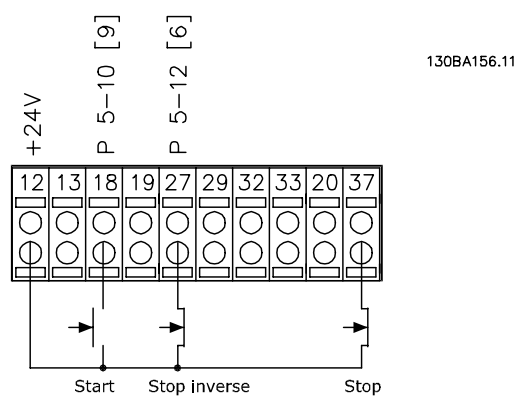
Figure 5.87 Terminal 37 available with Safe Torque Off Function only.

5.2.14 Electrical Installation, Control Cables

Figure 5.88 Interconnect Diagram for D-frames

5
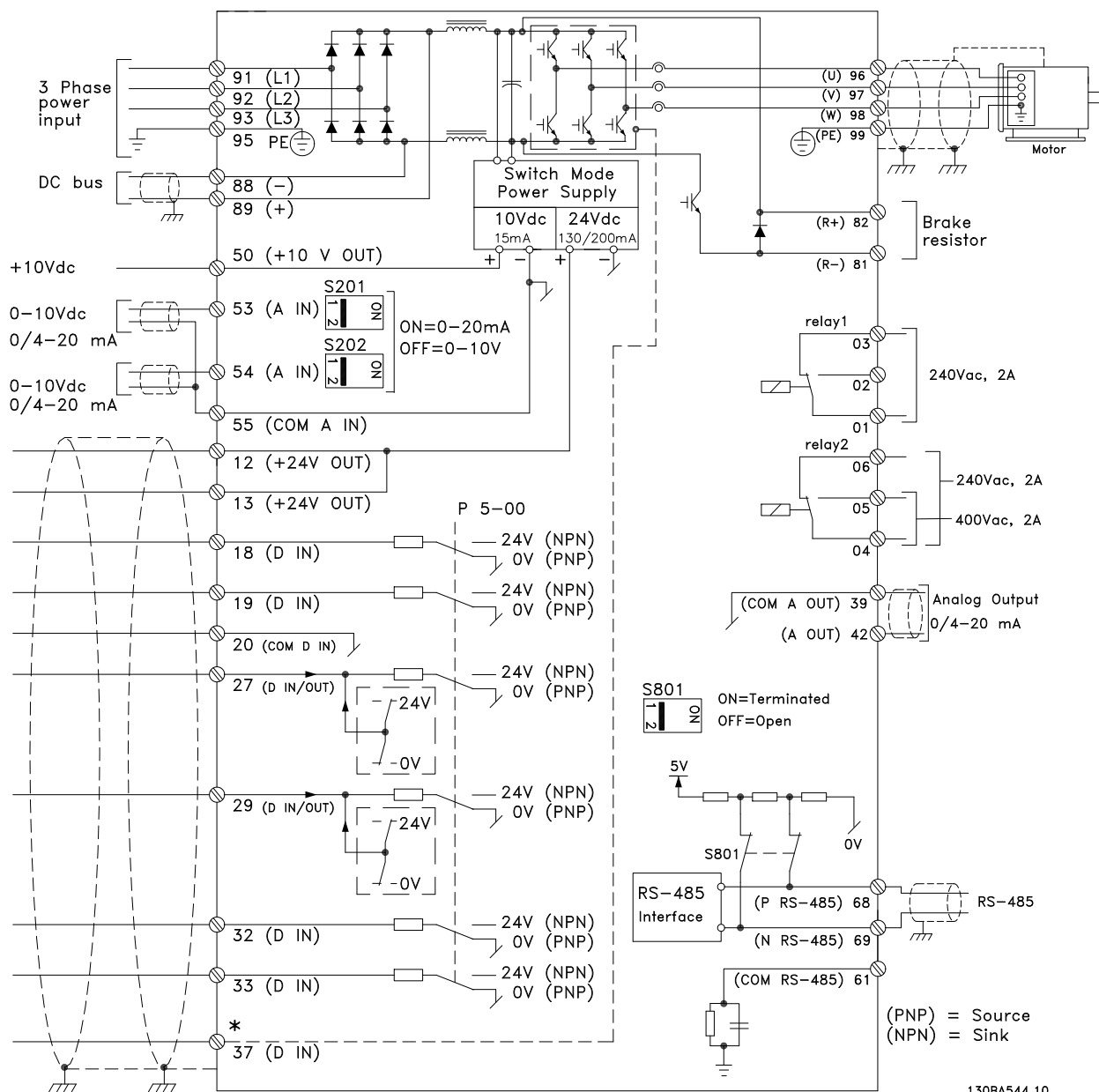
Figure 5.89 Interconnect Diagram E-frames and F-frames (6-pulse)

*Safe Torque Off (STO) input available with STO function only

Very long control cables and analog signals occasionally result in 50/60 Hz ground loops due to noise from 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.
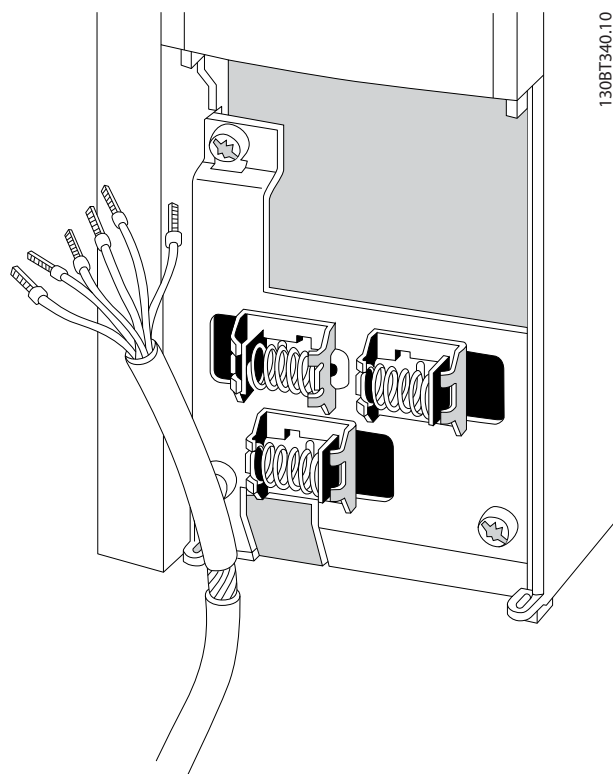
Figure 5.90 Shielded Control Cable

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How to Install**Design Guide**

5.2.15 12-Pulse Control Cables
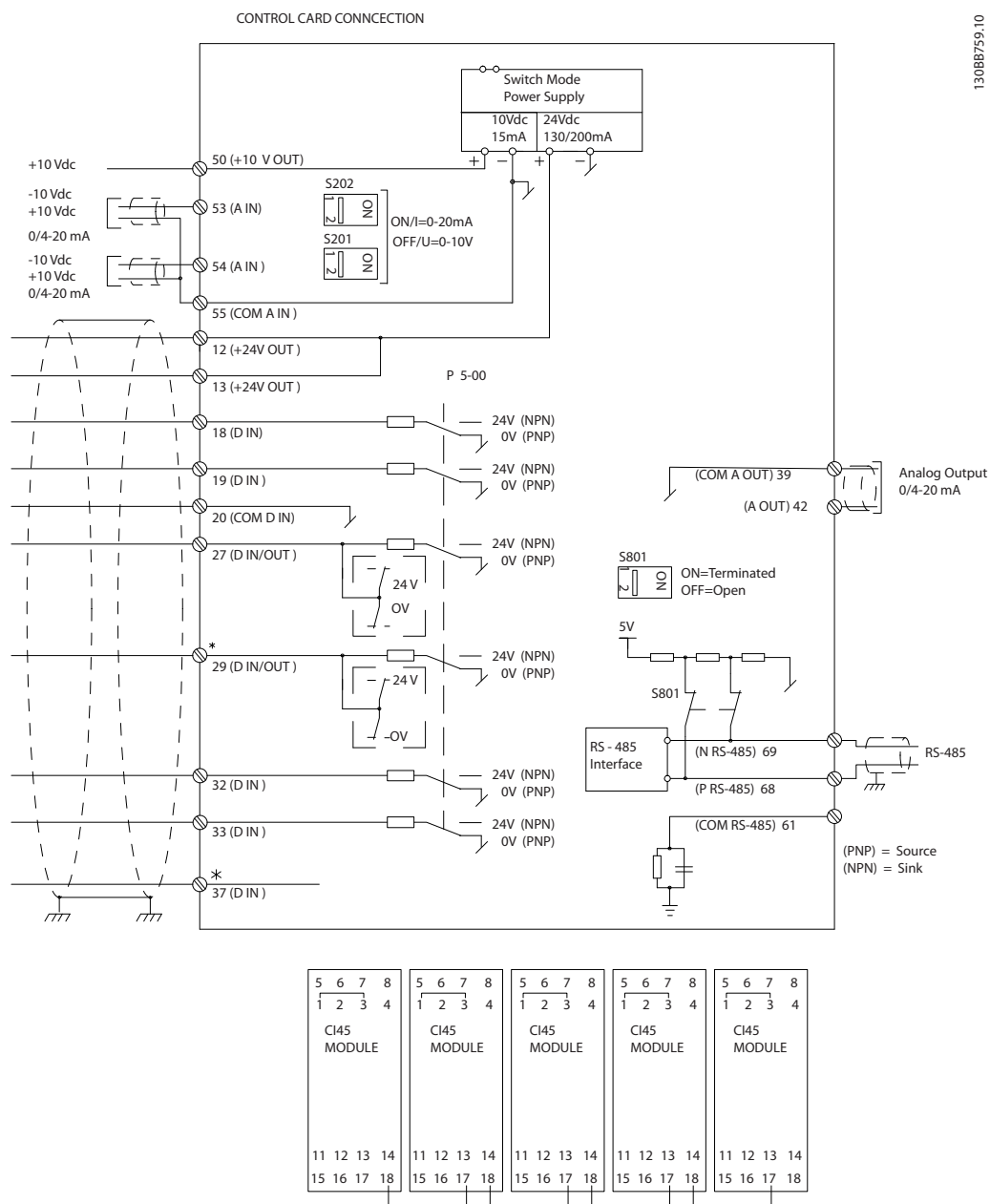
Figure 5.91 Control Cable Diagram

156Danfoss A/S © Rev. 2014-01-13 All rights reserved.MG16C122
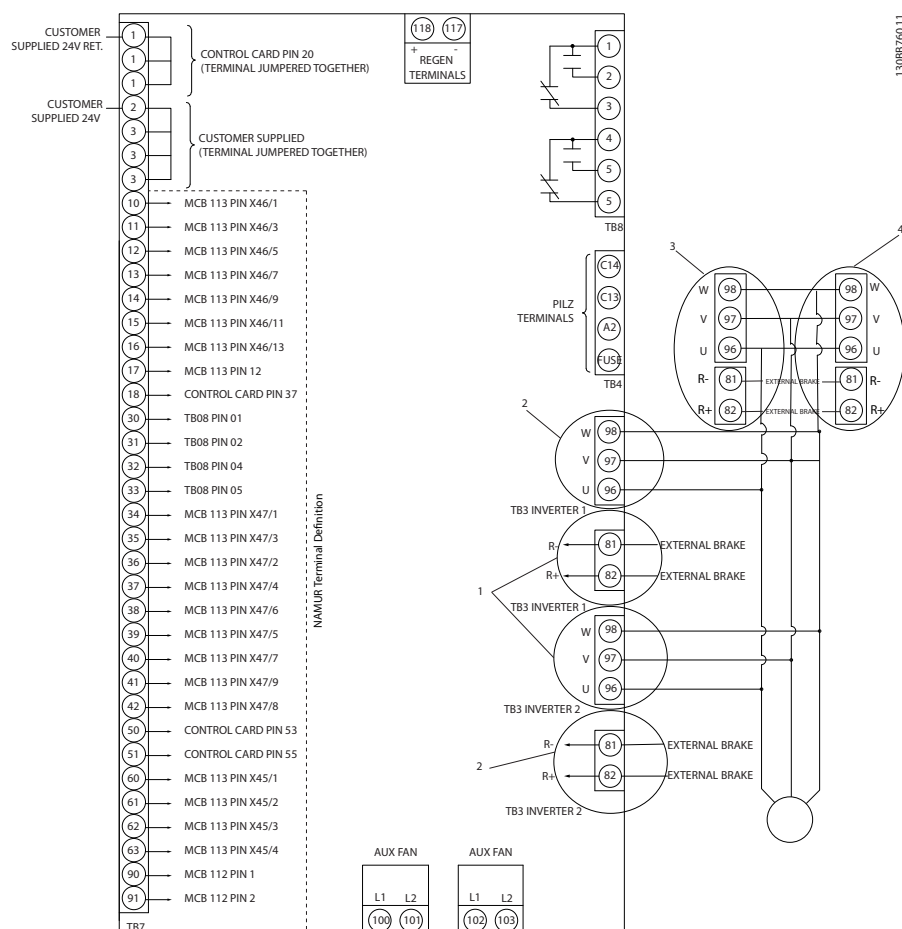
Figure 5.92 Electrical Terminals without Options

1	F8/F9, one set of terminals
2	F10/F11, two sets of terminals
3	F12/F13, three sets of terminals
4	F14/F15, four sets of terminals

Table 5.68 F-frame Numbers of Terminals

Terminal 37 is the input to be used for safe torque off. For instructions on safe torque off installation, refer to *chapter 2.6 Safe Torque Off*.

5

Input polarity of control terminals
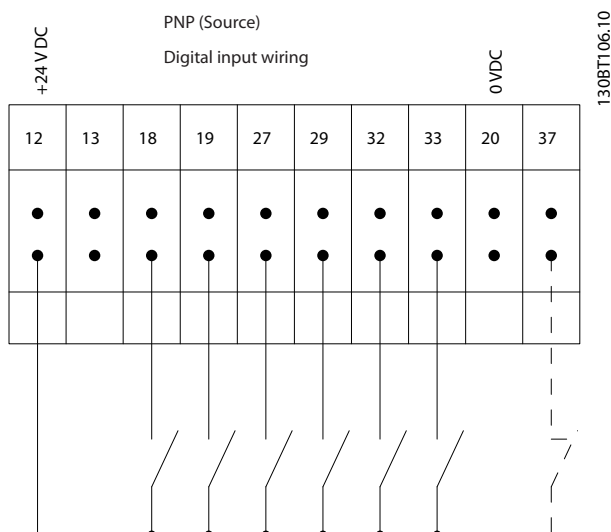
Figure 5.93 Input Polarity of Control Terminals, PNP
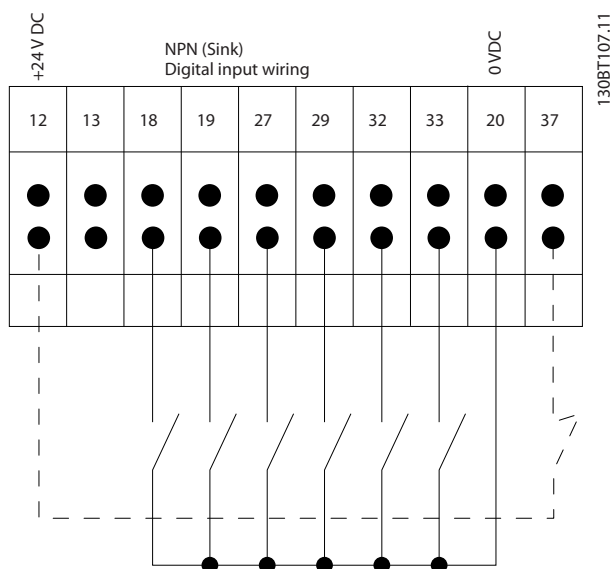
Figure 5.94 Input Polarity of Control Terminals, NPN

5.2.16 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 5.87*
Default setting:

> S201 (A53) = OFF (voltage input)

> S202 (A54) = OFF (voltage input)

> S801 (Bus termination) = OFF

NOTICE!

Change the switch position at power off only.
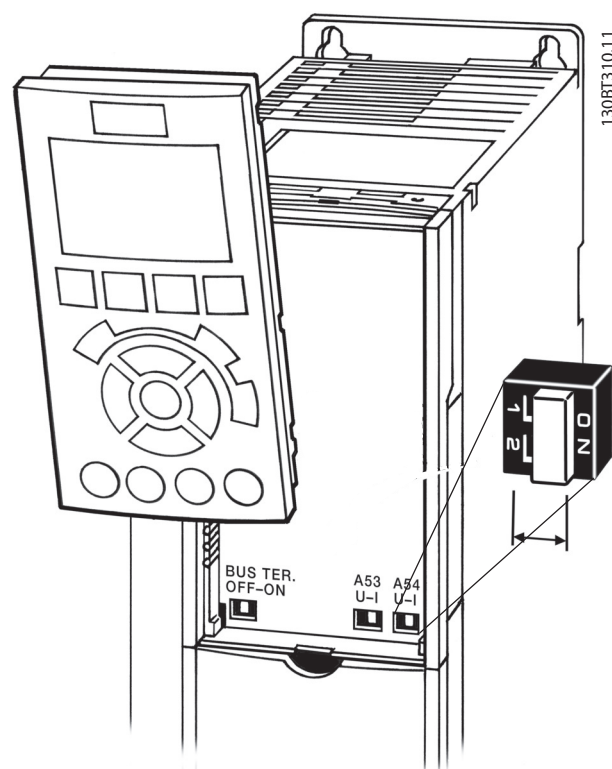
Figure 5.95 Switch Location

5.3 Final Set-up and Test

Before operating the adjustable frequency drive, perform a final test of the installation:

1. Locate the motor nameplate to find out whether the motor is star- (Y) or delta-connected (Δ).

2. Enter the motor nameplate data in the parameter list. Access the list by pressing the [QUICK MENU] key and selecting Q2 Quick Set-up. See *Table 5.69*.

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

Table 5.69 Quick Set-up Parameters
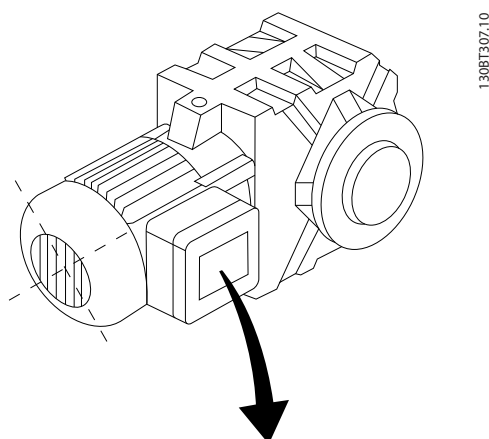
BAUER D-7 3734 ESLINGEN					
3~ MOTOR NR. 1827421 2003					
S/E005A9					
	1,5	KW			
n₂ 31,5	/MIN.	400	Y	V	
n₁ 1400	/MIN.		50	Hz	
cos 0,80			3,6	A	
1,7L					
B	IP 65	H1/1A			

Figure 5.96 Motor Nameplate

3. Perform an Automatic Motor Adaptation (AMA) to ensure optimum performance.

a. Connect terminal 27 to terminal 12 or set *5-12 Terminal 27 Digital Input* to 'No function' (*5-12 Terminal 27 Digital Input* [0]).

b. Activate the AMA *1-29 Automatic Motor Adaptation (AMA)*.

c. 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.

d. Press [OK]. The display shows "Press [Hand On] to start."

e. Press [Hand On]. A progress bar indicates if the AMA is in progress.

f. Press [OFF] - the adjustable frequency drive enters into alarm mode and the display shows that the AMA was terminated by the user.

Stop the AMA during operation

Successful AMA

- The display shows "Press [OK] to finish AMA".

- Press [OK] to exit the AMA state.

Unsuccessful AMA

- The adjustable frequency drive enters into alarm mode. A description of the alarm can be found in *chapter 8.6 Troubleshooting*.

- "Report Value" in the alarm log shows the last measuring sequence carried out by the AMA, before the adjustable frequency drive entered alarm mode. This number, along with the description of the alarm, will assist in troubleshooting. Mention the number and alarm description when contacting Danfoss service personnel.

Unsuccessful AMA is often caused by incorrectly registered motor nameplate data or too big a difference between the motor power size and the adjustable frequency drive power size.

5

Set up the desired limits for speed and ramp time.

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

Table 5.70 Reference Parameters

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

Table 5.71 Speed Limits

Ramp-up Time 1 [s]	*3-41 Ramp 1 Ramp-up Time*
Ramp-down Time 1 [s]	*3-42 Ramp 1 Ramp-down Time*

Table 5.72 Ramp Times

5.4 Additional Connections

5.4.1 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 5.73 Line Power Disconnects, D, E and F- frame Adjustable Frequency Drives

5

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 5.74 Line Power Disconnects, 12-Pulse Adjustable Frequency Drives

5.4.2 Circuit Breakers

Frame Size	Voltage [V]	Drive Model	Circuit Breaker Type	Default breaker settings (Trip level - Amps)	
				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 5.75 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 5.76 F-frame Circuit Breakers

5.4.3 Line Power Contactors

Frame size	Power & Voltage	Contactor
D6h	N90K-N132 380–500 V	GE CK95CE311N
	N110-N160 380–480 V	GE CK95BE311N
	N55-N132 525–690 V	GE CK95CE311N
	N75-N160 525–690 V	GE CK95BE311N
D8h	N160-N250 380–500 V	GE CK11CE311N
	N200-N315 380–480 V	
	N160-N315 525–690 V	
	N200-N400 525–690 V	

Table 5.77 D-frame Contactors

Frame size	Power & Voltage	Contactor
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 5.78 F-frame Contactors

NOTICE!

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

5.4.4 Brake Resistor Temperature Switch

Torque: 0.5–0.6 Nm (5 in-lbs)
Screw size: M3

This input can be used to monitor the temperature of an externally connected brake resistor. If the input between 104 and 106 is established, the adjustable frequency drive trips on warning/alarm 27, "Brake IGBT." If the connection is closed between 104 and 105, the adjustable frequency drive trips on warning/alarm 27, "Brake IGBT."
Install a KLIXON switch that is 'normally closed.' If this function is not used, short circuit 106 and 104 together.
Normally closed: 104-106 (factory installed jumper)
Normally open: 104-105

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

Table 5.79 Terminals for Brake Resister Temperature Switch

NOTICE!

If the temperature of the brake resistor gets too high and the thermal switch drops out, the adjustable frequency drive stops braking. The motor starts coasting.

5.4.5 External Fan Supply

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

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

Table 5.80 External Fan Supply Terminals

The connector located on the power card provides the connection of line voltage for the cooling fans. The fans are factory-equipped to be supplied from a common AC line (jumpers between 100-102 and 101-103). If an external supply is needed, the jumpers are removed and the supply is connected to terminals 100 and 101. Use a 5 Amp fuse for protection. In UL applications, use a Littelfuse KLK-5 or equivalent.

5.4.6 Relay Output D Frame

Relay 1

- Terminal 01: common

- Terminal 02: normally open 400 V AC

- Terminal 03: normally closed 240 V AC

Relay 2

- Terminal 04: common

- Terminal 05: normally open 400 V AC

- Terminal 06: normally 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*.

Use option module MCB 105 for additional relay outputs.
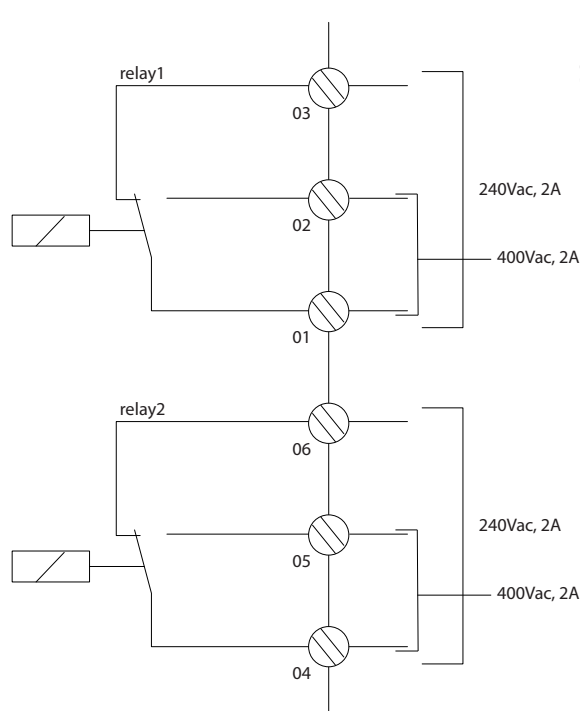
Figure 5.97 D-Frame Additional Relay Outputs

5.4.7 Relay Output E & F-Frame

Relay 1

- Terminal 01: common

- Terminal 02: normally open 240 V AC

- Terminal 03: normally closed 240 V AC

Relay 2

- Terminal 04: common

- Terminal 05: normally open 400 V AC

- Terminal 06: normally 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*.

Use option module MCB 105 for additional relay outputs.
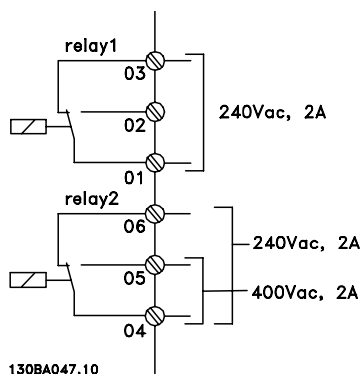
Figure 5.98 E- and F-Frame Additional Relay Outputs

5.4.8 Parallel Connection of Motors

The adjustable frequency drive can control several motors connected in parallel. The total current consumption of the motors must not exceed the rated output current I$_{INV}$ for the adjustable frequency drive.

When motors are connected in parallel, *1-29 Automatic Motor Adaptation (AMA)* cannot be used.

Small motors have relatively high ohmic resistance in the stator, which can cause problems at start and low RPM.

The electronic thermal relay (ETR) of the adjustable frequency drive cannot be used as motor protection for the individual motor of systems with parallel-connected motors. Provide further motor protection with, for example, thermistors in each motor or individual thermal relays (circuit breakers are not a suitable means of protection).
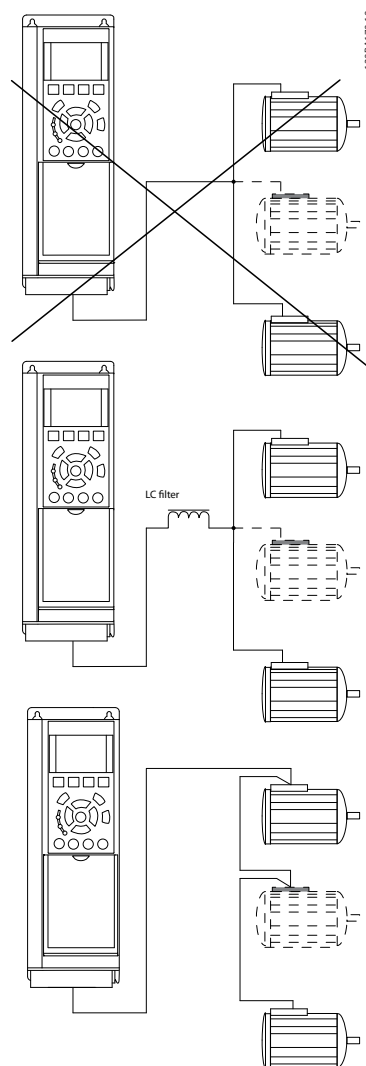
Figure 5.99 Correct Parallel Motor Connection

5.4.9 Direction of Motor Rotation

The default setting is clockwise rotation with the adjustable frequency drive output connected as follows.

Terminal 96 connected to U-phase
Terminal 97 connected to V-phase
Terminal 98 connected to W-phase

The direction of motor rotation is changed by switching two motor phases.

Motor rotation check can be performed using *1-28 Motor Rotation Check* and following the steps shown in the display.
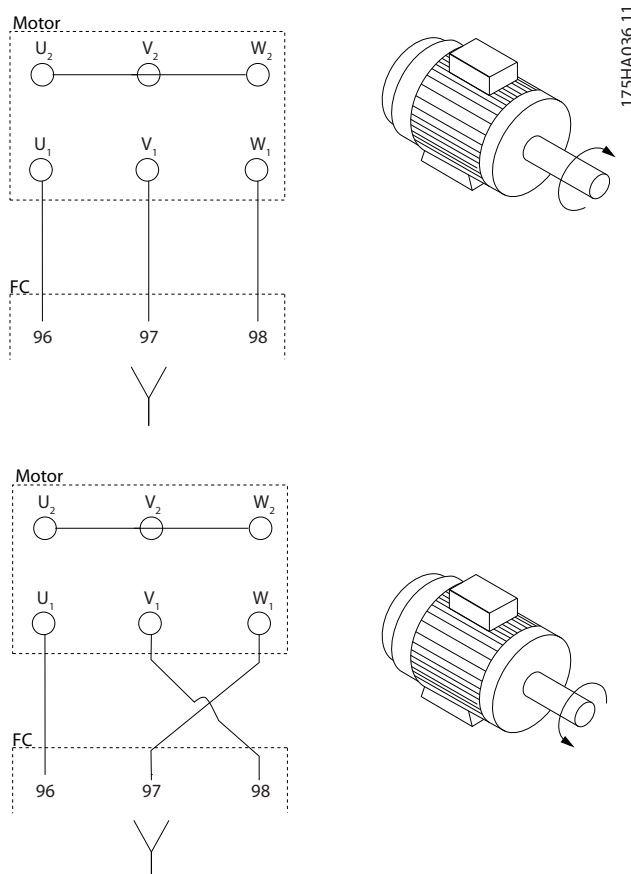
Figure 5.100 Changing Motor Rotation

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

5.4.10 Motor Insulation

For motor cable lengths ≤ the maximum cable length listed in *chapter 8 General Specifications and Trouble-shooting*, the recommended motor insulation ratings are in *Table 5.81*. The peak voltage can be up to twice the DC link voltage, 2.8 times the AC line voltage, due to transmission line effects in the motor cable. If a motor has a lower insulation rating, use a dU/dt or sine-wave filter.

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

Table 5.81 Motor Insulation at Various Nominal AC Line Voltages

5.4.11 Motor Bearing Currents

For motors with a rating of 110 kW or higher operating via adjustable frequency drives use NDE (Non-Drive End) insulated bearings to eliminate circulating bearing currents due to the physical size of the motor. To minimize DE (Drive End) bearing and shaft currents proper grounding of the adjustable frequency drive, motor, driven machine, and motor to the driven machine is required. Although failure due to bearing currents is rare, if it occurs, use the following mitigation strategies.

5

Standard mitigation strategies

- Use an insulated bearing

- Apply rigorous installation procedures

    Ensure the motor and load motor are aligned

    Strictly follow the EMC Installation guideline

    Reinforce the PE so the high frequency impedance is lower in the PE than the input power leads.

    Provide a good high frequency connection between the motor and the adjustable frequency drive by shielded cable, which has a 360° connection in the motor and adjustable frequency drive

    Ensure that the impedance from adjustable frequency drive to building ground is lower than the grounding impedance of the machine. Make a direct ground connection between the motor and load motor.

- Apply conductive lubrication

- Try to ensure that the line voltage is balanced to ground. This can be difficult for IT, TT, TN-CS or Grounded leg systems

- Use an insulated bearing as recommended by the motor manufacturer

NOTICE!

Motors from reputable manufacturers will typically have these fitted as standard in motors of this size.
If none of these strategies works, consult the factory.
If necessary after consulting Danfoss:

- Lower the IGBT switching frequency

- Modify the inverter waveform, 60° AVM vs. SFAVM

- Install a shaft grounding system or use an isolating coupling between motor and load

- Use minimum speed settings, if possible.

- Use a dU/dt or sinus filter

5.5 Installation of Misc. Connections

5.5.1 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.
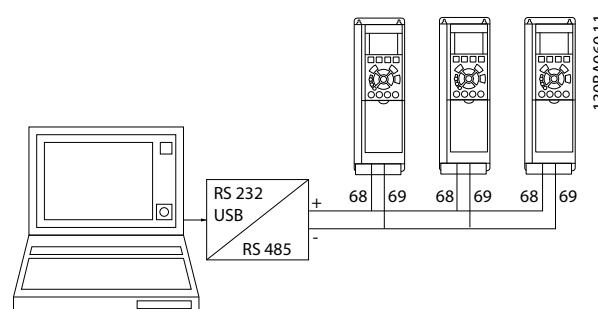
Figure 5.101 RS-485 Connecting Multiple Adjustable Frequency Drives to Master

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

For EMC-compliant installation, refer to *chapter 5.7 EMC-compatible Installation*.

Bus termination
The RS-485 bus must be terminated by a resistor network at both ends. Set switch S801 on the control card for "ON". For more information, see *chapter 5.2.16 Switches S201, S202, and S801*.

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

5.5.2 How to Connect a PC to the Adjustable Frequency Drive

To control or program the adjustable frequency drive from a PC, install the PC-based configuration tool MCT 10 Set-up Software.
The PC is connected via a standard (host/device) USB cable, or via the RS-485 interface as shown in *chapter 5.5.1 RS-485 Bus Connection*.

NOTICE!

The USB connection is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals. The USB connection is connected to protection ground. Use only an isolated laptop as PC connection to the USB connector on the adjustable frequency drive.
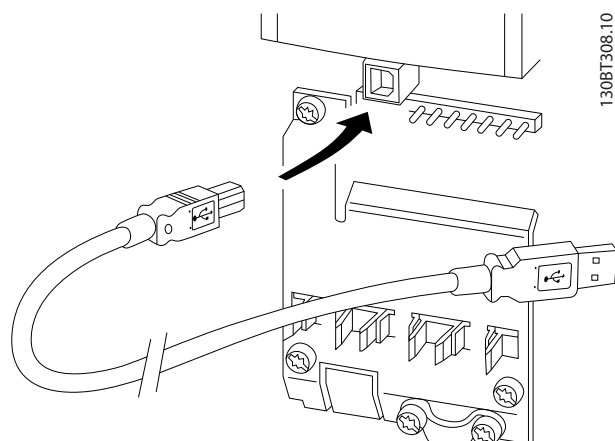
Figure 5.102 For Control Cable Connections, see
chapter 5.2.11 Control Terminals

PC-based Configuration Tool MCT 10 Set-up Software
All adjustable frequency drives are equipped with a serial communication port. Danfoss provides a PC tool for communication between PC and adjustable frequency drive, PC-based configuration tool MCT 10 Set-up Software.

MCT 10 Set-up Software
MCT 10 Set-up Software has been designed as an easy to use interactive tool for setting parameters.
The PC-based configuration tool MCT 10 Set-up Software will be useful for:

- Planning a communication network offline. MCT 10 Set-up Software 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

The PC-based configuration tool MCT 10 Set-up Software supports Profibus DP-V1 via a master class 2 connection. This makes it possible to access read/write parameters online in an adjustable frequency drive via the Profibus network. This will eliminate the need for an extra communication network. Consult the Profibus Instruction Manual for more information about the features supported by the Profibus DP V1 functions.

Save Drive Settings:
1. Connect a PC to the unit via the USB com port.
2. Open PC-based configuration tool MCT 10 Set-up Software
3. Select "Read from drive"
4. Select "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 PC-based configuration tool MCT 10 Set-up Software
3. Select "Open." Stored files will be shown
4. Open the appropriate file
5. Select "Write to drive"

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

A separate manual for PC-based configuration tool MCT 10 Set-up Software is available.

The PC-based configuration tool 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

Table 5.82 MCT 10 Modules

Ordering number:
Order the CD containing the PC-based configuration tool MCT 10 Set-up Software, using code number 130B1000.

5.5.3 MCT 31

The MCT 31 harmonic calculation PC tool enables easy estimation of the harmonic distortion in a given application.

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

5.6 Safety

5.6.1 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 1 s 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.

5.6.2 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.

5.7 EMC-compatible Installation

5.7.1 Electrical Installation - EMC Precautions

Follow the EMC-compatible guidelines below to comply with EN 61800-3 *First environment*. If the installation is in EN 61800-3 *Second environment*, deviation from these guidelines is allowed but not recommended. See also paragraphs *chapter 2.2 CE Labeling*, *chapter 2.9 General aspects of EMC* and *chapter 2.9.3 EMC Test Results (Emission)*

Good engineering practice to ensure EMC-compatible electrical installation:

- Use only braided shielded/armored motor cables and braided shielded/armored control cables. The shield should provide a minimum coverage of 80%. The shield material is metal, typically copper, aluminum, steel or lead. There are no special requirements for the line cable.

- Installations using rigid metal conduits do not require shielded cable, but the motor cable must be installed in conduit separate from the control and line cables. Full connection of the conduit from the drive to the motor is required. The EMC performance of flexible conduits varies. Contact the manufacturer for more information.

- Connect the shield/armor/conduit to ground at both ends for motor cables as well as for control cables. In some cases, it is not possible to connect the shield at both ends. In such cases, connect the shield at the adjustable frequency drive. See also *chapter 5.7.1 Electrical Installation - EMC Precautions* .

5

Good engineering practice to ensure EMC-compatible electrical installation:

- Avoid terminating the shield/armor with twisted ends (pigtails). It increases the high frequency impedance of the shield, which reduces its effectiveness at high frequencies. Use low impedance cable clamps or EMC cable connectors instead.

- Avoid using non-shielded/unarmored motor or control cables inside cabinets housing the adjustable frequency drive, whenever possible.

Leave the shield as close to the connectors as possible.

Figure 5.103 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.

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.
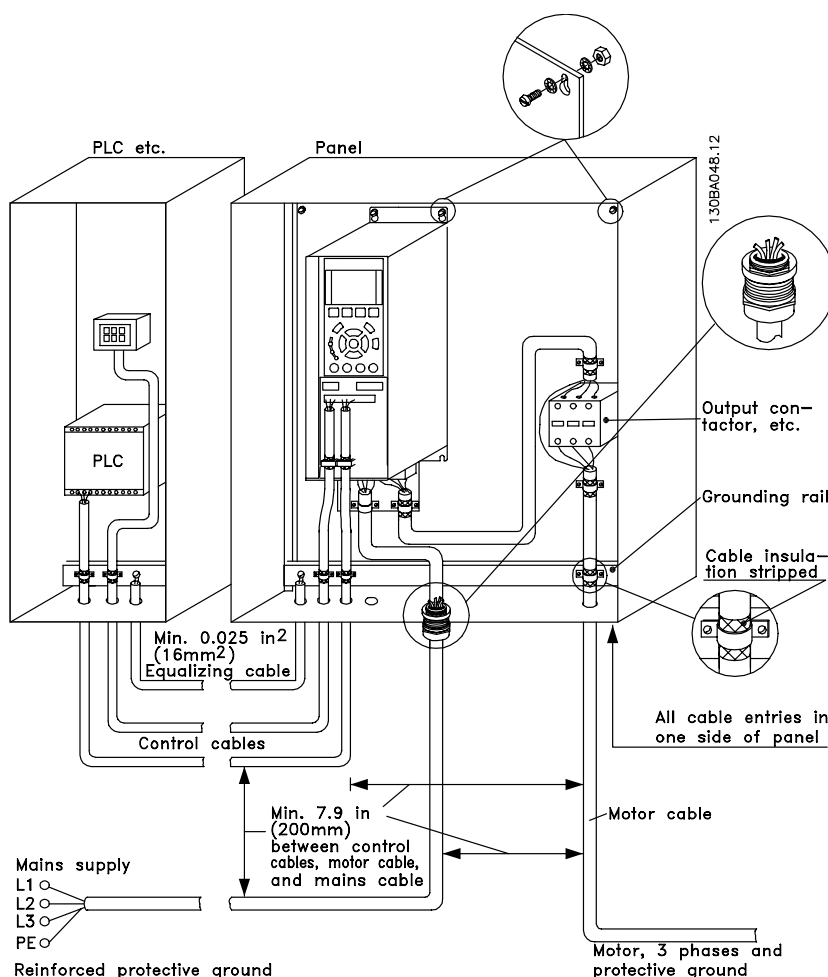
Figure 5.103 EMC-compatible Electrical Installation of an Adjustable Frequency Drive in Cabinet
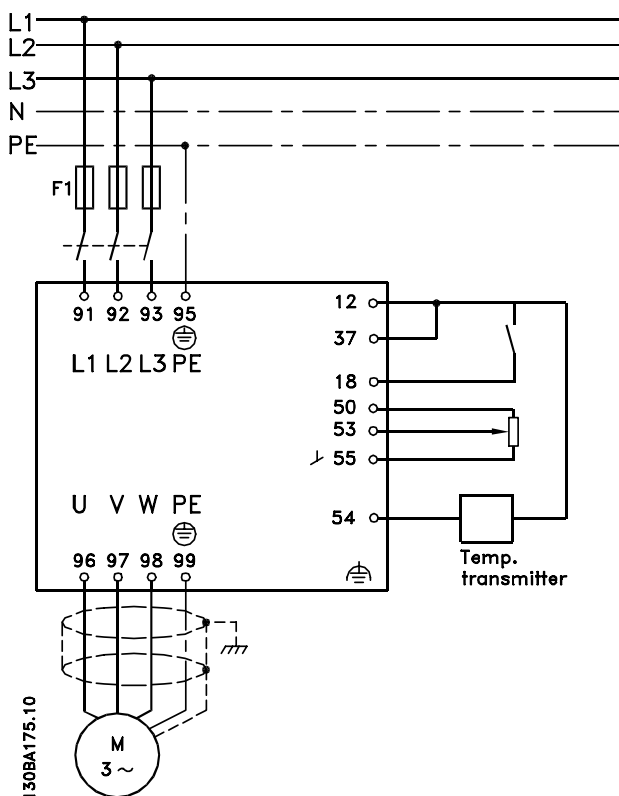
Figure 5.104 Electrical Connection Diagram, 6-pulse Example

5.7.2 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).

Transfer impedance (Z_T) is rarely stated by cable manufacturers, but it is often possible to estimate transfer impedance (Z_T) by assessing the physical design of the cable.

Transfer impedance (Z_T) can be assessed by the following:

- The conductibility of the shield material.

- The contact resistance between the individual shield conductors.

- The shield coverage, which is the physical area of the cable covered by the shield, often stated as a percentage value.

- Braided or twisted shield type.
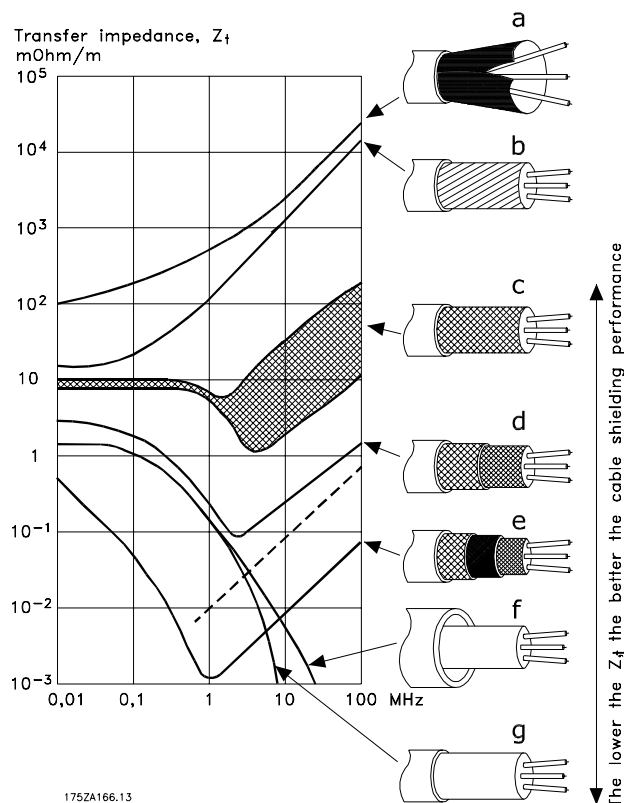
Figure 5.105 Cable Types

a	Aluminum-clad with copper wire.
b	Twisted copper wire or armored steel wire cable.
c	Single-layer braided copper wire with varying percentage shield coverage. This is the typical Danfoss reference cable.
d	Double-layer braided copper wire.
e	Twin layer of braided copper wire with a magnetic, shielded/armored intermediate layer.
f	Cable that runs in copper tube or steel tube.
g	Lead cable with 0.43 in [1.1 mm] wall thickness.

Table 5.83 Legend to *Figure 5.105*

5.7.3 Grounding of Shielded/Armored Control Cables

Control cables should 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 5.106* shows correct grounding examples.
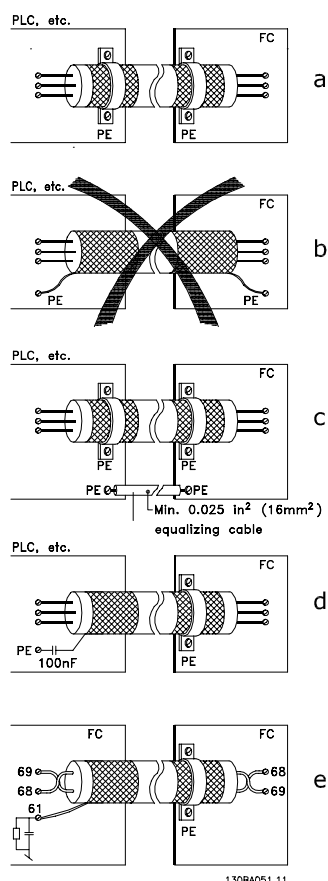
Figure 5.106 Grounding Examples

a	Correct grounding
b	Incorrect grounding
c	Protection from potential between PLC and adjustable frequency drive
d	50/60 Hz ground loops
e	Cables for Serial Communication

Table 5.84 Legend to *Figure 5.106*

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

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

c. **Protection from potential between PLC and adjustable frequency drive**
If the ground potential between the adjustable frequency drive and the PLC (etc.) is different, electric noise that disturbs the entire system is possible. Fit an equalizing cable next to the control cable. Minimum cable cross-section: 0.025 in^2 [16 mm^2].

d. **For 50/60 Hz ground loops**
Using long control cables sometimes causes 50/60 Hz ground loops. Connect 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 to reduce the differential mode interference between the conductors.

5.8 Residual Current Device

Use RCD relays, multiple protective grounding or grounding as extra protection in compliance with local safety regulations.
If a ground fault appears, a DC content may develop in the faulty current.
If using RCD relays, observe local regulations. Relays must be suitable for protecting 3-phase equipment with a bridge rectifier and for a brief discharge on power-up. See *chapter 2.11 Ground Leakage Current* for more information.

6 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)
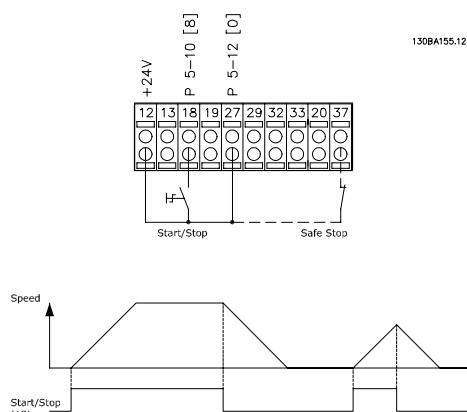
Figure 6.1 Terminal 37: Available only with STO Function

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
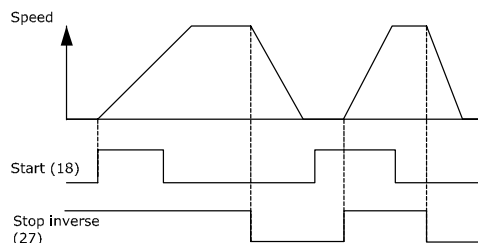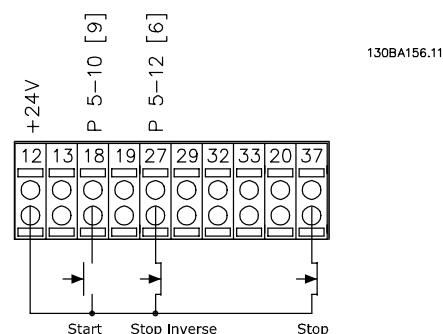
Figure 6.2 Terminal 37: Available only with STO Function

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)
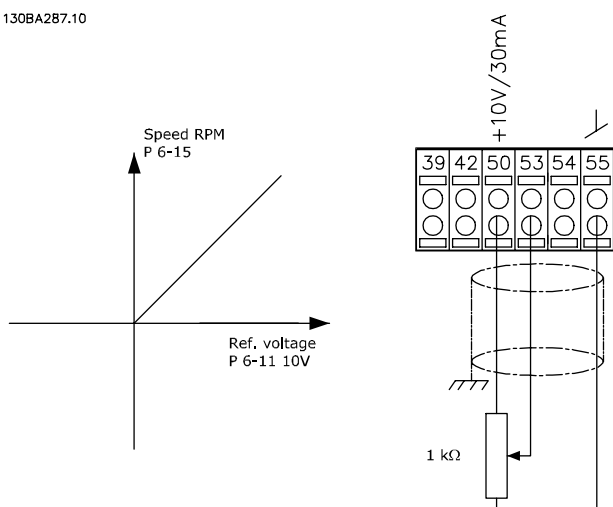
Figure 6.3 Potentiometer Voltage Reference

6.1.4 Automatic Motor Adaptation (AMA)

AMA is an algorithm to measure the electrical motor parameters on a motor at standstill. This means that AMA itself does not supply any torque.
AMA is useful when commissioning systems and optimizing the adjustment of the applied motor. This feature is particularly 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 may heat the motor, resulting in an increase of the stator resistance, Rs. Normally, this is not critical.

- AMA can only be performed 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 oversized 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 using synchronous motors, run a reduced AMA and manually set the extended motor data. The AMA function does not apply to permanent magnet (PM) 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).

6.1.5 Smart Logic Control

In applications where a PLC is generating a simple
sequence the Smart Logic Controller (SLC) can take 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.

6.1.6 Smart Logic Control Programming

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. This means that when *event [1]* is
fulfilled (attains the value TRUE), *action [1]* is executed.
After this, the conditions of *event [2]* is evaluated and if
evaluated TRUE, *action [2]* is executed and so on. Events
and actions are placed in array parameters.

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]*.
Figure 6.4 shows an example with three events/actions:
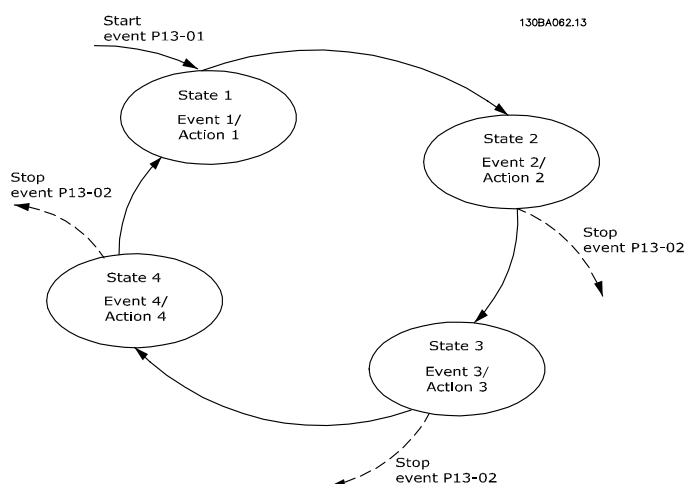
Figure 6.4 Example of Events and Actions

6.1.7 SLC Application Example

One Sequence 1
Start – ramp up – run at reference speed 2 s – ramp down and hold shaft until stop.
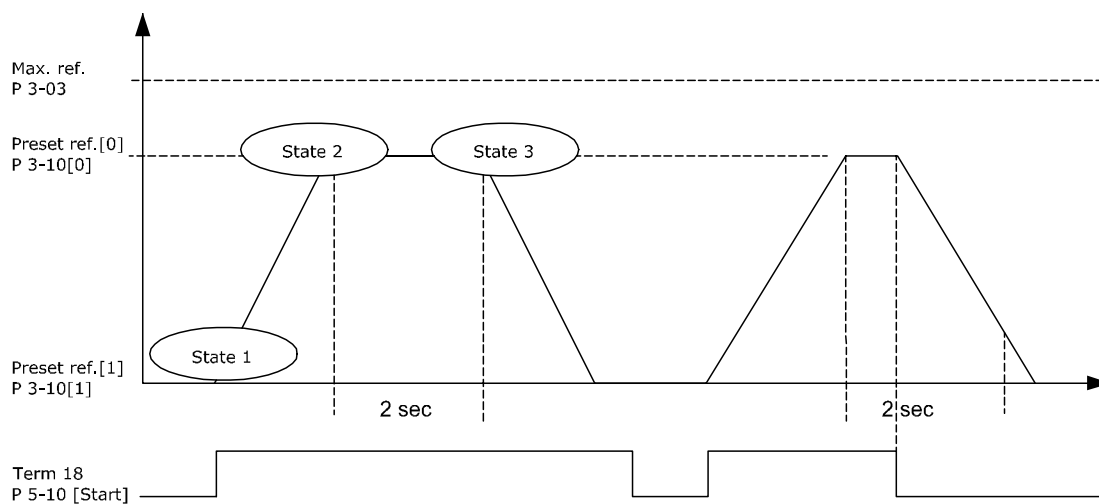
Figure 6.5 SLC Example

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 terminal 27 to *No Operation* (*5-12 Terminal 27 Digital Input*)

1. 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%

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

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

4. Set Event 1 in *13-51 SL Controller Event* [1] to *True* [1]

5. Set Event 2 in *13-51 SL Controller Event* [2] to *On Reference* [4]

6. Set Event 3 in *13-51 SL Controller Event* [3] to *Time Out 0* [30]

7. Set Event 4 in *13-51 SL Controller Event* [4] to *False* [0]

8. Set Action 1 in *13-52 SL Controller Action* [1] to *Select preset 0* [10]

9. Set Action 2 in *13-52 SL Controller Action* [2] to *Start Timer 0* [29]

10. Set Action 3 in *13-52 SL Controller Action* [3] to *Select preset 1* [11]

11. Set Action 4 in *13-52 SL Controller Action* [4] to *No Action* [1]

6
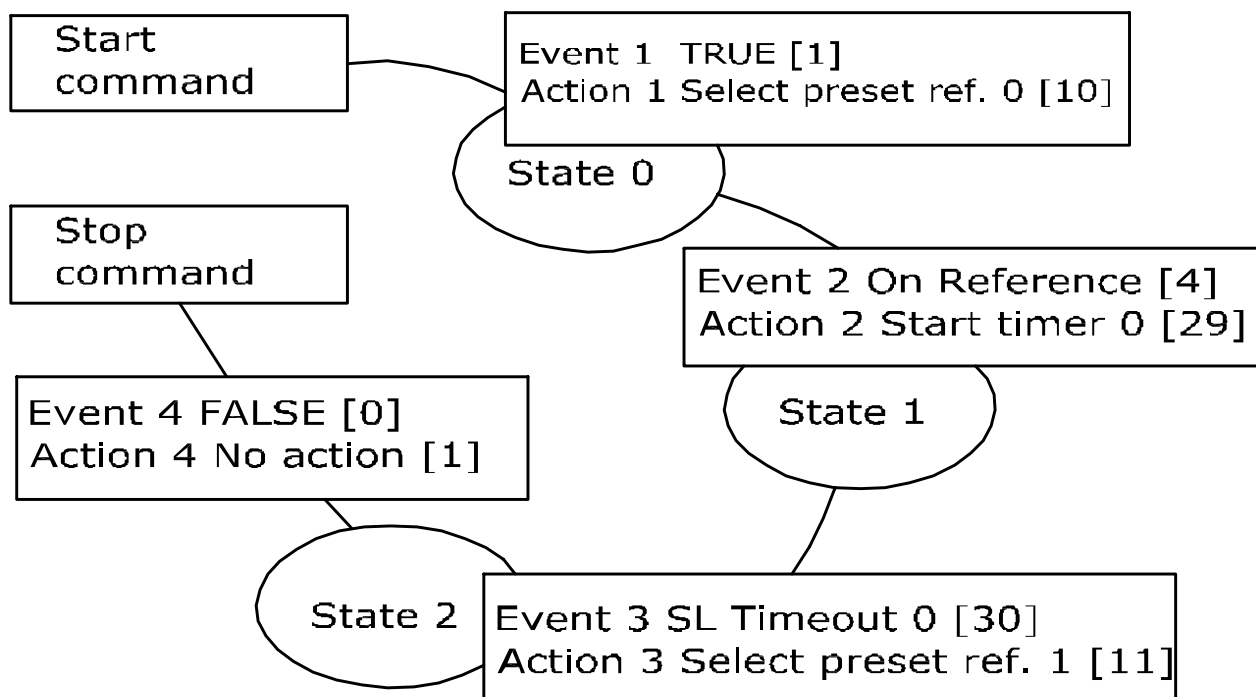
Figure 6.6 Set Actions

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

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

 MG16C122

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6.1.8 BASIC Cascade Controller
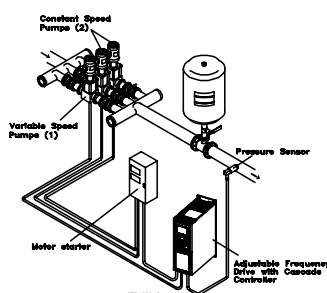
Figure 6.7 BASIC Cascade Controller

The BASIC cascade controller is used for pump applications where a certain pressure ("head") or level needs to be maintained over a wide dynamic range. Running a large pump at variable speed over a wide range is not an ideal solution because of low pump efficiency, and because there is a practical limit of about 25% rated full load speed for running a pump.

In the BASIC cascade controller, the adjustable frequency drive controls a variable speed motor as the variable speed pump (lead) 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. This maintains constant pressure while eliminating pressure surges, resulting in reduced system stress and quieter operation.

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 two built-in relays. When the variable pump (lead) is connected directly to the drive, the other two pumps are controlled by the two built-in relays. When lead pump alternations are enabled, pumps are connected to the built-in relays and the adjustable frequency drive is capable of operating two pumps.

Lead Pump Alternation
When the motors are of equal size, lead pump alteration enables the adjustable frequency drive to cycle the drive between the pumps in the system (maximum of two pumps). In this operation, the run time between pumps is equalized, thus reducing the required pump maintenance and increasing reliability and system lifetime. 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. Staging is determined by the actual system load.

A separate parameter limits alternation to take place only 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, the desired system pressure is kept within a bandwidth rather than at a constant level to avoid frequent switching of fixed-speed pumps. 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 has been established.

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

6.1.9 Pump Staging with Lead Pump Alternation
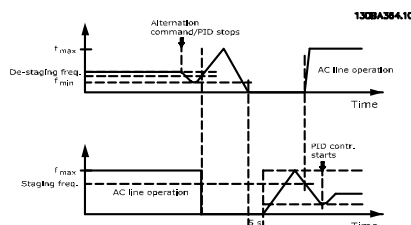
Figure 6.8 Pump Staging with Lead Pump Alternation

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

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, avoiding a water circulation problem.

6.1.10 System Status and Operation

If the lead pump goes into sleep mode, the function is displayed in the LCP. It is possible to alternate the lead pump on 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 line power/motor starter
- Cascade Status is a readout of the status for the cascade controller. The display shows the following conditions:
    - Cascade controller is disabled
    - All pumps are off
    - An emergency has stopped all the pumps
    - All pumps are running
    - Fixed-speed pumps are being staged/ destaged
    - Lead pump alternation is occurring.
- Destage at no-flow ensures that all fixed-speed pumps are stopped individually until the no-flow status disappears.

6.1.11 Fixed Variable-speed Pump Wiring Diagram
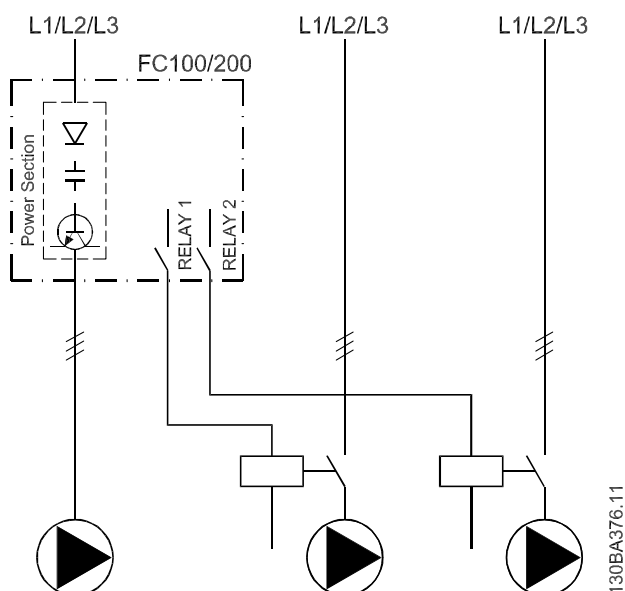
Figure 6.9 Fixed Variable-speed Pump Wiring Diagram

6.1.12 Lead Pump Alternation Wiring Diagram
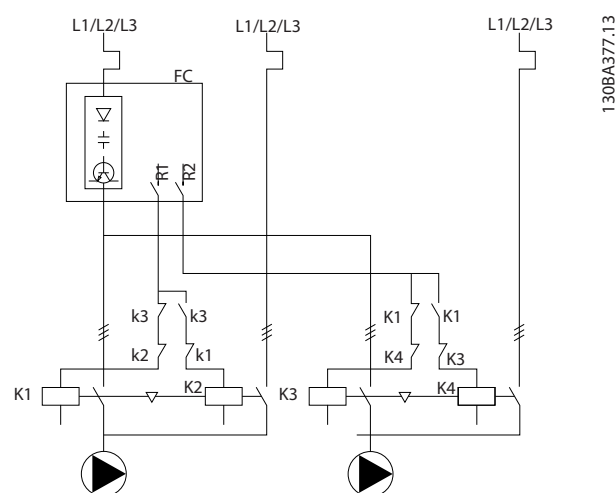
Figure 6.10 Lead Pump Alternation Wiring Diagram

Every pump must be connected to two contactors (K1/K2 and K3/K4) with a mechanical interlock. Apply thermal relays or other motor protection devices 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 to be energized cuts in the contactor corresponding to the pump controlled by the relay.

- 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 is energized as the first relay.

6.1.13 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.
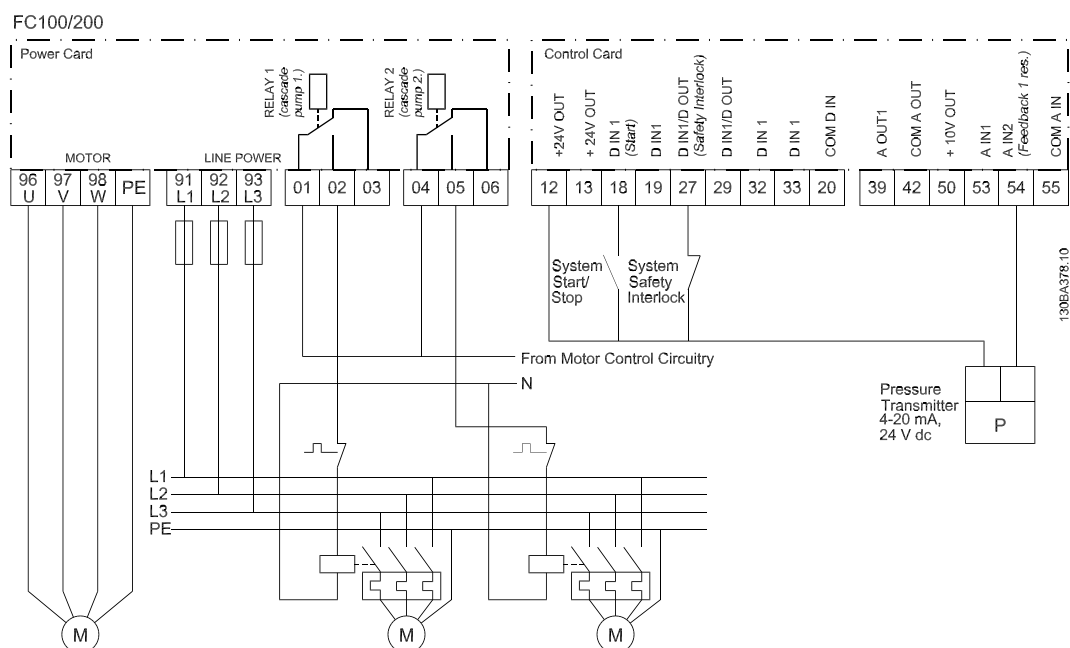
Figure 6.11 Cascade Controller Wiring Diagram

6.1.14 Start/Stop Conditions

For more information, see parameter group *5-1* Digital Inputs*.

Command	Variable-speed pump (lead)	Fixed-speed pumps (lag)
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 (corresponding relays, terminal 27/29 and 42/45)
External Interlock	Coast to stop	Cut out (built in relays are de-energized)

Table 6.1 Commands Assigned to Digital Inputs

	Variable-speed pump (lead)	Fixed-speed pumps (lag)
Hand On	Ramps up (if stopped by a normal stop command) or stays in operation if already running.	Destaging (if running)
Off	Ramps down	Destaging
Auto On	Starts and stops according to commands via terminals or serial bus. Cascade controller can only work when the adjustable frequency drive is in "Auto ON" mode	Staging/Destaging

Table 6.2 Function of LCP Keys

7 Installation and Set-up

7.1 Installation and Set-up

RS-485 is a 2-wire bus interface compatible with multi-drop network topology, i.e., nodes can be connected as a bus, or via drop cables from a common trunk line. A total of 32 nodes can be connected to one network segment. Repeaters divide network segments. Note that each repeater functions as a node within the segment in which it is installed. Each node connected within a given network must have a unique node address across all segments. Terminate each segment at both ends using either the termination switch (S801) of the adjustable frequency drives or a biased termination resistor network. Always use shielded twisted pair (STP) cable for bus cabling, and always follow good common installation practice. Low-impedance ground connection of the shield at every node is important. Connect a large surface of the shield to ground with a cable clamp or a conductive cable connector. If needed, 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. 1640 ft [500 m] station-to-station

Table 7.1 Motor Cable Specifications

7.1.1 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 *chapter 5.6.2 Safety Ground Connection chapter 5.7.3 Grounding of Shielded/Armored Control Cables*

If more than one adjustable frequency drive is connected to a master, use parallel connections.
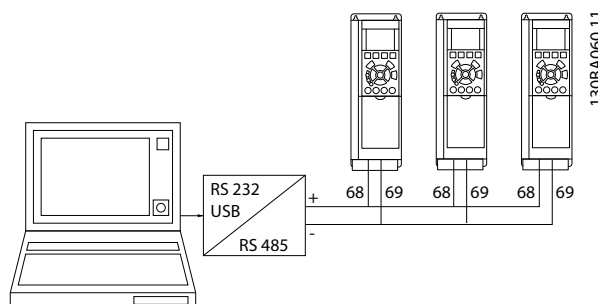
Figure 7.1 Parallel Connections

To avoid potential equalizing currents in the shield, ground the cable shield via terminal 61, which is connected to the frame with an RC link.
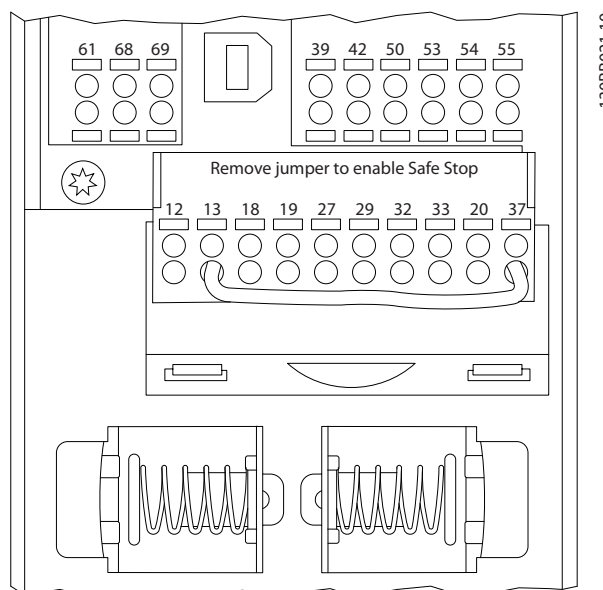
Figure 7.2 Control Card Terminals

7.1.2 Hardware Set-up

Use the terminator dip switch on the main control board of the adjustable frequency drive to terminate the RS-485 bus.
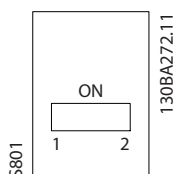
Figure 7.3 Terminator Switch Factory Setting

The factory setting for the dip switch is OFF.

7.1.3 Parameter Settings for Modbus Communication

The following parameters 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. This can be used for overcoming modem turnaround delays
8-36 Maximum 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 if transmission is interrupted.

Table 7.2 RS-485 Parameters

7.1.4 EMC Precautions

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

Observe relevant national and local regulations regarding protective ground connection. Keep the RS-485 communication cable away from motor and brake resistor cables to avoid coupling of high frequency noise from one cable to another. Normally a distance of 200 mm (8 inches) is sufficient, but it is best to keep the greatest possible distance between the cables, 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 a 90° angle.
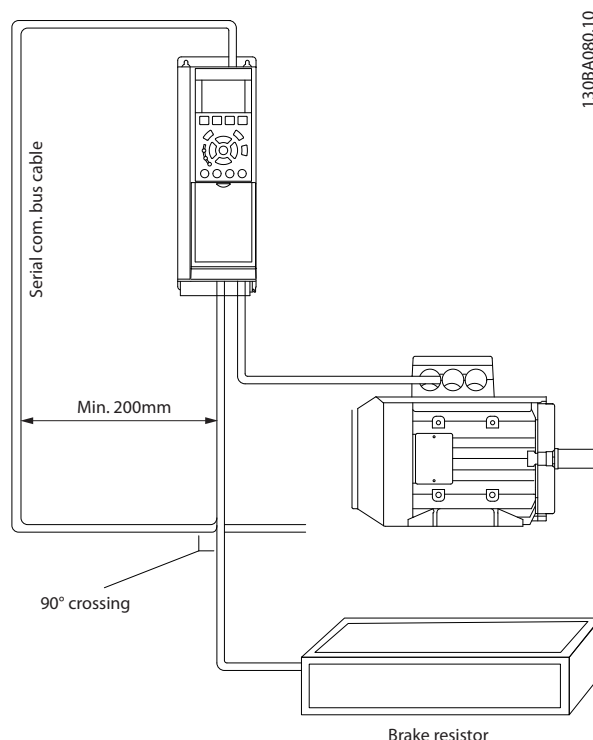
Figure 7.4 Crossing Cables

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 FC with 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 a variety of preset speeds

- Run in reverse

- Change of the active set-up

- Control of the two relays built into 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. This permits a range of control options, including controlling the setpoint of the adjustable frequency drive when its internal PID controller is used.

7.3 Network Configuration

7.3.1 Adjustable Frequency Drive Set-up

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

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

Table 7.3 FC Protocol Parameters

7.4 FC Protocol Message Framing Structure

7.4.1 Content of a Character (byte)

Each character transferred begins with a start bit. Eight data bits are transferred, corresponding to a byte. Each character is secured via a parity bit. This bit is set at "1" when it reaches parity. Parity is when there is an equal number of 1's in the 8 data bits and the parity bit in total. A stop bit completes a character, thus consisting of 11 bits in all.
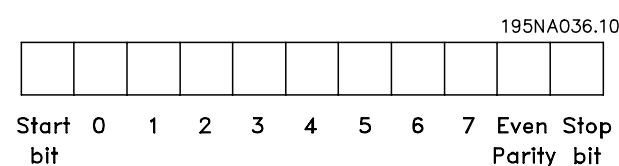
Figure 7.5 Example Character

7

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.
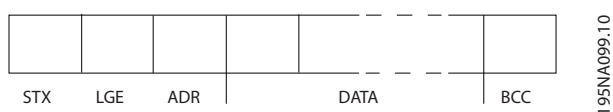
Figure 7.6 Example Message

7.4.3 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 four 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 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.

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 message types, and the type applies for both control messages (master=>slave) and response messages (slave=>master).
The three types of message are:

Process block (PCD)
The PCD is made up of a data block of four bytes (two words) and contains:

- Control word and reference value (from master to slave)

- Status word and present output frequency (from slave to master)
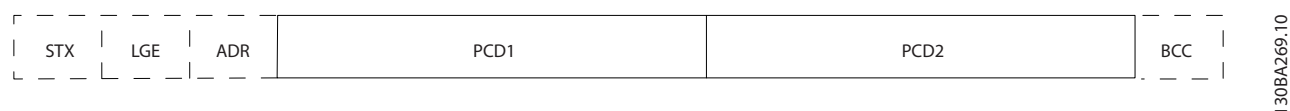
Figure 7.7 Example Process Block

Parameter block
The parameter block is used to transfer parameters between master and slave. The data block is made up of 12 bytes (six words) and also contains the process block.
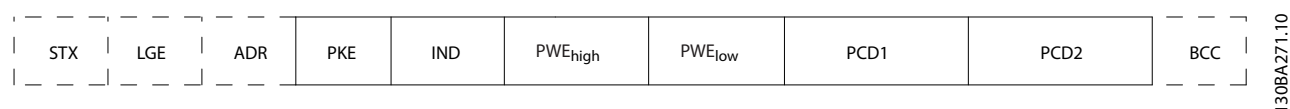
Figure 7.8 Example Parameter Block

Text block
The text block is used to read or write texts via the data block.
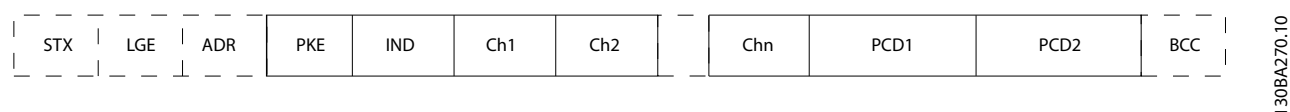
Figure 7.9 Example Text Block

7.4.7 The PKE Field

The PKE field contains two sub-fields: Parameter command and response AK, and Parameter number PNU.
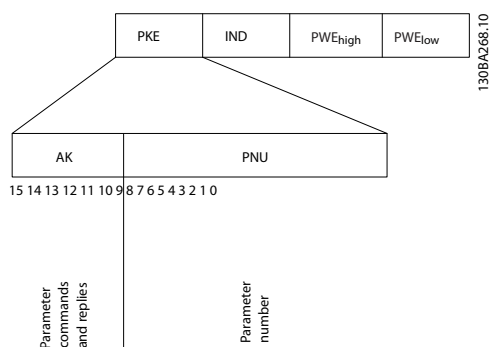
Figure 7.10 PKE Sub-fields

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 7.4 Parameter Commands, Master to 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 7.5 Response, Slave to Master

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

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

Table 7.6 Faults

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. The index consists of two bytes, a low byte and a high byte.

Only the low byte is used as an index.

7.4.10 Parameter Value (PWE)

The parameter value block consists of two words (four bytes), and the value depends on the defined command (AK). The master prompts for a parameter value when the PWE block contains no value. To change a parameter value (write), write the new value in the PWE block and send it 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, select the data value by entering the value in the PWE block. 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 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."

	PKE	IND	PWE high	PWE low
Read text	Fx xx	04 00		
Write text	Fx xx	05 00		
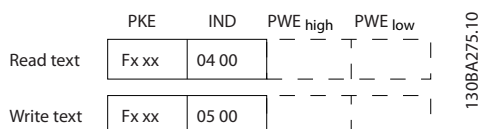
Figure 7.11 Read and Write Text

7.4.11 Data Types Supported by the Adjustable Frequency Drive

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 7.7 Supported Data Types

7.4.12 Conversion

Parameter values are transferred as whole numbers only. Conversion factors are 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

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 7.8 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 (master⇒ slave control word)	Reference value
Control (slave ⇒ master) status word	Present output frequency

Table 7.9 Process Words

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
PWEHIGH = 0000 Hex
PWELOW = 03E8 Hex - Data value 1000, corresponding to 100 Hz, see *chapter 7.4.12 Conversion*.

The message looks like this:

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

Figure 7.12 Example 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.**

The response from the slave to the master is:

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

Figure 7.13 Slave to Master Response

7.5.2 Reading a Parameter Value

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

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

Figure 7.14 Reading a Parameter Value

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

Table 7.10 Legend to *Figure 7.14*

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

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

Figure 7.15 Slave to Master Response

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

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 user 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 taking the action requested in the query.

The master can address individual slaves or initiate a broadcast message to all slaves. Slaves return a message (called a response) to queries that are addressed to them individually. No responses are returned to broadcast queries from the master. The Modbus RTU protocol establishes the format for the master's query by placing into it the device (or broadcast) address, a function code defining the requested action, any data to be sent and an error-checking field. The slave's response message is also constructed using Modbus protocol. It contains fields confirming the action taken, any data to be returned and an error-checking field. If an error occurs in receipt of the message, or if the slave is unable to perform the requested action, the slave will construct an error message, and send it in response, or a timeout occurs.

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 a variety of preset speeds

- Run in reverse

- Change the active set-up

- Control the built-in relay

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

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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)

Table 7.11 Modbus RTU Parameters

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 7.12*.

Start bit	Data byte								Stop/ parity	Stop

Table 7.12 Format for Each Byte

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

Table 7.13 Byte Information

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. This allows receiving devices to begin at the start of the message, read the address portion, determine which device is addressed (or all devices, if the message is broadcast), and to recognize when the message is completed. Partial messages are detected, and errors are set as a result. Characters for transmission must be in hexadecimal 00 to FF format in each field. The adjustable frequency drive continuously monitors the network bus, also during 'silent' intervals. When the first field (the address field) is received, each adjustable frequency drive or device decodes it to determine which device is being addressed. Modbus RTU messages addressed to zero are broadcast messages. No response is permitted for broadcast messages. A typical message frame is shown in *Table 7.14*.

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 7.14 Typical Modbus RTU Message Structure

7.8.3 Start/Stop Field

Messages start with a silent period of at least 3.5 character intervals. This is implemented as a multiple of character intervals at the selected network baud rate (shown as Start T1-T2-T3-T4). The first field to be transmitted is the device address. Following the last transmitted character, a similar period of at least 3.5 character intervals marks the end of the message. A new message can begin after this period.

The entire message frame must be transmitted as a continuous stream. If a silent period of more than 1.5 character intervals occurs before completion of the frame, the receiving device flushes the incomplete message and assumes that the next byte is the address field of a new message. Similarly, if a new message begins before 3.5 character intervals after a previous message, the receiving device considers it a continuation of the previous message. This causes a timeout (no response from the slave), since the value in the final CRC field is not valid for the combined messages.

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 kind of action to perform. When the slave responds to the master, it uses the function code field to indicate either a normal (error-free) response, or that some kind of error occurred (called an exception response). For a normal response, the slave simply echoes the original function code. For an exception response, the slave returns a code that is equivalent to the original function code with its most significant bit set to logic 1. The slave places a unique code into the data field of the response message, telling the master what kind of error occurred, or the reason. Refer to *chapter 7.8.11 Modbus Exception Codes* for more information.

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 are made up of one RTU character. The data field of messages sent from a master to slave device contains additional information that the slave must use to take the action defined by the function code. This can include items such as:

- Coil or register addresses
- Quantity of items to be handled
- Count of actual data bytes in the field

7.8.7 CRC Check Field

Messages include an error-checking field, operating on the basis of a Cyclical Redundancy Check (CRC) method. The CRC field checks the contents of the entire message. It is applied regardless of any parity check method used for the individual characters of the message. The CRC value is calculated by the transmitting device, which appends the CRC as the last field in the message. The receiving device recalculates a CRC during receipt of the message and compares the calculated value to the actual value received in the CRC field. If the two values are unequal, a bus timeout results. The error-checking field contains a 16-bit binary value implemented as two 8-bit bytes. When this is done, the low-order byte of the field is appended first, followed by the high-order byte. The CRC high-order byte is the last byte sent in the message.

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

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Coil Number	Description		Signal Direction
1-16	Adjustable frequency drive control word		Master to slave
17-32	Adjustable frequency driver speed or setpoint reference Range 0x0–0xFFFF (-200% ... ~200%)		Master to slave
33-48	Adjustable frequency drive status word		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 7.15 Coil Descriptions

Coil	0	1
01	Preset reference LSB	
02	Preset reference MSB	
03	DC brake	No DC brake
04	Coast stop	No coast stop
05	Quick stop	No quick stop
06	Freeze freq.	No freeze freq.
07	Ramp stop	Start
08	No reset	Reset
09	No jog	Jog
10	Ramp 1	Ramp 2
11	Data not valid	Data valid
12	Relay 1 off	Relay 1 on
13	Relay 2 off	Relay 2 on
14	Set up LSB	
15	Set up MSB	
16	No reversing	Reversing
control word (FC profile)		

Table 7.16 Coil Descriptions

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

Table 7.17 Coil Descriptions

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 7.18 Holding Registers

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

7.8.9 How to Control the Adjustable Frequency Drive

This section describes codes that can be used in the function and data fields of a Modbus RTU message.

7.8.10 Function Codes Supported by Modbus RTU

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

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

Table 7.19 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 7.20 Sub-function Codes

7.8.11 Modbus Exception Codes

For a full explanation of the structure of an exception code response, refer to *chapter 7.8.5 Function Field*.

Code	Name	Meaning
1	Illegal function	The function code received in the query is not an allowable action for the server (or slave). This can be because the function code is only applicable to newer devices, and was not implemented in the unit selected. It could also indicate that the server (or slave) is in the wrong state to process a request of this type, because it is not configured and is being asked to return register values, for example.

Code	Name	Meaning
2	Illegal data address	The data address received in the query is not an allowable address for the server (or slave). More specifically, the combination of reference number and transfer length is invalid. For a controller with 100 registers, a request with offset 96 and length 4 succeeds, a request with offset 96 and length 5 generates exception 02.
3	Illegal data value	A value contained in the query data field is not an allowable value for server (or slave). This indicates a fault in the structure of the remainder of a complex request, such as that the implied length is incorrect. It specifically does NOT mean that a data item submitted for storage in a register has a value outside the expectation of the application program, since the Modbus protocol is unaware of the significance of any particular value of any particular register.
4	Slave device failure	An unrecoverable error occurred while the server (or slave) was attempting to perform the requested action.

Table 7.21 Modbus Exception Codes

7.9 Parameter Access

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 (10 x parameter 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).

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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 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

Since a parameter value can only be transferred as a whole number, use a conversion factor 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 one register (16 bits), and the function 10HEX "Preset Multiple Registers" for two registers (32 bits). Readable sizes range from one register (16 bits) up to ten registers (20 characters).

Non-standard Data Types
Non-standard data types are text strings and are stored as 4x registers (40001 – 4FFFF). The parameters are read using function 03HEX "Read Holding Registers" and written using function 10HEX "Preset Multiple Registers." Readable sizes range from one register (two characters) up to ten registers (20 characters).

7.10 Examples

The following examples illustrate various Modbus RTU commands. If an error occurs, refer to *chapter 8 General Specifications and Troubleshooting*.

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 be read. Coil addresses start at zero, i.e., coil 33 is addressed as 32.

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 7.22 Example of a request to read coils 33-48 (Status Word) from slave device 01

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 8, 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.

Field Name	Example (HEX)
Slave address	01 (adjustable frequency drive address)
Function	01 (read coils)
Byte count	02 (two bytes of data)
Data (coils 40-33)	07
Data (coils 48-41)	06 (STW=0607hex)
Error check (CRC)	-

Table 7.23 Master Response

NOTICE!

Coils and registers are addressed explicit with an off-set of -1 in Modbus.
For example, Coil 33 is addressed as Coil 32.

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 7.24 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 7.25 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 to 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 7.26 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 7.27 Response

7

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 be read. Register addresses start at zero, so 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, i.e., two registers)
Error check (CRC)	-

Table 7.28 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 7.29 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, i.e., 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 7.30 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 7.31 Response

7.10.6 Preset Multiple Registers (10 HEX)

Description
This function presets values into a sequence of holding registers.

Query
The query message specifies the register references to be preset. Register addresses start at zero, i.e., register 1 is addressed as 0. Example of a request to preset two registers (set parameter 1-24 = 738 (7.38 A)):

Field Name	Example (HEX)
Slave address	01
Function	10
Starting address HI	04
Starting address LO	D7
No. of registers HI	00
No. of registers LO	02
Byte count	04
Write data HI (register 4: 1049)	00
Write data LO (register 4: 1049)	00
Write data HI (register 4: 1050)	02
Write data LO (register 4: 1050)	E2
Error check (CRC)	-

Table 7.32 Query

Response
The normal response returns the slave address, function code, starting address and quantity of preset registers.

Field Name	Example (HEX)
Slave address	01
Function	10
Starting address HI	04
Starting address LO	D7
No. of registers HI	00
No. of registers LO	02
Error check (CRC)	-

Table 7.33 Response

7.11 Danfoss FC Control Profile

7.11.1 Control Word According to FC Profile (*8-10 Control Profile* = FC profile)
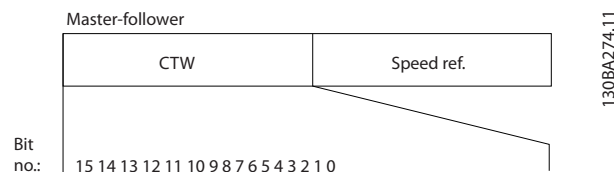
Figure 7.16 Control Word

Bit	Bit value = 0	Bit value = 1
00	Reference value	external selection lsb
01	Reference value	external selection msb
02	DC brake	Ramp
03	Coasting	No coasting
04	Quick stop	Ramp
05	Hold output frequency	use ramp
06	Ramp stop	Start
07	No function	Reset
08	No function	Jog
09	Ramp 1	Ramp 2
10	Data invalid	Data valid
11	No function	Relay 01 active
12	No function	Relay 02 active
13	Parameter set-up	selection lsb
14	Parameter set-up	selection msb
15	No function	Reverse

Table 7.34 Bit Definitions

7

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 7.35*:

Programmed ref. value	Parameter	Bit 01	Bit 00
1	*3-10 Preset Reference* [0]	0	0
2	*3-10 Preset Reference* [1]	0	1
3	*3-10 Preset Reference* [2]	1	0
4	*3-10 Preset Reference* [3]	1	1

Table 7.35 Explanation of the 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 by means of the digital inputs (*5-10 Terminal 18 Digital Input* to *5-15 Terminal 33 Digital Input*) programmed to *Speed up* and *Slow-down*.

NOTICE!

If freeze output is active, the adjustable frequency drive can only be stopped by the following:

- **Bit 03 coasting stop**

- **Bit 02 DC braking**

- **Digital input (*5-10 Terminal 18 Digital Input* to *5-15 Terminal 33 Digital Input*) programmed to *DC braking*, *coasting stop*, or *reset* and *coasting stop*.**

Bit 06, Ramp stop/start:

Bit 06 = '0': Causes a stop and makes the motor speed ramp down to stop via the selected ramp-down parameter. Bit 06 = '1': Permits the adjustable frequency drive to start the motor if the other starting conditions are met.

Make a selection in *8-53 Start Select* to define how Bit 06 Ramp stop/start gates with the corresponding function on a digital input.

Bit 07, Reset:

Bit 07 = '0': No reset. Bit 07 = '1': Resets a trip. Reset is activated on the signal's leading edge, when changing from logic '0' to logic '1', for example.

Bit 08, Jog:

Bit 08 = '1': The output frequency is determined by *3-19 Jog Speed [RPM]*.

Bit 09, Selection of ramp 1/2:

Bit 09 = "0": Ramp 1 is active (*3-41 Ramp 1 Ramp-up Time* to *3-42 Ramp 1 Ramp-down Time*). Bit 09 = "1": Ramp 2 (*3-51 Ramp 2 Ramp-up Time* to *3-52 Ramp 2 Ramp-down Time*) is active.

Bit 10, Data not valid/Data valid:

Tell the adjustable frequency drive whether to use or ignore the control word. Bit 10 = '0': The control word is ignored. Bit 10 = '1': The control word is used. This function is relevant because the message always contains the control word, regardless of the message type. 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 provided that *Control word bit 11* is selected in *5-40 Function Relay*.

Bit 12, Relay 04:

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

Bits 13/14, Selection of Set-up:

Use bits 13 and 14 to choose from the four menu set-ups according to *Table 7.36*.

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

Table 7.36 Bits 13 and 14 Selection

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 Set. communication, Logic and or Logic or is selected.

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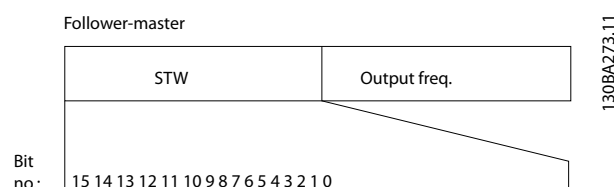

Figure 7.17 Status Word

Bit	Bit = 0	Bit = 1
00	Control not ready	Control ready
01	Drive not ready	Drive ready
02	Coasting	Enable
03	No error	Trip
04	No error	Error (no trip)
05	Reserved	-
06	No error	Trip lock
07	No warning	Warning
08	Speed ≠ reference	Speed = reference
09	Local operation	Bus control
10	Out of frequency limit	Frequency limit OK
11	No operation	In operation
12	Drive OK	Stopped, auto-start
13	Voltage OK	Voltage exceeded
14	Torque OK	Torque exceeded
15	Timer OK	Timer exceeded

Table 7.37 Status Bits

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/trip lock:

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. This can occur 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. It is impossible to control the adjustable frequency drive via serial communication. Bit 09 = '1' It is possible to control the adjustable frequency drive via the serial communication bus/serial communication.

Bit 10, Out of frequency limit:

Bit 10='0': The output frequency has reached the value in *4-11 Motor Speed Low Limit [RPM]* or *4-13 Motor Speed High Limit [RPM]*. Bit 10 = "1": The output frequency is within the defined limits.

Bit 11, No operation/in operation:

Bit 11= '0': The motor is not running. Bit 11='1': The adjustable frequency drive has a start signal, or the output frequency is greater than 0 Hz.

Bit 12, Drive OK/stopped, auto-start:

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 do not exceed 100%. Bit 15 = '1': One of the timers exceeds 100%.

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

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 by means of 2's complement. The Actual Output frequency (MAV) is scaled in the same way as the bus reference.
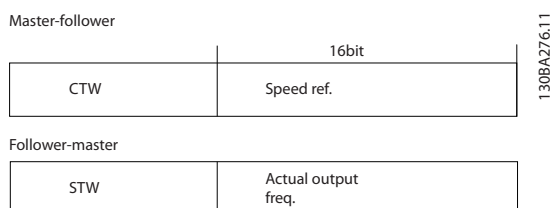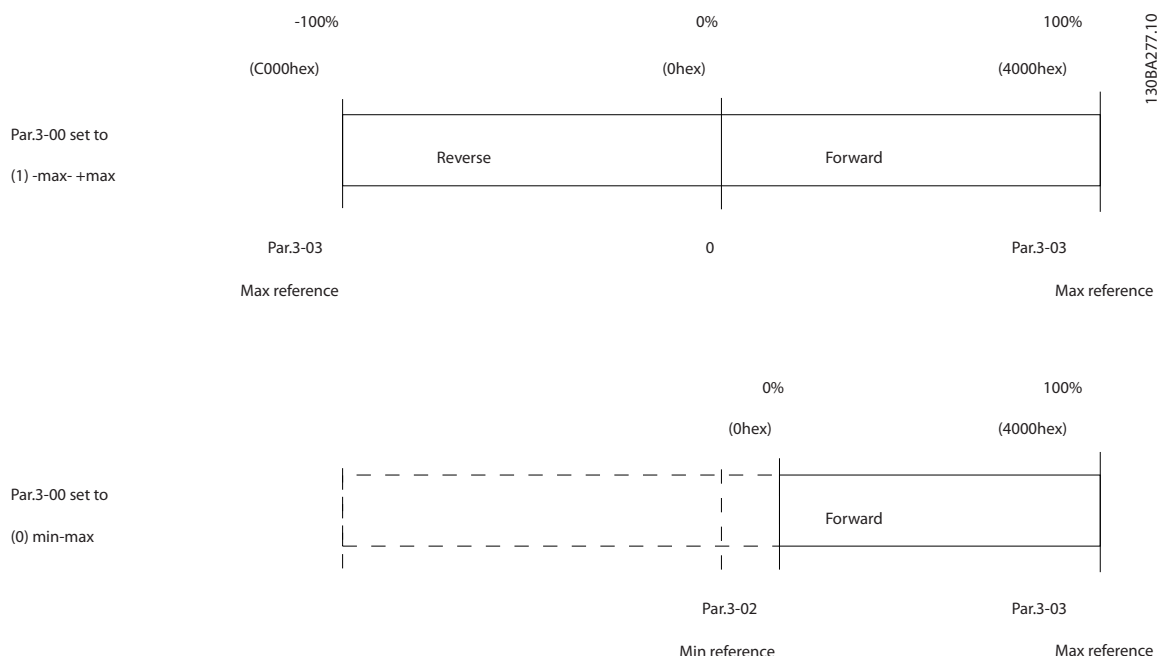

Figure 7.18 Speed Reference

Figure 7.19 Reference and MAV scaling

8 General Specifications and Troubleshooting

8.1 General Specifications

8.1.1 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 (mm²/AWG[2] [5])							4 x 240 4 x 500 mcm	
Line power (mm²/AWG[2] [5])	2 x 95 2 x 3/0			2 x 185 2 x 350 mcm				
Load sharing (mm²/AWG[2] [5])								
Brake (mm²/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 [°C]	110							
Power card ambient trip [°C]	75						85	

Table 8.1 Line Power Supply 3x380–480 V AC

	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])		8 x 150 8 x 300 mcm				12 x 150 12 x 300 mcm	
Line power (mm²/AWG[2])	4 x 240 4 x 500 mcm	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 [°C]	110	95					
Power card ambient trip [°C]	85						

Table 8.2 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 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 (IE2/IE3 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.*

5) *Wiring terminals on N132, N160, and N315 adjustable frequency drives cannot receive cables one size larger.*

8.1.2 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 (mm²/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 [°C]	110					
Power card ambient trip [°C]	75					

Table 8.3 Line Power Supply 3 x 525–690 V AC

	N250	N315	N400	P450	P500	P560
Normal Overload	**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 (mm² / 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 [°C]	110			95		
Power card ambient trip [°C]	80			85		

Table 8.4 Line Power Supply 3 x 525–690 V AC

8

	P630	P710	P800	P900	P1M0	P1M2	P1M4
Normal Overload							
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 (mm^2/AWG$^{2)}$)	4x240 (4x500 mcm)	8x150 (8x300 mcm)			12x150 (12x300 mcm)		
Line power (mm^2/AWG^2)		8x240 (8x500 mcm)			8x240 (8x500 mcm)		
Load sharing (mm^2/AWG$^{2)}$)	2x185 (2x350 mcm)	4x185 (4x350 mcm)			6x185 (6x350 mcm)		
Brake (mm^2/AWG$^{2)}$)							
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 [°C]	110	95	105	95		105	95
Power card ambient trip [°C]	85						

Table 8.5 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 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 (IE2/IE3 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.

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 8.6 D5h–D8h Weights

8.1.3 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 (lbs)	263 (580)	270 (595)	272 (600)	313 (690)	1004 (2214)				1246 (2748)	
Weight enclosure IP 54 kg (lbs)										
Efficiency[4]	0.98									
Output Frequency	0–590 Hz									
Heatsink overtemp. trip	110°C				95°C					
Power card ambient trip	85°C									

Table 8.7 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 550 V) [A]	453	504	574	607	743	866	962	1079	1282	1440
Continuous (6 x 575 V) [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 (mm² /AWG[2])	8 x 300 MCM (8 x 150)							12 x 300 MCM (12 x 150)		
Line power (mm² /AWG[2])	8 x 500 MCM (8 x 250)									
Regeneration terminals (mm²/AWG[2])	4 x 250 MCM (4 x 120)									
Brake (mm² /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 (lbs)	440/656 (880/1443)			880/1096 (1936/2471)				1022/1238 (2248/2724)		
Weight enclosure IP 54 kg (lbs)										
Efficiency[4]	0.98									
Output Frequency	0–525 Hz									
Heatsink overtemp trip	110℃				95℃	105℃	95℃	95℃	105℃	95℃
Power card ambient trip	85℃									

Table 8.8 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.

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 ± 9°F [95°C ± 5°C]. An overload temperature cannot be reset until the temperature of the heatsink is below 158°F ± 9°F [70°C ± 5°C] (Guideline - these temperatures vary for different power sizes and enclosures). The adjustable frequency 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.

Cable lengths and cross-sections

Max. motor cable length, shielded/armored	500 ft [150 m]
Max. motor cable length, non-shielded/unarmored	1000 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 8.1 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.
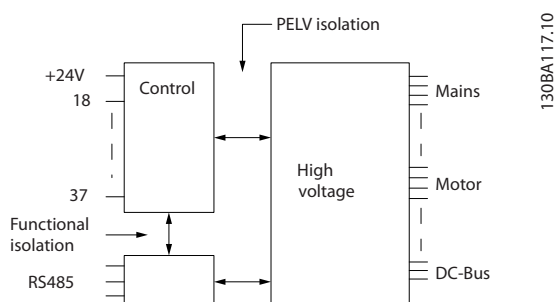
Figure 8.1 PELV Isolation of Analog Inputs

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 Digital Inputs
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

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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.

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

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	131°F [55°C]

Derating for high ambient temperature, see chapter 8.5.2 Derating for Ambient Temperature

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	10,000 ft [3000 m]

Derating for high altitude, see chapter 8.5 Special Conditions

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

See chapter 8.5 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 <u>not</u> galvanically isolated from ground protection. Use only an isolated laptop/PC as connection to the USB connector on the adjustable frequency drive or an isolated USB cable/converter.

8

8.2 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%.

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 also slightly reduced if 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 loads based on *Figure 8.2*. The factor in this graph must be multiplied with the specific efficiency factor listed in the specification tables:
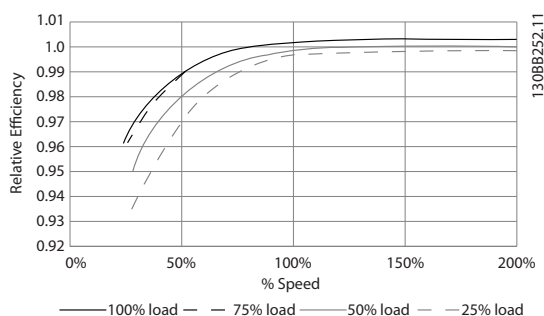
Figure 8.2 Typical Efficiency Curves

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

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

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

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

In general, the switching frequency does not affect the efficiency of small motors. Motors from 15 hp [11 kW] up have their efficiency improved (1-2%) because the sine shape of the motor current is almost perfect at high switching frequency.

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

8.3 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:

Frame size	dBA at full fan speed
N90k	71
N110	71
N132	72
N160	74
N200	75
N250	73
E1/E2-Frames[1]	74
E1/E2-Frames[2]	83
F-Frames	80

Table 8.9 Acoustic Noise

[1]*450 hp [315 kW], 380–480 V AC. 600 and 650 hp [450 and 500 kW], 525–690 V AC only.*
[2]*All other E-frame Units*

8.4 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:

- Motor cable

  - type

  - cross-section

  - length

  - shielded/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} affects 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 increase.

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 below, use the following guidelines:

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. $dU/dt = \dfrac{0.8 \times UPEAK}{Rise\ time}$

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

8

8

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 8.10 N110–N315, T4/380–480 V

Adjustable Frequency Drive, P400–P1M0, T4				
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
1) With Danfoss dU/dt filter.				

Table 8.11 P400–P1M0, T4/380–480 V

Adjustable Frequency Drive, P110–P400, T7				
Cable length (ft [m])	AC line voltage [V]	Rise time [µsec]	Vpeak [kV]	dU/dt [kV/µsec]
100 [30]	690	0.38	1.513	3.304
100 [30]	575	0.23	1.313	2.750
100 [30]	690 [1]	1.72	1.329	0.640
1) With Danfoss dU/dt filter.				

Table 8.12 P110–P400, T7/525–690 V

Adjustable Frequency Drive, P450–P1M4, T7				
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
1) With Danfoss dU/dt filter.				

Table 8.13 P450–P1M4, T7/525–690 V

8.5 Special Conditions

8.5.1 Purpose of Derating

Take derating into account when using the adjustable frequency drive in the following conditions:

- At low air pressure (heights)
- At low speeds
- With long motor cables
- Cables with a large section
- High ambient temperature

The required actions are described in this section.

8.5.2 Derating for Ambient Temperature

Frame model	Normal overload NO, 110% 60 AVM	Normal overload NO, 110% SFAVM
D-Frame N110 to N315 380–480 V		
E & F-Frame P355 to P1M0 380–480 V		

Table 8.14 Derating Tables for Adjustable Frequency Drives Rated 380–480 V (T4)

Frame model	Normal overload NO, 110% 60 AVM	Normal overload NO, 110% SFAVM
D-Frame N110 to N315 525–690 V	*Iout [%]* vs *fsw [kHz]*; curves labeled 45°C, 50°C, 55°C (130BX482.10)	*Iout [%]* vs *fsw [kHz]*; curves labeled 40°C, 45°C, 50°C, 55°C (130BX484.10)
D-Frame N400 525–690 V	*Iout [%]* vs *fsw [kHz]*; curves labeled 45°C, 50°C, 55°C (130BX486.10)	*Iout [%]* vs *fsw [kHz]*; curves labeled 40°C, 45°C, 50°C, 55°C (130BX488.10)
E & F-Frame P450 to P1M0 525–690 V	*Iout [%]* vs *fsw [kHz]*; curves labeled 45°C, 50°C, 55°C (130BX490.10)	*Iout [%]* vs *fsw [kHz]*; curves labeled 40°C, 45°C, 50°C, 55°C (130BX492.10)

Table 8.15 Derating Tables for Adjustable Frequency Drives Rated 525–690 V (T7)

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8.5.3 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 automatically reduce the output current extends the acceptable operating conditions even further.

8.5.4 Derating for Low Air Pressure

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

Below 3300 ft [1000 m] altitude, no derating is necessary but above 3300 ft [1000 m] the ambient temperature (T_{AMB}) or max. output current (I_{out}) should be derated in accordance with *Figure 8.3*.
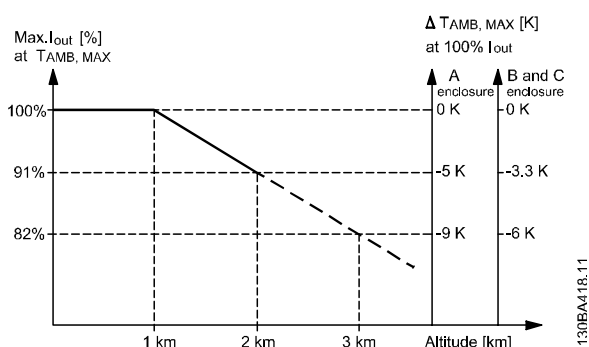
Figure 8.3 Derating of Output Current Versus Altitude

An alternative is to lower the ambient temperature at high altitudes and thereby ensure 100% output current at high altitudes. As an example of how to read the graph, the situation at 6,600 ft [2 km] is elaborated. At a temperature of 113°F [45°C] ($T_{AMB, MAX}$ - 3.3 K), 91% of the rated output current is available. At a temperature of 107°F [41.7°C], 100% of the rated output current is available.
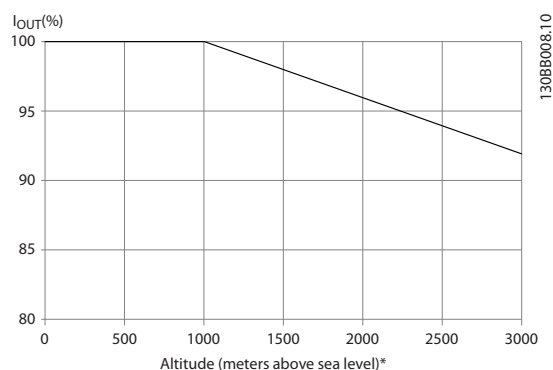
Figure 8.4 Derating of Output Current Versus Altitude at $T_{AMB, MAX}$
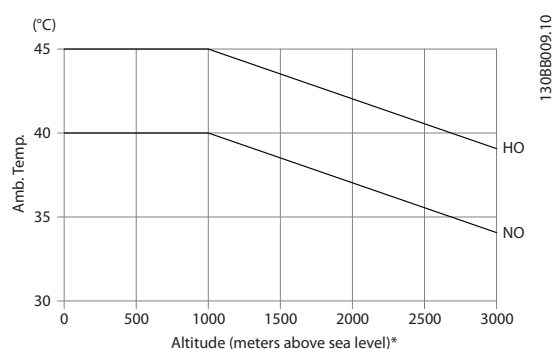
Figure 8.5 Derating of Output Current Versus Altitude at $T_{AMB, MAX}$

8.5.5 Derating for Running at Low Speed

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

Constant torque applications (CT mode)

A problem may occur at low RPM values in constant torque applications. A motor may overheat at low speeds due to less cooling air from the motor integral fan.

If the motor runs continuously at an RPM value lower than half of the rated value, additional air-cooling is needed. A motor designed for this type of operation may also be used.

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

Variable (Quadratic) Torque Applications (VT)

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

In *Figure 8.6*, the typical VT curve is below the maximum torque with derating and maximum torque with forced cooling at all speeds.
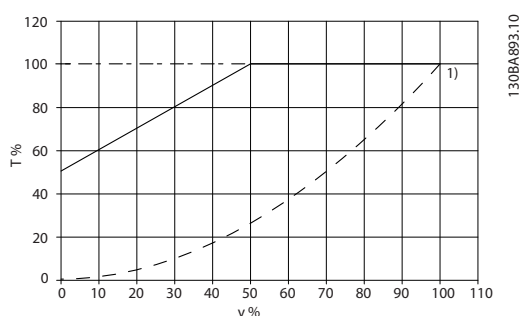
Figure 8.6 Maximum Load for a Standard Motor at 104°F [40°C] Driven by an Adjustable Frequency Drive

— — — —	Typical torque at VT load
—•—•—	Max torque with forced cooling
———	Max torque
Note 1) Oversynchronous speed operation will result in the available motor torque decreasing inversely proportional with the increase in speed. This must be considered during the design phase to avoid overloading the motor.	

Table 8.16 Legend to *Figure 8.6*

8.6 Troubleshooting

A warning or 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 terminated. Under certain circumstances, operation of the motor may still continue. Warning messages are sometimes critical, but not always.

In the event of an alarm, the adjustable frequency drive trips. Reset alarms to restart operation once their cause has been rectified.

There are four ways to restart after an event:
1. Pressing [RESET] on the LCP.
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® HVAC Drive. See *14-20 Reset Mode* in the *VLT® HVAC Programming Guide*

NOTICE!

After pressing [RESET], press the [Auto On] or [Hand On] button to restart the motor.

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If an alarm cannot be reset, the reason may be that its cause has not been rectified, or the alarm is trip-locked (see also *Table 8.17*).

⚠CAUTION

Alarms that are trip-locked offer additional protection, meaning that the line power supply must be switched off before the alarm can be reset. After switching line power supply back on, the adjustable frequency drive is no longer blocked and may be reset as described above 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* (Warning: automatic wake-up is possible)

If a warning and alarm is marked against a code in *Table 8.17*, 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 to be 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.

NOTICE!

No missing motor phase detection (no 30-32) and no stall detection is active when *1-10 Motor Construction* is set to [1] PM non salient SPM.

No.	Description	Warning	Alarm/Trip	Alarm/Trip Lock	Parameter Reference
1	10 Volts low	X			
2	Live zero error	(X)	(X)		6-01
3	No motor	(X)			1-80
4	Mains phase loss	(X)	(X)	(X)	14-12
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
11	Motor thermistor overtemp.	(X)	(X)		1-90
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	Control word timeout	(X)	(X)		8-04
18	Start failed		X		
23	Internal Fan Fault	X			
24	External Fan Fault	X			14-53
25	Brake resistor short-circuited	X			
26	Brake resistor power limit	(X)	(X)		2-13
27	Brake chopper fault	X	X		
28	Brake check	(X)	(X)		2-15
29	Heatsink temp	X	X	X	
30	Motor phase U missing	(X)	(X)	(X)	4-58
31	Motor phase V missing	(X)	(X)	(X)	4-58
32	Motor phase W missing	(X)	(X)	(X)	4-58
33	Inrush fault		X	X	
34	Fieldbus communication fault	X	X		
35	Out of frequency range	X	X		

No.	Description	Warning	Alarm/Trip	Alarm/Trip Lock	Parameter Reference
36	Mains failure	X	X		
37	Phase imbalance	X	X		
38	Internal fault		X	X	
39	Heatsink sensor		X	X	
40	Overload of digital output terminal 27	(X)			5-00, 5-01
41	Overload of digital output terminal 29	(X)			5-00, 5-02
42	Overload of digital output on X30/6	(X)			5-32
42	Overload of digital output on X30/7	(X)			5-33
46	Pwr. card supply		X	X	
47	24 V supply low	X	X	X	
48	1.8 V supply low		X	X	
49	Speed limit	X	(X)		1-86
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 parameter 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	External interlock	X			
62	Output frequency at maximum limit	X			
64	Voltage limit	X			
65	Control Card Overtemperature	X	X	X	
66	Heatsink temperature low	X			
67	Option module configuration has changed		X		
68	Safe Stop activated	(X)	X[1]		5-19
69	Pwr. card temp (E- and F-frame only)		X	X	
70	Illegal FC configuration			X	
71	PTC 1 safe torque off	X	X[1]		
72	Dangerous failure			X[1]	
73	Safe stop auto restart				
76	Power 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*
93	Dry pump	X	X		22-2*
94	End of curve	X	X		22-5*
95	Broken belt	X	X		22-6*
96	Start delayed	X			22-7*
97	Stop delayed	X			22-7*
98	Clock fault	X			0-7*
104	Mixing fan fault	X	X		14-53
201	Fire M was active				
202	Fire M limits exceeded				
203	Missing motor				
204	Locked rotor				

No.	Description	Warning	Alarm/Trip	Alarm/Trip Lock	Parameter Reference
243	Brake IGBT	X	X		
244	Heatsink temp	X	X	X	
245	Heatsink sensor		X	X	
246	Pwr.card supply		X	X	
247	Pwr.card temp		X	X	
248	Illegal PS config		X	X	
250	New spare parts			X	
251	New type code		X	X	

Table 8.17 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 will coast the motor and can be reset by pressing the reset button or making a reset by a digital input (parameter group 5-1* [1]). The original event that caused an alarm cannot damage the adjustable frequency drive or cause dangerous conditions. A trip lock is an action that occurs in conjunction with an alarm, which may cause damage to 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 8.18 LED Indications

8

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	10 V 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	24 V Supply Low	24 V Supply Low	
24	01000000	16777216	Mains Failure	Mains Failure	
25	02000000	33554432	1.8 V 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 torque off	Unused	
31	80000000	2147483648	Mech. brake low (A63)	Extended Status Word	

Table 8.19 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*.

8.6.1 Alarm Words

16-90 Alarm Word

Bit (Hex)	Alarm Word (*16-90 Alarm Word*)
00000001	
00000002	Power card over temperature
00000004	Ground fault
00000008	
00000010	Control word timeout
00000020	Overcurrent
00000040	
00000080	Motor thermistor over-temp.
00000100	Motor ETR overtemperature
00000200	Inverter overloaded
00000400	DC link undervoltage
00000800	DC link overvoltage
00001000	Short-circuit
00002000	
00004000	Mains phase loss
00008000	AMA not OK
00010000	Live zero error
00020000	Internal fault
00040000	
00080000	Motor phase U is missing
00100000	Motor phase V is missing
00200000	Motor phase W is missing
00800000	Control Voltage Fault
01000000	
02000000	VDD, supply low
04000000	Brake resistor short-circuit
08000000	Brake chopper fault
10000000	Ground fault DESAT
20000000	Drive initialized
40000000	Safe torque off [A68]
80000000	

Table 8.20 Alarm Word

16-91 Alarm Word 2

Bit (Hex)	Alarm Word 2 (*16-91 Alarm Word 2*)
00000001	
00000002	Reserved
00000004	Service Trip, Type code / Spare part
00000008	Reserved
00000010	Reserved
00000020	
00000040	
00000080	
00000100	Broken Belt
00000200	Not used
00000400	Not used
00000800	Reserved
00001000	Reserved
00002000	Reserved
00004000	Reserved
00008000	Reserved
00010000	Reserved
00020000	Not used
00040000	Fans error
00080000	ECB error
00100000	Reserved
00200000	Reserved
00400000	Reserved
00800000	Reserved
01000000	Reserved
02000000	Reserved
04000000	Reserved
08000000	Reserved
10000000	Reserved
20000000	Reserved
40000000	PTC 1 Safe Torque Off [A71]
80000000	Dangerous Failure [A72]

Table 8.21 Alarm Word 2

8

8.6.2 Warning Words

16-92 Warning Word

Bit (Hex)	Warning Word (*16-92 Warning Word*)
00000001	
00000002	Power card over temperature
00000004	Ground fault
00000008	
00000010	Control word timeout
00000020	Overcurrent
00000040	
00000080	Motor thermistor over-temp.
00000100	Motor ETR overtemperature
00000200	Inverter overloaded
00000400	DC link undervoltage
00000800	DC link overvoltage
00001000	
00002000	
00004000	Mains phase loss
00008000	No motor
00010000	Live zero error
00020000	
00040000	
00080000	
00100000	
00200000	
00400000	
00800000	
01000000	
02000000	Current limit
04000000	
08000000	
10000000	
20000000	
40000000	Safe torque off [W68]
80000000	Not used

Table 8.22 Warning Words

16-93 Warning Word 2

Bit (Hex)	Warning Word 2 (*16-93 Warning Word 2*)
00000001	
00000002	
00000004	Clock Failure
00000008	Reserved
00000010	Reserved
00000020	
00000040	
00000080	End of Curve
00000100	Broken Belt
00000200	Not used
00000400	Reserved
00000800	Reserved
00001000	Reserved
00002000	Reserved
00004000	Reserved
00008000	Reserved
00010000	Reserved
00020000	Not used
00040000	Fans warning
00080000	
00100000	Reserved
00200000	Reserved
00400000	Reserved
00800000	Reserved
01000000	Reserved
02000000	Reserved
04000000	Reserved
08000000	Reserved
10000000	Reserved
20000000	Reserved
40000000	PTC 1 Safe Torque Off [W71]
80000000	Reserved

Table 8.23 Warning Words 2

8.6.3 Extended Status Words

Extended status word, 16-94 Ext. Status Word

Bit (Hex)	Extended Status Word (*16-94 Ext. Status Word*)
00000001	Ramping
00000002	AMA tuning
00000004	Start CW/CCW
00000008	Not used
00000010	Not used
00000020	Feedback high
00000040	Feedback low
00000080	Output current high
00000100	Output current low
00000200	Output frequency high
00000400	Output frequency low
00000800	Brake check OK
00001000	Braking max
00002000	Braking
00004000	Out of speed range
00008000	OVC active
00010000	AC brake
00020000	Password timelock
00040000	Password protection
00080000	Reference high
00100000	Reference low
00200000	Local ref./remote ref.
00400000	Reserved
00800000	Reserved
01000000	Reserved
02000000	Reserved
04000000	Reserved
08000000	Reserved
10000000	Reserved
20000000	Reserved
40000000	Reserved
80000000	Reserved

Table 8.24 Extended Status Word

Extended status word 2, 16-95 Ext. Status Word 2

Bit (Hex)	Extended Status Word 2 (*16-95 Ext. Status Word 2*)
00000001	Off
00000002	Hand/Auto
00000004	Not used
00000008	Not used
00000010	Not used
00000020	Relay 123 active
00000040	Start prevented
00000080	Control ready
00000100	Drive ready
00000200	Quick stop
00000400	DC brake
00000800	Stop
00001000	Standby
00002000	Freeze output request
00004000	Freeze output
00008000	Jog request
00010000	Jog
00020000	Start request
00040000	Start
00080000	Start applied
00100000	Start delay
00200000	Sleep
00400000	Sleep boost
00800000	Running
01000000	Bypass
02000000	Fire mode
04000000	Reserved
08000000	Reserved
10000000	Reserved
20000000	Reserved
40000000	Reserved
80000000	Reserved

Table 8.25 Extended Status Word 2

8

8.6.4 Warning and Alarm Introduction

The warning/alarm information below defines each warning/alarm condition, provides the probable cause for the condition, and details a remedy or troubleshooting procedure.

Test procedures are described in the service manual and should only be performed by qualified personnel.

WARNING 1, 10 Volts low
The control card voltage is below 10 V from terminal 50. Remove some of the load from terminal 50, as the 10 V supply is overloaded. Max. 15 mA or minimum 590 Ω.

This condition can be caused by a short in a connected potentiometer or improper wiring of the potentiometer.

Troubleshooting
Remove the wiring from terminal 50. If the warning clears, the problem is with the customer wiring. If the warning does not clear, replace the control card.

WARNING/ALARM 2, Live zero error
This warning or alarm only appears if programmed by the user in *6-01 Live Zero Timeout Function*. The signal on one of the analogue inputs is less than 50% of the minimum value programmed for that input. Broken wiring or faulty device sending the signal can cause this condition.

 Troubleshooting
Check connections on all the analog input terminals:

- Control card terminals 53 and 54 for signals, terminal 55 common.

- MCB 101 terminals 11 and 12 for signals, terminal 10 common.

- MCB 109 terminals 1, 3, 5 for signals, terminals 2, 4, 6 common).

Check that the adjustable frequency drive programming and switch settings match the analog signal type.

Perform input terminal signal test.

WARNING/ALARM 4, Mains phase loss
A phase is missing on the supply side, or the line voltage imbalance is too high. This message also appears for a fault in the input rectifier on the adjustable frequency drive. Options are programmed at *14-12 Function at Mains Imbalance*.

Troubleshooting
Check the supply voltage and supply currents to the adjustable frequency drive.

WARNING 5, DC link voltage high
The intermediate circuit voltage (DC) is higher than the high voltage warning limit. The limit is dependent on the adjustable frequency drive voltage rating. The unit is still active.

WARNING 6, DC link voltage low
The intermediate circuit voltage (DC) is lower than the low voltage warning limit. The limit is dependent on the adjustable frequency drive voltage rating. The unit is still active.

WARNING/ALARM 7, DC overvoltage
If the intermediate circuit voltage exceeds the limit, the adjustable frequency drive trips after a time.

 Troubleshooting
Connect a brake resistor

Extend the ramp time

Change the ramp type

Activate the functions in *2-10 Brake Function*

Increase *14-26 Trip Delay at Inverter Fault*

WARNING/ALARM 8, DC under voltage
If the intermediate circuit voltage (DC link) drops below the undervoltage limit, the adjustable frequency drive checks for a 24 V DC backup supply. If no 24 V DC backup supply is connected, the adjustable frequency drive trips after a fixed time delay. The time delay varies with unit size.

 Troubleshooting
Make sure that the supply voltage matches the adjustable frequency drive voltage.

Perform input voltage test.

Perform soft charge circuit test.

WARNING/ALARM 9, Inverter overload
The adjustable frequency drive is about to cut out because of an overload (current too high for too long). The counter for electronic, thermal inverter protection gives a warning at 98% and trips at 100%, while giving an alarm. The adjustable frequency drive cannot be reset until the counter is below 90%.
The fault is that the adjustable frequency drive is overloaded by more than 100% for too long.

Troubleshooting

> Compare the output current on the LCP with the adjustable frequency drive rated current.
>
> Compare the output current on the LCP with measured motor current.
>
> Display the thermal drive load on the LCP and monitor the value. When running above the adjustable frequency drive continuous current rating, the counter increases. When running below the adjustable frequency drive continuous current rating, the counter decreases.

See *chapter 8.5 Special Conditions* for more details if a high switching frequency is required.

WARNING/ALARM 10, Motor overload temperature
According to the electronic thermal protection (ETR), the motor is too hot. Select whether the adjustable frequency drive gives a warning or an alarm when the counter reaches 100% in *1-90 Motor Thermal Protection*. The fault occurs when the motor is overloaded by more than 100% for too long.

Troubleshooting

> Check for motor overheating.
>
> Check if the motor is mechanically overloaded.
>
> Check that the motor current set in *1-24 Motor Current* is correct.
>
> Ensure that motor data in parameters 1-20 through 1-25 are set correctly.
>
> If an external fan is in use, check in *1-91 Motor External Fan* that it is selected.
>
> Run AMA in *1-29 Automatic Motor Adaptation (AMA)* to tune the adjustable frequency drive to the motor more accurately and reduce thermal loading.

WARNING/ALARM 11, Motor thermistor over temp
The thermistor may be disconnected. Select whether the adjustable frequency drive gives a warning or an alarm in *1-90 Motor Thermal Protection*.

Troubleshooting

> Check for motor overheating.
>
> Check if the motor is mechanically overloaded.
>
> When using terminal 53 or 54, check that the thermistor is connected correctly between either terminal 53 or 54 (analogue voltage input) and terminal 50 (+10 V supply) and that the terminal switch for 53 or 54 is set for voltage. Check that *1-93 Thermistor Source* selects terminal 53 or 54.

When using digital inputs 18 or 19, check that the thermistor is connected correctly between either terminal 18 or 19 (digital input PNP only) and terminal 50. Check *1-93 Thermistor Source* selects terminal 18 or 19.

WARNING/ALARM 12, Torque limit
The torque has exceeded the value in *4-16 Torque Limit Motor Mode* or the value in *4-17 Torque Limit Generator Mode*. *14-25 Trip Delay at Torque Limit* can change this from a warning only condition to a warning followed by an alarm.

Troubleshooting

> If the motor torque limit is exceeded during ramp-up, extend the ramp-up time.
>
> If the generator torque limit is exceeded during ramp-down, extend the ramp-down time.
>
> If torque limit occurs while running, possibly increase the torque limit. Be sure the system can operate safely at a higher torque.
>
> Check the application for excessive current draw on the motor.

WARNING/ALARM 13, Over current
The inverter peak current limit (approximately 200% of the rated current) is exceeded. The warning lasts about 1.5 s, then the adjustable frequency drive trips and issues an alarm. This fault may be caused by shock loading or fast acceleration with high inertia loads. If extended mechanical brake control is selected, trip can be reset externally.

Troubleshooting

> Remove power and check if the motor shaft can be turned.
>
> Make sure that the motor size matches the adjustable frequency drive.
>
> Check parameters 1-20 through 1-25 for correct motor data.

ALARM 14, Earth (ground) fault
There is current from the output phases to ground, either in the cable between the adjustable frequency drive and the motor or in the motor itself.

Troubleshooting:

> Remove power to the adjustable frequency drive and repair the ground fault.
>
> Check for ground faults in the motor by measuring the resistance to ground of the motor leads and the motor with a megohmmeter.

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ALARM 15, Hardware mismatch
A fitted option is not operational with the present control board hardware or software.

Record the value of the following parameters and contact Danfoss.

>   *15-40 FC Type*
>
>   *15-41 Power Section*
>
>   *15-42 Voltage*
>
>   *15-43 Software Version*
>
>   *15-45 Actual Typecode String*
>
>   *15-49 SW ID Control Card*
>
>   *15-50 SW ID Power Card*
>
>   *15-60 Option Mounted*
>
>   *15-61 Option SW Version* (for each option slot)

ALARM 16, Short circuit
There is short-circuiting in the motor or motor wiring.

Remove power to the adjustable frequency drive and repair the short circuit.

WARNING/ALARM 17, Control word timeout
There is no communication to the adjustable frequency drive.
The warning is only active when *8-04 Control Timeout Function* is not set to OFF.
If *8-04 Control Timeout Function* is set to *Stop* and *Trip*, a warning appears and the adjustable frequency drive ramps down until it stops then displays an alarm.

 Troubleshooting:
>   Check connections on the serial communication cable.
>
>   Increase *8-03 Control Timeout Time*
>
>   Check the operation of the communication equipment.
>
>   Verify a proper installation based on EMC requirements.

ALARM 18, Start failed
The speed has not exceeded *1-77 Compressor Start Max Speed [RPM]* during start within the allowed time. (set in *1-79 Compressor Start Max Time to Trip*). This may be caused by a blocked motor.

WARNING 23, Internal fan fault
The fan warning function is an extra protective function that checks if the fan is running/mounted. The fan warning can be disabled in *14-53 Fan Monitor* ([0] Disabled).

For the D, E, and F Frame units, the regulated voltage to the fans is monitored.

 Troubleshooting
>   Check for proper fan operation.
>
>   Cycle power to the adjustable frequency drive and check that the fan operates briefly at start-up.
>
>   Check the sensors on the heatsink and control card.

WARNING 24, External fan fault
The fan warning function is an extra protective function that checks if the fan is running/mounted. The fan warning can be disabled in *14-53 Fan Monitor* ([0] Disabled).

 Troubleshooting
>   Check for proper fan operation.
>
>   Cycle power to the adjustable frequency drive and check that the fan operates briefly at start-up.
>
>   Check the sensors on the heatsink and control card.

WARNING 25, Brake resistor short circuit
The brake resistor is monitored during operation. If a short circuit occurs, the brake function is disabled and the warning appears. The adjustable frequency drive is still operational but without the brake function. Remove power to the adjustable frequency drive and replace the brake resistor (see *2-15 Brake Check*).

WARNING/ALARM 26, Brake resistor power limit
The power transmitted to the brake resistor is calculated as a mean value over the last 120 s of run time. The calculation is based on the intermediate circuit voltage and the brake resistance value set in *2-16 AC Brake Max. Current*. The warning is active when the dissipated braking energy is higher than 90% of the brake resistance power. If *[2] Trip* is selected in *2-13 Brake Power Monitoring*, the adjustable frequency drive trips when the dissipated braking energy reaches 100%.

WARNING/ALARM 27, Brake chopper fault
The brake transistor is monitored during operation and if a short circuit occurs, the brake function is disabled and a warning is issued. The adjustable frequency drive is still operational but, since the brake transistor has short-circuited, substantial power is transmitted to the brake resistor, even if it is inactive.
Remove power to the adjustable frequency drive and remove the brake resistor.

WARNING/ALARM 28, Brake check failed

The brake resistor is not connected or not working. Check *2-15 Brake Check*.

ALARM 29, Heatsink temp

The maximum temperature of the heatsink has been exceeded. The temperature fault does not reset until the temperature falls below a defined heatsink temperature. The trip and reset points are different based on the adjustable frequency drive power size.

 Troubleshooting

Check for the following conditions.

> Ambient temperature too high.
>
> Motor cable too long.
>
> Incorrect airflow clearance above and below the adjustable frequency drive.
>
> Blocked airflow around the adjustable frequency drive.
>
> Damaged heatsink fan.
>
> Dirty heatsink.

ALARM 30, Motor phase U missing

Motor phase U between the adjustable frequency drive and the motor is missing.

Remove power from the adjustable frequency drive and check motor phase U.

ALARM 31, Motor phase V missing

Motor phase V between the adjustable frequency drive and the motor is missing.

Remove power from the adjustable frequency drive and check motor phase V.

ALARM 32, Motor phase W missing

Motor phase W between the adjustable frequency drive and the motor is missing.

Remove power from the adjustable frequency drive and check motor phase W.

ALARM 33, Inrush fault

Too many power-ups have occurred within a short time period. Let the unit cool to operating temperature.

WARNING/ALARM 34, Fieldbus communication fault

The serial communication bus on the communication option card is not working.

WARNING/ALARM 36, Mains failure

This warning/alarm is only active if the supply voltage to the adjustable frequency drive is lost and *14-10 Mains Failure* is not set to *[0] No Function*. Check the fuses to the adjustable frequency drive and line power supply to the unit.

ALARM 38, Internal fault

When an internal fault occurs, a code number defined in *Table 8.26* is displayed.

 Troubleshooting

> Cycle power
>
> Check that the option is properly installed
>
> Check for loose or missing wiring

If necessary, contact the Danfoss supplier or service department. Note the code number for further trouble-shooting directions.

No.	Text
0	Serial port cannot be initialized. Contact the Danfoss supplier or Danfoss service department.
256-258	Power EEPROM data is defective or too old.
512-519	Internal fault. Contact your Danfoss supplier or Danfoss Service Department.
783	Parameter value outside of min/max limits.
1024-1284	Internal fault. Contact your Danfoss supplier or the Danfoss Service Department.
1299	Option SW in slot A is too old.
1300	Option SW in slot B is too old.
1302	Option SW in slot C1 is too old.
1315	Option SW in slot A is not supported (not allowed).
1316	Option SW in slot B is not supported (not allowed).
1318	Option SW in slot C1 is not supported (not allowed).
1379-2819	Internal fault. Contact your Danfoss supplier or Danfoss Service Department.
2820	LCP stack overflow.
2821	Serial port overflow.
2822	USB port overflow.
3072-5122	Parameter value is outside its limits.
5123	Option in slot A: Hardware incompatible with control board hardware.
5124	Option in slot B: Hardware incompatible with control board hardware.
5125	Option in slot C0: Hardware incompatible with control board hardware.
5126	Option in slot C1: Hardware incompatible with control board hardware.
5376-6231	Internal fault. Contact your Danfoss supplier or Danfoss Service Department.

Table 8.26 Internal Fault Codes

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ALARM 39, Heatsink sensor
No feedback from the heatsink temperature sensor.

The signal from the IGBT thermal sensor is not available on the power card. The problem could be on the power card, gate drive card, or ribbon cable between the power card and gate drive card.

WARNING 40, Overload of digital output terminal 27
Check the load connected to terminal 27 or remove short-circuit connection. Check *5-00 Digital I/O Mode* and *5-01 Terminal 27 Mode*.

WARNING 41, Overload of digital output terminal 29
Check the load connected to terminal 29 or remove short-circuit connection. Check *5-00 Digital I/O Mode* and *5-02 Terminal 29 Mode*.

WARNING 42, Overload of digital output on X30/6 or overload of digital output on X30/7
For X30/6, check the load connected to X30/6 or remove the short-circuit connection. Check *5-32 Term X30/6 Digi Out (MCB 101)*.

For X30/7, check the load connected to X30/7 or remove the short-circuit connection. Check *5-33 Term X30/7 Digi Out (MCB 101)*.

ALARM 45, Earth fault 2
Ground fault on start-up.

 Troubleshooting

> Check for proper grounding and loose connections.
>
> Check for proper wire size.
>
> Check motor cables for short-circuits or leakage currents.

ALARM 46, Power card supply
The supply on the power card is out of range.

There are three power supplies generated by the switch mode power supply (SMPS) on the power card: 24 V, 5 V, +/- 18 V. When powered with 24 V DC with the MCB 107 option, only the 24 V and 5 V supplies are monitored. When powered with three phase AC line voltage, all three supplies are monitored.

 Troubleshooting

> Check for a defective power card.
>
> Check for a defective control card.
>
> Check for a defective option card.
>
> If a 24 V DC power supply is used, verify proper supply power.

WARNING 47, 24 V supply low
The 24 V DC is measured on the control card. The external 24 V DC backup power supply may be overloaded. If not, contact Danfoss.

WARNING 48, 1.8 V supply low
The 1.8 V DC supply used on the control card is outside of allowable limits. The power supply is measured on the control card. Check for a defective control card. If an option card is present, check for an overvoltage condition.

WARNING 49, Speed limit
When the speed is not within the specified range in *4-11 Motor Speed Low Limit [RPM]* and *4-13 Motor Speed High Limit [RPM]*, the adjustable frequency drive shows a warning. When the speed is below the specified limit in *1-86 Trip Speed Low [RPM]* (except when starting or stopping) the adjustable frequency drive trips.

ALARM 50, AMA calibration failed
Contact the Danfoss supplier or service department.

ALARM 51, AMA check U$_{nom}$ and I$_{nom}$
The settings for motor voltage, motor current, and motor power are wrong. Check the settings in parameters 1-20 to 1-25.

ALARM 52, AMA low I$_{nom}$
The motor current is too low. Check the settings.

ALARM 53, AMA motor too big
The motor is too big for the AMA to operate.

ALARM 54, AMA motor too small
The motor is too small for the AMA to operate.

ALARM 55, AMA Parameter out of range
The parameter values of the motor are outside of the acceptable range. AMA will not run.

ALARM 56, AMA interrupted by user
The user has interrupted the AMA.

ALARM 57, AMA internal fault
Try to restart AMA again. Repeated restarts may overheat the motor.

ALARM 58, AMA internal fault
Contact your Danfoss supplier.

WARNING 59, Current limit
The current is higher than the value in *4-18 Current Limit*. Ensure that motor data in parameters 1-20 through 1-25 are set correctly. Increase the current limit, if necessary. Be sure that the system can operate safely at a higher limit.

WARNING 60, External interlock
A digital input signal indicates a fault condition external to the adjustable frequency drive. An external interlock has commanded the adjustable frequency drive to trip. Clear the external fault condition. To resume normal operation, apply 24 V DC to the terminal programmed for external interlock. Reset the adjustable frequency drive.

WARNING 62, Output frequency at maximum limit
The output frequency has reached the value set in *4-19 Max Output Frequency*. Check the application to determine the cause. Possibly increase the output frequency limit. Be sure the system can operate safely at a higher output frequency. The warning clears when the output drops below the maximum limit.

WARNING/ALARM 65, Control card over temperature
The cutout temperature of the control card is 176° F [80°C].

  Troubleshooting
- Check that the ambient operating temperature is within limits.
- Check for clogged filters.
- Check fan operation.
- Check the control card.

WARNING 66, Heatsink temperature low
The adjustable frequency drive is too cold to operate. This warning is based on the temperature sensor in the IGBT module.
Increase the ambient temperature of the unit. A trickle amount of current can be supplied to the adjustable frequency drive whenever the motor is stopped by setting *2-00 DC Hold/Preheat Current* at 5% and *1-80 Function at Stop*.

ALARM 67, Option module configuration has changed
One or more options have either been added or removed since the last power-down. Check that the configuration change is intentional and reset the unit.

ALARM 68, Safe Stop activated
Loss of the 24 V DC signal on terminal 37 has caused the unit to trip. To resume normal operation, apply 24 V DC to terminal 37 and reset the unit.

ALARM 69, Power card temperature
The temperature sensor on the power card is either too hot or too cold.

  Troubleshooting
  Check that the ambient operating temperature is within limits.
  Check for clogged filters.
  Check fan operation.
  Check the power card.

ALARM 70, Illegal FC configuration
The control card and power card are incompatible. Contact the supplier with the type code of the unit from the nameplate and the part numbers of the cards to check compatibility.

ALARM 71, PTC 1 safe torque off
Safe torque off has been activated from the MCB 112 PTC thermistor card (motor too warm). Normal operation can resume when the MCB 112 applies 24 V DC to T-37 again (when the motor temperature reaches an acceptable level) and when the digital input from the MCB 112 is deactivated. When that happens, a reset signal is sent (via Bus, Digital I/O, or by pressing [RESET]).

ALARM 72, Dangerous failure
Safe torque off with trip lock. The dangerous failure alarm is issued if the combination of safe torque off commands is unexpected. This occurs if the MCB 112 VLT PTC Thermistor Card enables X44/10 but safe torque off is not enabled. Furthermore, if the MCB 112 is the only device using safe torque off (specified through selection [4] or [5] in *5-19 Terminal 37 Digital Input*), an unexpected combination is activation of safe torque off without the X44/10 being activated. *Table 8.26* summarizes the unexpected combinations that lead to Alarm 72. Note that if X44/10 is activated in selection 2 or 3, this signal is ignored. However, the MCB 112 is still able to activate safe torque off.

ALARM 80, Drive initialized to default value
Parameter settings are initialized to default settings after a manual reset. Reset the unit to clear the alarm.

ALARM 92, No flow
A no-flow condition has occurred. *22-23 No-Flow Function* is set for alarm. Troubleshoot the system and reset the adjustable frequency drive after the fault has been cleared.

ALARM 93, Dry pump
A no-flow condition in the system with the adjustable frequency drive operating at high speed may indicate a dry pump. *22-26 Dry Pump Function* is set for alarm. Troubleshoot the system and reset the adjustable frequency drive after clearing the fault.

ALARM 94, End of curve
Feedback is lower than the setpoint. This may indicate leakage in the system. *22-50 End of Curve Function* is set for alarm. Troubleshoot the system and reset the adjustable frequency drive after the fault has been cleared.

ALARM 95, Broken belt
Torque is below the torque level set for no load, indicating a broken belt. *22-60 Broken Belt Function* is set for alarm. Troubleshoot the system and reset the after the fault has been cleared.

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ALARM 96, Start delayed

Motor start has been delayed due to short-cycle protection. *22-76 Interval between Starts* is enabled. Troubleshoot the system and reset the adjustable frequency drive after the fault has been cleared.

WARNING 97, Stop delayed

Stopping the motor has been delayed due to short cycle protection. *22-76 Interval between Starts* is enabled. Troubleshoot the system and reset the adjustable frequency drive after the fault has been cleared.

WARNING 98, Clock fault

Time is not set or the RTC clock has failed. Reset the clock in *0-70 Date and Time*.

WARNING/ALARM 104, Mixing fan fault

The fan monitor checks that the fan is spinning at drive power-up or whenever the mixing fan is turned on. If the fan is not operating, then the fault is annunciated. The mixing-fan fault can be configured as a warning or an alarm trip by parameter 14-53 (Fan Monitor).

Troubleshooting cycle power to the adjustable frequency drive to determine if the warning/alarm returns.

WARNING 200, Fire mode

This indicates the adjustable frequency drive is operating in fire mode. The warning clears when fire mode is removed. See the fire mode data in the alarm log.

WARNING 201, Fire Mode was Active

This indicates the adjustable frequency drive had entered fire mode. Cycle power to the unit to remove the warning. See the fire mode data in the alarm log.

WARNING 202, Fire mode limits exceeded

While operating in fire mode one or more alarm conditions have been ignored which would normally trip the unit. Operating in this condition voids unit warranty. Cycle power to the unit to remove the warning. See the fire mode data in the alarm log.

WARNING 203, Missing motor

With an adjustable frequency drive operating multi-motors, an underload condition was detected. This could indicate a missing motor. Inspect the system for proper operation.

WARNING 204, Locked rotor

With an adjustable frequency drive operating multi-motors, an overload condition was detected. This could indicate a locked rotor. Inspect the motor for proper operation.

WARNING 250, New spare part

A component in the adjustable frequency drive has been replaced. Reset the adjustable frequency drive for normal operation.

WARNING 251, New typecode

The power card or other components have been replaced and the type code changed. Reset to remove the warning and resume normal operation.

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