ENGINEERING
TOMORROW

Design Guide

VLT® HVAC Basic Drive FC 101

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Contents

8 Basic Operating Principles

1 Introduction

1.1 Purpose of the Design Guide

This design guide is intended for qualified personnel, such as:

- Project and systems engineers.
- Design consultants.
- Application and product specialists.

The design guide provides technical information to understand the capabilities of the drive for integration into motor control and monitoring systems. Its purpose is to provide design considerations and planning data for integration of the drive into a system. It caters for selection of drives and options for a diversity of applications and installations. Reviewing the detailed product information in the design stage enables developing a well-conceived system with optimal functionality and efficiency.

This manual is targeted at a worldwide audience. Therefore, wherever occurring, both SI and imperial units are shown.

VLT® is a registered trademark for Danfoss A/S.

1.2 Additional Resources

1.2.1 Other Resources

Other resources are available to understand advanced drive functions and programming.

- *VLT® HVAC Basic Drive FC 101 Operating Guide* provides basic information on mechanical dimensions, installation, and basic commissioning.
- *VLT® HVAC Basic Drive FC 101 Programming Guide* provides information on how to program, and includes complete parameter descriptions.
- Danfoss VLT® Energy Box software. Search VLT® Energy Box at www.danfoss.com.

VLT® Energy Box software allows energy consumption comparisons of HVAC fans and pumps driven by Danfoss drives and alternative methods of flow control. Use this tool to accurately project the costs, savings, and payback of using Danfoss drives on HVAC fans, pumps, and cooling towers.

Supplementary publications and guides are available from the Danfoss website www.danfoss.com.

1.2.2 MCT 10 Setup Software Support

Download the software from the service and support section on www.danfoss.com.

During the installation process of the software, enter access code 81463800 to activate the VLT® HVAC Basic Drive FC 101 functionality. A license key is not required for using the VLT® HVAC Basic Drive FC 101 functionality.

The latest software does not always contain the latest updates for drives. Contact the local sales office for the latest drive updates (in the form of *.upd files), or download the drive updates from the service and support section on www.danfoss.com.

1.3 Version History

This guide is regularly reviewed and updated. All suggestions for improvement are welcome.

The original language of this guide is English.

Table 1: Version History

Edition	Remarks
AJ275648114271, version 1201	For UL 61800-5-1 updates; TOC adjusted.

2 Safety

2.1 Safety Symbols

The following symbols are used in Danfoss documentation.

DANGER

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

WARNING

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

CAUTION

Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.

NOTICE

Indicates information considered important, but not hazard-related (for example, messages relating to property damage).

The guide also includes ISO symbols for general warnings, warnings related to hot surfaces and burn hazard, high voltage and electric shock, and referring to the instructions.

	ISO warning symbol for general warnings
	ISO warning symbol for hot surfaces and burn hazard
	ISO warning symbol for high voltage and electric shock
	ISO action symbol for referring to the instructions

2.2 Qualified Personnel

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

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

3 Approvals and Certifications

3.1 Product Approvals and Certifications

3.1.1 Introduction

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

3.1.2 CE Mark

3.1.2.1 Overview of CE Mark

The CE mark (Communauté Européenne) indicates that the product manufacturer conforms to all applicable EU directives. The EU directives applicable to the design and manufacture of drives are listed in the following table.

NOTICE

The CE mark does not regulate the quality of the product. Technical specifications cannot be deduced from the CE mark.

NOTICE

Drives with an integrated safety function must comply with the machinery directive.

Table 2: EU Directives Applicable to Drives

EU directive	Version
Low Voltage Directive	2014/35/EU
EMC Directive	2014/30/EU
ErP Directive	2009/125/EC

Declarations of conformity are available on request.

3.1.2.2 Low Voltage Directive

The aim of the Low Voltage Directive is to protect persons, domestic animals, and property against dangers caused by the electrical equipment, when operating electrical equipment that is installed and maintained correctly in its intended application. The directive applies to all electrical equipment in the 50–1000 V AC and the 75–1600 V DC voltage ranges.

3.1.2.3 EMC Directive

The purpose of the EMC (electromagnetic compatibility) Directive is to reduce electromagnetic interference and enhance immunity of electrical equipment and installations. The basic protection requirement of the EMC Directive states that devices that generate electromagnetic interference (EMI), or whose operation could be affected by EMI, must be designed to limit the generation of electromagnetic interference and shall have a suitable degree of immunity to EMI when properly installed, maintained, and used as intended. Electrical equipment devices used alone or as part of a system must bear the CE mark. Systems do not require the CE mark, but must comply with the basic protection requirements of the EMC Directive.

3.1.2.4 ErP Directive

The ErP directive is the European Ecodesign Directive for energy-related products. The directive sets ecodesign requirements for energy-related products, including drives, and aims at reducing the energy consumption and environmental impact of products by establishing minimum energy-efficiency standards.

3.1.3 CSA/cUL

Figure 1: CSA/cUL Mark

The CSA/cUL approval is for drives of voltage rated at 600 V or lower. Compliance with the relevant UL/CSA standard assures that safety design and relevant information and markings ensure that the equipment meets the UL standards for electrical and thermal safety when the drive is installed and maintained according to the provided operating/installation guide. This mark shows that the product complies with all required engineering specifications and testing. A certificate of compliance is provided on request.

NOTICE

- IP54 units are not certified for CSA/cUL.

NOTICE

- T6 types and IP54 types are not UL61800-5-1 certified.

NOTICE

It is not allowed to install FC 101 types with UL61800-5-1 in an isolated mains source (IT mains or floating delta) or TT/TN-S mains with a grounded leg (grounded delta).

The drive complies with UL 508C thermal memory retention requirements. For more information, refer to the section *Motor Thermal Protection*.

3.1.4 RCM Mark Compliance

Figure 2: RCM Mark

The RCM Mark label indicates compliance with the applicable technical standards for Electromagnetic Compatibility (EMC). An RCM Mark label is required for placing electrical and electronic devices on the market in Australia and New Zealand. The RCM Mark regulatory arrangements only deal with conducted and radiated emission. For drives, the emission limits specified in EN/IEC 61800-3 apply. A declaration of conformity can be provided on request.

3.1.5 EAC

Figure 3: EAC Mark

The EurAsian Conformity (EAC) Mark indicates that the product conforms to all requirements and technical regulations applicable to the product per the EurAsian Customs Union, which is composed of the member states of the EurAsian Economic Union.

The EAC logo must be both on the product label and on the packaging label. All products used within the EAC area must be bought at Danfoss inside the EAC area.

3.1.6 UkrSEPRO

Figure 4: UkrSEPRO Mark

The UkrSEPRO certificate indicates quality and safety of both products and services, in addition to manufacturing stability according to Ukrainian regulatory standards. The UkrSEPRO certificate is a required document to clear customs for any products coming into and out of the territory of Ukraine.

3.1.7 Korea Certification

Figure 5: Korea Certification (KC) Mark

The Korea Certification (KC) Mark indicates that the product conforms to relevant Korean standards.

3.1.8 Moroccan Conformity Mark

Figure 6: Moroccan Conformity Mark

The drive complies with relevant directives and their related standards for the Morocco market.

3.2 Standards

Installation must be in accordance with national regulations, for example NEC NFPA 70, or IEC 60364 series of standards.

The following standards are recommended as guidelines for the installation and operation of drives:

- **EN IEC 61800-2: 2015 Adjustable speed electrical power drive systems - Part 2**: General requirements - Rating specifications for low voltage adjustable speed AC power drive systems.
- **EN IEC 61800-3: 2018 Adjustable speed electrical power drive systems - Part 3**: EMC requirements and specific test methods.
- **EN IEC 61800-5-1: 2017 Adjustable speed electrical power drive systems - Part 5-1**: Safety requirements - Electrical, thermal, and energy.
- **EN IEC 61800-9-2: 2017 Adjustable speed electrical power drive systems - Part 9-2**: Ecodesign for power drive systems, motor starters, power electronics, and their driven applications - Energy efficiency indicators for power drive systems and motor starters.

Declarations of Conformity are available at www.danfoss.com/en/service-and-support/documentation/.

3.3 Enclosure Protection Ratings

The VLT® drive series are available in various enclosure protections to accommodate the needs of the application. Enclosure protection ratings are provided based on 2 international standards:

- UL type validates that the enclosures meet NEMA (National Electrical Manufacturers Association) standards. The construction and testing requirements for enclosures are provided in NEMA Standards Publication 250–2003 and UL 50, Eleventh Edition.
- IP (Ingress Protection) ratings outlined by IEC (International Electrotechnical Commission) in the rest of the world.

Standard Danfoss VLT® drive series are available in various enclosure protections to meet the requirements of IP00 (Chassis), IP20 (Protected chassis) or IP21 (UL Type 1), or IP54 (UL Type 12). In this guide, UL Type is written as Type. For example, IP21/Type 1.

UL type standard

Type 1 – Enclosures constructed for indoor use to provide a degree of protection to personnel against incidental contact with the enclosed units and to provide a degree of protection against falling dirt.

Type 12 – General-purpose enclosures are intended for use indoors to protect the enclosed units against the following:

- Fibers
- Lint
- Dust and dirt
- Light splashing
- Seepage
- Dripping and external condensation of noncorrosive liquids

There can be no holes through the enclosure and no conduit knockouts or conduit openings, except when used with oil-resistant gaskets to mount oil-tight or dust-tight mechanisms. Doors are also provided with oil-resistant gaskets. In addition, enclosures for combination controllers have hinged doors, which swing horizontally and require a tool to open.

IP standard

Table 3 provides a cross-reference between the 2 standards. Table 4 demonstrates how to read the IP number and then defines the levels of protection. The drives meet the requirements of both.

Table 3: NEMA and IP Number Cross-reference

NEMA and UL	IP
Chassis	IP00
Protected chassis	IP20
Type 1	IP21
Type 12	IP54

Table 4: IP Number Breakdown

1st digit	2nd digit	Level of protection
0	–	No protection.
1	–	Protected to 50 mm (2.0 in). No hands would be able to get into the enclosure.
2	–	Protected to 12.5 mm (0.5 in). No fingers would be able to get into the enclosure.
3	–	Protected to 2.5 mm (0.1 in). No tools would be able to get into the enclosure.
4	–	Protected to 1.0 mm (0.04 in). No wires would be able to get into the enclosure.
5	–	Protected against dust – limited entry.
6	–	Protected totally against dust.
–	0	No protection.
–	1	Protected from vertical dripping water.
–	2	Protected from dripping water at 15° angle.
–	3	Protected from water at 60° angle.
–	4	Protected from splashing water.
–	5	Protected from water jets.
–	6	Protected from strong water jets.

Table 4: IP Number Breakdown - (continued)

1st digit	2nd digit	Level of protection
–	7	Protected from temporary immersion.
–	8	Protected from permanent immersion.

4 Product Overview

4.1 Power Ratings, Weights, and Dimensions

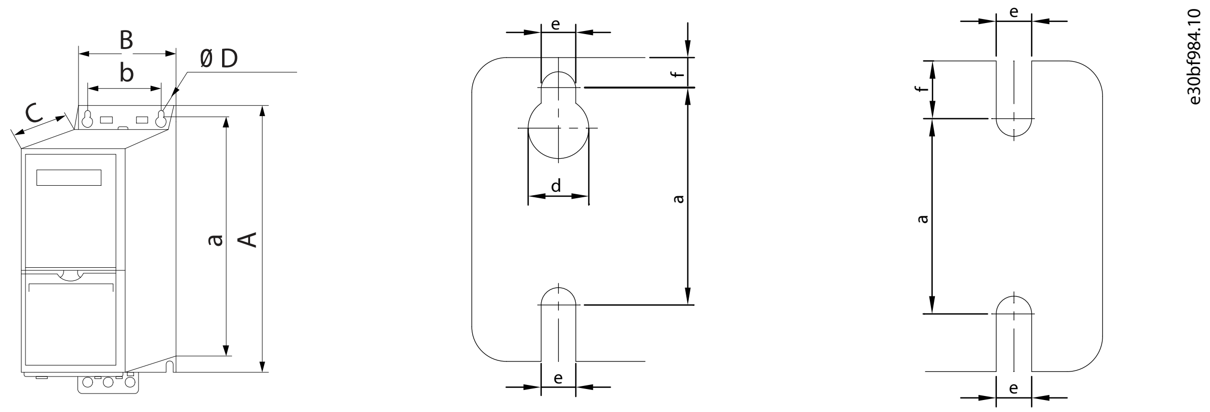

Figure 7: Dimensions

Table 5: Power Ratings, Weights, and Dimensions, Enclosure Sizes H1–H5

Enclosure Size		H1	H2	H3	H4	H5
IP class		IP20/Open type	IP20/Open type	IP20/Open type	IP20/Open type	IP20/Open type
Power [kW (hp)]	3x200–240 V	0.25–1.5 (0.33–2.0)	2.2 (3.0)	3.7 (5.0)	5.5–7.5 (7.5–10)	11 (15)
	3x380–480 V	0.37–1.5 (0.5–2.0)	2.2–4.0 (3.0–5.0)	5.5–7.5 (7.5–10)	11–15 (15–20)	18.5–22 (25–30)
	3x525–600 V	–	–	–	–	–
Height [mm (in)]	A	195 (7.7)	227 (8.9)	255 (10)	296 (11.7)	334 (13.1)
	A(1)	273 (10.7)	303 (11.9)	329 (13)	359 (14.1)	402 (15.8)
	a	183 (7.2)	212 (8.3)	240 (9.4)	275 (10.8)	314 (12.4)
Width [mm (in)]	B	75 (3.0)	90 (3.5)	100 (3.9)	135 (5.3)	150 (5.9)
	b	56 (2.2)	65 (2.6)	74 (2.9)	105 (4.1)	120 (4.7)
Depth [mm (in)]	C	168 (6.6)	190 (7.5)	206 (8.1)	241 (9.5)	255 (10)
Mounting hole [mm (in)]	d	9 (0.35)	11 (0.43)	11 (0.43)	12.6 (0.50)	12.6 (0.50)
	e	4.5 (0.18)	5.5 (0.22)	5.5 (0.22)	7 (0.28)	7 (0.28)
	f	5.3 (0.21)	7.4 (0.29)	8.1 (0.32)	8.4 (0.33)	8.5 (0.33)
Maximum weight kg (lb)		2.1 (4.6)	3.4 (7.5)	4.5 (9.9)	7.9 (17.4)	9.5 (20.9)

1) Including decoupling plate.

Table 6: Power Ratings, Weights, and Dimensions, Enclosure Sizes H6–H10

Enclosure Size		H6	H7	H8	H9	H10
IP class		IP20/Open type	IP20/Open type	IP20/Open type	IP20/Open type	IP20/Open type
Power [kW (hp)]	3x200–240 V	15–18.5 (20–25)	22–30 (30–40)	37–45 (50–60)	–	–
	3x380–480 V	30–45 (40–60)	55–75 (70–100)	90 (125)	–	–
	3x525–600 V	18.5–30 (25–40)	37–55 (50–70)	75–90 (100–125)	2.2–7.5 (3.0–10)	11–15 (15–20)
Height [mm (in)]	A	518 (20.4)	550 (21.7)	660 (26)	269 (10.6)	399 (15.7)
	A(1)	595 (23.4)/635 (25), 45 kW	630 (24.8)/690 (27.2), 75 kW	800 (31.5)	374 (14.7)	419 (16.5)
	a	495 (19.5)	521 (20.5)	631 (24.8)	257 (10.1)	380 (15)
Width [mm (in)]	B	239 (9.4)	313 (12.3)	375 (14.8)	130 (5.1)	165 (6.5)
	b	200 (7.9)	270 (10.6)	330 (13)	110 (4.3)	140 (5.5)
Depth [mm (in)]	C	242 (9.5)	335 (13.2)	335 (13.2)	205 (8.0)	248 (9.8)
Mounting hole [mm (in)]	d	–	–	–	11 (0.43)	12 (0.47)
	e	8.5 (0.33)	8.5 (0.33)	8.5 (0.33)	5.5 (0.22)	6.8 (0.27)
	f	15 (0.6)	17 (0.67)	17 (0.67)	9 (0.35)	7.5 (0.30)
Maximum weight kg (lb)		24.5 (54)	36 (79)	51 (112)	6.6 (14.6)	12 (26.5)

1) Including decoupling plate.

Table 7: Power Ratings, Weights, and Dimensions, Enclosure Sizes I2–I8

Enclosure Size		I2	I3	I4	I6	I7	I8
IP class		IP54	IP54	IP54	IP54	IP54	IP54
Power [kW (hp)]	3x380–480 V	0.75–4.0 (1.0–5.0)	5.5–7.5 (7.5–10)	11–18.5 (15–25)	22–37 (30–50)	45–55 (60–70)	75–90 (100–125)
Height [mm (in)]	A	332 (13.1)	368 (14.5)	476 (18.7)	650 (25.6)	680 (26.8)	770 (30)
	a	318.5 (12.53)	354 (13.9)	460 (18.1)	624 (24.6)	648 (25.5)	739 (29.1)
Width [mm (in)]	B	115 (4.5)	135 (5.3)	180 (7.0)	242 (9.5)	308 (12.1)	370 (14.6)
	b	74 (2.9)	89 (3.5)	133 (5.2)	210 (8.3)	272 (10.7)	334 (13.2)
Depth [mm (in)]	C	225 (8.9)	237 (9.3)	290 (11.4)	260 (10.2)	310 (12.2)	335 (13.2)
Mounting hole [mm (in)]	d	11 (0.43)	12 (0.47)	12 (0.47)	19 (0.75)	19 (0.75)	19 (0.75)
	e	5.5 (0.22)	6.5 (0.26)	6.5 (0.26)	9 (0.35)	9 (0.35)	9 (0.35)
	f	9 (0.35)	9.5 (0.37)	9.5 (0.37)	9 (0.35)	9.8 (0.39)	9.8 (0.39)
Maximum weight kg (lb)		5.3 (11.7)	7.2 (15.9)	13.8 (30.42)	27 (59.5)	45 (99.2)	65 (143.3)

The dimensions are only for the physical units. When installing in an application, allow space above and below the units for cooling. The amount of space for free air passage is listed in 6.2 Side-by-side Installation.

4.2 Advantages

4.2.1 Why Use a Drive for Controlling Fans and Pumps?

4.2.1.1 Overview

A drive takes advantage of the fact that centrifugal fans and pumps follow the laws of proportionality for such fans and pumps. For further information, see 4.2.1.3 Example of Energy Savings.

4.2.1.2 The Clear Advantage - Energy Savings

The clear advantage of using a drive for controlling the speed of fans or pumps lies in the electricity savings.

When comparing with alternative control systems and technologies, a drive is the optimum energy control system for controlling fan and pump systems.

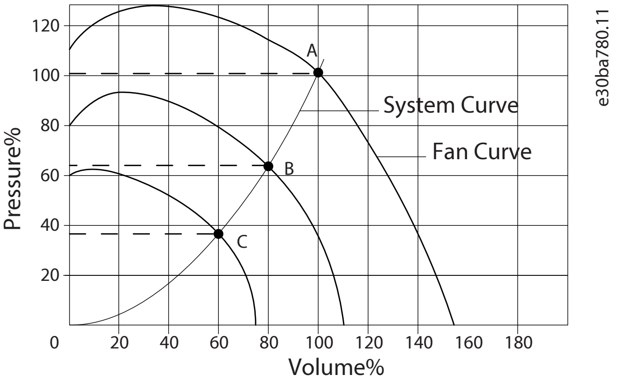

Figure 8: Fan Curves (A, B, and C) for Reduced Fan Volumes

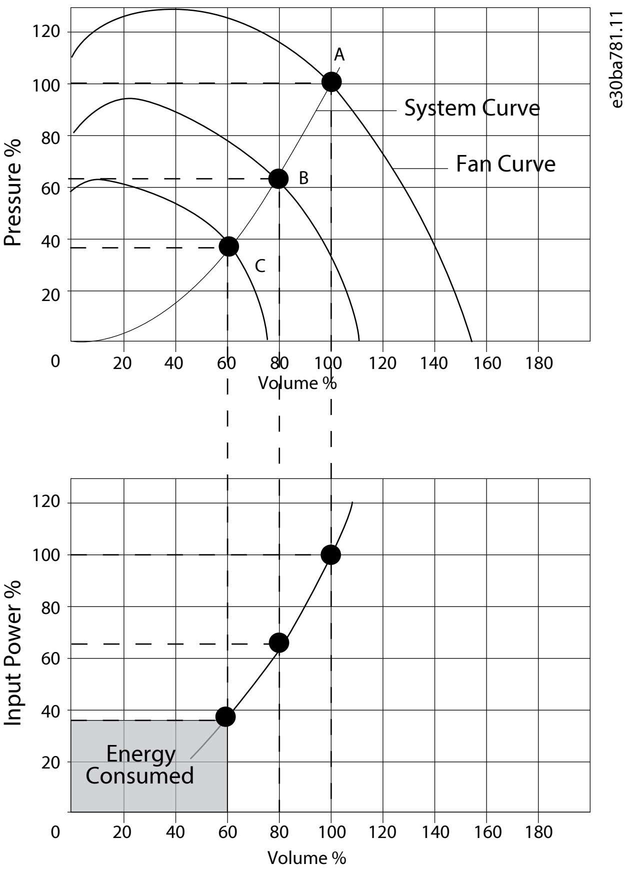

Figure 9: Energy Savings with Drive Solution

When using a drive to reduce fan capacity to 60% - more than 50% energy savings may be obtained in typical applications.

4.2.1.3 Example of Energy Savings

As shown in Figure 10, the flow is controlled by changing the RPM. By reducing the speed by only 20% from the rated speed, the flow is also reduced by 20%. This is because the flow is directly proportional to the RPM. The consumption of electricity, however, is reduced by 50%.

If the system in question only needs to be able to supply a flow that corresponds to 100% a few days in a year, while the average is below 80% of the rated flow for the remainder of the year, the amount of energy saved is even more than 50%.

Figure 10 describes the dependence of flow, pressure, and power consumption on RPM.

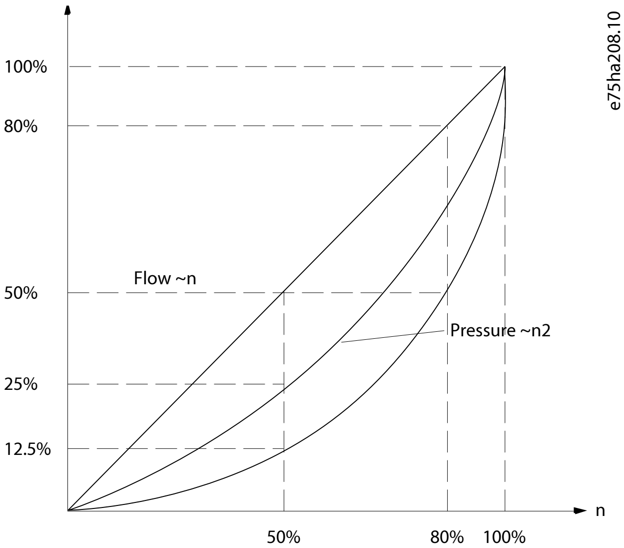

Figure 10: Laws of Proportionally

$$Flow: \frac{Q_1}{Q_2} = \frac{n_1}{n_2}$$

$$Pressure: \frac{H_1}{H_2} = \left(\frac{n_1}{n_2}\right)^2$$

$$Power: \frac{P_1}{P_2} = \left(\frac{n_1}{n_2}\right)^3$$

Table 8: The Laws of Proportionality

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

4.2.1.4 Comparison of Energy Savings

The Danfoss drive solution offers major savings compared with traditional energy-saving solutions such as discharge damper solution and inlet guide vanes (IGV) solution. This is because the drive is able to control fan speed according to thermal load on the system, and the drive has a built-in facility that enables the drive to function as a building management system, BMS.

The figure in 4.2.1.3 Example of Energy Savings shows typical energy savings obtainable with 3 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.

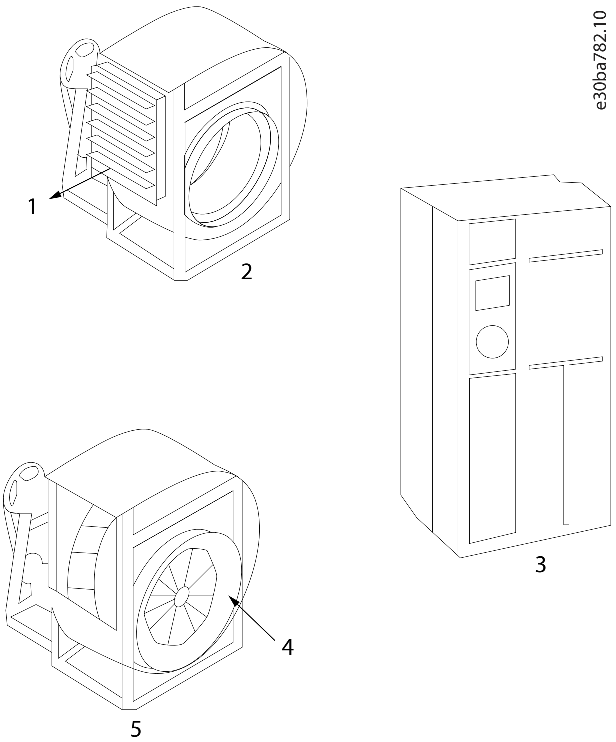

Figure 11: The 3 Common Energy Saving Systems

1	Discharge damper	**2**	Less energy savings
3	Maximum energy savings	**4**	IGV
5	Costlier installation		

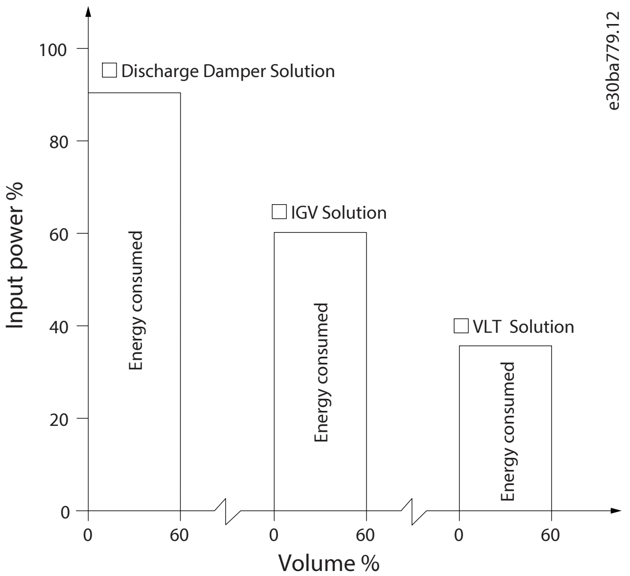

Figure 12: Energy Savings

Discharge dampers reduce power consumption. Inlet guide vanes offer a 40% reduction, but are expensive to install. The Danfoss drive solution reduces energy consumption with more than 50% and is easy to install. It also reduces noise, mechanical stress, and wear-and-tear, and extends the life span of the entire application.

4.2.1.5 Example with Varying Flow over 1 Year

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

Energy savings

$P_{shaft} = P_{shaftoutput}$

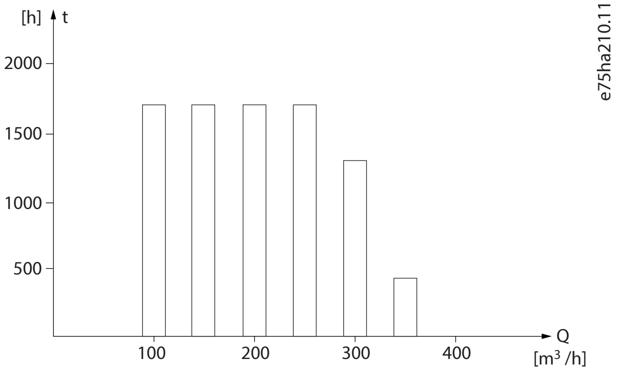

Figure 13: Flow Distribution over 1 Year

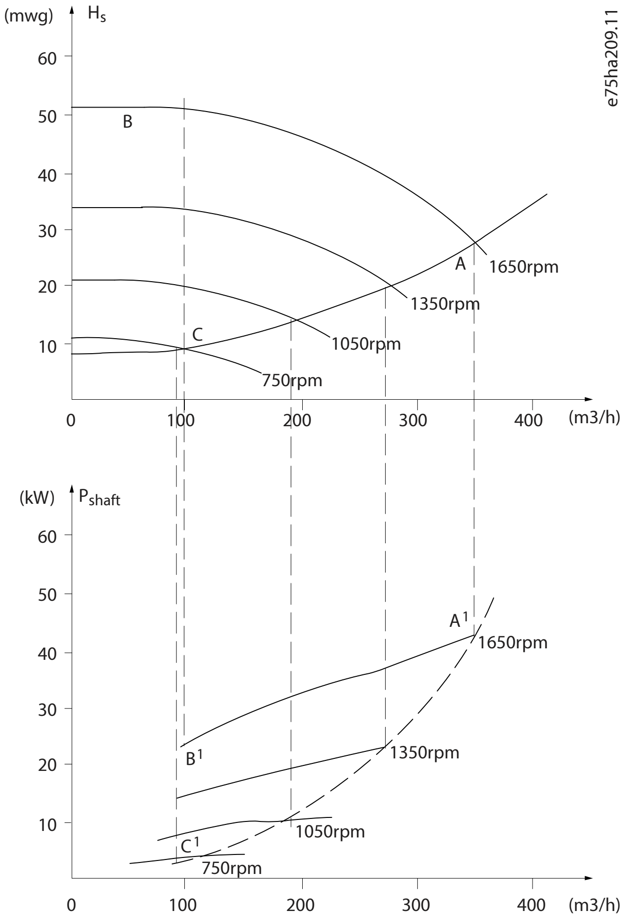

Figure 14: Energy

Table 9: Result

m^3/h	Distribution		Valve regulation		Drive 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

4.2.1.6 Better Control

If a drive is used for controlling the flow or pressure of a system, improved control is obtained.

A drive can vary the speed of the fan or pump, obtaining variable control of flow and pressure. Furthermore, a 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 PI control.

4.2.1.7 Star/Delta Starter or Soft Starter not Required

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

As shown in Figure 15, a drive does not consume more than rated current.

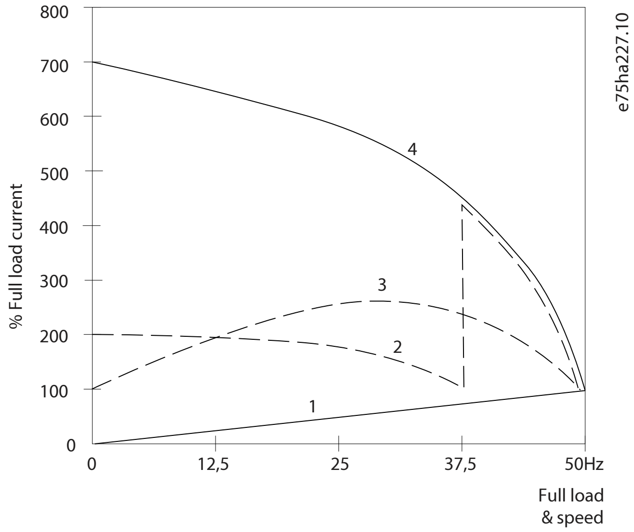

Figure 15: Start-up Current

1	VLT® HVAC Basic Drive FC 101	**2**	Star/delta starter
3	Soft starter	**4**	Start directly on mains

4.2.1.8 Using a Drive Saves Money

The examples in 4.2.1.9 Traditional Fan System without a Drive and 4.2.1.10 Fan System Controlled by Drives show that a drive replaces other equipment. It is possible to calculate the cost of installing the 2 different systems. In the example, the 2 systems can be established at roughly the same price.

Use the VLT® Energy Box software that is introduced in *chapter Additional Resources* to calculate the cost savings that can be achieved by using a drive.

4.2.1.9 Traditional Fan System without a Drive

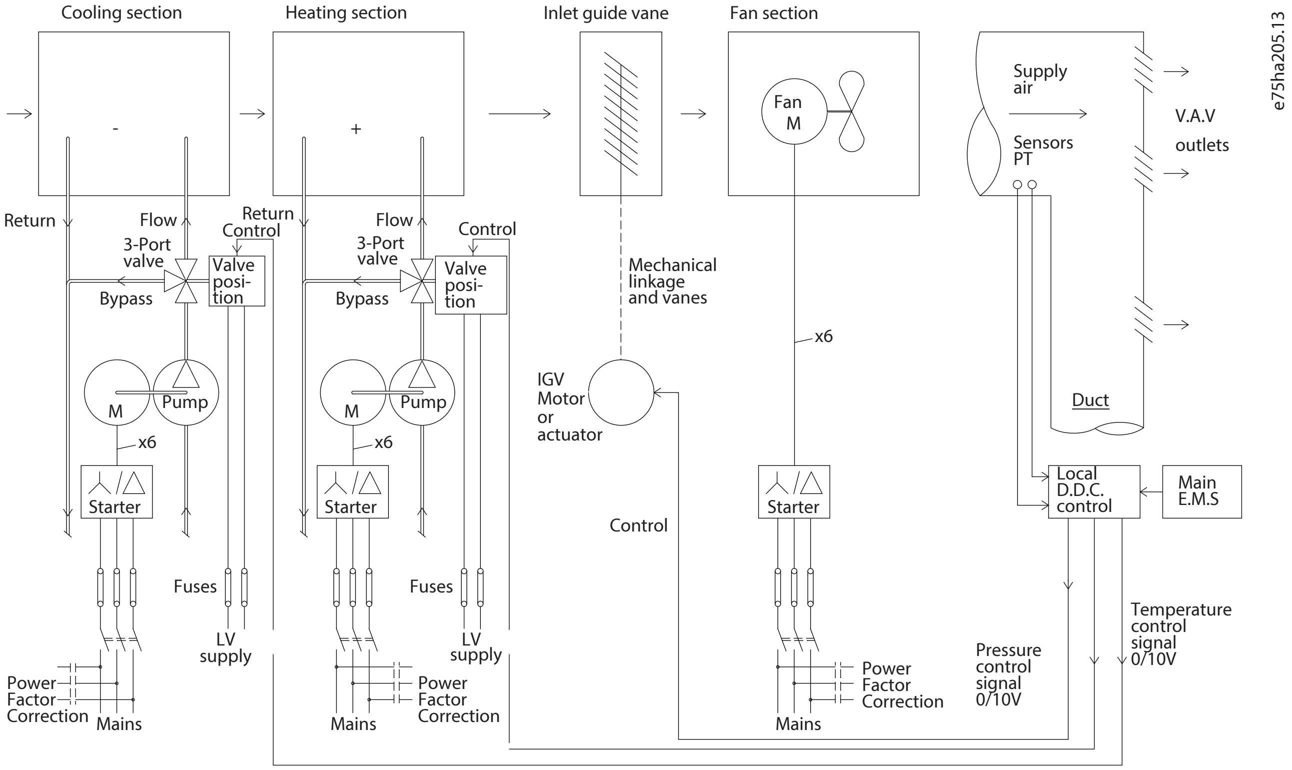

Figure 16: Traditional Fan System without a Drive

D.D.C.	Direct digital control
E.M.S.	Energy management system
V.A.V.	Variable air volume
Sensor P	Pressure
Sensor T	Temperature

4.2.1.10 Fan System Controlled by Drives

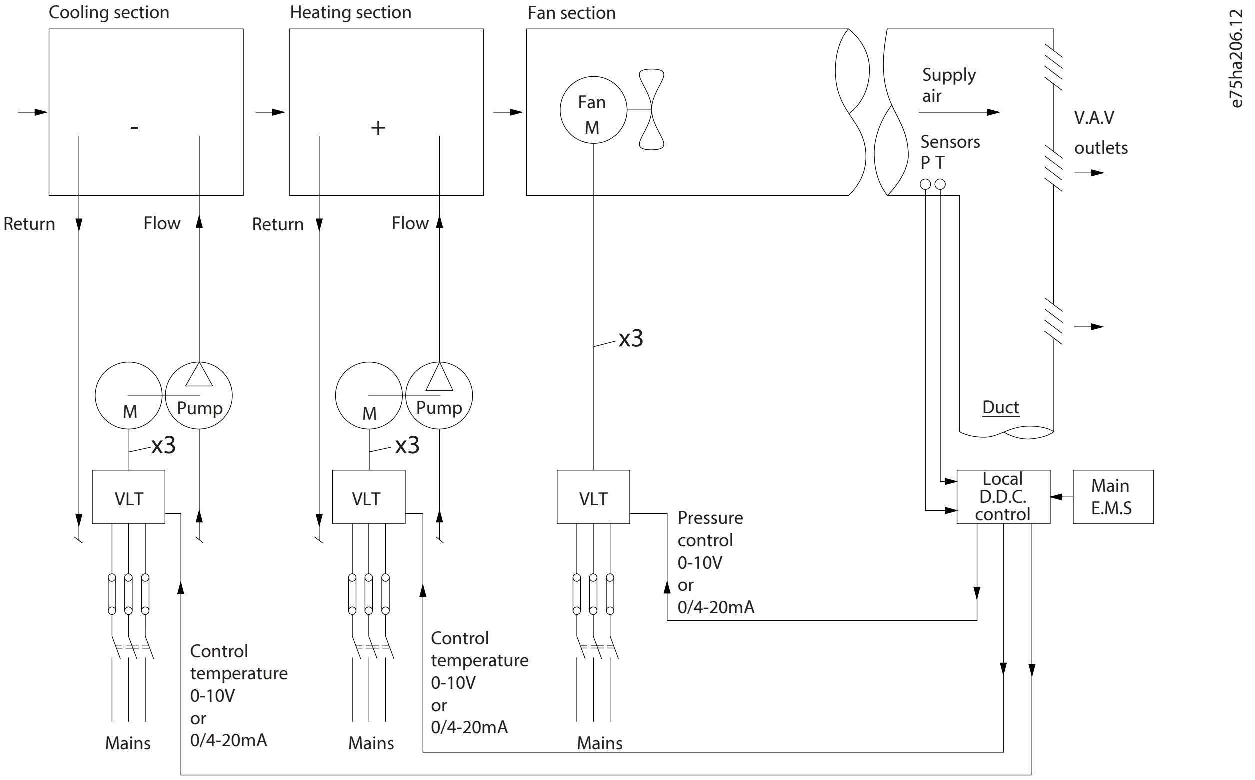

Figure 17: Fan System Controlled by Drives

D.D.C.	Direct digital control
E.M.S.	Energy management system
V.A.V.	Variable air volume
Sensor P	Pressure
Sensor T	Temperature

5 Specifications

5.1 Electrical Data

5.1.1 Electrical Data, 3x200–240 V AC and 3x200Y/115–240Y/139 V AC

IMPORTANT: If type code position 23 = 6: UL 61800-5-1, the supply voltage is 3x200Y/115–240Y/139 V.

Table 10: Mains Supply 3x200–240 V AC and 3x200Y/115–240Y/139 V AC, 0.25–7.5 kW (0.33–10 hp), Enclosure Sizes H1–H4

Drive	PK25	PK37	PK75	P1K5	P2K2	P3K7	P5K5	P7K5
Typical shaft output [kW]	0.25	0.37	0.75	1.5	2.2	3.7	5.5	7.5
Typical shaft output [hp]	0.33	0.5	1.0	2.0	3.0	5.0	7.5	10
IP20/Open type	H1	H1	H1	H1	H2	H3	H4	H4
Maximum cable size in terminals (mains, motor) [m^2 (AWG)]	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	16 (6)	16 (6)
Output current 40 °C (104 °F) ambient temperature								
Continuous (3x200–240 V) [A]	1.5	2.2	4.2	6.8	9.6	15.2	22	28
Intermittent (3x200–240 V) [A]	1.7	2.4	4.6	7.5	10.6	16.7	24.2	30.8
Maximum input current								
Continuous (3x200–240 V) [A]	1.1	1.6	2.8	5.6	8.6/7.2	14.1/12	21.0/18	28.3/24
Intermittent (3x200–240 V) [A]	1.2	1.8	3.1	6.2	9.5/7.9	15.5/13.2	23.1/19.8	31.1/26.4
Maximum mains fuses	See 7.5.5 Recommendation of Fuses and Circuit Breakers.							
Estimated power loss [W], Best case/typical[1]	12/14	15/18	21/26	48/60	80/102	97/120	182/204	229/268
Weight enclosure protection rating IP20/Open type [kg (lb)]	2.0 (4.4)	2.0 (4.4)	2.0 (4.4)	2.1 (4.6)	3.4 (7.5)	4.5 (9.9)	7.9 (17.4)	7.9 (17.4)
Efficiency [%], best case/typical[2]	97/96.5	97.3/96.8	98/97.6	97.6/97	97.1/96.3	97.9/97.4	97.3/97	98.5/97.1
Output current 50 °C (122 °F) ambient temperature								
Continuous (3x200–240 V) [A]	1.5	1.9	3.5	6.8	9.6	13	19.8	23
Intermittent (3x200–240 V) [A]	1.7	2.1	3.9	7.5	10.6	14.3	21.8	25.3

1) *Applies for dimensioning of drive cooling. If the switching frequency is higher than the default setting, the power losses may increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50598-2, refer to Efficiency Calculator in Danfoss MyDrive® Energy website.*

2) *Efficiency measured at nominal current. For energy efficiency class, see chapter Ambient Conditions. For part load losses, see Efficiency Calculator in Danfoss MyDrive® Energy website.*

Table 11: Mains Supply 3x200–240 V AC and 3x200Y/115–240Y/139 V AC, 11–45 kW (15–60 hp), Enclosure Sizes H5–H8

Drive	P11K	P15K	P18K	P22K	P30K	P37K	P45K
Typical shaft output [kW]	11	15	18.5	22	30	37	45
Typical shaft output [hp]	15	20	25	30	40	50	60
IP20/Open type	H5	H6	H6	H7	H7	H8	H8
Maximum cable size in terminals (mains, motor) [m^2 (AWG)]	16 (6)	35 (2)	35 (2)	50 (1)	50 (1)	95 (0)	120 (4/0)

Table 11: Mains Supply 3x200–240 V AC and 3x200Y/115–240Y/139 V AC, 11–45 kW (15–60 hp), Enclosure Sizes H5–H8 - (continued)

Drive	P11K	P15K	P18K	P22K	P30K	P37K	P45K
Output current 40 °C (104 °F) ambient temperature							
Continuous (3x200–240 V) [A]	42	59.4	74.8	88	115	143	170
Intermittent (3x200–240 V) [A]	46.2	65.3	82.3	96.8	126.5	157.3	187
Maximum input current							
Continuous 3x200–240 V) [A]	41/38.2	52.7	65	76	103.7	127.9	153
Intermittent (3x200–240 V) [A]	45.1/42	58	71.5	83.7	114.1	140.7	168.3
Maximum mains fuses	See 7.5.5 Recommendation of Fuses and Circuit Breakers.						
Estimated power loss [W], Best case/typical(1)	369/386	512	697	879	1149	1390	1500
Weight enclosure protection rating IP20/Open type [kg (lb)]	9.5 (20.9)	24.5 (54)	24.5 (54)	36 (79.4)	36 (79.4)	51 (112.4)	51 (112.4)
Efficiency [%], best case/typical(2)	97.2/97.1	97	97.1	96.8	97.1	97.1	97.3
Output current 50 °C (122 °F) ambient temperature							
Continuous (3x200–240 V) [A]	33	41.6	52.4	61.6	80.5	100.1	119
Intermittent (3x200–240 V) [A]	36.3	45.8	57.6	67.8	88.6	110.1	130.9

1) *Applies for dimensioning of drive cooling. If the switching frequency is higher than the default setting, the power losses may increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50598-2, refer to Efficiency Calculator in Danfoss MyDrive® Energy website.*

2) *Efficiency measured at nominal current. For energy efficiency class, see chapter Ambient Conditions. For part load losses, see Efficiency Calculator in Danfoss MyDrive® Energy website.*

5.1.2 Electrical Data, 3x380–480 V AC and 3x380Y/220–480Y/277 V AC

IMPORTANT: For enclosure sizes H1–H8, if type code position 23 = 6: UL 61800-5-1, the supply voltage is 3x380Y/220–480Y/277 V.

Table 12: Mains Supply 3x380–480 V AC and 3x380Y/220–480Y/277 V AC, 0.37–15 kW (0.5–20 hp), Enclosure Sizes H1–H4

Drive	PK37	PK75	P1K5	P2K2	P3K0	P4K0	P5K5	P7K5	P11K	P15K
Typical shaft output [kW]	0.37	0.75	1.5	2.2	3.0	4.0	5.5	7.5	11	15
Typical shaft output [hp]	0.5	1.0	2.0	3.0	4.0	5.0	7.5	10	15	20
IP20/Open type	H1	H1	H1	H2	H2	H2	H3	H3	H4	H4
Maximum cable size in terminals (mains, motor) [mm^2 (AWG)]	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	16 (6)	16 (6)
Output current 40 °C (104 °F) ambient temperature										
Continuous (3x380–440 V)[A]	1.2	2.2	3.7	5.3	7.2	9.0	12	15.5	23	31
Intermittent (3x380–440 V) [A]	1.3	2.4	4.1	5.8	7.9	9.9	13.2	17.1	25.3	34
Continuous (3x441–480 V) [A]	1.1	2.1	3.4	4.8	6.3	8.2	11	14	21	27

Table 12: Mains Supply 3x380–480 V AC and 3x380Y/220–480Y/277 V AC, 0.37–15 kW (0.5–20 hp), Enclosure Sizes H1–H4 - (continued)

Drive	PK37	PK75	P1K5	P2K2	P3K0	P4K0	P5K5	P7K5	P11K	P15K
Intermittent (3x441–480 V) [A]	1.2	2.3	3.7	5.3	6.9	9.0	12.1	15.4	23.1	29.7
Maximum input current										
Continuous (3x380–440 V) [A]	1.2	2.1	3.5	4.7	6.3	8.3	11.2	15.1	22.1	29.9
Intermittent (3x380–440 V) [A]	1.3	2.3	3.9	5.2	6.9	9.1	12.3	16.6	24.3	32.9
Continuous (3x441–480 V) [A]	1.0	1.8	2.9	3.9	5.3	6.8	9.4	12.6	18.4	24.7
Intermittent (3x441–480 V) [A]	1.1	2.0	3.2	4.3	5.8	7.5	10.3	13.9	20.2	27.2
Maximum mains fuses	See 7.5.5 Recommendation of Fuses and Circuit Breakers.									
Estimated power loss [W], best case/typical [1]	13/15	16/21	46/57	46/58	66/83	95/118	104/131	159/198	248/274	353/379
Weight enclosure protection rating IP20/Open type [kg (lb)]	2.0 (4.4)	2.0 (4.4)	2.1 (4.6)	3.3 (7.3)	3.3 (7.3)	3.4 (7.5)	4.3 (9.5)	4.5 (9.9)	7.9 (17.4)	7.9 (17.4)
Efficiency [%], best case/typical[2]	97.8/97.3	98/97.6	97.7/97.2	98.3/97.9	98.2/97.8	98/97.6	98.4/98	98.2/97.8	98.1/97.9	98/97.8
Output current 50 °C (122 °F) ambient temperature										
Continuous (3x380–440 V) [A]	1.04	1.93	3.7	4.85	6.3	8.4	10.9	14	20.9	28
Intermittent (3x380–440 V) [A]	1.1	2.1	4.07	5.4	6.9	9.2	12	15.4	23	30.8
Continuous (3x441–480 V) [A]	1.0	1.8	3.4	4.4	5.5	7.5	10	12.6	19.1	24
Intermittent (3x441–480 V) [A]	1.1	2.0	3.7	4.8	6.1	8.3	11	13.9	21	26.4

1) *Applies for dimensioning of drive cooling. If the switching frequency is higher than the default setting, the power losses may increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50598-2, refer to Efficiency Calculator in Danfoss MyDrive® Energy website.*

2) *Typical: under rated condition. Best case: the optimal condition is adopt, such as the higher input voltage and lower switching frequency.*

Table 13: Mains Supply 3x380–480 V AC and 3x380Y/220–480Y/277 V AC, 18.5–90 kW (25–125 hp), Enclosure Sizes H5–H8

Drive	P18K	P22K	P30K	P37K	P45K	P55K	P75K	P90K
Typical shaft output [kW]	18.5	22	30	37	45	55	75	90
Typical shaft output [hp]	25	30	40	50	60	70	100	125
IP20/Open type	H5	H5	H6	H6	H6	H7	H7	H8
Maximum cable size in terminals (mains, motor) [mm^2 (AWG)]	16 (6)	16 (6)	35 (2)	35 (2)	35 (2)	50 (1)	95 (0)	120 (250 MCM)
Output current 40 °C (104 °F) ambient temperature								
Continuous (3x380–440 V) [A]	37	42.5	61	73	90	106	147	177

Table 13: Mains Supply 3x380–480 V AC and 3x380Y/220–480Y/277 V AC, 18.5–90 kW (25–125 hp), Enclosure Sizes H5–H8 - (continued)

Drive	P18K	P22K	P30K	P37K	P45K	P55K	P75K	P90K
Intermittent (3x380–440 V) [A]	40.7	46.8	67.1	80.3	99	116	161	194
Continuous (3x441–480 V) [A]	34	40	52	65	80	105	130	160
Intermittent (3x441–480 V) [A]	37.4	44	57.2	71.5	88	115	143	176
Maximum input current								
Continuous (3x380–440 V) [A]	35.2	41.5	57	70	84	103	140	166
Intermittent (3x380–440 V) [A]	38.7	45.7	62.7	77	92.4	113	154	182
Continuous (3x441–480 V) [A]	29.3	34.6	49.2	60.6	72.5	88.6	120.9	142.7
Intermittent (3x441–480 V) [A]	32.2	38.1	54.1	66.7	79.8	97.5	132.9	157
Maximum mains fuses	See 7.5.5 Recommendation of Fuses and Circuit Breakers.							
Estimated power loss [W], best case/typical(1)	412/456	475/523	733	922	1067	1133	1733	2141
Weight enclosure protection rating IP20/Open type [kg (lb)]	9.5 (20.9)	9.5 (20.9)	24.5 (54)	24.5 (54)	24.5 (54)	36 (79.4)	36 (79.4)	51 (112.4)
Efficiency [%], best case/typical(2)	98.1/97.9	98.1/97.9	97.8	97.7	98	98.2	97.8	97.9
Output current 50 °C (122 °F) ambient temperature								
Continuous (3x380–440 V) [A]	34.1	38	48.8	58.4	72	74.2	102.9	123.9
Intermittent (3x380–440 V) [A]	37.5	41.8	53.7	64.2	79.2	81.6	113.2	136.3
Continuous (3x441–480 V) [A]	31.3	35	41.6	52	64	73.5	91	112
Intermittent (3x441–480 V) [A]	34.4	38.5	45.8	57.2	70.4	80.9	100.1	123.2

1) *Applies for dimensioning of drive cooling. If the switching frequency is higher than the default setting, the power losses may increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50598-2, refer to Efficiency Calculator in Danfoss MyDrive® Energy website.*

2) *Efficiency measured at nominal current. For energy efficiency class, see chapter Ambient Conditions. For part load losses, see Efficiency Calculator in Danfoss MyDrive® Energy website.*

NOTE: UL61800-5-1 is not available for IP54 units.

Table 14: Mains Supply 3x380–480 V AC, 0.75–18.5 kW (1.0–25 hp), Enclosure Sizes I2–I4

Drive	PK75	P1K5	P2K2	P3K0	P4KO	P5K5	P7K5	P11K	P15K	P18K
Typical shaft output [kW]	0.75	1.5	2.2	3.0	4.0	5.5	7.5	11	15	18.5
Typical shaft output [hp]	1.0	2.0	3.0	4.0	5.0	7.5	10	15	20	25
Protection rating IP54	I2	I2	I2	I2	I2	I3	I3	I4	I4	I4
Maximum cable size in terminals (mains, motor) [mm^2 (AWG)]	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	16 (6)	16 (6)	16 (6)
Output current 40 °C (104 °F) ambient temperature										
Continuous (3x380–440 V) [A]	2.2	3.7	5.3	7.2	9.0	12	15.5	23	31	37
Intermittent (3x380–440 V) [A]	2.4	4.1	5.8	7.9	9.9	13.2	17.1	25.3	34	40.7

Table 14: Mains Supply 3x380–480 V AC, 0.75–18.5 kW (1.0–25 hp), Enclosure Sizes I2–I4 - (continued)

Drive	PK75	P1K5	P2K2	P3K0	P4KO	P5K5	P7K5	P11K	P15K	P18K
Continuous (3x441–480 V) [A]	2.1	3.4	4.8	6.3	8.2	11	14	21	27	34
Intermittent (3x441–480 V) [A]	2.3	3.7	5.3	6.9	9.0	12.1	15.4	23.1	29.7	37.4
Maximum input current										
Continuous (3x380–440 V) [A]	2.1	3.5	4.7	6.3	8.3	11.2	15.1	22.1	29.9	35.2
Intermittent (3x380–440 V) [A]	2.3	3.9	5.2	6.9	9.1	12.3	16.6	24.3	32.9	38.7
Continuous (3x441–480 V) [A]	1.8	2.9	3.9	5.3	6.8	9.4	12.6	18.4	24.7	29.3
Intermittent (3x441–480 V) [A]	2.0	3.2	4.3	5.8	7.5	10.3	13.9	20.2	27.2	32.2
Maximum mains fuses	See 7.5.5 Recommendation of Fuses and Circuit Breakers.									
Estimated power loss [W], best case/typical(1)	21/16	46/57	46/58	66/83	95/118	104/131	159/198	248/274	353/379	412/456
Weight enclosure protection rating IP54 [kg (lb)]	5.3 (11.7)	5.3 (11.7)	5.3 (11.7)	5.3 (11.7)	5.3 (11.7)	7.2 (15.9)	7.2 (15.9)	13.8 (30.4)	13.8 (30.4)	13.8 (30.4)
Efficiency [%], best case/typical(2)	98/97.6	97.7/97.2	98.3/97.9	98.2/97.8	98/97.6	98.4/98	98.2/97.8	98.1/97.9	98/97.8	98.1/97.9
Output current 50 °C (122 °F) ambient temperature										
Continuous (3x380–440 V) [A]	1.93	3.7	4.85	6.3	7.5	10.9	14	20.9	28	33
Intermittent (3x380–440 V) [A]	2.1	4.07	5.4	6.9	9.2	12	15.4	23	30.8	36.3
Continuous (3x441–480 V) [A]	1.8	3.4	4.4	5.5	6.8	10	12.6	19.1	24	30
Intermittent (3x441–480 V) [A]	2.0	3.7	4.8	6.1	8.3	11	13.9	21	26.4	33

1) *Applies for dimensioning of drive cooling. If the switching frequency is higher than the default setting, the power losses may increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50598-2, refer to Efficiency Calculator in Danfoss MyDrive® Energy website.*

2) *Efficiency measured at nominal current. For energy efficiency class, see chapter Ambient Conditions. For part load losses, see Efficiency Calculator in Danfoss MyDrive® Energy website.*

Table 15: Mains Supply 3x380–480 V AC, 22–90 kW (30–125 hp), Enclosure Sizes I6–I8

Drive	P22K	P30K	P37K	P45K	P55K	P75K	P90K
Typical shaft output [kW]	22	30	37	45	55	75	90
Typical shaft output [hp]	30	40	50	60	70	100	125
Protection rating IP54	I6	I6	I6	I7	I7	I8	I8
Maximum cable size in terminals (mains, motor) [mm^2 (AWG)]	35 (2)	35 (2)	35 (2)	50 (1)	50 (1)	95 (3/0)	120 (4/0)
Output current 40 °C (104 °F) ambient temperature							

Table 15: Mains Supply 3x380–480 V AC, 22–90 kW (30–125 hp), Enclosure Sizes I6–I8 - (continued)

Drive	P22K	P30K	P37K	P45K	P55K	P75K	P90K
Continuous (3x380–440 V) [A]	44	61	73	90	106	147	177
Intermittent (3x380–440 V) [A]	48.4	67.1	80.3	99	116.6	161.7	194.7
Continuous (3x441–480 V) [A]	40	52	65	80	105	130	160
Intermittent (3x441–480 V) [A]	44	57.2	71.5	88	115.5	143	176
Maximum input current							
Continuous (3x380–440 V) [A]	41.8	57	70.3	84.2	102.9	140.3	165.6
Intermittent (3x380–440 V) [A]	46	62.7	77.4	92.6	113.1	154.3	182.2
Continuous (3x441–480 V) [A]	36	49.2	60.6	72.5	88.6	120.9	142.7
Intermittent (3x441–480 V) [A]	39.6	54.1	66.7	79.8	97.5	132.9	157
Maximum mains fuses	See 7.5.5 Recommendation of Fuses and Circuit Breakers.						
Estimated power loss [W], best case/typical(1)	496	734	995	840	1099	1520	1781
Weight enclosure protection rating IP54 [kg (lb)]	27 (59.5)	27 (59.5)	27 (59.5)	45 (99.2)	45 (99.2)	65 (143.3)	65 (143.3)
Efficiency [%], best case/typical(2)	98	97.8	97.6	98.3	98.2	98.1	98.3
Output current 50 °C (122 °F) ambient temperature							
Continuous (3x380–440 V) [A]	35.2	48.8	58.4	63	74.2	102.9	123.9
Intermittent (3x380–440 V) [A]	38.7	53.9	64.2	69.3	81.6	113.2	136.3
Continuous (3x441–480 V) [A]	32	41.6	52	56	73.5	91	112
Intermittent (3x441–480 V) [A]	35.2	45.8	57.2	61.6	80.9	100.1	123.2

1) *Applies for dimensioning of drive cooling. If the switching frequency is higher than the default setting, the power losses may increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50598-2, refer to Efficiency Calculator in Danfoss MyDrive® Energy website.*

2) *Efficiency measured at nominal current. For energy efficiency class, see chapter Ambient Conditions. For part load losses, see Efficiency Calculator in Danfoss MyDrive® Energy website.*

5.1.3 Electrical Data, 3x525–600 V AC

NOTE: UL61800-5-1 is not available for drives of mains supply 3x525–600 V AC.

Table 16: Mains Supply 3x525–600 V AC, 2.2–15 kW (3.0–20 hp), Enclosure Sizes H9–H10

Drive	P2K2	P3K0	P3K7	P5K5	P7K5	P11K	P15K
Typical shaft output [kW]	2.2	3.0	3.7	5.5	7.5	11	15
Typical shaft output [hp]	3.0	4.0	5.0	7.5	10	15	20
IP20/Open type	H9	H9	H9	H9	H9	H10	H10
Maximum cable size in terminals (mains, motor) [mm^2 (AWG)]	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	10 (8)	10 (8)
Output current 40 °C (104 °F) ambient temperature							
Continuous (3x525–550 V) [A]	4.1	5.2	6.4	9.5	11.5	19	23
Intermittent (3x525–550 V) [A]	4.5	5.7	7.0	10.5	12.7	20.9	25.3

Table 16: Mains Supply 3x525–600 V AC, 2.2–15 kW (3.0–20 hp), Enclosure Sizes H9–H10 - (continued)

Drive	P2K2	P3K0	P3K7	P5K5	P7K5	P11K	P15K
Continuous (3x551–600 V) [A]	3.9	4.9	6.1	9.0	11	18	22
Intermittent (3x551–600 V) [A]	4.3	5.4	6.7	9.9	12.1	19.8	24.2
Maximum input current							
Continuous (3x525–550 V) [A]	3.7	5.1	5.0	8.7	11.9	16.5	22.5
Intermittent (3x525–550 V) [A]	4.1	5.6	6.5	9.6	13.1	18.2	24.8
Continuous (3x551–600 V) [A]	3.5	4.8	5.6	8.3	11.4	15.7	21.4
Intermittent (3x551–600 V) [A]	3.9	5.3	6.2	9.2	12.5	17.3	23.6
Maximum mains fuses	See 7.5.5 Recommendation of Fuses and Circuit Breakers.						
Estimated power loss [W], best case/typical(1)	65	90	110	132	180	216	294
Weight enclosure protection rating IP20/Open type [kg (lb)]	6.6 (14.6)	6.6 (14.6)	6.6 (14.6)	6.6 (14.6)	6.6 (14.6)	11.5 (25.3)	11.5 (25.3)
Efficiency [%], best case/typical(2)	97.9	97	97.9	98.1	98.1	98.4	98.4
Output current 50 °C (122 °F) ambient temperature							
Continuous (3x525–550 V) [A]	2.9	3.6	4.5	6.7	8.1	13.3	16.1
Intermittent (3x525–550 V) [A]	3.2	4.0	4.9	7.4	8.9	14.6	17.7
Continuous (3x551–600 V) [A]	2.7	3.4	4.3	6.3	7.7	12.6	15.4
Intermittent (3x551–600 V) [A]	3.0	3.7	4.7	6.9	8.5	13.9	16.9

1) *Applies for dimensioning of drive cooling. If the switching frequency is higher than the default setting, the power losses may increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50598-2, refer to Efficiency Calculator in Danfoss MyDrive® Energy website.*

2) *Efficiency measured at nominal current. For energy efficiency class, see chapter Ambient Conditions. For part load losses, see Efficiency Calculator in Danfoss MyDrive® Energy website.*

Table 17: Mains Supply 3x525–600 V AC, 18.5–90 kW (25–125 hp), Enclosure Sizes H6–H8

Drive	P18K	P22K	P30K	P37K	P45K	P55K	P75K	P90K
Typical shaft output [kW]	18.5	22	30	37	45	55	75	90
Typical shaft output [hp]	25	30	40	50	60	70	100	125
IP20/Open type	H6	H6	H6	H7	H7	H7	H8	H8
Maximum cable size in terminals (mains, motor) [mm^2 (AWG)]	35 (2)	35 (2)	35 (2)	50 (1)	50 (1)	50 (1)	95 (0)	120 (4/0)
Output current 40 °C (104 °F) ambient temperature								
Continuous (3x525–550 V) [A]	28	36	43	54	65	87	105	137
Intermittent (3x525–550 V) [A]	30.8	39.6	47.3	59.4	71.5	95.7	115.5	150.7
Continuous (3x551–600 V) [A]	27	34	41	52	62	83	100	131
Intermittent (3x551–600 V) [A]	29.7	37.4	45.1	57.2	68.2	91.3	110	144.1
Maximum input current								
Continuous (3x525–550 V) [A]	27	33.1	45.1	54.7	66.5	81.3	109	130.9
Intermittent (3x525–550 V) [A]	29.7	36.4	49.6	60.1	73.1	89.4	119.9	143.9
Continuous (3x551–600 V) [A]	25.7	31.5	42.9	52	63.3	77.4	103.8	124.5

Table 17: Mains Supply 3x525–600 V AC, 18.5–90 kW (25–125 hp), Enclosure Sizes H6–H8 - (continued)

Drive	P18K	P22K	P30K	P37K	P45K	P55K	P75K	P90K
Intermittent (3x551–600 V) [A]	28.3	34.6	47.2	57.2	69.6	85.1	114.2	137
Maximum mains fuses	See 7.5.5 Recommendation of Fuses and Circuit Breakers.							
Estimated power loss [W], best case/typical (1)	385	458	542	597	727	1092	1380	1658
Weight enclosure protection rating IP20/Open type [kg (lb)]	24.5 (54)	24.5 (54)	24.5 (54)	36 (79.3)	36 (79.3)	36 (79.3)	51 (112.4)	51 (112.4)
Efficiency [%], best case/typical(2)	98.4	98.4	98.5	98.5	98.7	98.5	98.5	98.5
Output current 50 °C (122 °F) ambient temperature								
Continuous (3x525–550 V) [A]	19.6	25.2	30.1	37.8	45.5	60.9	73.5	95.9
Intermittent (3x525–550 V) [A]	21.6	27.7	33.1	41.6	50	67	80.9	105.5
Continuous (3x551–600 V) [A]	18.9	23.8	28.7	36.4	43.3	58.1	70	91.7
Intermittent (3x551–600 V) [A]	20.8	26.2	31.6	40	47.7	63.9	77	100.9

1) Applies for dimensioning of drive cooling. If the switching frequency is higher than the default setting, the power losses may increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50598-2, refer to Efficiency Calculator in Danfoss MyDrive® Energy website.

2) Efficiency measured at nominal current. For energy efficiency class, see chapter Ambient Conditions. For part load losses, see Efficiency Calculator in Danfoss MyDrive® Energy website.

5.2 General Technical Data

5.2.1 Protection and Features

- Electronic motor thermal protection against overload.
- Temperature monitoring of the heat sink ensures that the drive trips if there is overtemperature.
- The drive is protected against short circuits between motor terminals U, V, W.
- When a motor phase is missing, the drive trips and issues an alarm.
- When a mains phase is missing, the drive trips or issues a warning (depending on the load).
- Monitoring of the DC-link voltage ensures that the drive trips when the DC-link voltage is too low or too high.
- The drive is protected against ground faults on motor terminals U, V, W.

5.2.2 Mains Supply (L1, L2, L3)

Supply voltage	200–240 V ±10%
Supply voltage	380–480 V ±10%
Supply voltage	525–600 V ±10%
Supply frequency	50/60 Hz ±5%
Maximum imbalance temporary between mains 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 the input supply L1, L2, L3 (power-ups) enclosure sizes H1–H5, I2, I3, I4	Maximum 1 time/30 s
Switching on the input supply L1, L2, L3 (power-ups) enclosure sizes H6–H10, I6–I8	Maximum 1 time/minute

Environment according to EN 60664-1	Overvoltage category III/pollution degree 2

The unit is suitable for use on a circuit capable of delivering not more than 100000 A_{rms} symmetrical Amperes, 240/480 V maximum.

5.2.3 Motor Output (U, V, W)

Output voltage	0–100% of supply voltage
Output frequency	0–400 Hz
Switching on output	Unlimited
Ramp time	0.05–3600 s

5.2.4 Cable Length and Cross-section

Maximum motor cable length, shielded/armored (EMC-correct installation)	See 7.6.3 EMC Emission Test Results.
Maximum motor cable length, unshielded/unarmoured	50 m (164 ft)
Maximum cross-section to motor, mains	See *chapter Electrical Data* for more information
Cross-section DC terminals for filter feedback on enclosure sizes H1–H3, I2, I3, I4	4 mm^2/11 AWG
Cross-section DC terminals for filter feedback on enclosure sizes H4–H5	16 mm^2/6 AWG
Maximum cross-section to control terminals, rigid wire	2.5 mm^2/14 AWG
Maximum cross-section to control terminals, flexible cable	2.5 mm^2/14 AWG
Minimum cross-section to control terminals	0.05 mm^2/30 AWG

5.2.5 Digital Inputs

Programmable digital inputs	4
Terminal number	18, 19, 27, 29
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	Approximately 4 kΩ
Digital input 29 as thermistor input	Fault: >2.9 kΩ and no fault: <800 Ω
Digital input 29 as pulse input	Maximum frequency 32 kHz push-pull-driven & 5 kHz (O.C.)

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

5.2.6 Analog Inputs

Number of analog inputs	2

Terminal number	53, 54
Terminal 53 mode	Parameter ***16-61 Terminal 53 Setting***: 1 = voltage, 0 = current
Terminal 54 mode	Parameter ***16-63 Terminal 54 Setting***: 1 = voltage, 0 = current
Voltage level	0–10 V
Input resistance, R_i	Approximately 10 kΩ
Maximum voltage	20 V
Current level	0/4–20 mA (scaleable)
Input resistance, R_i	<500 Ω
Maximum current	29 mA
Resolution for analog inputs	10 bit

5.2.7 Analog Outputs

Number of programmable analog outputs	2
Terminal number	42, 45[1]
Current range at analog outputs	0/4–20 mA
Maximum load to common at analog output	500 Ω
Maximum voltage at analog output	17 V
Accuracy on analog outputs	Maximum error: 0.4% of full scale
Resolution on analog output	10 bit

1) Terminals 42 and 45 can also be programmed as digital outputs.

5.2.8 Digital Output

Number of digital outputs	2
Terminals 42 and 45	
Terminals number	42, 45[1]
Voltage level at digital output	17 V
Maximum output current at digital output	20 mA
Maximum load at digital output	1 kΩ

1) Terminals 42 and 45 can also be programmed as analog output.

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

5.2.9 Control Card, RS485 Serial Communication

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

5.2.10 Control Card, 24 V DC Output

Terminal number	12
Maximum load	80 mA

5.2.11 Relay Output

Programmable relay outputs	2
Relay 01 and 02 (enclosure size I2–I4)	01–03 (NC), 01–02 (NO), 04–06 (NC), 04–05 (NO)
Maximum terminal load (AC-1)(1) on 01–02/04–05 (NO) (resistive load)	250 V AC, 3 A
Maximum terminal load (AC-15)(1) on 01–02/04–05 (NO) (inductive load @ cosφ 0.4)	250 V AC, 0.2 A
Maximum terminal load (DC-1)(1) on 01–02/04–05 (NO) (resistive load)	30 V DC, 2 A
Maximum terminal load (DC-13)(1) on 01–02/04–05 (NO) (inductive load)	24 V DC, 0.1 A
Maximum terminal load (AC-1)(1) on 01–03/04–06 (NC) (resistive load)	250 V AC, 3 A
Maximum terminal load (AC-15)(1) on 01–03/04–06 (NC) (inductive load @ cosφ 0.4)	250 V AC, 0.2 A
Maximum terminal load (DC-1)(1) on 01–03/04–06 (NC) (resistive load)	30 V DC, 2 A
Minimum terminal load on 01–03 (NC), 01–02 (NO)	24 V DC 10 mA, 24 V AC 20 mA
Environment according to EN 60664-1	Overvoltage category III/pollution degree 2
Programmable relay outputs	
Relay 01 terminal number (enclosure size H9)	01–03 (NC), 01–02 (NO)
Maximum terminal load (AC-1)(1) on 01–03 (NC), 01–02 (NO) (resistive load)	240 V AC, 2 A
Maximum terminal load (AC-15)(1) (inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1)(1) on 01–02 (NO), 01–03 (NC) (resistive load)	60 V DC, 1 A
Maximum terminal load (DC-13)(1) (inductive load)	24 V DC, 0.1 A
Relay 01 and 02 terminal number (enclosure size H6, H7, H8, H9 (relay 2 only), H10, and I6–I8)	01–03 (NC), 01–02 (NO), 04–06 (NC), 04– 05 (NO)
Maximum terminal load (AC-1)(1) on 04–05 (NO) (resistive load)(2)(3)	400 V AC, 2 A
Maximum terminal load (AC-15)(1) on 04–05 (NO) (inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1)(1) on 04–05 (NO) (resistive load)	80 V DC, 2 A
Maximum terminal load (DC-13)(1) on 04–05 (NO) (inductive load)	24 V DC, 0.1 A
Maximum terminal load (AC-1)(1) on 04–06 (NC) (resistive load)	240 V AC, 2 A
Maximum terminal load (AC-15)(1) on 04–06 (NC) (inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1)(1) on 04–06 (NC) (resistive load) 50 V DC, 2 A	50 V DC, 2 A
Maximum terminal load (DC-13)(1) on 04–06 (NC) (inductive load)	24 V DC, 0.1 A
Minimum terminal load on 01–03 (NC), 01–02 (NO), 04–06 (NC), 04–05 (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. Endurance of the relay varies with different load type, switching current, ambient temperature, driving configuration, working profile, and so forth. It is recommended to mount a snubber circuit when connecting inductive loads to the relays.

2) Overvoltage Category II.

3) UL applications 300 V AC 2 A.

5.2.12 Control Card, 10 V DC Output

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

5.2.13 Ambient Conditions

Enclosure protection rating	IP20/Open type, IP54
Enclosure kit available	IP21, TYPE 1
Vibration test	1.0 g
Maximum relative humidity	5–95% (IEC 60721-3-3; Class 3K3 (non-condensing)) during operation
Aggressive environment (IEC 60721-3-3), coated (standard) enclosure sizes H1–H5	Class 3C3
Aggressive environment (IEC 60721-3-3), non-coated enclosure sizes H6–H10	Class 3C2
Aggressive environment (IEC 60721-3-3), coated (optional) enclosure sizes H6–H10	Class 3C3
Aggressive environment (IEC 60721-3-3), non-coated enclosure sizes I2–I8	Class 3C2
Test method according to IEC 60068-2-43 H2S (10 days)	
Ambient temperature	See maximum output current at 40/50 °C (104/122 °F) in *chapter Electrical Data*.
Minimum ambient temperature during full-scale operation	0 °C (32 °F)
Minimum ambient temperature at reduced performance, enclosure sizes H1–H5 and I2–I4	-20 °C (-4 °F)
Minimum ambient temperature at reduced performance, enclosure sizes H6–H10 and I6–I8	-10 °C (14 °F)
Temperature during storage/transport	-30 to +65/70 °C (-22 to +149/158°F)
Maximum altitude above sea level without derating	1000 m (3281 ft)
Maximum altitude above sea level with derating	3000 m (9843 ft)
Energy efficiency class (1)	IE2

1) Determined according to EN 50598-2 at:

- *Rated load.*
- *90% rated frequency.*
- *Switching frequency factory setting.*
- *Switching pattern factory setting.*

5.3 Shipping Dimensions

Table 18: Shipping Dimensions

Enclosure size	Power [kW (hp)]			Protection rating	Maximum weight [kg (lb)]	Height [mm (in)]	Width [mm (in)]	Depth [mm (in)]
	3x200–240 V	3x380–480 V	3x525–600 V					
H1	0.25–1.5 (0.33–2.0)	0.37–1.5 (0.5–2.0)	–	IP20/Open type	2.1 (4.6)	265 (10.4)	230 (9.1)	135 (5.3)
H2	2.2 (3.0)	2.2–4.0 (3.0–5.5)	–	IP20/Open type	3.4 (7.5)	300 (11.8)	265 (10.4)	155 (6.1)
H3	3.7 (5.0)	5.5–7.5 (7.5–10)	–	IP20/Open type	4.5 (9.9)	280 (11)	155 (6.1)	320 (12.6)
H4	5.5–7.5 (7.5–10)	11–15 (15–20)	–	IP20/Open type	7.9 (17.4)	380 (15)	200 (7.9)	315 (12.4)
H5	11 (15)	18.5–22 (25–30)	–	IP20/Open type	9.5 (20.9)	395 (15.6)	233 (9.2)	380 (15)
H6	15–18.5 (20–25)	30–45 (40–60)	18.5–30 (25–40)	IP20/Open type	24.5 (54)	850 (33.5)	370 (15.6)	460 (18.1)
H7	22–30 (30–40)	55–75 (75–100)	37–55 (50–75)	IP20/Open type	36 (79.4)	850 (33.5)	410 (16.1)	540 (21.3)
H8	37–45 (50–60)	90 (125)	75–90 (100–125)	IP20/Open type	51 (112.4)	850 (33.5)	490 (19.3)	490 (19.3)
H9	–	–	2.2–7.5 (3.0–10)	IP20/Open type	6.6 (14.6)	380 (15)	290 (11.4)	200 (7.9)
H10	–	–	11–15 (15–20)	IP20/Open type	11.5 (25.4)	500 (19.7)	330 (13)	350 (13.8)
I2	–	0.75–4.0 (1.0–5.0)	–	IP54	6.1 (13.4)	310 (12.2)	205 (8.1)	435 (17.1)
I3	–	5.5–7.5 (7.5–10)	–	IP54	7.8 (17.2)	325 (12.8)	230 (9.1)	480 (18.9)
I4	–	11–18.5 (15–25)	–	IP54	13.8 (30.4)	390 (15.4)	295 (11.6)	635 (25)
I6	–	22–37 (30–50)	–	IP54	28.3 (62.4)	850 (33.5)	370 (15.6)	460 (18.1)
I7	–	45–55 (60–70)	–	IP54	41.5 (91.5)	850 (33.5)	410 (16.1)	540 (21.3)
I8	–	75–90 (100–125)	–	IP54	60.5 (133.4)	950 (37.4)	490 (19.3)	490 (19.3)

6 Mechanical Installation Considerations

6.1 Maintenance Considerations

6.1.1 DrivePro® Preventive Maintenance

Generally, all technical equipment, including Danfoss AC drives, need a minimum level of preventive maintenance. To ensure trouble-free operation and long life of the drive, regular maintenance is recommended. Under specific conditions, the combination of stressful operation and environmental conditions work together to reduce the lifetime of the components significantly. These conditions can include, for example, extreme temperature, dust, high humidity, hours of use, corrosive environment, and loading.

For operation in stressful conditions, Danfoss offers the DrivePro® Preventive Maintenance service. DrivePro® services extend the lifetime and increase the performance of the product with scheduled maintenance including customized part replacements. DrivePro® services are tailored to the specific application and operating conditions. For more information, see DrivePro Services (danfoss.com)

To maintain optimal performance and longevity of a Danfoss drive, refer to the *Maintenance* chapter in the operating guide for a comprehensive maintenance/inspection schedule.

6.1.2 Service Access

When planning the installation, proper access for service and maintenance needs must be considered. In general, it is recommended to ensure:

- Access to power cabling and connectors.
- Access to control wiring.
- Access to clean the cooling channel and fan filters (if applicable).
- Access to the port to connect the drive to a PC.

6.2 Side-by-side Installation

The drive can be mounted side by side but requires the clearance above and below for cooling.

Table 19: Clearance Required for Cooling

Enclosure size	Protection rating	Power [kW (hp)]			Clearance above/below [mm (in)][1]
		3x200–240 V	3x380–480 V	3x525–600 V	
H1	IP20/Open type	0.25–1.5 (0.33–2.0)	0.37–1.5 (0.5–2.0)	–	100 (4)
H2	IP20/Open type	2.2 (3.0)	2.2–4.0 (3.0–5.0)	–	100 (4)
H3	IP20/Open type	3.7 (5.0)	5.5–7.5 (7.5–10)	–	100 (4)
H4	IP20/Open type	5.5–7.5 (7.5–10)	11–15 (15–20)	–	100 (4)
H5	IP20/Open type	11 (15)	18.5–22 (25–30)	–	100 (4)
H6	IP20/Open type	15–18.5 (20–25)	30–45 (40–60)	18.5–30 (25–40)	200 (7.9)
H7	IP20/Open type	22–30 (30–40)	55–75 (70–100)	37–55 (50–70)	200 (7.9)
H8	IP20/Open type	37–45 (50–60)	90 (125)	75–90 (100–125)	225 (8.9)
H9	IP20/Open type	–	–	2.2–7.5 (3.0–10)	100 (4)
H10	IP20/Open type	–	–	11–15 (15–20)	200 (7.9)
I2	IP54	–	0.75–4.0 (1.0–5.0)	–	100 (4)
I3	IP54	–	5.5–7.5 (7.5–10)	–	100 (4)
I4	IP54	–	11–18.5 (15–25)	–	100 (4)

Table 19: Clearance Required for Cooling - (continued)

Enclosure size	Protection rating	Power [kW (hp)]			Clearance above/below [mm (in)](1)
		3x200–240 V	3x380–480 V	3x525–600 V	
I6	IP54	–	22–37 (30–50)	–	200 (7.9)
I7	IP54	–	45–55 (60–70)	–	200 (7.9)
I8	IP54	–	75–90 (100–125)	–	225 (8.9)

1) See chapter Fuses and Circuit Breakers for detailed test cabinet size requirements for drives complying with UL61800-5-1.

NOTICE

With IP21/NEMA Type1 option kit mounted, a distance of 50 mm (2.0 in) between the units is required.

6.3 Ambient Running Conditions

6.3.1 Derating for Ambient Temperature and Switching Frequency

The drive has been designed to meet the IEC/EN 60068-2-3 standard, EN 50178 9.4.2.2 at 50 °C (122 °F).

The ambient temperature measured over 24 hours should be at least 5 °C (9 °F) lower than the maximum ambient temperature. If the drive is operated at high ambient temperature, decrease the continuous output current.

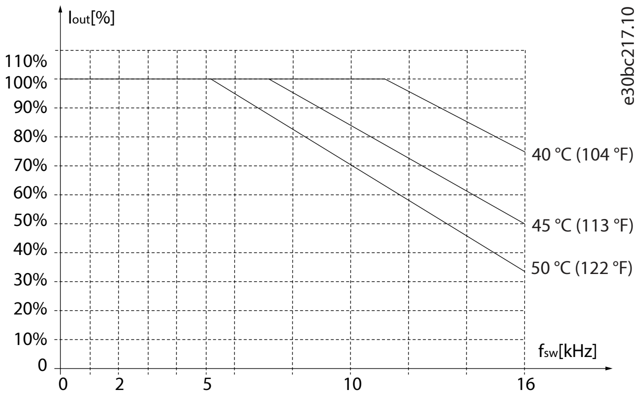

Figure 18: 0.25–0.75 kW (0.34–1.0 hp), 200 V, Enclosure Size H1, IP20/Open type

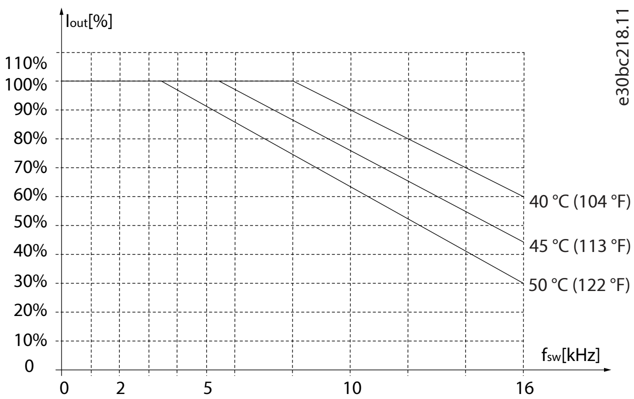

Figure 19: 0.37–1.5 kW (0.5–2.0 hp), 400 V, Enclosure Size H1, IP20/Open type

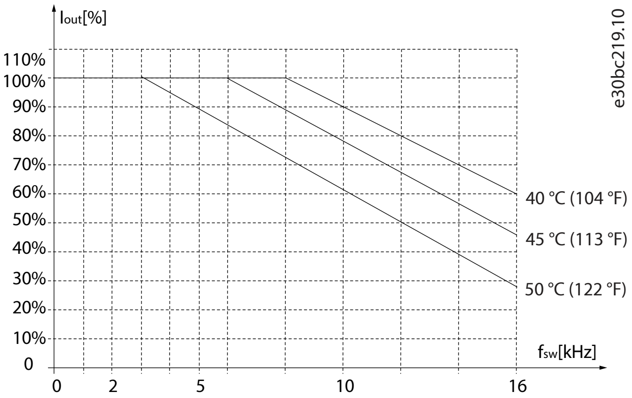

Figure 20: 2.2 kW (3.0 hp), 200 V, Enclosure Size H2, IP20/Open type

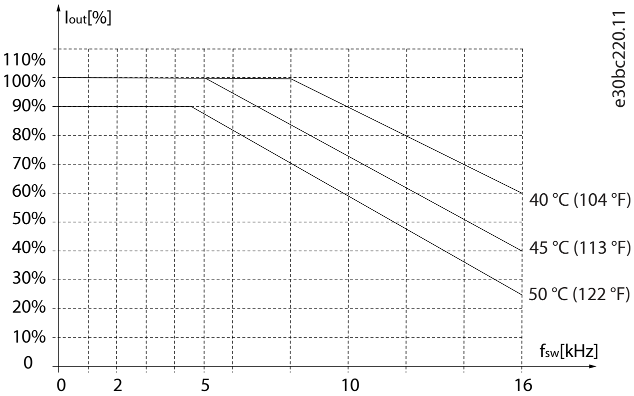

Figure 21: 2.2–4.0 kW (3.0–5.5 hp), 400 V, Enclosure Size H2, IP20/Open type

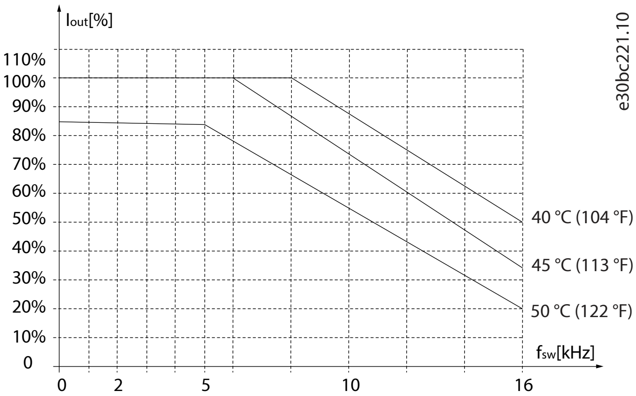

Figure 22: 3.7 kW (5.0 hp), 200 V, Enclosure Size H3, IP20/Open type

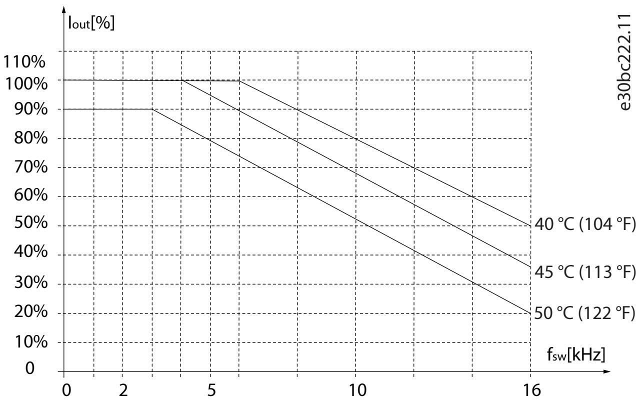

Figure 23: 5.5–7.5 kW (7.5–10 hp), 400 V, Enclosure Size H3, IP20/Open type

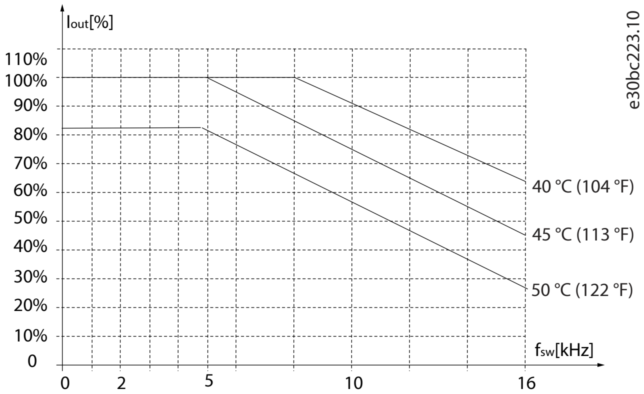

Figure 24: 5.5–7.5 kW (7.5–10 hp), 200 V, Enclosure Size H4, IP20/Open type

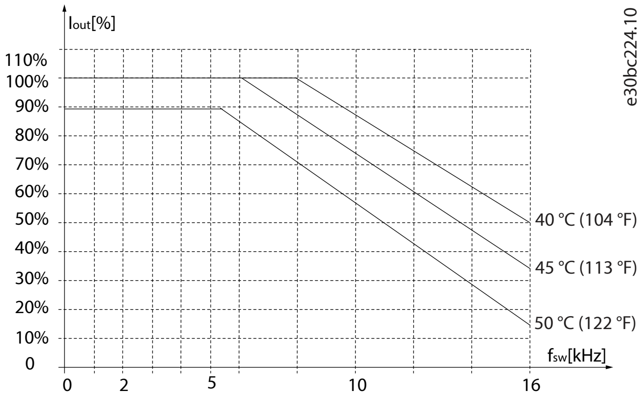

Figure 25: 11–15 kW (15–20 hp), 400 V, Enclosure Size H4, IP20/Open type

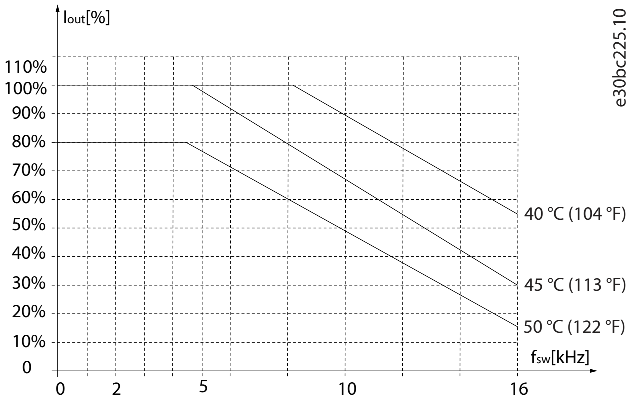

Figure 26: 11 kW (15 hp), 200 V, Enclosure Size H5, IP20/Open type

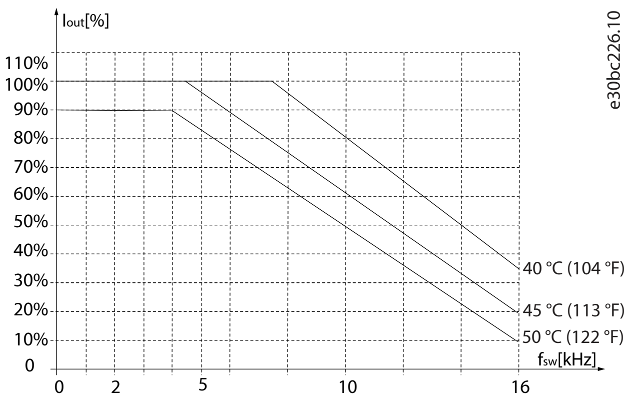

Figure 27: 18.5–22 kW (25–30 hp), 400 V, Enclosure Size H5, IP20/Open type

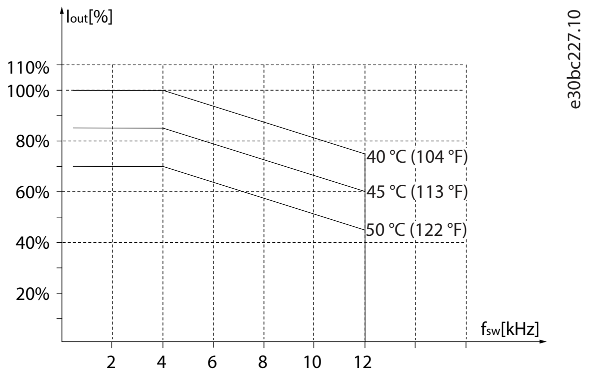

Figure 28: 15–18.5 kW (20–25 hp), 200 V, Enclosure Size H6, IP20/Open type

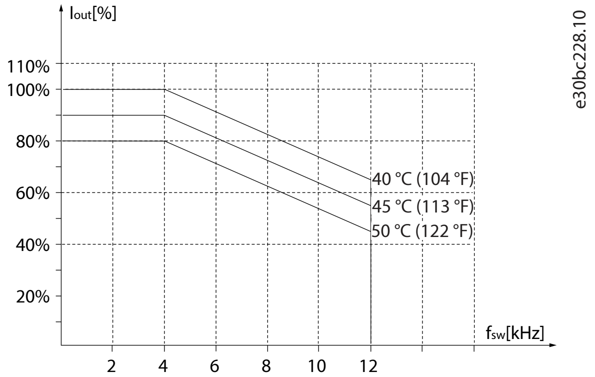

Figure 29: 30–37 kW (40–50 hp), 400 V, Enclosure Size H6, IP20/Open type

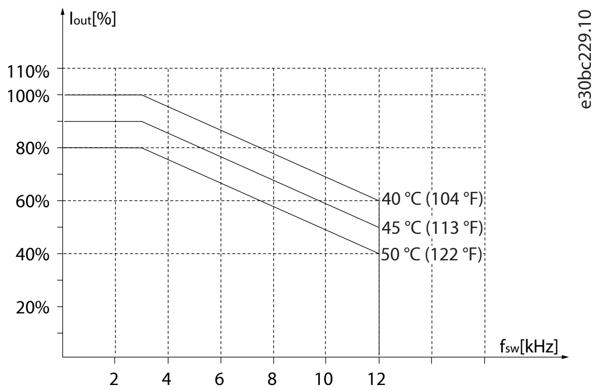

Figure 30: 45 kW (60 hp), 400 V, Enclosure Size H6, IP20/Open type

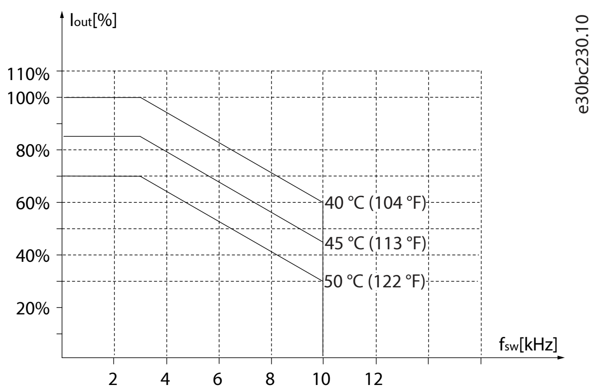

Figure 31: 22–30 kW (30–40 hp), 600 V, Enclosure Size H6, IP20/Open type

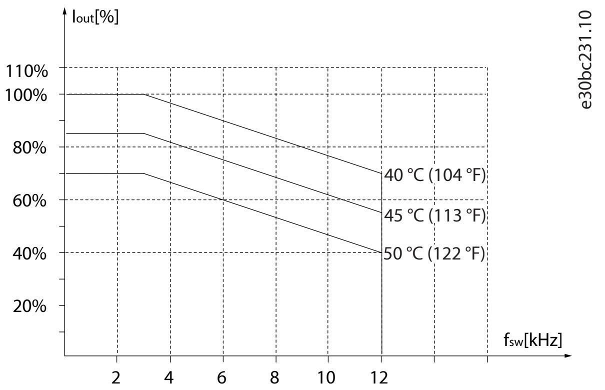

Figure 32: 22–30 kW (30–40 hp), 200 V, Enclosure Size H7, IP20/Open type

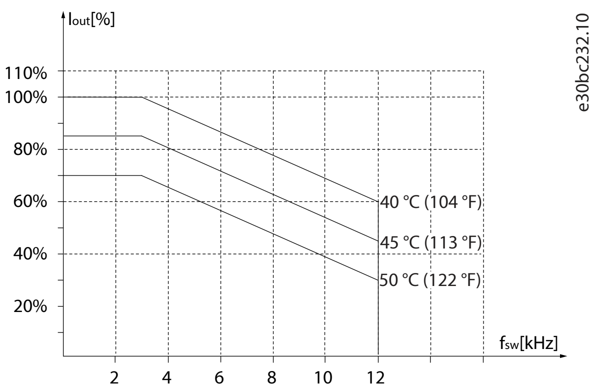

Figure 33: 55–75 kW (74–100 hp), 400 V, Enclosure Size H7, IP20/Open type

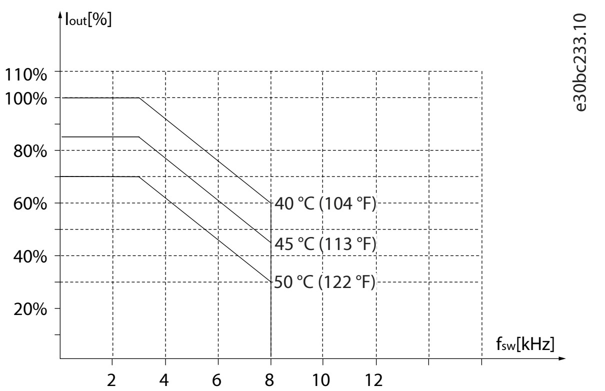

Figure 34: 45–55 kW (60–74 hp), 600 V, Enclosure Size H7, IP20/Open type

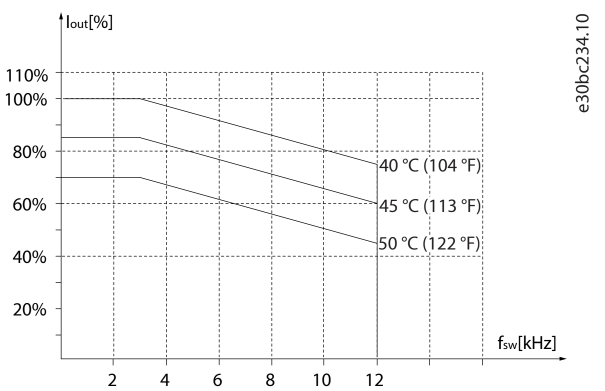

Figure 35: 37–45 kW (50–60 hp), 200 V, Enclosure Size H8, IP20/Open type

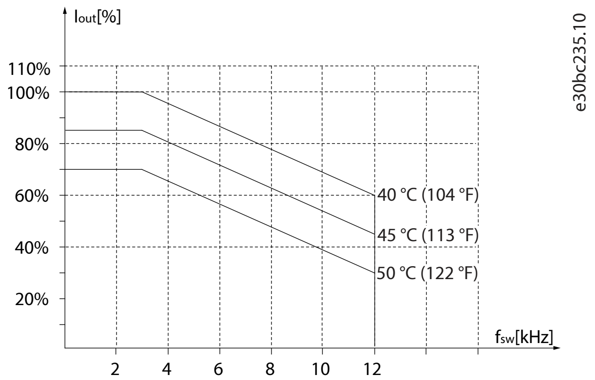

Figure 36: 90 kW (120 hp), 400 V, Enclosure Size H8, IP20/Open type

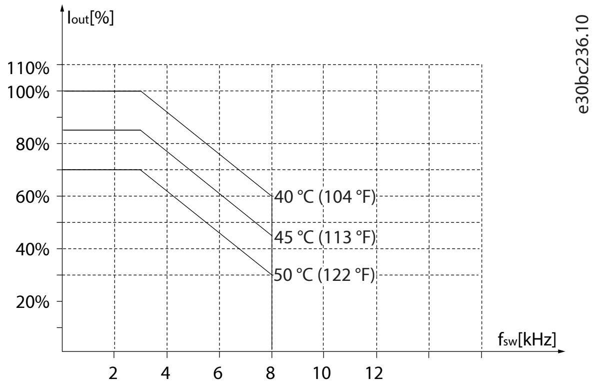

Figure 37: 75–90 kW (100–120 hp), 600 V, Enclosure Size H8, IP20/Open type

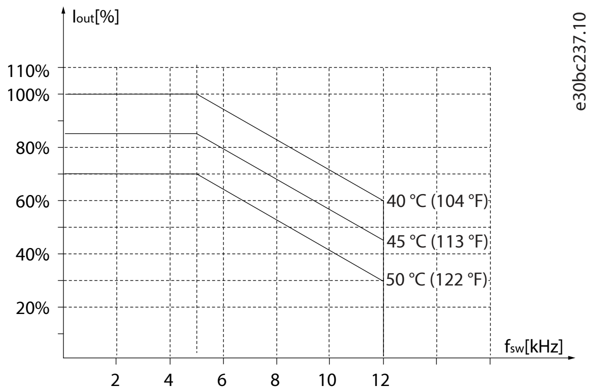

Figure 38: 2.2–3.0 kW (3.0–4.0 hp), 600 V, Enclosure Size H9, IP20/Open type

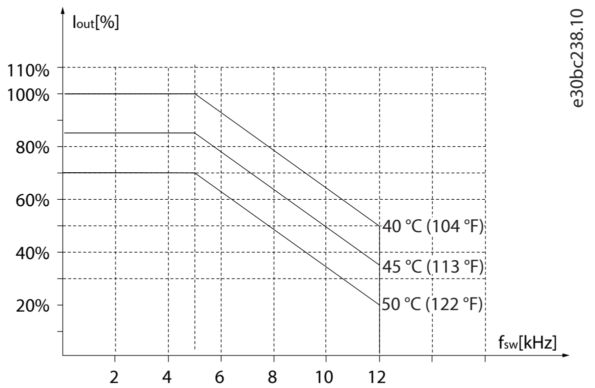

Figure 39: 5.5–7.5 kW (7.5–10 hp), 600 V, Enclosure Size H9, IP20/Open type

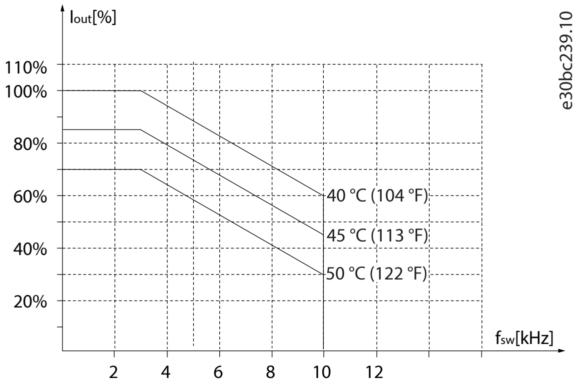

Figure 40: 11–15 kW (15–20 hp), 600 V, Enclosure Size H10, IP20/Open type

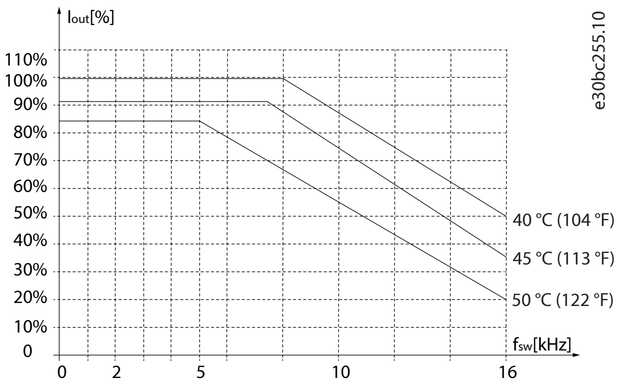

Figure 41: 0.75–4.0 kW (1.0–5.5 hp), 400 V, Enclosure Size I2, IP54

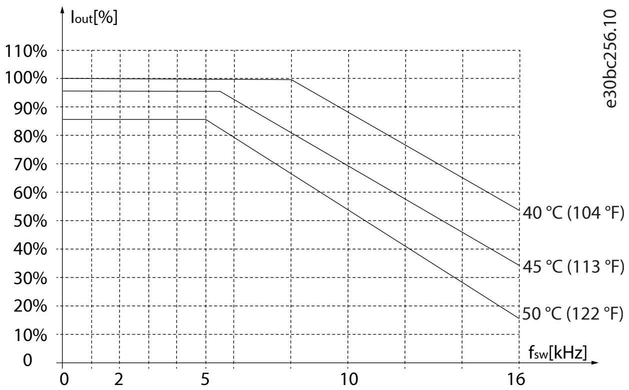

Figure 42: 5.5–7.5 kW (7.5–10 hp), 400 V, Enclosure Size I3, IP54

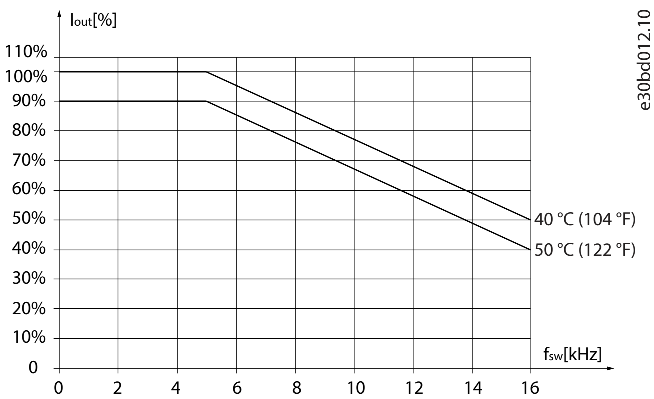

Figure 43: 11–18.5 kW (15–25 hp), 400 V, Enclosure Size I4, IP54

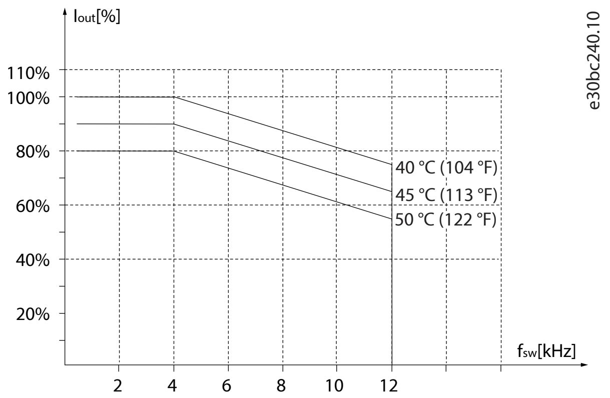

Figure 44: 22–30 kW (30–40 hp), 400 V, Enclosure Size I6, IP54

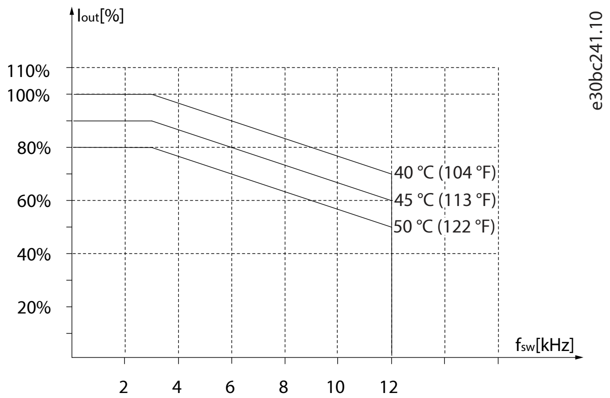

Figure 45: 37 kW (50 hp), 400 V, Enclosure Size I6, IP54

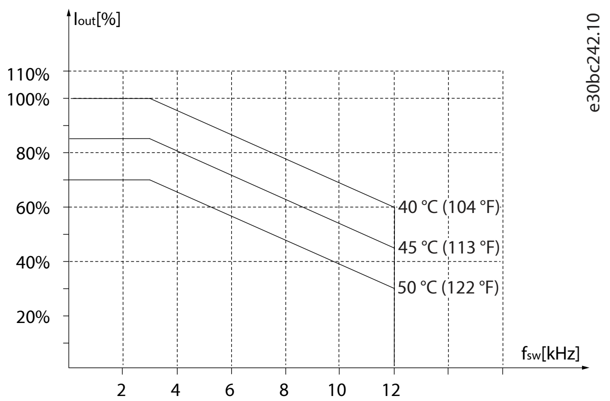

Figure 46: 45–55 kW (60–75 hp), 400 V, Enclosure Size I7, IP54

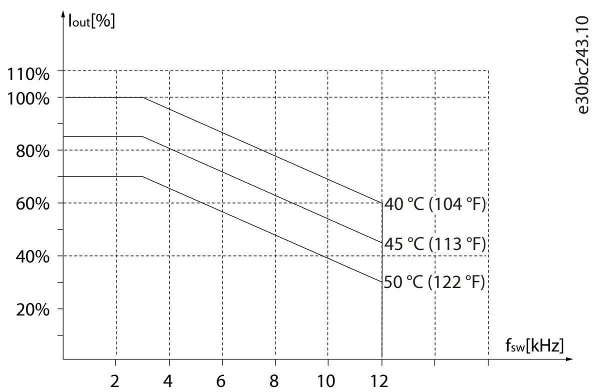

Figure 47: 75–90 kW (100–120 hp), 400 V, Enclosure Size I8, IP54

6.3.2 Aggressive Environments

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

⚠ CAUTION

INSTALLATION ENVIRONMENTS

Failure to take necessary protective measures increases the risk of stoppages, potentially causing equipment damage and personnel injury.

- Do not install the drive in environments with airborne liquids, particles, or gases that may affect or damage the electronic components.

Liquids can be carried through the air and condense in the drive and may cause corrosion of components and metal parts. Steam, oil, and salt water may cause corrosion of components and metal parts. In such environments, use equipment with enclosure rating IP54. As an extra protection, coated printed circuit boards can be ordered as an option (standard on some power sizes).

Airborne particles such as dust may cause mechanical, electrical, or thermal failure in the drive. A typical indicator of excessive levels of airborne particles is dust particles around the drive fan. In dusty environments, use equipment with enclosure rating IP54 or a cabinet for IP20/TYPE 1 equipment.

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

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

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

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

6.4 Field Mounting

If the environment, air quality, or surroundings require extra protection of the drive, an IP21/NEMA Type 1 kit can be ordered additionally and mounted on the drive, or the drive can be ordered and delivered in an IP54 version.

NOTICE

The IP20, IP21, and IP54 versions are not suitable for outdoor mounting.

7 Electrical Installation Considerations

7.1 Electrical Wiring

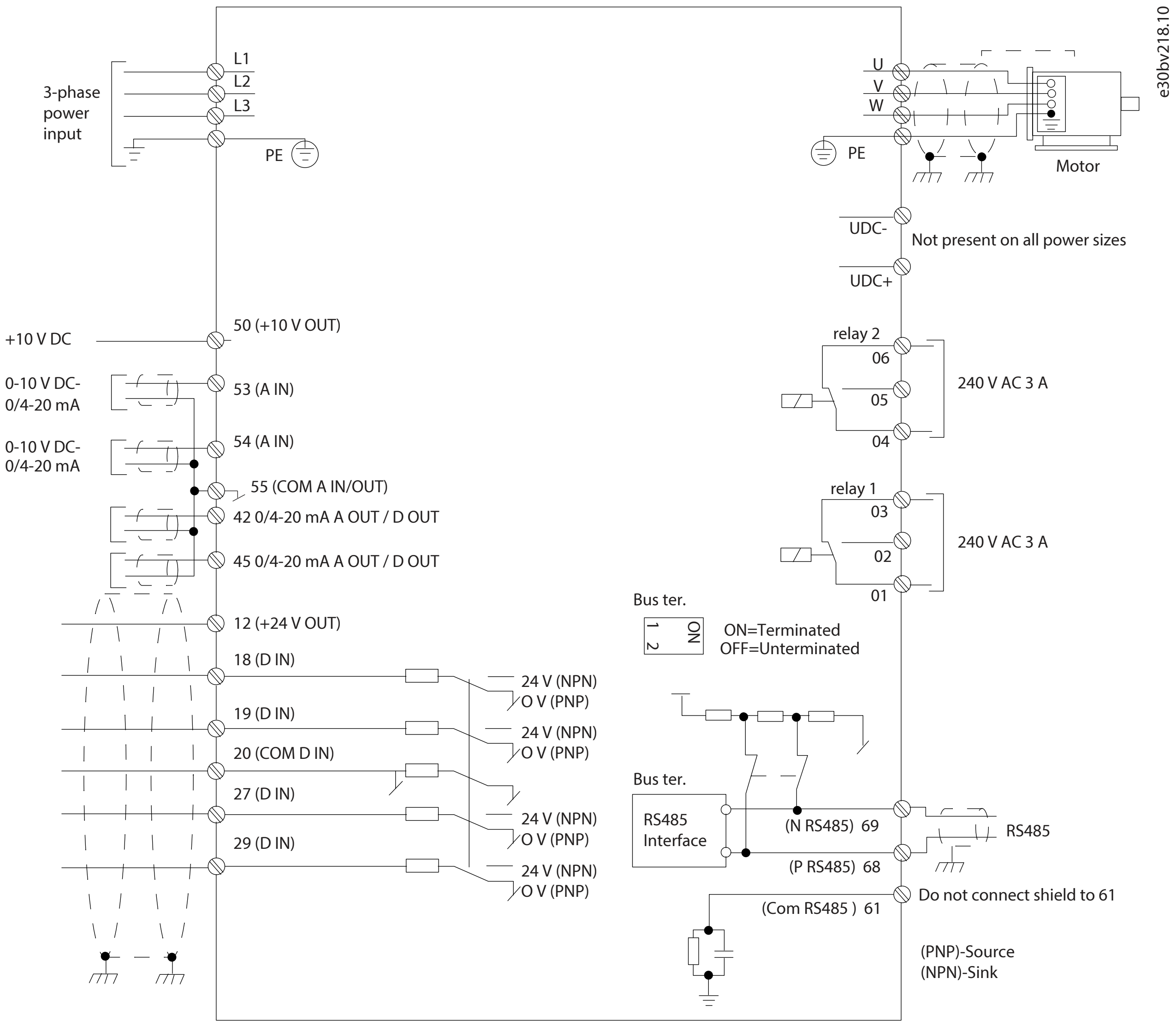

Figure 48: Basic Wiring Diagram

NOTE: There is no access to UDC- and UDC+ on the following units:

- IP20/Open type, 380–480 V, 30–90 kW (40–125 hp)
- IP20/Open type, 200–240 V, 15–45 kW (20–60 hp)
- IP20/Open type, 525–600 V, 2.2–90 kW (3.0–125 hp)
- IP54, 380–480 V, 22–90 kW (30–125 hp)

NOTE: For drives of UL61800-5-1 types, terminals +DC and -DC are protected by a factory-installed load share terminal insert which must NOT be removed from drives of enclosure size H1–H5.

7.2 Electrical Installation in General

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

Table 20: Tightening Torques for Enclosure Sizes H1–H8, 3x200–240 V and 3x380–480 V

Power [kW (hp)]				Torque [Nm (in-lb)]					
Enclosure size	Protection rating	3x200–240 V	3x380–480 V	Mains	Motor	DC connection	Control terminals	Ground	Relay
H1	IP20/Open type	0.25–1.5 (0.33–2.0)	0.37–1.5 (0.5–2.0)	0.8 (7)	0.8 (7)	0.8 (7)	0.5 (4)	0.8 (7)	0.5 (4)
H2	IP20/Open type	2.2 (3.0)	2.2–4.0 (3.0–5.0)	0.8 (7)	0.8 (7)	0.8 (7)	0.5 (4)	0.8 (7)	0.5 (4)
H3	IP20/Open type	3.7 (5.0)	5.5–7.5 (7.5–10)	0.8 (7)	0.8 (7)	0.8 (7)	0.5 (4)	0.8 (7)	0.5 (4)
H4	IP20/Open type	5.5–7.5 (7.5–10)	11–15 (15–20)	1.2 (11)	1.2 (11)	1.2 (11)	0.5 (4)	0.8 (7)	0.5 (4)
H5	IP20/Open type	11 (15)	18.5–22 (25–30)	1.2 (11)	1.2 (11)	1.2 (11)	0.5 (4)	0.8 (7)	0.5 (4)
H6	IP20/Open type	15–18.5 (20–25)	30–45 (40–60)	4.5 (40)	4.5 (40)	–	0.5 (4)	3 (27)	0.5 (4)
H7	IP20/Open type	22–30 (30–40)	55 (70)	10 (89)	10 (89)	–	0.5 (4)	3 (27)	0.5 (4)
H7	IP20/Open type	–	75 (100)	14 (124)	14 (124)	–	0.5 (4)	3 (27)	0.5 (4)
H8	IP20/Open type	37–45 (50–60)	90 (125)	24 (212)(1)	24 (212)(1)	–	0.5 (4)	3 (27)	0.5 (4)

1) Cable dimensions >95 mm^2.

Table 21: Tightening Torques for Enclosure Sizes I2–I8

Power [kW (hp)]			Torque [Nm (in-lb)]					
Enclosure size	Protection rating	3x380–480 V	Mains	Motor	DC connection	Control terminals	Ground	Relay
I2	IP54	0.75–4.0 (1.0–5.0)	0.8 (7)	0.8 (7)	0.8 (7)	0.5 (4)	0.8 (7)	0.5 (4)
I3	IP54	5.5–7.5 (7.5–10)	0.8 (7)	0.8 (7)	0.8 (7)	0.5 (4)	0.8 (7)	0.5 (4)
I4	IP54	11–18.5 (15–25)	1.2 (11)	1.2 (11)	0.8 (7)	0.5 (4)	0.8 (7)	0.5 (4)
I6	IP54	22–37 (30–50)	4.5 (40)	4.5 (40)	–	0.5 (4)	3 (27)	0.6 (5)
I7	IP54	45–55 (60–70)	10 (89)	10 (89)	–	0.5 (4)	3 (27)	0.6 (5)
I8	IP54	75–90 (100–125)	14 (124)/24 (212)(1)	14 (124)/24 (212)(1)	–	0.5 (4)	3 (27)	0.6 (5)

1) Cable dimensions ≤95 mm^2.

Table 22: Tightening Torques for Enclosure Sizes H6–H10, 3x525–600 V

Power [kW (hp)]			Torque [Nm (in-lb)]					
Enclosure size	Protection rating	3x525–600 V	Mains	Motor	DC connection	Control terminals	Ground	Relay
H9	IP20/Open type	2.2–7.5 (3.0–10)	1.8 (16)	1.8 (16)	Not recom-mended	0.5 (4)	3 (27)	0.6 (5)
H10	IP20/Open type	11–15 (15–20)	1.8 (16)	1.8 (16)	Not recom-mended	0.5 (4)	3 (27)	0.6 (5)
H6	IP20/Open type	18.5–30 (25–40)	4.5 (40)	4.5 (40)	–	0.5 (4)	3 (27)	0.5 (4)
H7	IP20/Open type	37–55 (50–70)	10 (89)	10 (89)	–	0.5 (4)	3 (27)	0.5 (4)
H8	IP20/Open type	75–90 (100–125)	14 (124)/24 (212)(1)	14 (124)/24 (212)(1)	–	0.5 (4)	3 (27)	0.5 (4)

1) Cable dimensions ≤95 mm^2.

7.3 IT Mains

⚠ CAUTION

IT MAINS

Installation on isolated mains source, that is, IT mains.

- Ensure that the supply voltage does not exceed 440 V (3x380–480 V units) when connected to mains.

On IP20/Open type, 200–240 V, 0.25–11 kW (0.33–15 hp) and 380–480 V, IP20/Open type, 0.37–22 kW (0.5–30 hp) units, open the RFI switch by removing the screw on the side of the drive when at IT grid.

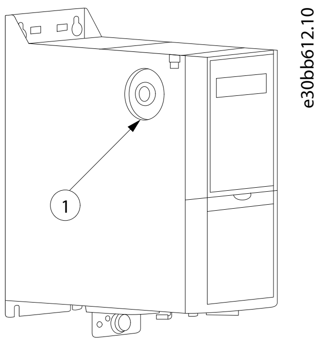

Figure 49: IP20/Open type, 200–240 V, 0.25–11 kW (0.33–15 hp), IP20/Open type, 0.37–22 kW (0.5–30 hp), 380–480 V

1	EMC screw

On 400 V, 30–90 kW (40–125 hp) and 600 V units, set parameter ***14-50 RFI Filter*** to ***[0] Off*** when operating in IT mains.

For IP54, 400 V, 0.75–18.5 kW (1.0–25 hp) units, the EMC screw is inside the drive, as shown in Figure 50.

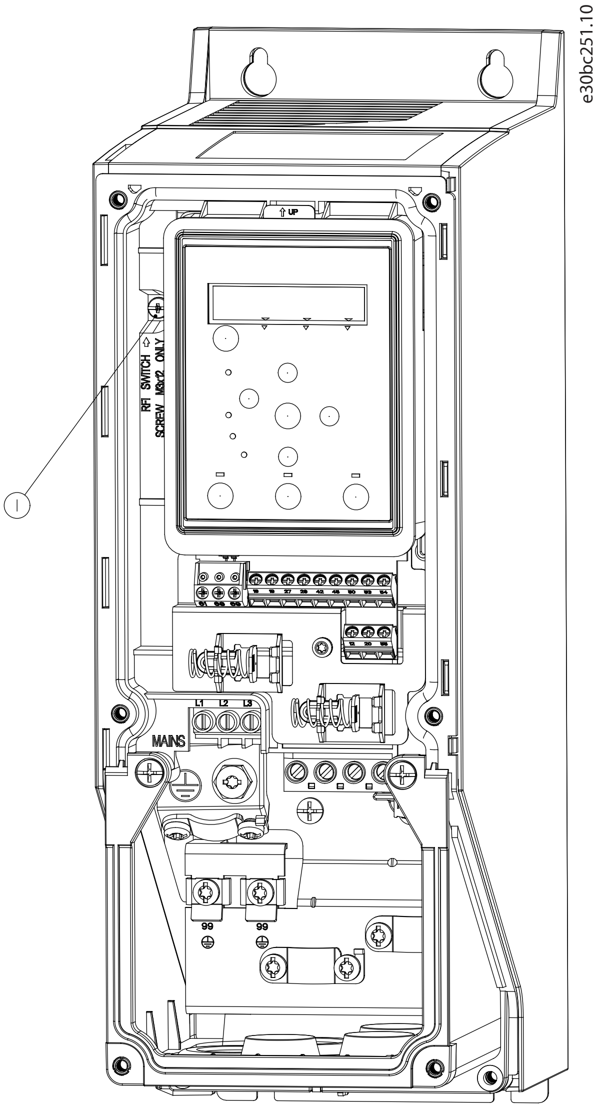

Figure 50: IP54, 400 V, 0.75–18.5 kW (1.0–25 hp)

1	EMC screw

NOTICE

If reinserted, use only M3x12 screw.

7.4 Mains and Motor Connection

7.4.1 Introduction

The drive is designed to operate all standard 3-phase induction motors.

- Use a shielded/armored motor cable to comply with EMC emission specifications and connect this cable to both the decoupling plate and the motor.
- Keep the motor cable as short as possible to reduce the noise level and leakage currents.
- For further details on mounting the decoupling plate, see the relevant *Decoupling Plate Installation Guide*.
- Also see EMC-correct Installation in *chapter EMC-correct Electrical Installation*.

7.4.2 Connecting to Mains and Motor

1. Mount the ground cables to the ground terminal.
2. Connect the motor to terminals U, V, and W, and then tighten the screws according to the torques.
3. Connect the mains supply to terminals L1, L2, and L3, and then tighten the screws according to the torques described in 7.2 Electrical Installation in General.

7.4.3 Relays and Terminals on Enclosure Sizes H1–H5

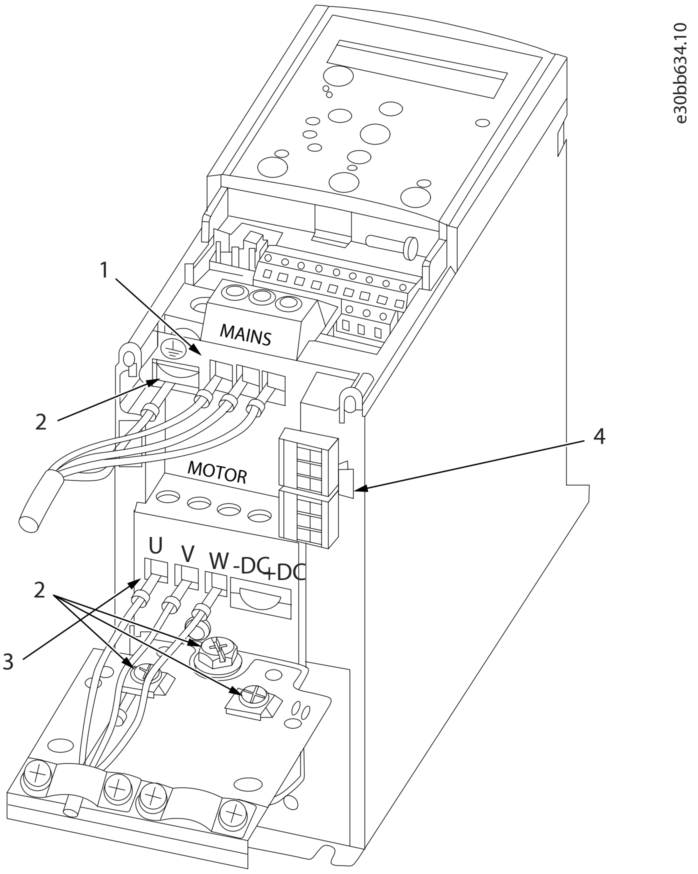

Figure 51: Enclosure Sizes H1–H5, IP20/Open type, 200–240 V, 0.25–11 kW (0.33–15 hp), IP20/Open type, 380–480 V, 0.37–22 kW (0.5–30 hp)

1	Mains	2	Ground
3	Motor	4	Relays

7.4.4 Relays and Terminals on Enclosure Size H6

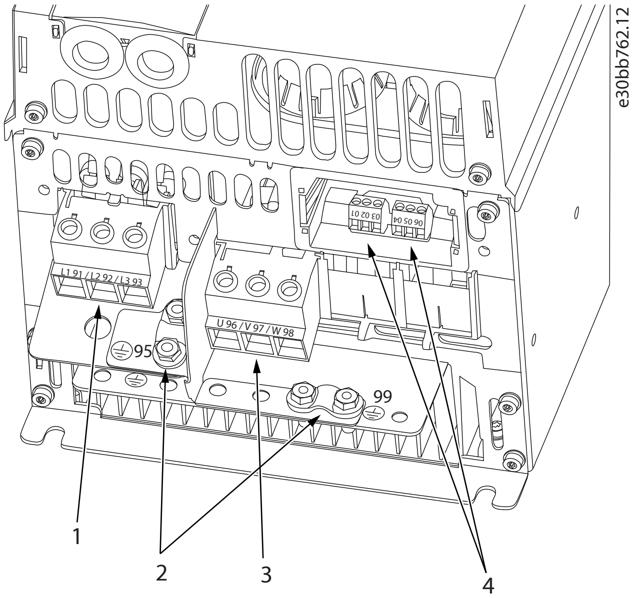

Figure 52: Enclosure Size H6 , IP20/Open type, 380–480 V, 30–45 kW (40–60 hp) , IP20/Open type, 200–240 V, 15–18.5 kW (20–25 hp) , IP20/Open type, 525–600 V, 18.5–30 kW (25–40 hp)

1	Mains	**2**	Ground
3	Motor	**4**	Relays

7.4.5 Relays and Terminals on Enclosure Size H7

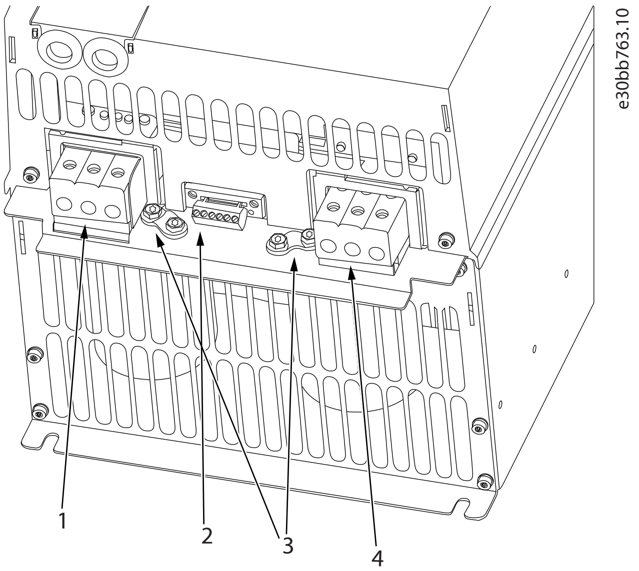

Figure 53: Enclosure Size H7 , IP20/Open type, 380–480 V, 55–75 kW (70–100 hp) , IP20/Open type, 200–240 V, 22–30 kW (30–40 hp) , IP20/Open type, 525–600 V, 37–55 kW (50–70 hp)

1	Mains	**2**	Relays
3	Ground	**4**	Motor

7.4.6 Relays and Terminals on Enclosure Size H8

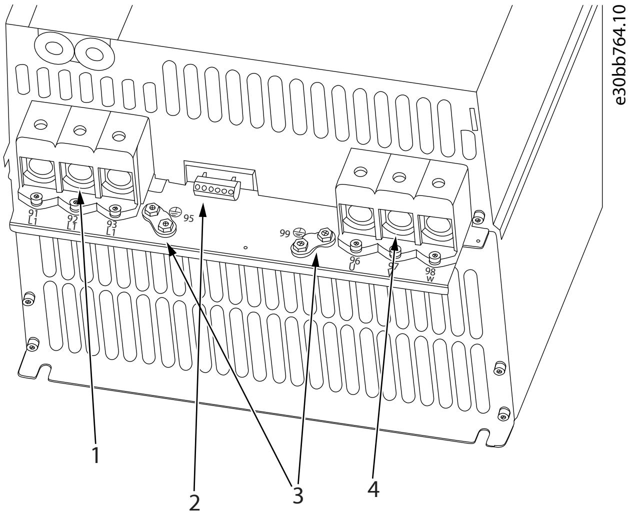

Figure 54: Enclosure Size H8 , IP20/Open type, 380–480 V, 90 kW (125 hp) , IP20/Open type, 200–240 V, 37–45 kW (50–60 hp) , IP20/Open type, 525–600 V, 75–90 kW (100–125 hp)

1	Mains	**2**	Relays
3	Ground	**4**	Motor

7.4.7 Connecting to Mains and Motor for Enclosure Size H9

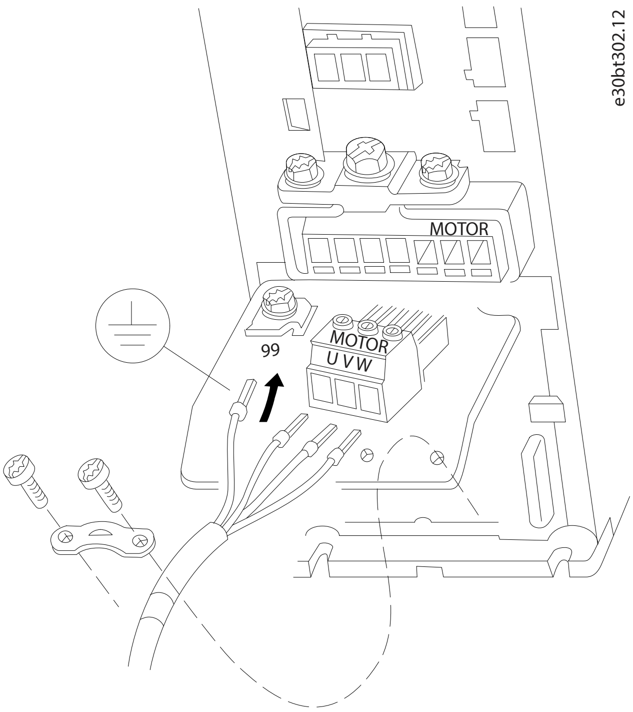

Figure 55: Connecting the Drive to the Motor, Enclosure Size H9 IP20/Open type, 525–600 V, 2.2–7.5 kW (3.0–10 hp)

1. Slide the mounting plate into place and tighten the 2 screws as shown in Figure 56.

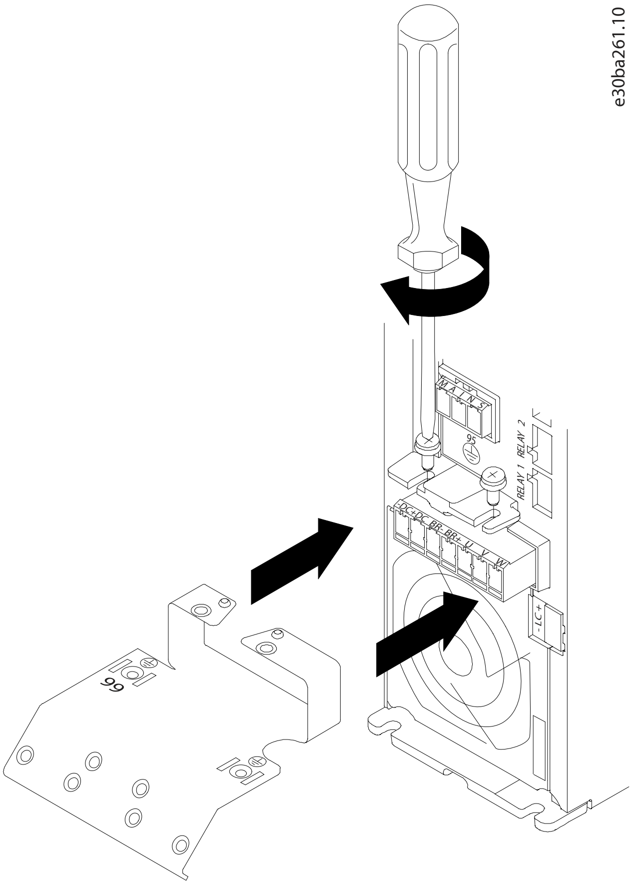

Figure 56: Mounting the Mounting Plate

2. Mount the ground cable as shown in Figure 57.

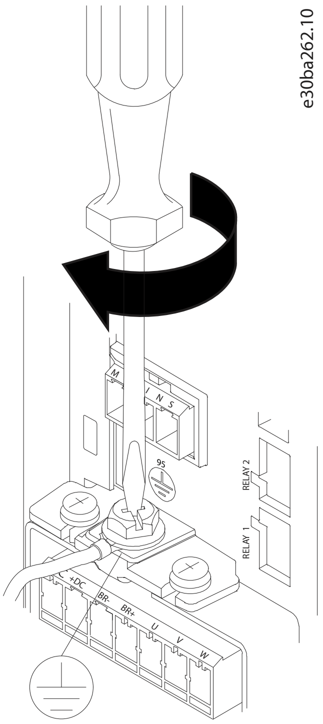

Figure 57: Mounting the Ground Cable

3. Insert the mains cables to the mains plug and tighten the screws as shown in Figure 58. Use the tightening torques described in 7.2 Electrical Installation in General.

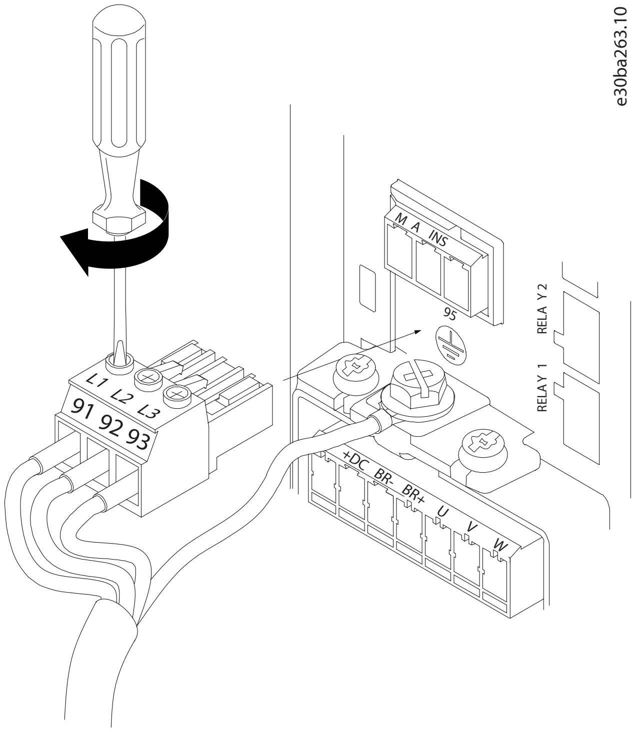

Figure 58: Mounting the Mains Plug

4. Mount the support bracket across the mains cables and tighten the screws as shown in Figure 59. Use the tightening torques described in 7.2 Electrical Installation in General.

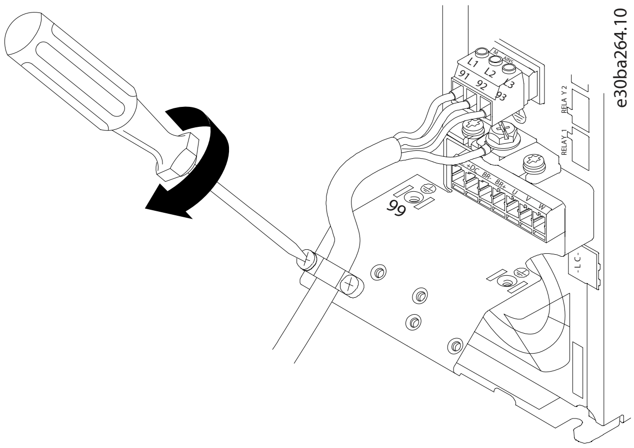

Figure 59: Mounting the Support Bracket

7.4.8 Relays and Terminals on Enclosure Size H10

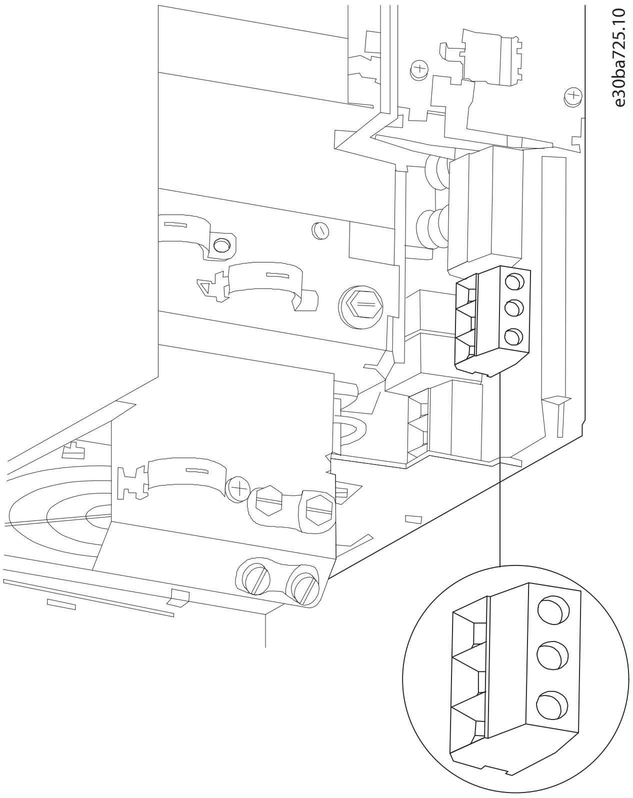

Figure 60: Enclosure Size H10 , IP20/Open type, 525–600 V, 11–15 kW (15–20 hp)

7.4.9 Enclosure Size I2

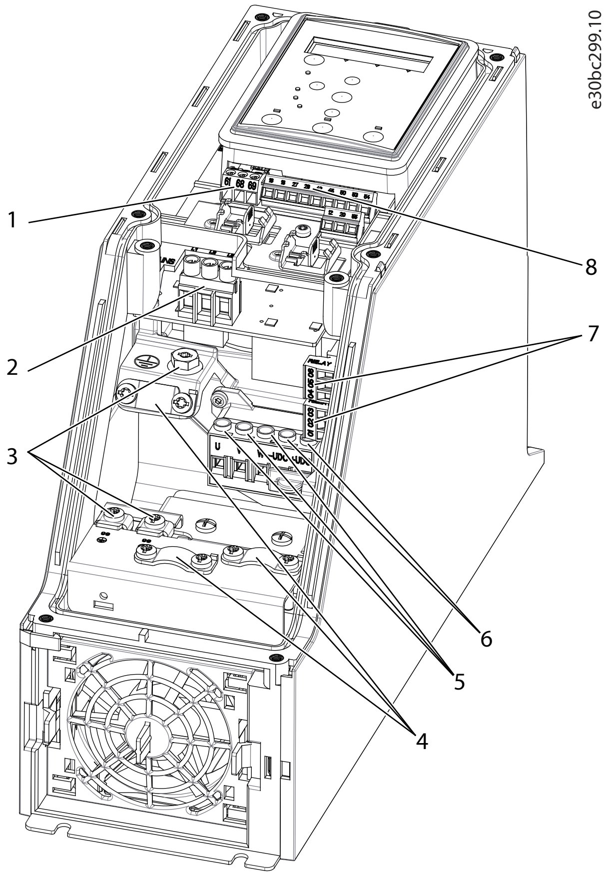

Figure 61: Enclosure Size I2, IP54, 380–480 V, 0.75–4.0 kW (1–5 hp)

1	RS485	**2**	Mains
3	Ground	**4**	Cable clamps
5	Motor	**6**	UDC
7	Relays	**8**	I/O

7.4.10 Enclosure Size I3

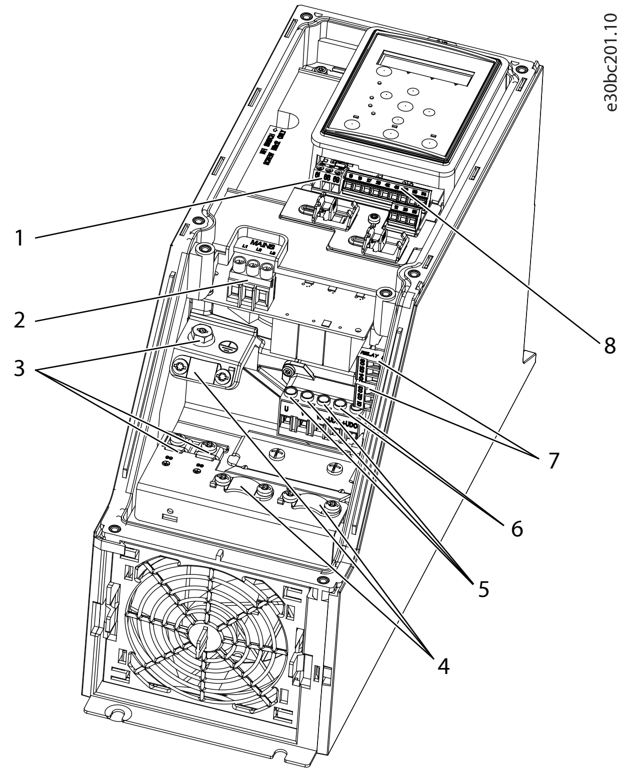

Figure 62: Enclosure Size I3, IP54, 380–480 V, 5.5–7.5 kW (7.5–10 hp)

1	RS485	**2**	Mains
3	Ground	**4**	Cable clamps
5	Motor	**6**	UDC
7	Relays	**8**	I/O

7.4.11 Enclosure Size I4

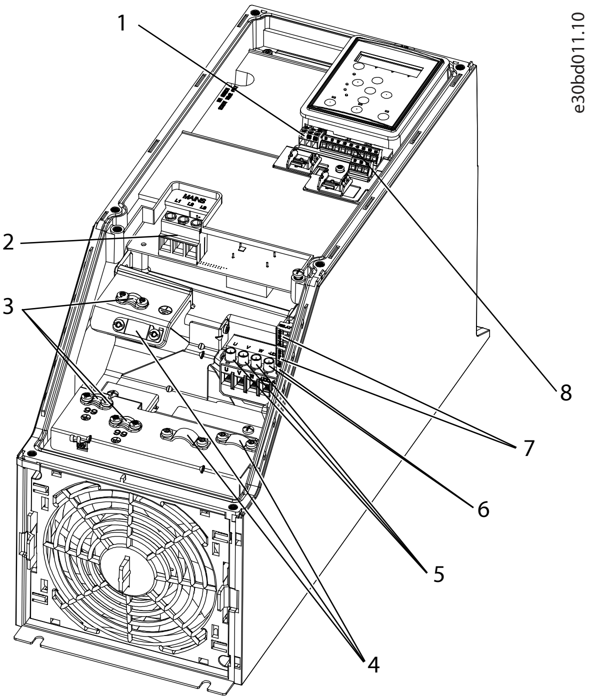

Figure 63: Enclosure Size I4, IP54, 380–480 V, 11–18.5 kW (15–25 hp)

1	RS485	**2**	Mains
3	Ground	**4**	Cable clamps
5	Motor	**6**	UDC
7	Relays	**8**	I/O

7.4.12 IP54 Enclosure Sizes I2, I3, I4

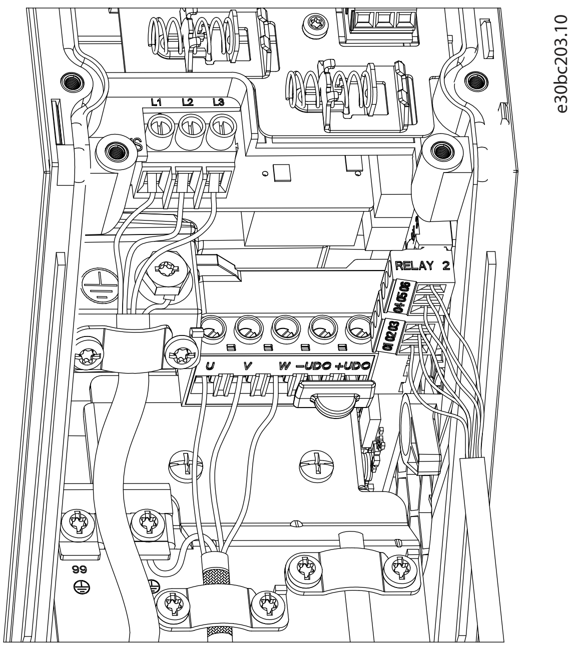

Figure 64: IP54 Enclosure Sizes I2, I3, I4

7.4.13 Enclosure size I6

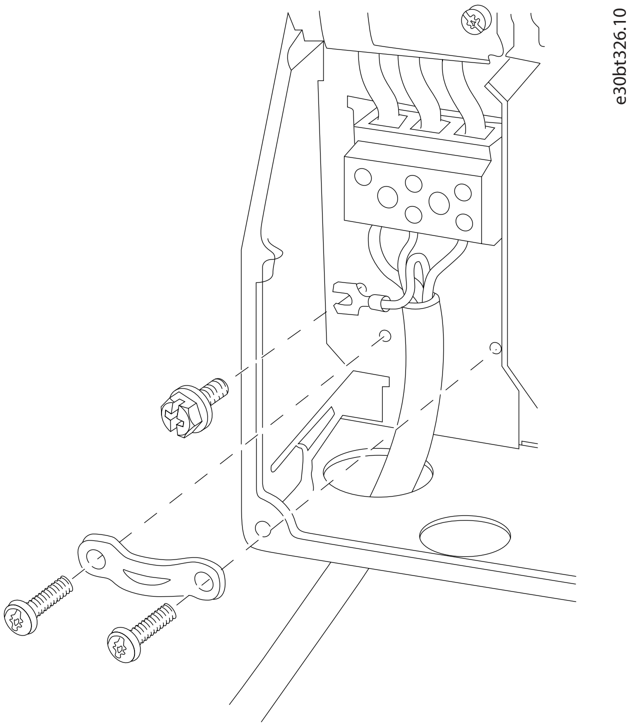

Figure 65: Connecting to Mains for Enclosure Size I6, IP54, 380–480 V, 22–37 kW (30–50 hp)

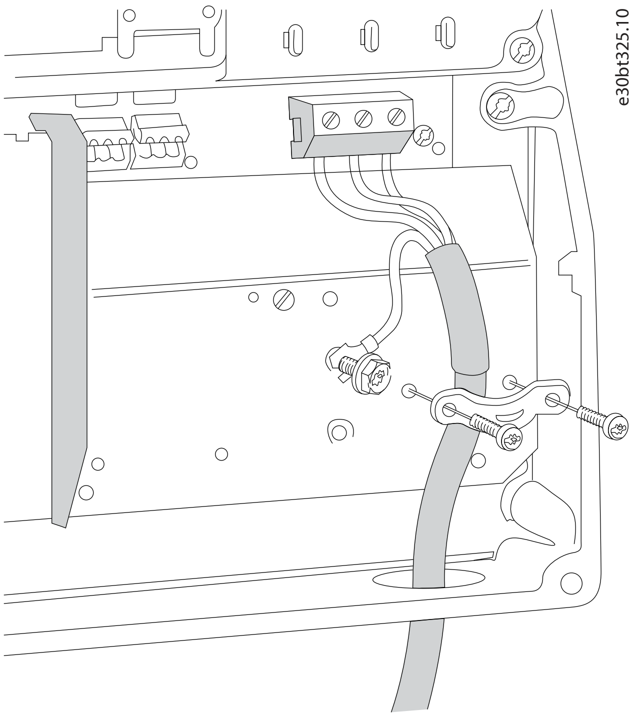

Figure 66: Connecting to Motor for Enclosure Size I6, IP54, 380–480 V, 22–37 kW (30–50 hp)

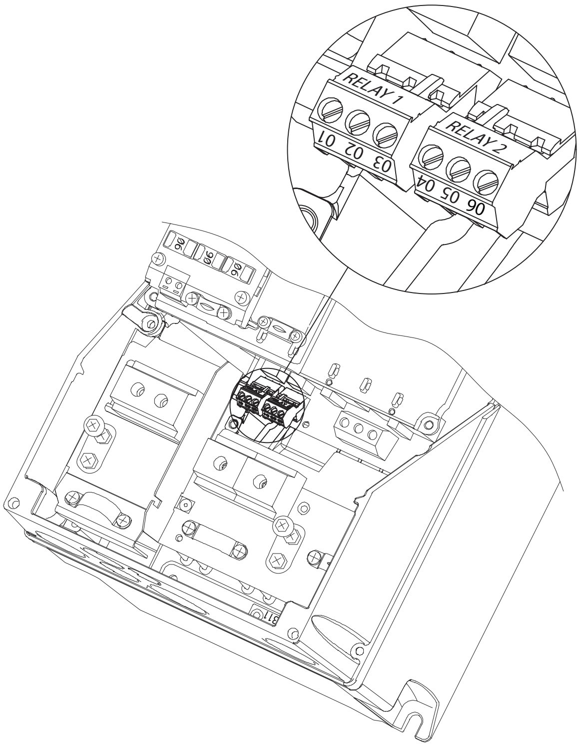

Figure 67: Relays on Enclosure Size I6, IP54, 380–480 V, 22–37 kW (30–50 hp)

7.4.14 Enclosure size I7, I8

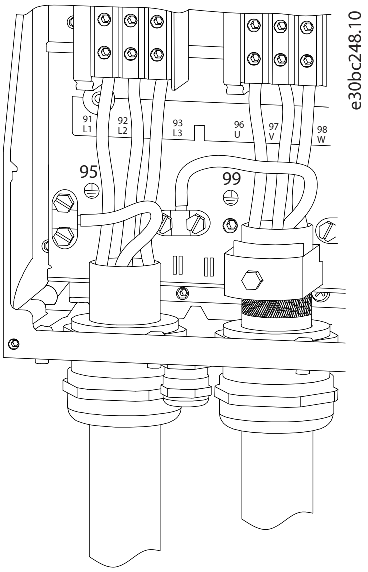

Figure 68: Enclosure Sizes I7, I8, IP54, 380–480 V, 45–55 kW (60–70 hp), IP54, 380–480 V, 75–90 kW (100–125 hp)

7.5 Fuses and Circuit Breakers

7.5.1 Branch Circuit Protection

To prevent fire hazards, protect the branch circuits in an installation - switch gear, machines, and so on - against short circuits and overcurrent. Follow national and local regulations.

7.5.2 Short-circuit Protection

Danfoss recommends using the fuses and circuit breakers listed in this chapter to protect service personnel or other equipment in case of an internal failure in the unit or a short circuit on the DC link. The drive provides full short-circuit protection in case of a short circuit on the motor.

7.5.3 Overcurrent Protection

Provide overload protection to avoid overheating of the cables in the installation. Overcurrent protection must always be carried out according to local and national regulations. Design circuit breakers and fuses for protection in a circuit capable of supplying a maximum of 100000 A_{rms} (symmetrical), 480 V maximum.

7.5.4 UL/Non-UL Compliance

To ensure compliance with UL or IEC 61800-5-1, use the circuit breakers or fuses listed in this chapter. Circuit breakers must be designed for protection in a circuit capable of supplying a maximum of 10000 $_{Arms}$ (symmetrical), 480 V maximum.

7.5.5 Recommendation of Fuses and Circuit Breakers

NOTICE

In the event of malfunction, failure to follow the protection recommendation may result in damage to the drive.

Table 23: Recommended Fuses and Circuit Breakers for UL508C Types

Enclosure size	Power rating [kW (hp)]	Circuit breaker		Fuse				
		UL	Non-UL	UL				Non-UL
				Bussmann	Bussmann	Bussmann	Bussmann	Maximum fuse
				Type RK5	Type RK1	Type J	Type T	Type G
3x200–240 V IP20/Open type								
H1	0.25–1.5 (0.33–2.0)	–	–	FRS-R-10	KTN-R10	JKS-10	JJN-10	10
H2	2.2 (3.0)	–	–	FRS-R-15	KTN-R15	JKS-15	JJN-15	16
H3	3.7 (5.0)	–	–	FRS-R-25	KTN-R25	JKS-25	JJN-25	25
H4	5.5–7.5 (7.5–10)	–	–	FRS-R-50	KTN-R50	JKS-50	JJN-50	50
H5	11 (15)	–	–	FRS-R-80	KTN-R80	JKS-80	JJN-80	65
H6	15–18.5 (20–25)	Cutler-Hammer EGE3100FFG	Moeller NZMB1- A125	FRS-R-100	KTN-R100	JKS-100	JJN-100	125
H7	22–30 (30–40)	Cutler-Hammer JGE3150FFG	Moeller NZMB1- A160	FRS-R-150	KTN-R150	JKS-150	JJN-150	160
H8	37–45 (50–60)	Cutler-Hammer JGE3200FFG	Moeller NZMB1- A200	FRS-R-200	KTN-R200	JKS-200	JJN-200	200
3x380–480 V IP20/Open type								
H1	0.37–1.5 (0.5–2.0)	–	–	FRS-R-10	KTS-R10	JKS-10	JJS-10	10
H2	2.2–4.0 (3.0–5.0)	–	–	FRS-R-15	KTS-R15	JKS-15	JJS-15	16

Table 23: Recommended Fuses and Circuit Breakers for UL508C Types - (continued)

Enclosure size	Power rating [kW (hp)]	Circuit breaker		Fuse				
		UL	Non-UL	UL				Non-UL
				Bussmann	Bussmann	Bussmann	Bussmann	Maximum fuse
				Type RK5	Type RK1	Type J	Type T	Type G
H3	5.5–7.5 (7.5–10)	–	–	FRS-R-25	KTS-R25	JKS-25	JJS-25	25
H4	11–15 (15–20)	–	–	FRS-R-50	KTS-R50	JKS-50	JJS-50	50
H5	18.5–22 (25–30)	–	–	FRS-R-80	KTS-R80	JKS-80	JJS-80	65
H6	30 (40)	Cutler-Hammer EGE3125FFG	Moeller NZMB1- A125	FRS-R-125	KTS-R125	JKS-R125	JJS-R125	80
	37 (50)							100
	45 (60)							125
H7	55 (70)	Cutler-Hammer JGE3200FFG	Moeller NZMB1- A200	FRS-R-200	KTS-R200	JKS-R200	JJS-R200	150
	75 (100)							200
H8	90 (125)	Cutler-Hammer JGE3250FFG	Moeller NZMB2- A250	FRS-R-250	KTS-R250	JKS-R250	JJS-R250	250
3x525–600 V IP20/Open type								
H9	2.2–7.5 (3.0–10)	–	–	FRS-R-20	KTS-R20	JKS-20	JJS-20	20
H10	11–15 (15–20)	–	–	FRS-R-30	KTS-R30	JKS-30	JJS-30	35
H6	18.5–30 (25–40)	Cutler-Hammer EGE3080FFG	Cutler-Hammer EGE3080FFG	FRS-R-80	KTS-R80	JKS-80	JJS-80	80
H7	37–55 (50–70)	Cutler-Hammer JGE3125FFG	Cutler-Hammer JGE3125FFG	FRS-R-125	KTS-R125	JKS-125	JJS-125	125
H8	75–90 (100–125)	Cutler-Hammer JGE3200FAG	Cutler-Hammer JGE3200FAG	FRS-R-200	KTS-R200	JKS-200	JJS-200	200
3x380–480 V IP54								
I2	0.75–4.0 (1.0–5.0)	–	PKZM0-16	–	–	–	–	16
I3	5.5–7.5 (7.5–10)	–	PKZM0-25	–	–	–	–	25
I4	11–18.5 (15–25)	–	PKZM4-63	–	–	–	–	63
I6	22–37 (30–50)	–	–	–	–	–	–	125
I7	45–55 (60–70)	–	–	–	–	–	–	160
I8	75–90 (100–125)	–	–	–	–	–	–	200

Table 24: Recommended Fuses for UL61800-5-1 Types

FC 101		UL Compliance (UL61800-5-1) Short Circuit Current Ratings (SCCR) 5kA and 100kA: 0–37 kW (0–50 hp) 10kA and 100kA: 45–90 kW (60–125 hp)			CE Compliance 5 kA and 10 kA(1)
Enclosure size	Power rating [kW (hp)]	Listed fuse RK5/RK1(2)/J/T/CC Amperes ratings (A)	Test cabinet size(3), (4) [Height x Width x Depth] [mm (in)]	Minimum cabinet volume [L]	gG Amperes ratings (A)
3x200Y/115-240Y/139 V					
H1	0.25–1.5 (0.33–2.0)	10	500 x 400 x 260 (19.7 x 15.7 x 10.2)	52	gG-10
H2	2.2 (3.0)	15			gG-16
H3	3.7 (5.0)	25			gG-25
H4	5.5–7.5 (7.5–10)	50	800 x 400 x 300 (31.5 x 15.7 x 11.8)	96	gG-50
H5	11 (15)	80			gG-65
H6	15–18.5 (20–25)	100	–	–	gG-125
H7	22–30 (30–40)	150	800 x 600 x 400 (31.5 x 23.6 x 15.7)	192	gG-160
H8	37–45 (50–60)	200	1200 x 600 x 500 (47.2 x 23.6 x 19.7)	360	gG-200
3x380Y/220-480Y/277 V					
H1	0.37–1.5 (0.5–2.0)	10	500 x 400 x 260 (19.7 x 15.7 x 10.2)	52	gG-10
H2	2.2–4.0 (3.0–5.0)	15			gG-16
H3	5.5–7.5 (7.5–10)	25			gG-25
H4	11–15 (15–20)	50	800 x 400 x 300 (31.5 x 15.7 x 11.8)	96	gG-50
H5	18.5–22 (25–30)	80			gG-65
H6	30 (40)	125	–	–	gG-80
	37 (50)				gG-100
	45 (60)				gG-125
H7	55 (75)	200	800 x 600 x 400 (31.5 x 23.6 x 15.7)	192	gG-150
	75 (100)				gG-200
H8	90 (125)	250	1200 x 600 x 500 (47.2 x 23.6 x 19.7)	360	gG-250

1) *For drives above 37 kW (50 hp), it is 10 kA for CE compliance.*

2) *RK1 and RK5 fuses are not allowed for H6-H8 drives.*

3) *H1–H8 drives meet UL 61800-5-1 certification based on the drive being mounted within a larger enclosure (approximately 1.5x the drive) and being centered on the back panel of the larger enclosure. See Figure 69 to Figure 72 for dimensions and allowed vent openings and cable entry points for the tested units. To maintain UL 61800-5-1 certification and to provide the required shielding for vented enclosures, ensure that the spatial relationship between the drive and the vent openings in the larger enclosure is maintained, at a minimum. Larger enclosures can use greater distances to openings. For more information, contact Danfoss support.*

4) *Cabinet is not required for H6 drives if type 1 kit is used. For H6 drives without type 1 kit installed, normal cabinet rules apply.*

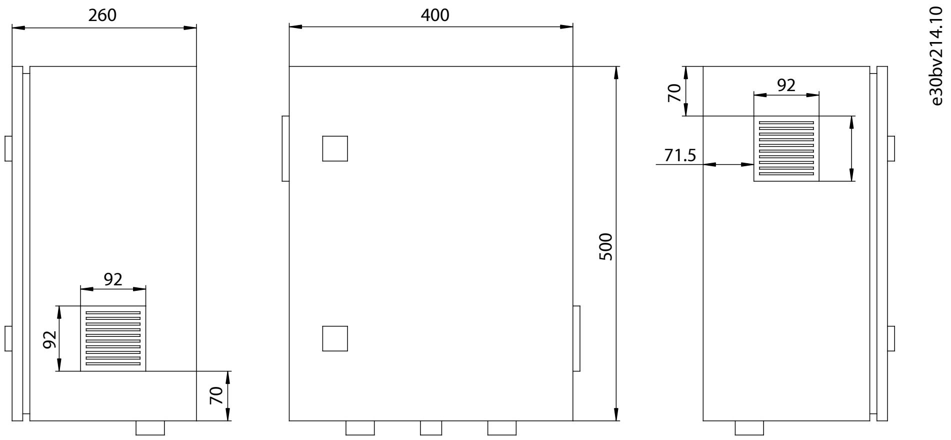

Figure 69: Allowed Ventilation Openings for H1–H3 Enclosures as Tested for UL61800-5-1 Compliance

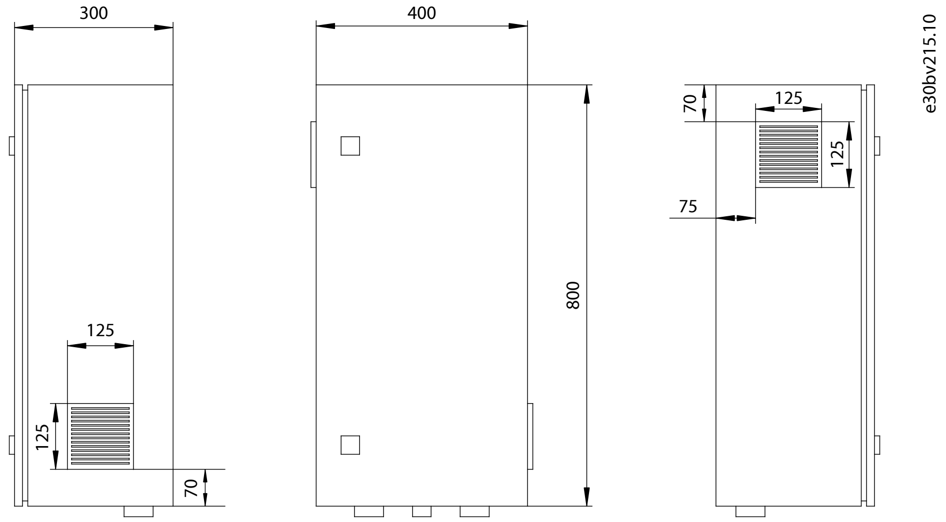

Figure 70: Allowed Ventilation Openings for H4–H5 Enclosures as Tested for UL61800-5-1 Compliance

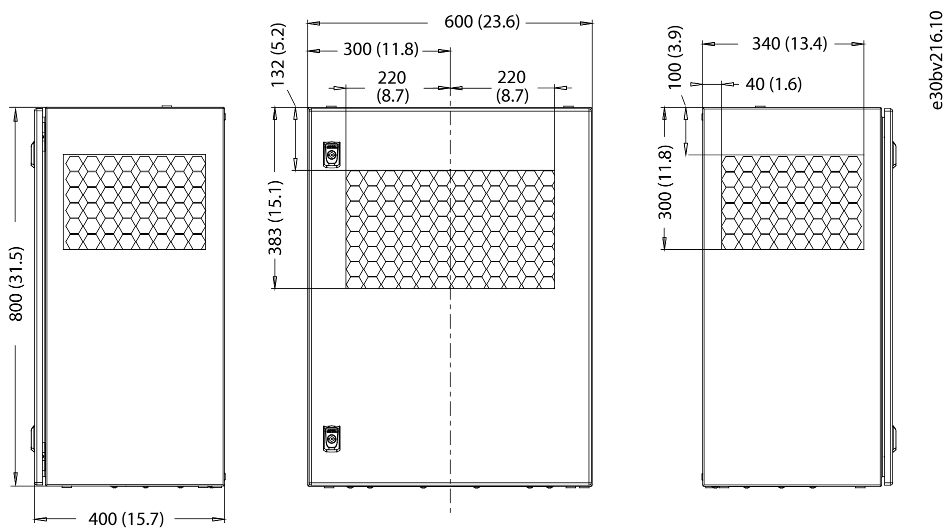

Figure 71: Allowed Ventilation Openings for H7 Enclosures as Tested for UL61800-5-1 Compliance

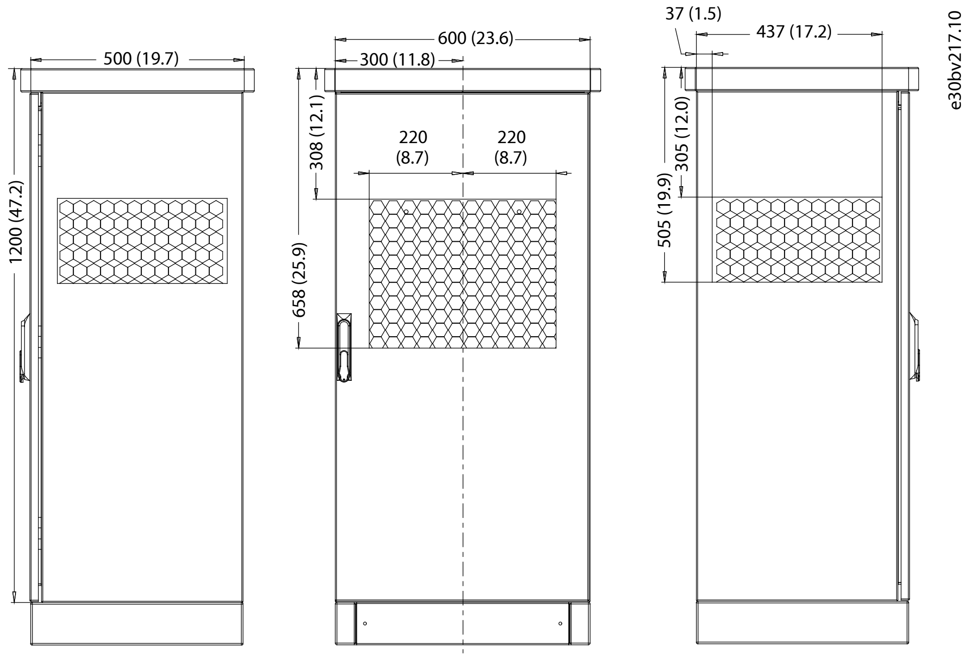

Figure 72: Allowed Ventilation Openings for H8 Enclosures as Tested for UL61800-5-1 Compliance

7.6 General Aspects of EMC

7.6.1 Overview of EMC Emissions

Drives (and other electrical devices) generate electronic or magnetic fields that may interfere with their environment. The electromagnetic compatibility (EMC) of these effects depends on the power and the harmonic characteristics of the devices.

Uncontrolled interaction between electrical devices in a system can degrade compatibility and impair reliable operation. Interference may take the form of mains harmonics distortion, electrostatic discharges, rapid voltage fluctuations, or high-frequency interference. Electrical devices generate interference along with being affected by interference from other generated sources.

Electrical interferences usually occur at frequencies in the range 150 kHz to 30 MHz. Airborne interference from the drive system in the range 30 MHz to 1 GHz is generated from the inverter, the motor cable, and the motor.

Capacitive currents in the motor cable coupled with a high dU/dt from the motor voltage generate leakage currents, as shown in the Figure 73.

The use of a shielded motor cable increases the leakage current (see Figure 73) because shielded cables have higher capacitance to ground than unshielded cables. If the leakage current is not filtered, it causes greater interference on the mains 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 according to Figure 73.

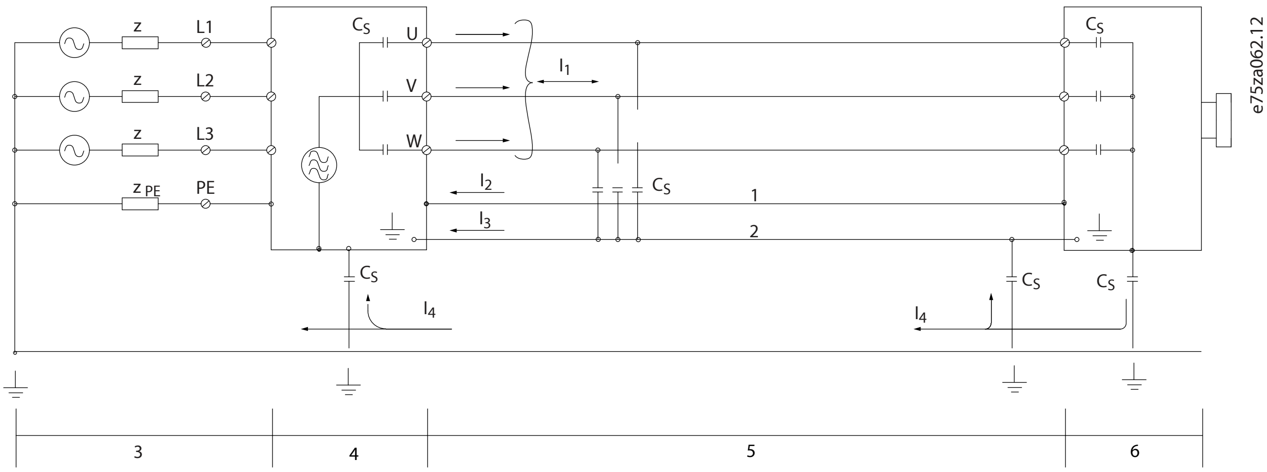

Figure 73: Generation of Leakage Currents

1	Ground wire	**2**	Shield
3	AC mains supply	**4**	Drive
5	Shielded motor cable	**6**	Motor

The shield reduces the radiated interference, but increases the low-frequency interference on the mains. Connect the motor cable shield to the drive enclosure and on the motor enclosure. This is best done by using integrated shield clamps to avoid twisted shield ends (pigtails). Pigtails increase the shield impedance at higher frequencies, which reduces the shield effect and increases the leakage current (I_4).

If a shielded cable is used for relay, control cable, signal interface, and brake, mount the shield on the enclosure at both ends. In some situations, however, it is necessary to break the shield to avoid current loops.

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

When using unshielded cables, some emission requirements are not complied with, although most immunity requirements are observed.

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

7.6.2 Emission Requirements

The EMC product standard for drives defines 4 categories (C1, C2, C3, and C4) with specified requirements for emission and immunity. The following table states the definition of the 4 categories and the equivalent classification from EN 55011.

Table 25: Correlation between IEC 61800-3 and EN 55011

EN/IEC 61800-3 Category	Definition	Equivalent emission class in EN 55011
C1	Drives installed in the 1st environment (home and office) with a supply voltage less than 1000 V.	Class B
C2	Drives installed in the 1st 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

Table 25: Correlation between IEC 61800-3 and EN 55011 - (continued)

EN/IEC 61800-3 Category	Definition	Equivalent emission class in EN 55011
C3	Drives installed in the 2nd environment (industrial) with a supply voltage lower than 1000 V.	Class A Group 2
C4	Drives installed in the 2nd 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. Make an EMC plan.

When the generic (conducted) emission standards are used, the drives are required to comply with the limits in the following table.

Table 26: Correlation between Generic Emission Standards and EN 55011

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

7.6.3 EMC Emission Test Results

The following test results have been obtained using a system with a drive, a shielded control cable, a control box with potentiometer, and a shielded motor cable.

Table 27: EMC Emission Test Results

RFI filter type	Conduct emission. Maximum shielded cable length [m (ft)]						Radiated emission			
	Industrial environment									
EN 55011	Class A Group 2 Industrial environment		Class A Group 1 Industrial environment		Class B Housing, trades and light industries		Class A Group 1 Industrial environment		Class B Housing, trades and light industries	
EN/IEC 61800-3	Category C3 Second environment Industrial		Category C2 First environment Home and office		Category C1 First environment Home and office		Category C2 First environment Home and office		Category C1 First environment Home and office	
	Without external filter	With external filter	Without external filter	With external filter	Without external filter	With external filter	Without external filter	With external filter	Without external filter	With external filter
H4 RFI filter (EN55011 A1, EN/IEC61800-3 C2)										
0.25–11 kW (0.34–15 hp) 3x200–240 V IP20/Open type	–	–	25 (82)	50 (164)	–	20 (66)	Yes	Yes	–	No
0.37–22 kW (0.5–30 hp) 3x380–480 V IP20/Open type	–	–	25 (82)	50 (164)	–	20 (66)	Yes	Yes	–	No
H2 RFI filter (EN 55011 A2, EN/IEC 61800-3 C3)										

Table 27: EMC Emission Test Results - (continued)

RFI filter type	Conduct emission. Maximum shielded cable length [m (ft)]						Radiated emission			
15–45 kW (20–60 hp) 3x200–240 V IP20/Open type	25 (82)	–	–	–	–	–	No	–	No	–
30–90 kW (40–120 hp) 3x380–480 V IP20/Open type	25 (82)	–	–	–	–	–	No	–	No	–
0.75–18.5 kW (1.0–25 hp) 3x380–480 V IP54	25 (82)	–	–	–	–	–	Yes	–	–	–
22–90 kW (30–120 hp) 3x380–480 V IP54	25 (82)	–	–	–	–	–	No	–	No	–
H3 RFI filter (EN55011 A1/B, EN/IEC 61800-3 C2/C1)										
15–45 kW (20–60 hp) 3x200–240 V IP20/Open type	–	–	50 (164)	–	20 (66)	–	Yes	–	No	–
30–90 kW (40–120 hp) 3x380–480 V IP20/Open type	–	–	50 (164)	–	20 (66)	–	Yes	–	No	–
0.75–18.5 kW (1.0–25 hp) 3x380–480 V IP54	–	–	25 (82)	–	10 (33)	–	Yes	–	–	–
22–90 kW (30–120 hp) 3x380–480 V IP54	–	–	25 (82)	–	10 (33)	–	Yes	–	No	–

7.6.4 Harmonics Emission

7.6.4.1 Overview of Harmonics Emission

A drive takes up a non-sinusoidal current from mains, which increases the input current I_{RMS}. A non-sinusoidal current is transformed with a Fourier analysis and split into sine-wave currents with different frequencies, that is, different harmonic currents I_n with 50 Hz basic frequency:

Table 28: Harmonic Currents

	I_1	I_5	I_7
Hz	50	250	350

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

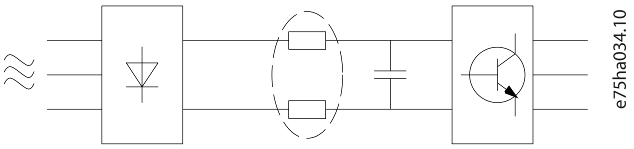

Figure 74: DC-link Coils

NOTICE

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

To ensure low harmonic currents, the drive is equipped with DC-link coils as standard. This normally reduces the input current I_{RMS} by 40%.

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

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

(U_N% of U)

7.6.4.2 Harmonics Emission Requirements

Equipment is connected to the public supply network.

Table 29: Connected Equipment

Options	Definition
1	IEC/EN 61000-3-2 Class A for 3-phase balanced equipment (for professional equipment only up to 1 kW (1.3 hp) total power).
2	IEC/EN 61000-3-12 Equipment 16–75 A and professional equipment as from 1 kW (1.3 hp) up to 16 A phase current.

7.6.4.3 Harmonics Test Results (Emission)

Power sizes up to PK75 in T4 and P3K7 in T2 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.

Table 30: Harmonic Current 0.25–11 kW (0.34–15 hp), 200 V

	Individual harmonic current I_n/I_1 (%)			
	I_5	I_7	I_{11}	I_{13}
Actual 0.25–11 kW (0.34–15 hp), IP20/Open type, 200 V (typical)	32.6	16.6	8.0	6.0
Limit for R_{sce}≥120	40	25	15	10
	Harmonic current distortion factor (%)			
	THDi		**PWHD**	

Table 30: Harmonic Current 0.25–11 kW (0.34–15 hp), 200 V - (continued)

Actual 0.25–11 kW (0.34–15 hp), 200 V (typical)	39	41.4
Limit for R_{sce}≥120	48	46

Table 31: Harmonic Current 0.37–22 kW (0.5–30 hp), 380–480 V

	Individual harmonic current I_n/I_1 (%)			
	I_5	**I_7**	**I_{11}**	**I_{13}**
Actual 0.37–22 kW (0.5–30 hp), IP20/Open type, 380–480 V (typical)	36.7	20.8	7.6	6.4
Limit for R_{sce}≥120	40	25	15	10
	Harmonic current distortion factor (%)			
	THDi		**PWHD**	
Actual 0.37–22 kW (0.5–30 hp), 380–480 V (typical)	44.4		40.8	
Limit for R_{sce}≥120	48		46	

Table 32: Harmonic Current 30–90 kW (40–120 hp), 380–480 V

	Individual harmonic current I_n/I_1 (%)			
	I_5	**I_7**	**I_{11}**	**I_{13}**
Actual 30–90 kW (40–120 hp), IP20/Open type, 380–480 V (typical)	36.7	13.8	6.9	4.2
Limit for R_{sce}≥120	40	25	15	10
	Harmonic current distortion factor (%)			
	THDi		**PWHD**	
Actual 30–90 kW (40–120 hp), 380–480 V (typical)	40.6		28.8	
Limit for R_{sce}≥120	48		46	

Table 33: Harmonic Current 2.2–15 kW (3–20 hp), 525–600 V

	Individual harmonic current I_n/I_1 (%)			
	I_5	**I_7**	**I_{11}**	**I_{13}**
Actual 2.2–15 kW (3.0–20 hp), IP20/Open type, 525–600 V (typical)	48	25	7	5
	Harmonic current distortion factor (%)			
	THDi		**PWHD**	
Actual 2.2–15 kW (3.0–20 hp), 525–600 V (typical)	55		27	

Table 34: Harmonic Current 18.5–90 kW (25–120 hp), 525–600 V

	Individual harmonic current I_n/I_1 (%)			
	I_5	**I_7**	**I_{11}**	**I_{13}**
Actual 18.5–90 kW (25–120 hp), IP20/Open type, 525–600 V (typical)	48.8	24.7	6.3	5

Table 34: Harmonic Current 18.5–90 kW (25–120 hp), 525–600 V - (continued)

	Harmonic current distortion factor (%)	
	THDi	PWHD
Actual 18.5–90 kW (25–120 hp), 525–600 V (typical)	55.7	25.3

Table 35: Harmonic Current 22–90 kW (30–120 hp), 400 V

	Individual harmonic current I_n/I_1 (%)			
	I_5	I_7	I_{11}	I_{13}
Actual 22–90 kW (30–120 hp), IP54, 400 V (typical)	36.3	14	7	4.3
Limit for R_{sce}≥120	40	25	15	10
	Harmonic current distortion factor (%)			
	THDi		**PWHD**	
Actual 22–90 kW (30–120 hp), IP54 400 V (typical)	40.1		27.1	
Limit for R_{sce}≥120	48		46	

Table 36: Harmonic Current 0.75–18.5 kW (1.0–25 hp), 380–480 V

	Individual harmonic current I_n/I_1 (%)			
	I_5	I_7	I_{11}	I_{13}
Actual 0.75–18.5 kW (1.0–25 hp), IP54, 380–480 V (typical)	36.7	20.8	7.6	6.4
Limit for R_{sce}≥120	40	25	15	10
	Harmonic current distortion factor (%)			
	THDi		**PWHD**	
Actual 0.75–18.5 kW (1.0–25 hp), 380–480 V (typical)	44.4		40.8	
Limit for R_{sce}≥120	48		46	

Table 37: Harmonic Current 15–45 kW (20–60 hp), 200 V

	Individual harmonic current I_n/I_1 (%)			
	I_5	I_7	I_{11}	I_{13}
Actual 15–45 kW (20–60 hp), IP20/Open type, 200 V (typical)	26.7	9.7	7.7	5
Limit for R_{sce}≥120	40	25	15	10
	Harmonic current distortion factor (%)			
	THDi		**PWHD**	
Actual 15–45 kW (20–60 hp), 200 V (typical)	30.3		27.6	
Limit for R_{sce}≥120	48		46	

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

$$S_{SC} = \sqrt{3} \times R_{SCE} \times U_{mains} \times I_{equ} = \sqrt{3} \times 120 \times 400 \times I_{equ}$$

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 specified above. 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 above tables are given in accordance with IEC/EN 61000-3-12 about the Power Drive Systems product standard. They may be used as the basis for calculation of the harmonic currents' influence on the power supply system and for the documentation of compliance with relevant regional guidelines: IEEE 519 -1992; G5/4.

7.6.5 Immunity Requirements

The immunity requirements for 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 environment. All Danfoss drives comply with the requirements for the industrial environment and therefore comply also with the lower requirements for home and office environment with a large safety margin.

7.7 EMC-correct Electrical Installation

General points to be observed to ensure EMC-correct electrical installation:

- Use only shielded/armored motor cables and shielded/armored control cables.
- Ground the shield at both ends.
- Avoid installation with twisted shield ends (pigtails), because it reduces the shielding effect at high frequencies. Use the cable clamps provided.
- Ensure the same potential between the drive and the ground potential of PLC.
- It is important to ensure good electrical contact from the installation plate through the installation screws to the metal cabinet of the drive.
- Use star washers and galvanically conductive installation plates.

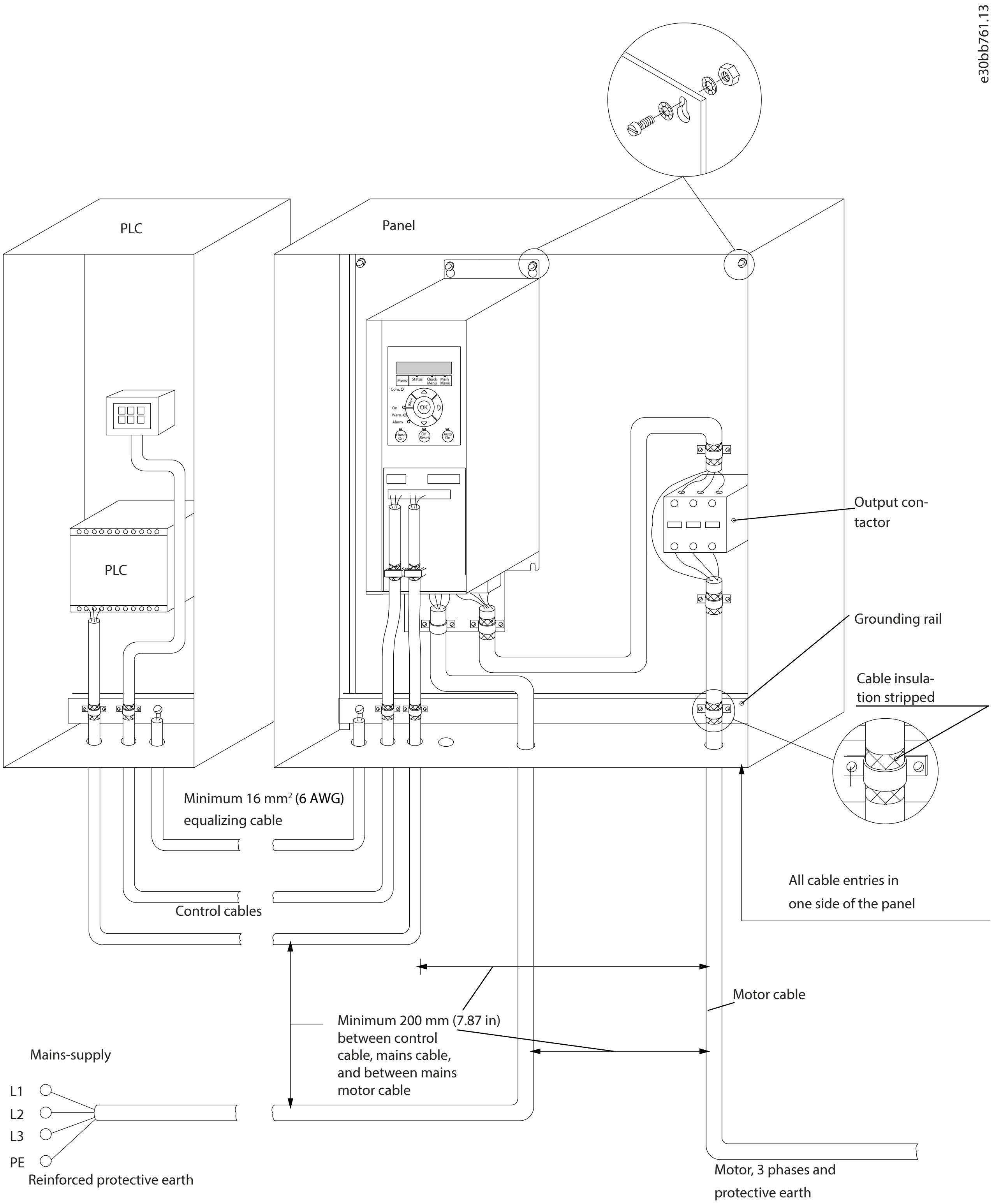

Figure 75: EMC-correct Electrical Installation

NOTICE

For North America, use metal conduits instead of shielded cables.

7.8 Galvanic Isolation (PELV)

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

All control terminals and relay terminals 01-03/04-06 comply with PELV (protective extra low voltage) (does not apply to grounded delta leg above 440 V).

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

The components that make up the electrical isolation, as described, also comply with the requirements for higher isolation and the relevant test as described in EN 61800-5-1. The PELV galvanic isolation can be shown in Figure 77.

To maintain PELV, all connections made to the control terminals must be PELV, for example, thermistors must be reinforced/double insulated.

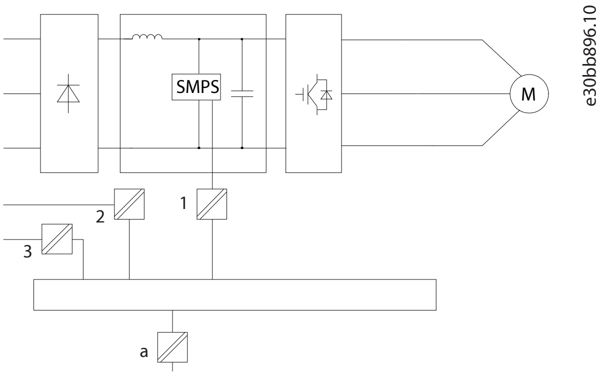

Figure 76: Galvanic Isolation 0.25–22 kW (0.34–30 hp)

1	Supply (SMPS)	**2**	Optocouplers, communication between AOC and BOC
3	Custom relays	**a**	Control card terminals

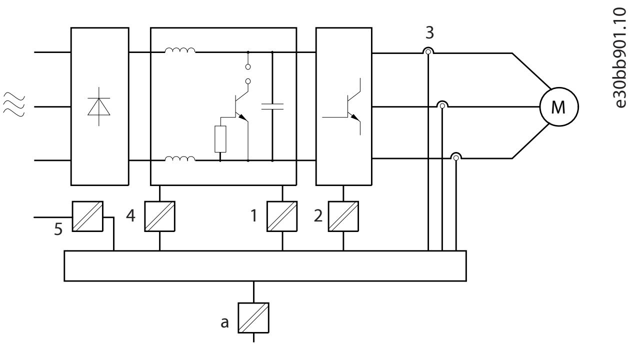

Figure 77: Galvanic Isolation 30–90 kW (40–125 hp)

1	Supply (SMPS) including signal isolation of UDC, indicating the intermediate current voltage	**2**	Gate drive that runs the IGBTs (trigger transformers/ optocouplers)
3	Current transducers	**4**	Internal soft-charge, RFI, and temperature measurement circuits
5	Custom relays	**a**	Control card terminals

The functional galvanic isolation (see Figure 76) is for the RS485 standard bus interface.

CAUTION

INSTALLATION AT HIGH ALTITUDE

At altitudes above 2000 m (6500 ft), contact Danfoss regarding PELV.

7.9 Ground Leakage Current

7.9.1 Overview of Ground Leakage Current

Follow national and local codes regarding protective earthing of equipment where leakage current exceeds 3.5 mA. Drive technology implies high frequency switching at high power. This generates a leakage current in the ground connection.

The ground leakage current is made up of several contributions and depends on various system configurations, including:

- RFI filtering.
- Motor cable length.
- Motor cable shielding.
- Drive power.

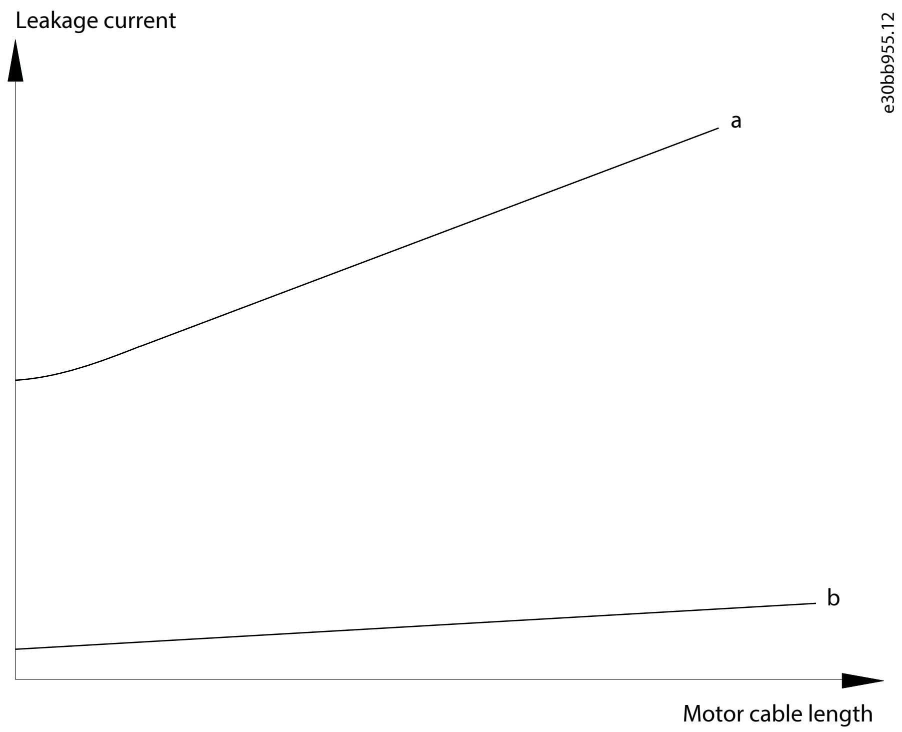

Figure 78: Influence of the Cable Length and Power Size on Leakage Current, Power Size a > Power Size b

The leakage current also depends on the line distortion.

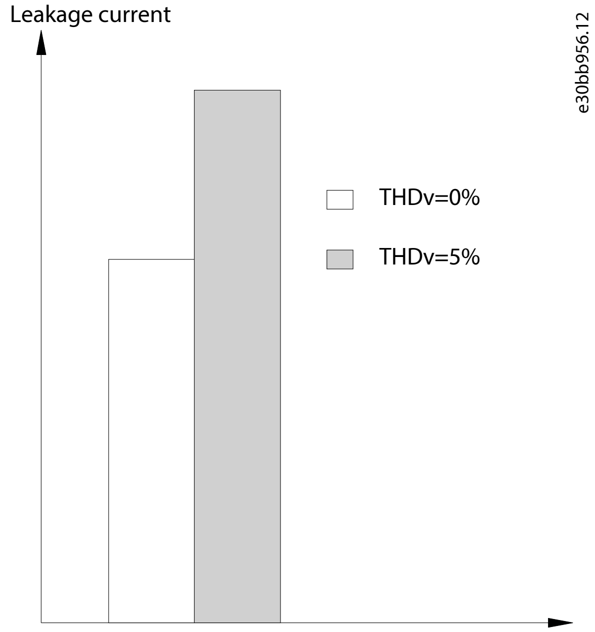

Figure 79: Influence of Line Distortion on Leakage Current

If the leakage current exceeds 3.5 mA, compliance with EN/IEC 61800-5-1 (power drive system product standard) requires special care.

Reinforce grounding with the following protective earth connection requirements:

- Ground wire (terminal 95) of at least 10 mm^2 (8 AWG) cross-section.
- Two separate ground wires both complying with the dimensioning rules.

See EN/IEC 61800-5-1 and IEC EN 62477-1 for further information.

⚠ WARNING

DISCHARGE TIME

Touching the electrical parts, even after the equipment has been disconnected from mains, could be fatal.

- Make sure that other voltage inputs have been disconnected, such as load sharing (linkage of DC link), and the motor connection for kinetic backup.
- Before touching any electrical parts, wait at least the amount of time indicated in the safety chapter. Shorter time is allowed only if indicated on the nameplate for the specific unit.

⚠ WARNING

LEAKAGE CURRENT HAZARD

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

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

7.9.2 Using a Residual Current Device (RCD)

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

- Use RCDs of type B only, which are capable of detecting AC and DC currents.
- Use RCDs with an inrush delay to prevent faults caused by transient ground currents.
- Dimension RCDs according to the system configuration and environmental considerations.

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

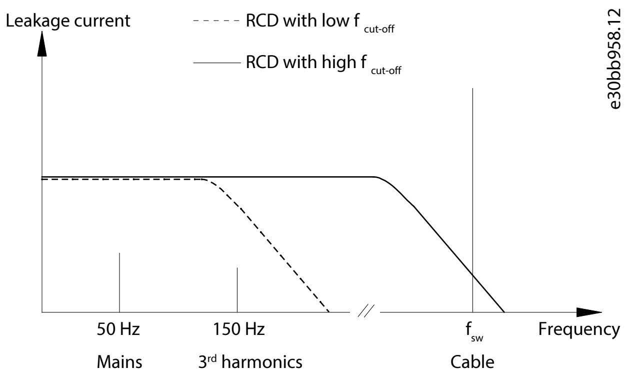

Figure 80: Mains Contributions to Leakage Current

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

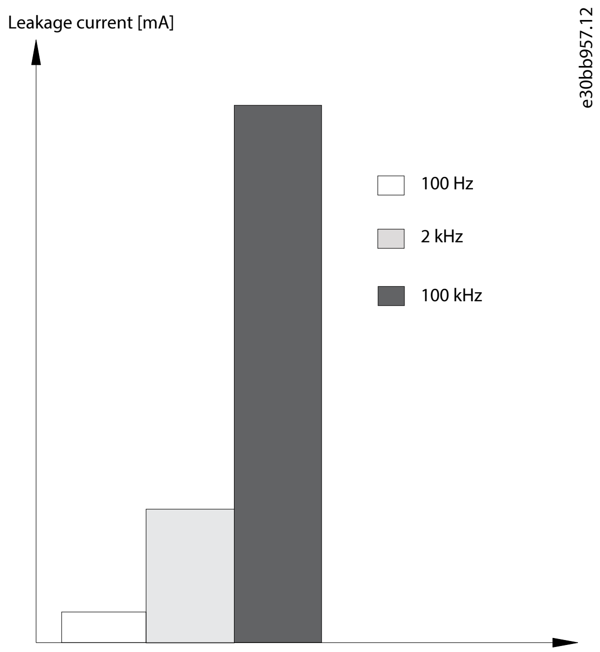

Figure 81: Influence of Cut-off Frequency of the RCD on what is Responded to/Measured

For more details, refer to the RCD Application Note.

WARNING

RESIDUAL CURRENT DEVICE PROTECTION

This product can cause a DC current in the protective conductor. Where a residual current device (RCD) is used for protection in case of direct or indirect contact, only an RCD of Type B is allowed on the supply side of this product. Otherwise, apply another protective measure, such as separation from the environment by double or reinforced insulation, or isolation from the supply system by a transformer. See also application note Protection against Electrical Hazards.

- Protective grounding of the drive and the use of RCDs must always follow national and local regulations.

7.10 Control Terminals

Remove the terminal cover to access the control terminals.

Use a flat-edged screwdriver to push down the lock lever of the terminal cover under the LCP, then remove the terminal cover as shown in Figure 82.

For IP54 units, control terminals can be accessed after removing the front cover.

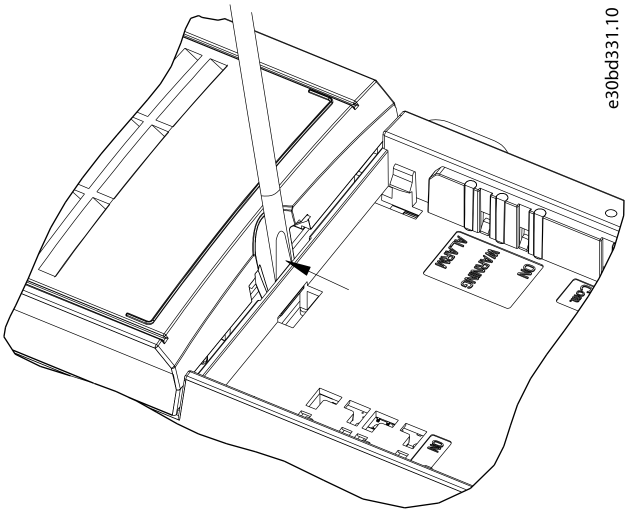

Figure 82: Removing the Terminal Cover

Figure 83 shows all the drive control terminals. Applying start (terminal 18), connection between terminals 12-27, and an analog reference (terminal 53 or 54, and 55) make the drive run.

The digital input mode of terminal 18, 19, and 27 is set in parameter ***5-00 Digital Input Mode*** (PNP is default value). Digital input 29 mode is set in parameter ***5-03 Digital Input 29 Mode*** (PNP is default value).

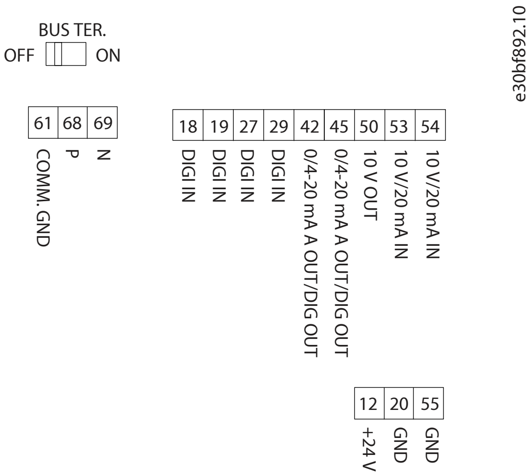

Figure 83: Control Terminals

7.11 Extreme Running Conditions

7.11.1 Introduction

Short circuit (motor phase-phase)

Current measurement in each of the 3 motor phases or in the DC link protects the drive against short circuits. A short circuit between 2 output phases causes an overcurrent in the inverter. The inverter is turned off individually when the short-circuit current exceeds the allowed value (***alarm 16***, ***Trip Lock***).

For information about protecting the drive against a short circuit at the load sharing and brake outputs, see *chapter Fuses and Circuit Breakers*.

Switching on the output

Switching on the output between the motor and the drive is allowed. The drive is not damaged in any way by switching on the output. However, fault messages may appear.

Motor-generated overvoltage

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

- The load drives the motor (at constant output frequency from the drive), that is the load generates energy.
- During deceleration (ramp-down), if the inertia moment 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 drive, the motor, and the installation.
- Incorrect slip compensation setting (parameter ***1-62 Slip Compensation***) may cause higher DC-link voltage.

The control unit may attempt to correct the ramp if parameter ***2-17 Over-voltage Control*** is enabled. The drive turns off to protect the transistors and the DC-link capacitors when a certain voltage level is reached.

Mains dropout

During a mains dropout, the drive keeps running until the DC-link voltage drops below the minimum stop level, which is typically 15% below the drive's lowest rated supply voltage. The mains voltage before the dropout and the motor load determines how long it takes for the drive to coast.

7.11.2 Motor Thermal Protection (ETR)

Danfoss uses ETR to protect the motor from being overheated. It is an electronic feature that simulates a bimetal relay based on internal measurements. The characteristic is shown in the Figure 84.

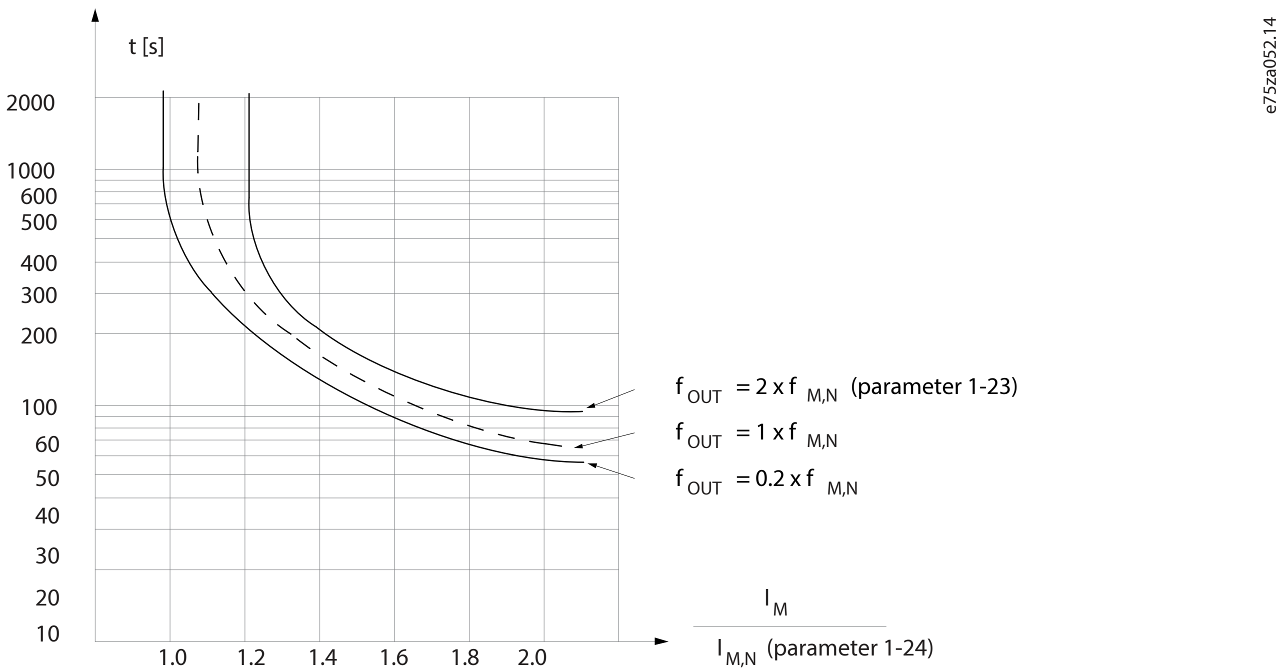

Figure 84: Motor Thermal Protection Characteristic

The X-axis shows the ratio between I_{motor} and I_{motor} nominal. The Y-axis shows the time in seconds before the ETR cuts off and trips the drive. The curves show the characteristic nominal speed at twice the nominal speed and at 0.2x the nominal speed.

It is clear that at lower speed, the ETR cuts off at lower heat due to less cooling of the motor. In that way, the motor is protected from being overheated even at low speed. The ETR feature calculates the motor temperature based on actual current and speed.

7.11.3 Thermistor Inputs

7.11.3.1 Overview of Thermistor Inputs

The thermistor cutout 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).
- Electronic thermal relay (ETR).

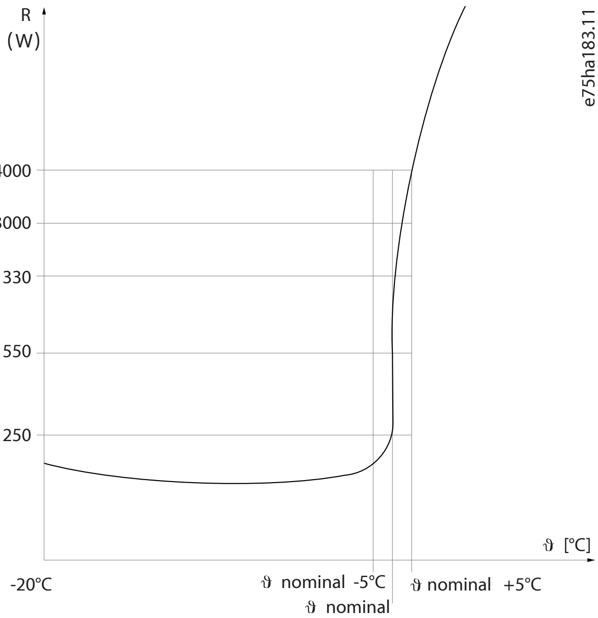

Figure 85: Trip due to High Motor Temperature

7.11.3.2 Example with Digital Input and 10 V Power Supply

The drive trips when the motor temperature is too high.

Parameter setup:

- Set parameter ***1-90 Motor Thermal Protection*** to ***[2] Thermistor Trip***.
- Set parameter ***1-93 Thermistor Source*** to ***[6] Digital Input 29***.

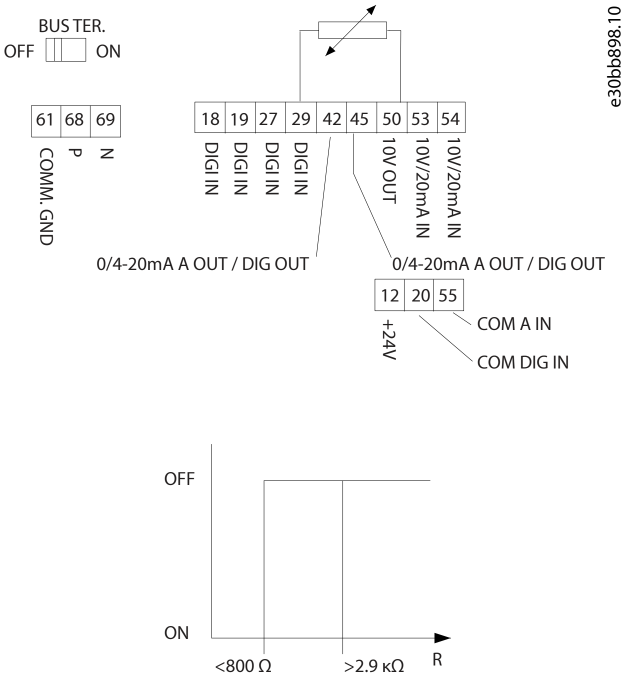

Figure 86: Digital Input/10 V Power Supply

7.11.3.3 Example with Analog Input and 10 V Power Supply

The drive trips when the motor temperature is too high.

Parameter setup:

- Set parameter ***1-90 Motor Thermal Protection*** to ***[2] Thermistor Trip***.
- Set parameter ***1-93 Thermistor Source*** to ***[1] Analog Input 53***.

NOTICE

Do not set Analog Input 54 as reference source.

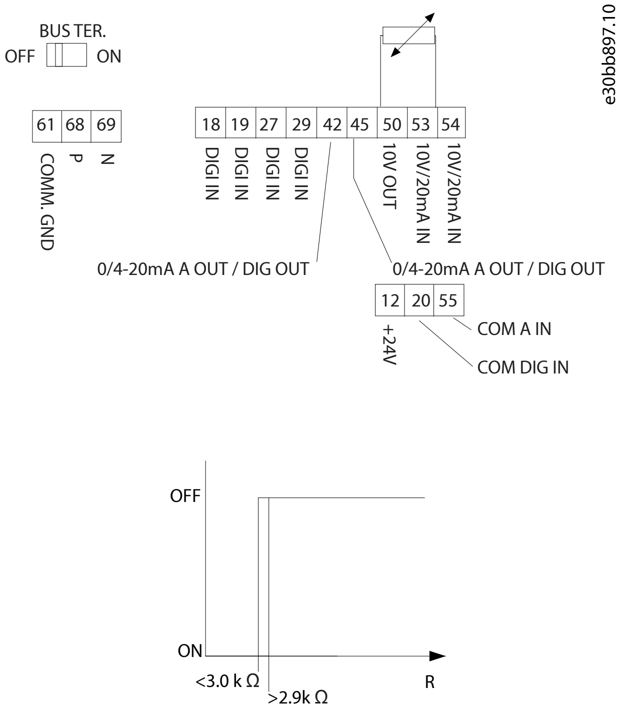

Figure 87: Analog Input/10 V Power Supply

Table 38: Supply Voltage

Input	Supply voltage [V]	Threshold cutout values [Ω]
Digital	10	<800⇒2.9 k
Analog	10	<800⇒2.9 k

NOTICE

Make sure that the selected supply voltage follows the specification of the used thermistor element.

ETR is activated in parameter ***1-90 Motor Thermal Protection***.

7.12 Acoustic Noise or Vibration

7.12.1 Overview of Acoustic Noise or Vibration

If the motor or the equipment driven by the motor - for example, a fan - makes noise or vibrations at certain frequencies, configure the following parameters or parameter groups to reduce or eliminate the noise or vibrations:

- Parameter group ***4-6* Speed Bypass***
- Set parameter ***14-03 Overmodulation*** to *[0] Off*.
- Switching pattern and switching frequency parameter group ***14-0* Inverter Switching***.
- Parameter ***1-64 Resonance Dampening***

7.12.2 Acoustic Noise

The acoustic noise from the drive comes from 3 sources:

- DC-link coils.
- Integral fan.
- RFI filter choke.

Table 39: Typical Values Measured at a Distance of 1 m (3.28 ft) from the Unit

Enclosure size	Level [dBA][1]
H1	43.6
H2	50.2
H3	53.8
H4	64
H5	63.7
H6	71.5
H7	67.5 (75 kW (100 hp) 71.5 dB)
H8	73.5
H9	60
H10	62.9
I2	50.2
I3	54
I4	67.4
I6	70
I7	65
I8	65.6

1) The values are measured under the background of 35 dBA noise and the fan running with full speed.

7.12.3 Vibration and Shock

The drive has been tested according to the following standards:

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

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

7.13 dU/dt

Table 40: dU/dt Data

	Cable length [m (ft)]	AC line voltage [V]	Rise time [µsec]	V_{peak} [kV]	dU/dt [kV/µsec]
200 V 0.25 kW (0.34 hp)	5 (16)	240	0.121	0.498	3.256
	25 (82)	240	0.182	0.615	2.706
	50 (164)	240	0.258	0.540	1.666
200 V 0.37 kW (0.5 hp)	5 (16)	240	0.121	0.498	3.256
	25 (82)	240	0.182	0.615	2.706
	50 (164)	240	0.258	0.540	1.666
200 V 0.75 kW (1.0 hp)	5 (16)	240	0.121	0.498	3.256
	25 (82)	240	0.182	0.615	2.706
	50 (164)	240	0.258	0.540	1.666

Table 40: dU/dt Data - (continued)

	Cable length [m (ft)]	AC line voltage [V]	Rise time [µsec]	V_{peak} [kV]	dU/dt [kV/µsec]
200 V 1.5 kW (2.0 hp)	5 (16)	240	0.121	0.498	3.256
	25 (82)	240	0.182	0.615	2.706
	50 (164)	240	0.258	0.540	1.666
200 V 2.2 kW (3.0 hp)	5 (16)	240	0.18	0.476	2.115
	25 (82)	240	0.230	0.615	2.141
	50 (164)	240	0.292	0.566	1.550
200 V 3.7 kW (5.0 hp)	5 (16)	240	0.168	0.570	2.714
	25 (82)	240	0.205	0.615	2.402
	50 (164)	240	0.252	0.620	1.968
200 V 5.5 kW (7.5 hp)	5 (16)	240	0.128	0.445	2.781
	25 (82)	240	0.224	0.594	2.121
	50 (164)	240	0.328	0.596	1.454
200 V 7.5 kW (10 hp)	5 (16)	240	0.18	0.502	2.244
	25 (82)	240	0.22	0.598	2.175
	50 (164)	240	0.292	0.615	1.678
200 V 11 kW (15 hp)	36 (118)	240	0.176	0.56	2.545
	50 (164)	240	0.216	0.599	2.204
400 V 0.37 kW (0.5 hp)	5 (16)	400	0.160	0.808	4.050
	25 (82)	400	0.240	1.026	3.420
	50 (164)	400	0.340	1.056	2.517
400 V 0.75 kW (1.0 hp)	5 (16)	400	0.160	0.808	4.050
	25 (82)	400	0.240	1.026	3.420
	50 (164)	400	0.340	1.056	2.517
400 V 1.5 kW (2.0 hp)	5 (16)	400	0.160	0.808	4.050
	25 (82)	400	0.240	1.026	3.420
	50 (164)	400	0.340	1.056	2.517
400 V 2.2 kW (3.0 hp)	5 (16)	400	0.190	0.760	3.200
	25 (82)	400	0.293	1.026	2.801
	50 (164)	400	0.422	1.040	1.971
400 V 3.0 kW (4.0 hp)	5 (16)	400	0.190	0.760	3.200
	25 (82)	400	0.293	1.026	2.801
	50 (164)	400	0.422	1.040	1.971
400 V 4.0 kW (5.5 hp)	5 (16)	400	0.190	0.760	3.200
	25 (82)	400	0.293	1.026	2.801
	50 (164)	400	0.422	1.040	1.971

Table 40: dU/dt Data - (continued)

	Cable length [m (ft)]	AC line voltage [V]	Rise time [µsec]	V_{peak} [kV]	dU/dt [kV/µsec]
400 V 5.5 kW (7.5 hp)	5 (16)	400	0.168	0.81	3.857
	25 (82)	400	0.239	1.026	3.434
	50 (164)	400	0.328	1.05	2.560
400 V 7.5 kW (10 hp)	5 (16)	400	0.168	0.81	3.857
	25 (82)	400	0.239	1.026	3.434
	50 (164)	400	0.328	1.05	2.560
400 V 11 kW (15 hp)	5 (16)	400	0.116	0.69	4.871
	25 (82)	400	0.204	0.985	3.799
	50 (164)	400	0.316	1.01	2.563
400 V 15 kW (20 hp)	5 (16)	400	0.139	0.864	4.955
	50 (82)	400	0.338	1.008	2.365
400 V 18.5 kW (25 hp)	5 (16)	400	0.132	0.88	5.220
	25 (82)	400	0.172	1.026	4.772
	50 (164)	400	0.222	1.00	3.603
400 V 22 kW (30 hp)	5 (16)	400	0.132	0.88	5.220
	25 (82)	400	0.172	1.026	4.772
	50 (164)	400	0.222	1.00	3.603
400 V 30 kW (40 hp)	10 (33)	400	0.376	0.92	1.957
	50 (164)	400	0.536	0.97	1.448
	100 (328)	400	0.696	0.95	1.092
	150 (492)	400	0.8	0.965	0.965
	10 (33)	480	0.384	1.2	2.5
	50 (164)	480	0.632	1.18	1.494
	100 (328)	480	0.712	1.2	1.348
	150 (492)	480	0.832	1.17	1.125
	10 (33)	500	0.408	1.24	2.431
	50 (164)	500	0.592	1.29	1.743
	100 (328)	500	0.656	1.28	1.561
	150 (492)	500	0.84	1.26	1.2
400 V 37 kW (50 hp)	10 (33)	400	0.276	0.928	2.69
	50 (164)	400	0.432	1.02	1.889
	10 (33)	480	0.272	1.17	3.441
	50 (164)	480	0.384	1.21	2.521
	10 (33)	500	0.288	1.2	3.333
	50 (164)	500	0.384	1.27	2.646

Table 40: dU/dt Data - (continued)

	Cable length [m (ft)]	AC line voltage [V]	Rise time [µsec]	V_{peak} [kV]	dU/dt [kV/µsec]
400 V 45 kW (60 hp)	10 (33)	400	0.3	0.936	2.496
	50 (164)	400	0.44	0.924	1.68
	100 (328)	400	0.56	0.92	1.314
	150 (492)	400	0.8	0.92	0.92
	10 (33)	480	0.3	1.19	3.173
	50 (164)	480	0.4	1.15	2.3
	100 (328)	480	0.48	1.14	1.9
	150 (492)	480	0.72	1.14	1.267
	10 (33)	500	0.3	1.22	3.253
	50 (164)	500	0.38	1.2	2.526
	100 (328)	500	0.56	1.16	1.657
	150 (492)	500	0.74	1.16	1.254
400 V 55 kW (75 hp)	10 (33)	400	0.46	1.12	1.948
		480	0.468	1.3	2.222
400 V 75 kW (100 hp)	10 (33)	400	0.502	1.048	1.673
		480	0.52	1.212	1.869
		500	0.51	1.272	1.992
400 V 90 kW (120 hp)	10 (33)	400	0.402	1.108	2.155
		400	0.408	1.288	2.529
		400	0.424	1.368	2.585
600 V 7.5 kW (10 hp)	5 (16)	525	0.192	0.972	4.083
	50 (164)	525	0.356	1.32	2.949
	5 (16)	600	0.184	1.06	4.609
	50 (164)	600	0.42	1.49	2.976

8 Basic Operating Principles

8.1 Introduction

This chapter provides an overview of the primary assemblies and circuitry of a Danfoss VLT® drive. It describes the internal electrical and signal processing functions. A description of the internal control structure is also included.

8.2 Overview of Drive Controls

A drive is an electronic controller that supplies a regulated amount of AC power to a 3-phase inductive motor. By supplying variable frequency and voltage to the motor, the drive varies the motor speed or maintains a constant speed as the load on the motor changes. Also, the drive can stop and start a motor without the mechanical stress associated with a line start.

In its basic form, the drive can be divided into 4 main areas:

- A rectifier consisting of SCRs or diodes that convert 3-phase AC voltage to pulsating DC voltage.
- A DC link consisting of inductors and their capacitor banks that stabilize the pulsating DC voltage.
- An inverter using IGBTs to convert the DC voltage to variable voltage and variable frequency AC.
- A control area consisting of software that runs the hardware to produce the variable voltage that controls and regulates the AC motor.

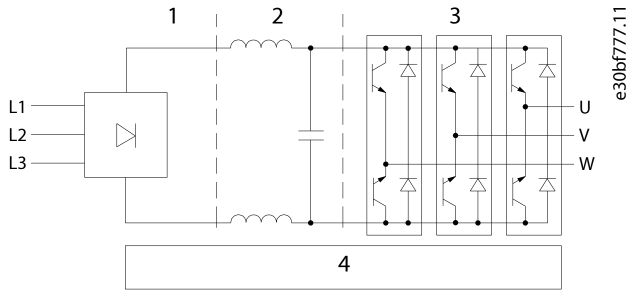

Figure 88: Internal Processing

1	Rectifier (SCR/diodes)	**2**	DC link (DC bus)
3	Inverter (IGBTs)	**4**	Control area

8.3 Control Structures

8.3.1 Introduction

There are 2 control modes for the drive:

- Open loop.
- Closed loop.

Select ***[0] Open loop*** or ***[1] Closed loop*** in parameter ***1-00 Configuration Mode***.

8.3.2 Control Structure Open Loop

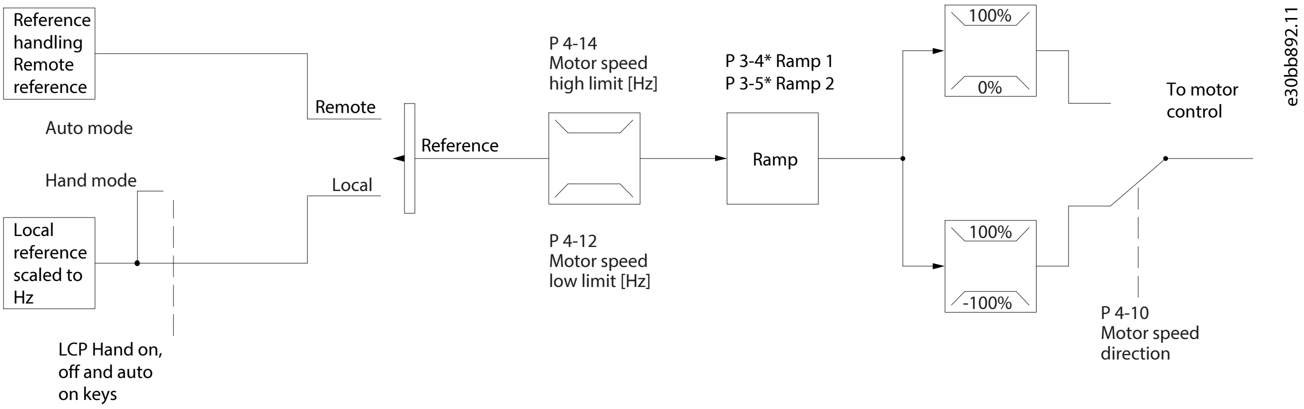

Figure 89: Open-loop Structure

In the configuration shown in Figure 89, parameter ***1-00 Configuration Mode*** is set to ***[0] Open loop***. The resulting reference from the reference handling system or the local reference is received and fed through the ramp limitation and speed limitation before being sent to the motor control. The output from the motor control is then limited by the maximum frequency limit.

8.3.3 PM/EC+ Motor Control

The Danfoss EC+ concept provides the possibility for using high-efficient PM motors (permanent magnet motors) in IEC standard enclosure sizes operated by Danfoss drives.

The commissioning procedure is comparable to the existing one for asynchronous (induction) motors by using the Danfoss VVC+ PM control strategy.

Customer advantages:

- Free choice of motor technology (permanent magnet or induction motor).
- Installation and operation are as known on induction motors.
- Manufacturer independent when selecting system components (for example, motors).
- Best system efficiency by selecting the best components.
- Possible retrofit of existing installations.
- Power range: 45 kW (60 hp) (200 V), 0.37–90 kW (0.5–121 hp) (400 V), 90 kW (125 hp) (600 V) for induction motors and 0.37–22 kW (0.5–30 hp) (400 V) for PM motors.

Current limitations for PM motors:

- Currently only supported up to 22 kW (30 hp).
- LC filters are not supported with PM motors.
- Kinetic backup algorithm is not supported with PM motors.
- Support only complete AMA of the stator resistance Rs in the system.
- No stall detection (supported from software version 2.80).

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

The drive can be operated manually via the local control panel (LCP) or remotely via analog/digital inputs or serial bus. If allowed in parameter ***0-40 [Hand on] Key on LCP***, parameter ***0-44 [Off/Reset] Key on LCP***, and parameter ***0-42 [Auto on] Key on LCP***, it is possible to start and stop the drive via LCP by pressing ***[Hand On]*** and ***[Off/Reset]***. Alarms can be reset via the ***[Off/Reset]*** key.

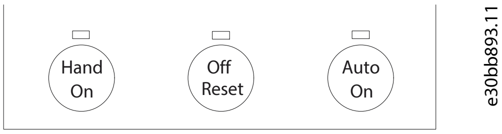

Figure 90: LCP Keys

Local reference forces the configuration mode to open loop, independent on the setting of parameter ***1-00 Configuration Mode***. Local reference is restored at power-down.

8.3.5 Control Structure Closed Loop

The internal controller allows the drive to become a part of the controlled system. The drive receives a feedback signal from a sensor in the system. It then compares this feedback to a setpoint reference value and determines the error, if any, between these 2 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 to be controlled to ensure a constant static pressure in a pipe. The static pressure value is supplied to the drive as the setpoint reference. A static pressure sensor measures the actual static pressure in the pipe and supplies this data to the drive as a feedback signal. If the feedback signal is greater than the setpoint reference, the drive slows the pump down to reduce the pressure. In a similar way, if the pipe pressure is lower than the setpoint reference, the drive automatically speeds the pump up to increase the pressure provided by the pump.

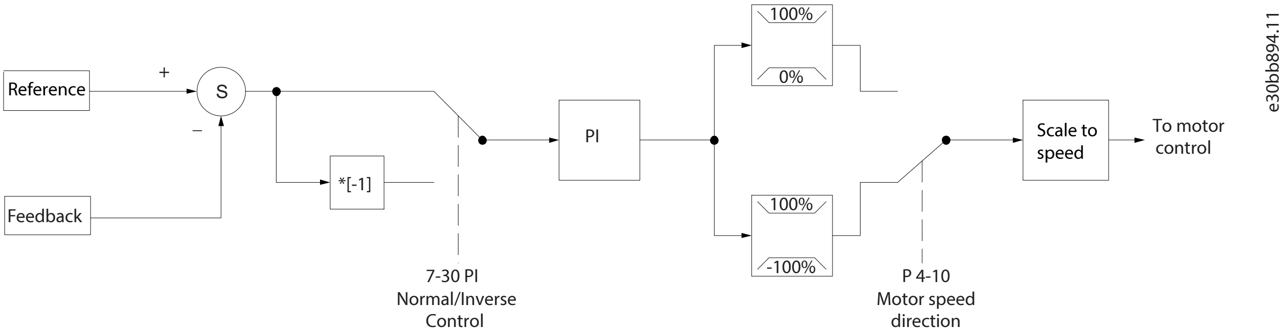

Figure 91: Control Structure Closed Loop

While the default values for the closed-loop controller of the drive often provide satisfactory performance, the control of the system can often be optimized by adjusting parameters.

8.3.6 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. See the Figure 92.

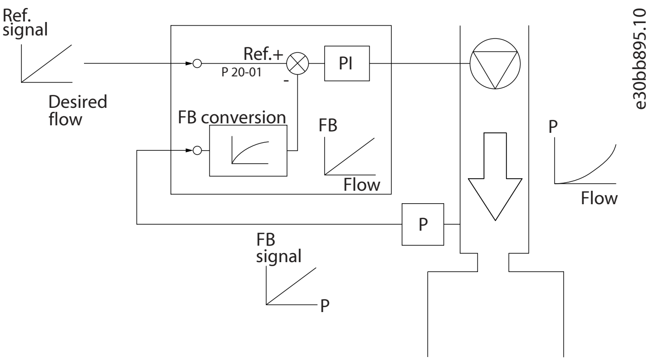

Figure 92: Feedback Signal Conversion

8.3.7 Reference Handling

Details for open-loop and closed-loop operation.

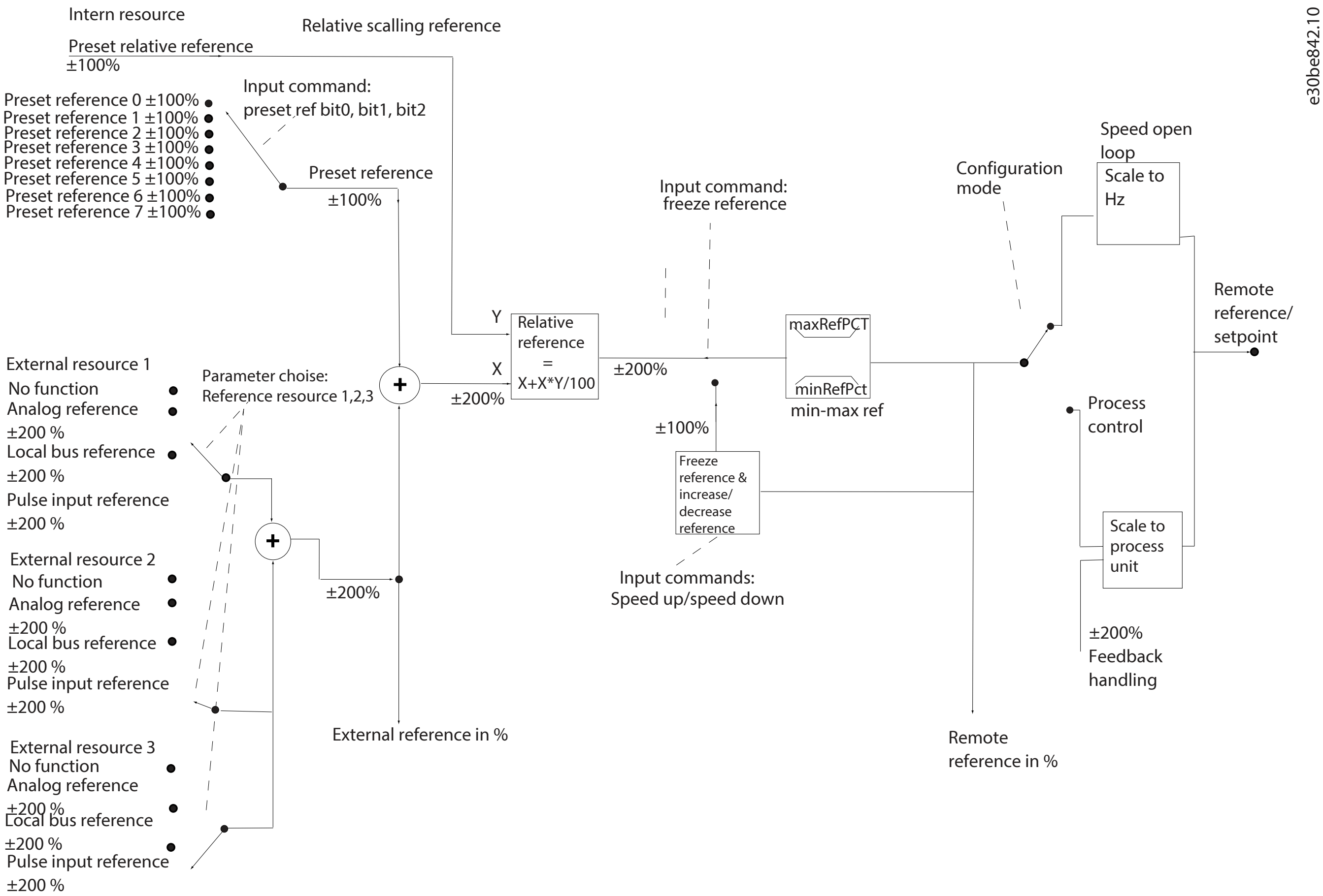

Figure 93: Block Diagram Showing Remote Reference

The remote reference consists of:

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

Up to 8 preset references can be programmed in the 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 1 of the 3 reference source parameters (parameter ***3-15 Reference 1 Source***, parameter 3-16 ***Reference 2 Source***, and parameter ***3-17 Reference 3 Source***). 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 2 can be selected to be the active reference. Finally, this reference can by be scaled using parameter ***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 parameter ***3-14 Preset Relative Reference*** in [%].

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

8.3.8 Tuning the Drive Closed-loop

Once the drive's closed-loop controller has been set up, test the performance of the controller. Often, its performance may be acceptable using the default values of parameter ***20-93 PI Proportional Gain*** and parameter ***20-94 PI Integral Time***. However, sometimes it may be helpful to optimize these parameter values to provide faster system response while still controlling speed overshoot.

8.3.9 Adjusting the Manual PI

1. Start the motor.
2. Set parameter ***20-93 PI Proportional Gain*** to 0.3 and increase it until the feedback signal begins to oscillate. If necessary, start and stop the drive or make step changes in the setpoint reference to attempt to cause oscillation.
3. Reduce the PI proportional gain until the feedback signal stabilizes.
4. Reduce the proportional gain by 40–60%.
5. Set parameter ***20-94 PI Integral Time*** to 20 s and reduce it until the feedback signal begins to oscillate. If necessary, start and stop the drive or make step changes in the setpoint reference to attempt to cause oscillation.
6. Increase the PI integral time until the feedback signal stabilizes.
7. Increase the integral time by 15–50%.

9 Application Examples

9.1 Overview of Application Examples

The following sections give typical examples of applications.

9.2 Variable Air Volume

VAV, or variable air volume systems, 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. By designing central systems instead of distributed systems, a greater efficiency can be obtained.

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

The VLT Solution

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

Centrifugal devices such as fans behave according to the centrifugal laws. This means that the fans decrease the pressure and flow they produce as their speed is reduced. Their power consumption is thereby significantly reduced. The PI controller of the drive can be used to eliminate the need for additional controllers.

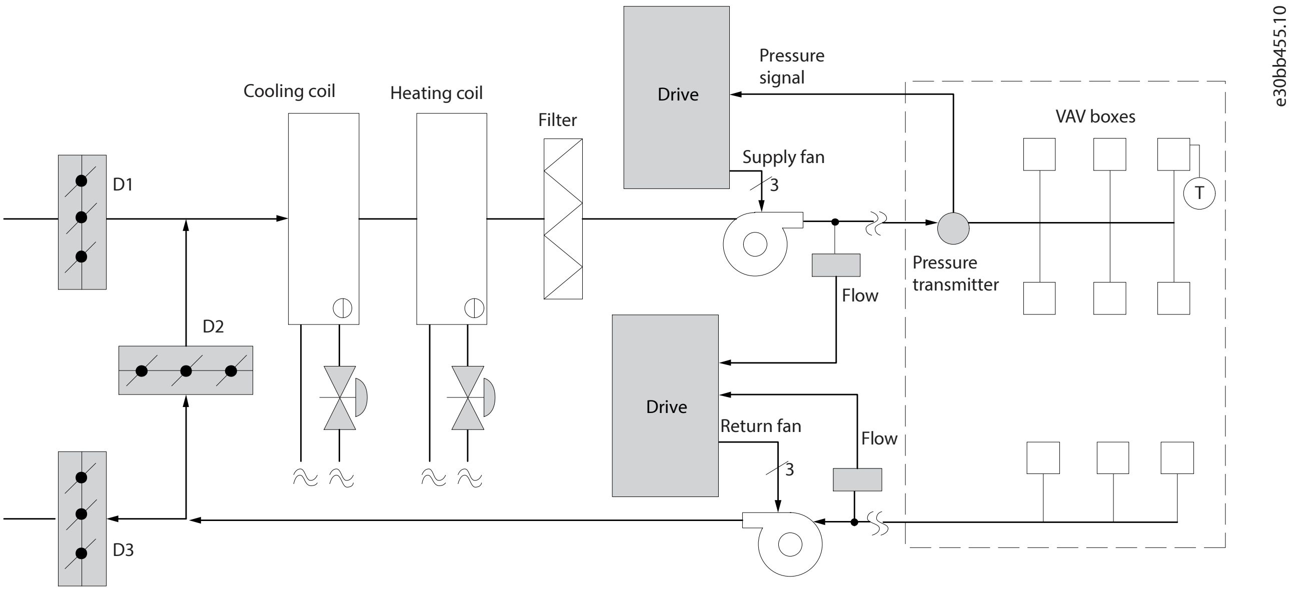

Figure 94: Variable Air Volume

9.3 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 therefore found in older multi-zoned commercial buildings as well. These systems preheat amounts of fresh air using air handling units (AHUs) with a heating coil, and many are also used to air condition buildings and have a cooling coil. Fan coil units are frequently used to assist in the heating and cooling requirements in the individual zones.

The VLT Solution

With a 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 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 fans speed. The return fan modulates to maintain a static pressure setpoint or fixed difference between the supply and return airflows.

Temperature control is especially used in air conditioning systems. As the outside temperature varies, and the number of people in the controlled zone changes, different cooling requirements exist. As the temperature decreases below the setpoint, the supply fan can decrease its speed. The return fan modulates to maintain a static pressure setpoint. By decreasing the airflow, energy used to heat or cool the fresh air is also reduced, adding further savings.

Several features of the Danfoss dedicated drive can be used to improve the performance of the 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 drive also includes a PI controller, which allows monitoring of both temperature and air quality. Even if the temperature requirement is fulfilled, the drive maintains enough supply air to satisfy the air quality sensor. The controller can monitor and compare 2 feedback signals to control the return fan by maintaining a fixed differential airflow between the supply and return ducts as well.

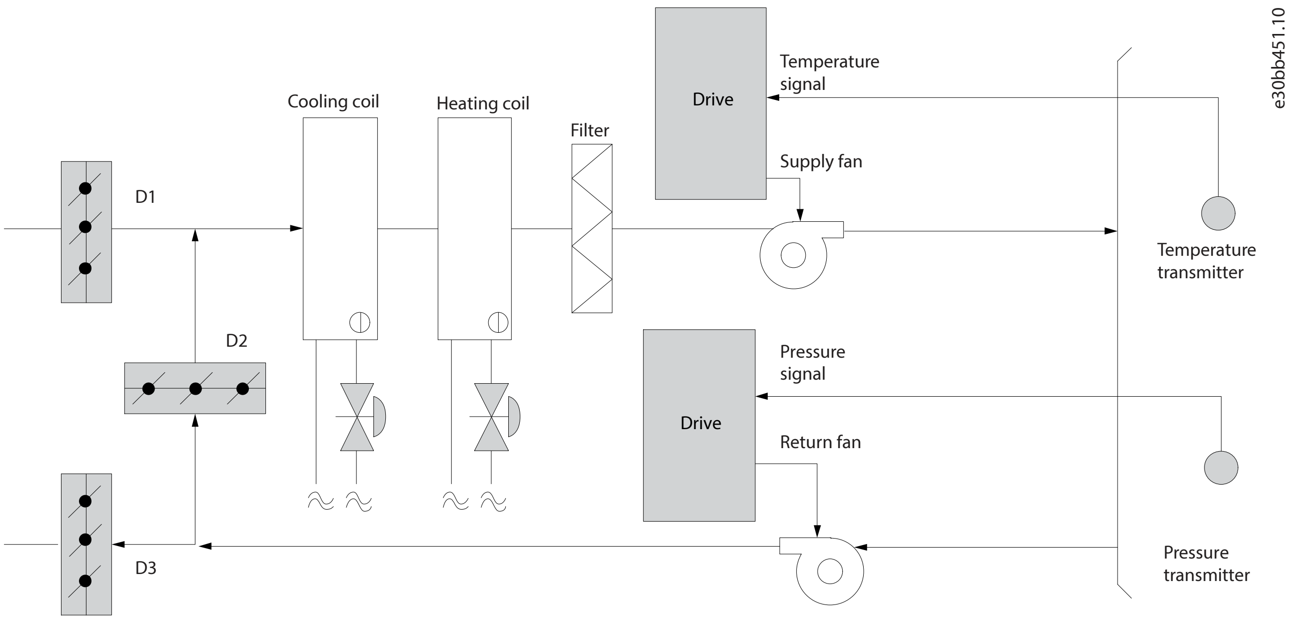

Figure 95: Constant Air Volume

9.4 Cooling Tower Fan

Cooling tower fans 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 the climate, cooling towers are often the most energy-efficient method of cooling the condenser water from chillers.

They cool the condenser water by evaporation. The condenser water is sprayed into the cooling tower until the cooling towers 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 dropping its temperature. The cooled water collects in the cooling towers basin where it is pumped back into the chillers condenser and the cycle is repeated.

The VLT Solution

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

Several features of the Danfoss dedicated drive can be used to improve the performance of cooling tower fans applications. As the cooling tower fans drop below a certain speed, the effect the fan has on cooling the water becomes small. Also, when using a gearbox to frequency control the tower fan, a minimum speed of 40–50% is 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.

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

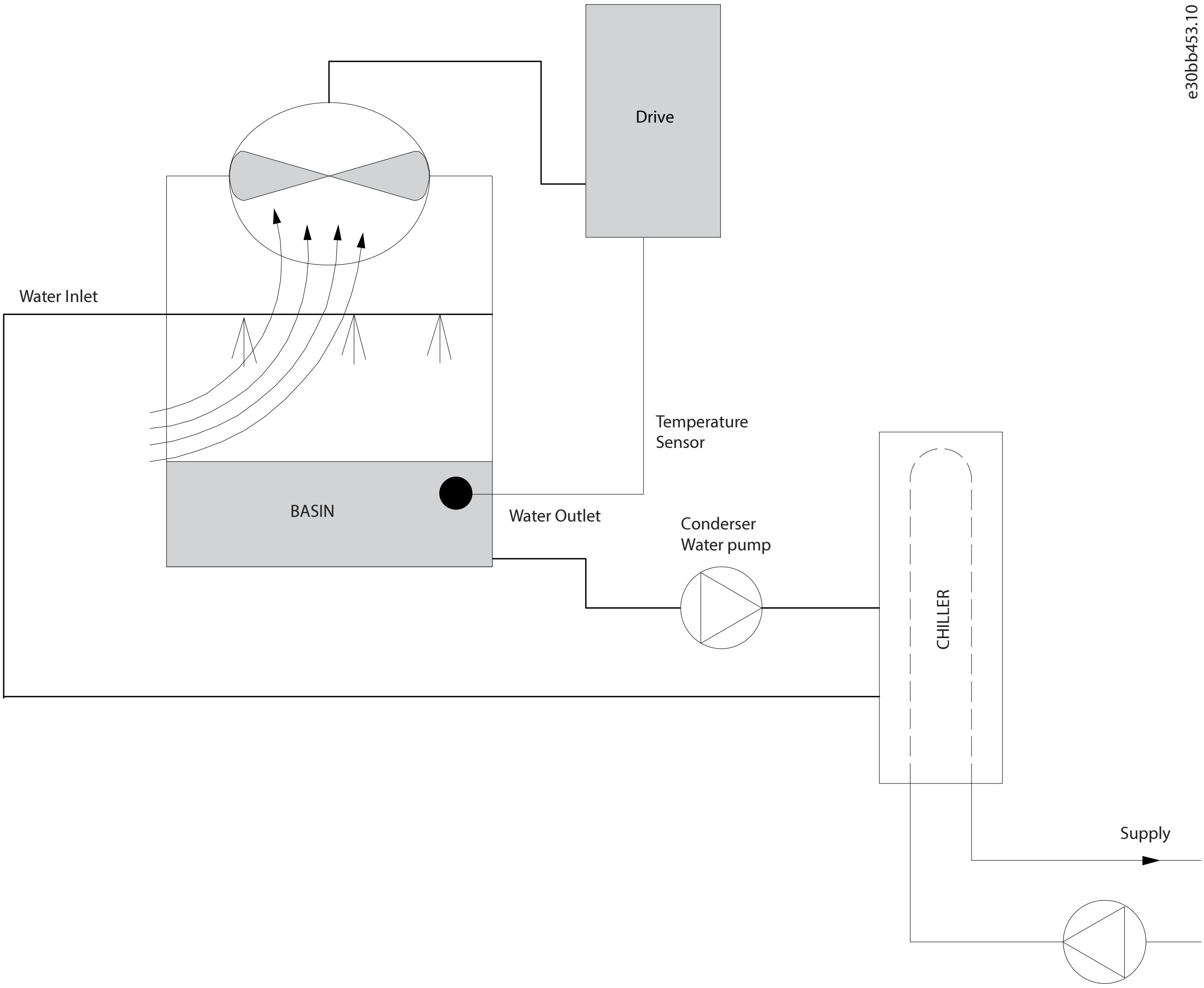

Figure 96: Cooling Tower Fan

9.5 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 chiller's condenser section and releases it into the atmosphere in the cooling tower. These systems are used to provide the most efficient means of creating chilled water, they are as much as 20% more efficient than air-cooled chillers.

The VLT Solution

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

Using a drive instead of a throttling valve simply saves the energy that would have been absorbed by the valve. This can amount to savings of 15–20% or more. Trimming the pump impeller is irreversible, thus if the conditions change and higher flow is required, the impeller must be replaced.

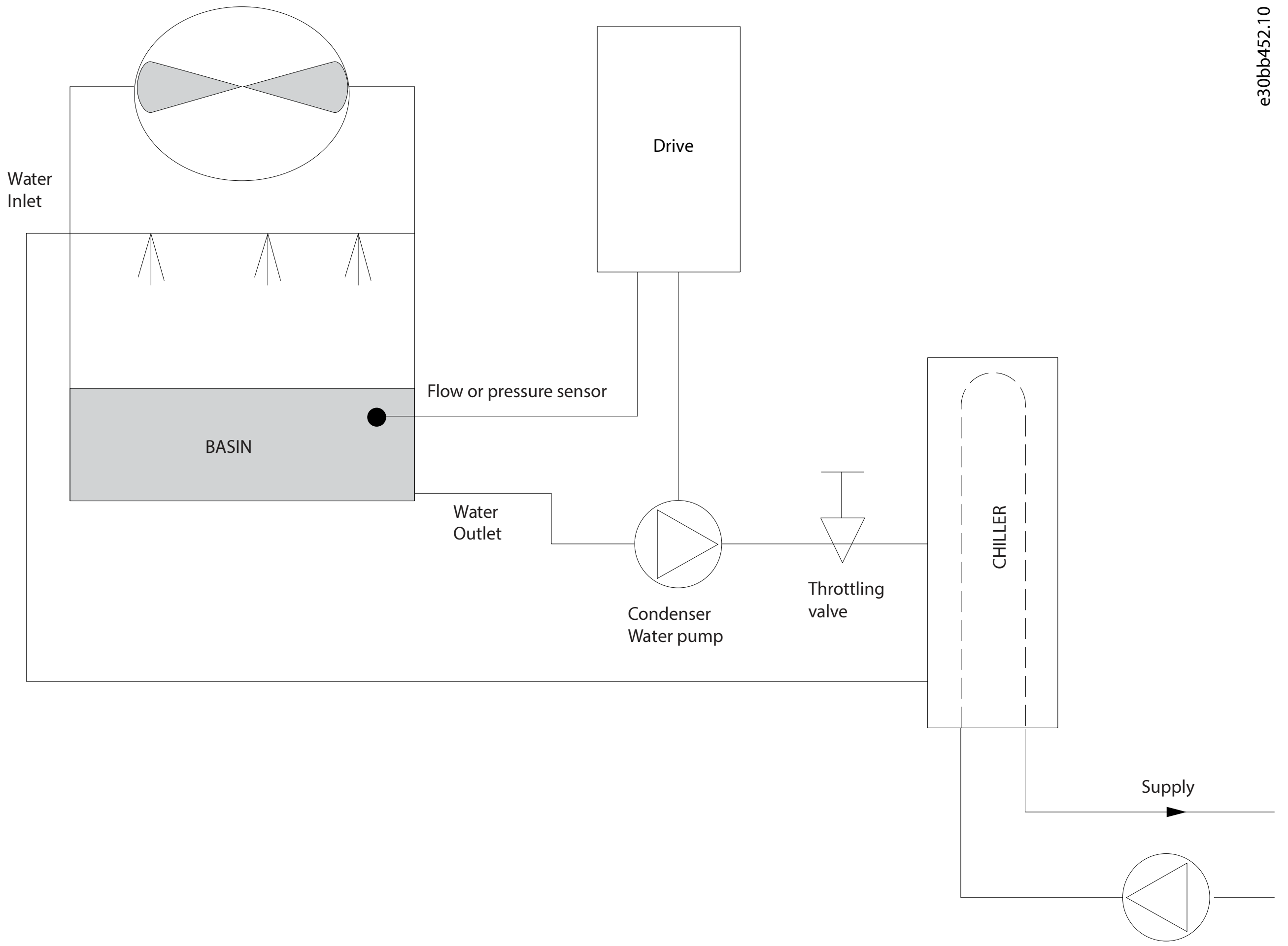

Figure 97: Condenser Pumps

9.6 Primary Pumps

Primary pumps in a primary/secondary pumping system can be used to 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. This 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 overchilled. 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 chiller's safety trips the chiller requiring a manual reset. This situation is common in large installations, especially when 2 or more chillers in parallel are installed if primary/secondary pumping is not used.

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.

A drive can be added to the primary system to replace the throttling valve and/or trimming of the impellers, leading to reduced operating expenses. 2 control methods are common:

Flow meter

Because the desired flow rate is known and is constant, a flow meter installed at the discharge of each chiller can be used to control the pump directly. Using the built-in PI controller, the 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.

Local speed determination

The operator simply decreases the output frequency until the design flow rate is achieved.

Using a drive to decrease the pump speed is similar to trimming the pump impeller, except it does not require any labor, and the pump efficiency remains higher. 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 anytime the chiller is staged on. Because the primary loop does not have control valves or other devices that can cause the system curve to change, and the variance due to staging pumps and chillers on and off is small, this fixed speed remains appropriate. If the flow rate needs to be increased later in the system's life, the drive can simply increase the pump speed instead of requiring a new pump impeller.

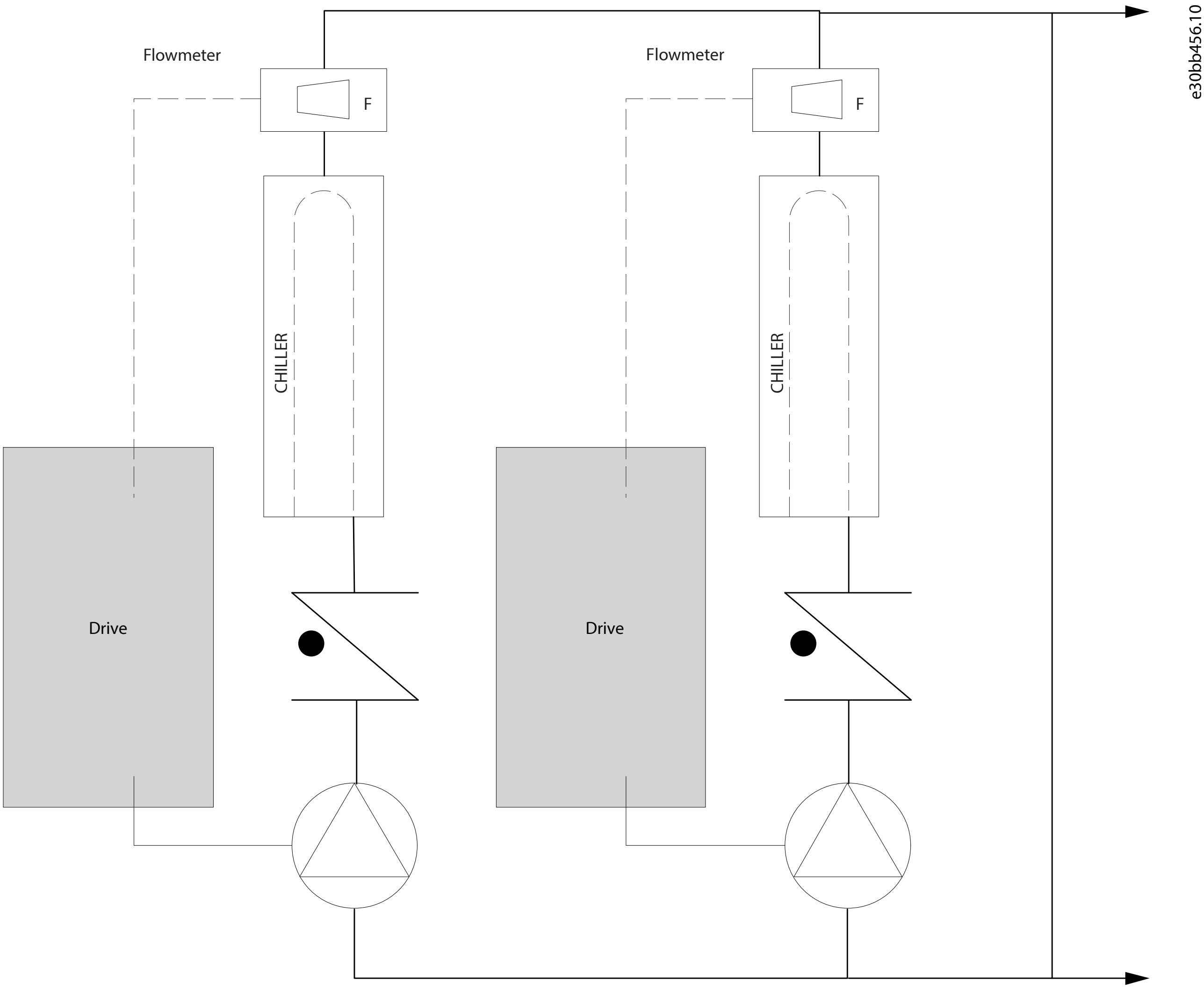

Figure 98: Primary Pumps

9.7 Secondary Pumps

Secondary pumps in a primary/secondary chilled water pumping system distribute the chilled water to the loads from the primary production loop. The primary/secondary pumping system is used to hydronically de-couple 1 piping loop from another. In this case, the primary pump is used to maintain a constant flow through the chillers while allowing the secondary pumps to vary in flow, increase control, and save energy.

If the primary/secondary concept is not used in the design of a variable volume system when the flow rate drops far enough or too quickly, the chiller cannot shed its load properly. The chiller's low evaporator temperature safety then trips the chiller requiring a manual reset. This situation is common in large installations, especially when 2 or more chillers in parallel are installed.

The VLT Solution

While the primary-secondary system with 2-way valves improves energy savings and eases system control problems, the true energy savings and control potential is realized by adding drives.

With the proper sensor location, the addition of drives allows the pumps to vary their speed to follow the system curve instead of the pump curve. This results in the elimination of wasted energy and eliminates most of the overpressurization that 2-way valves can be subjected to.

As the monitored loads are reached, the 2-way valves close down. This increases the differential pressure measured across the load and the 2-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 summing the pressure drop of the load and the 2-way valve together under design conditions.

NOTICE

When running multiple pumps in parallel, they must run at the same speed to maximize energy savings, either with individual dedicated drives or 1 drive running multiple pumps in parallel.

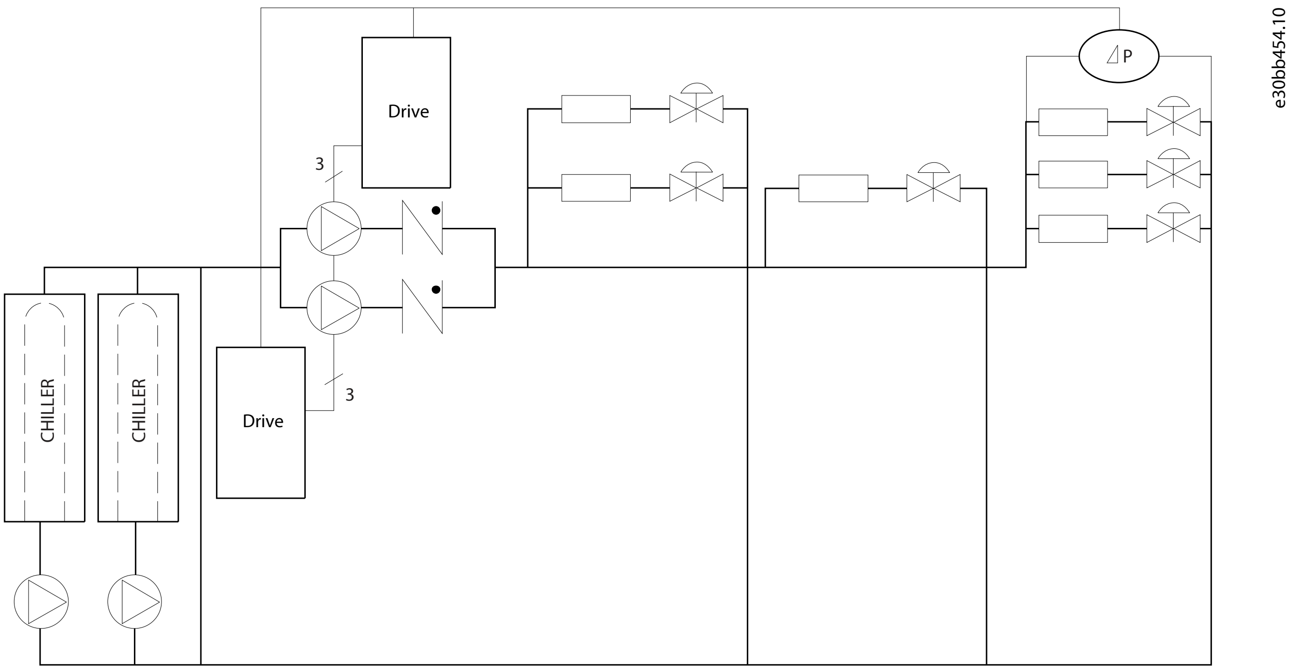

Figure 99: Secondary Pumps

10 RS485 Installation and Setup

10.1 RS485

10.1.1 Overview

RS485 is a 2-wire bus interface compatible with multi-drop network topology. The 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 1 network segment.

Repeaters divide network segments, see Figure 100.

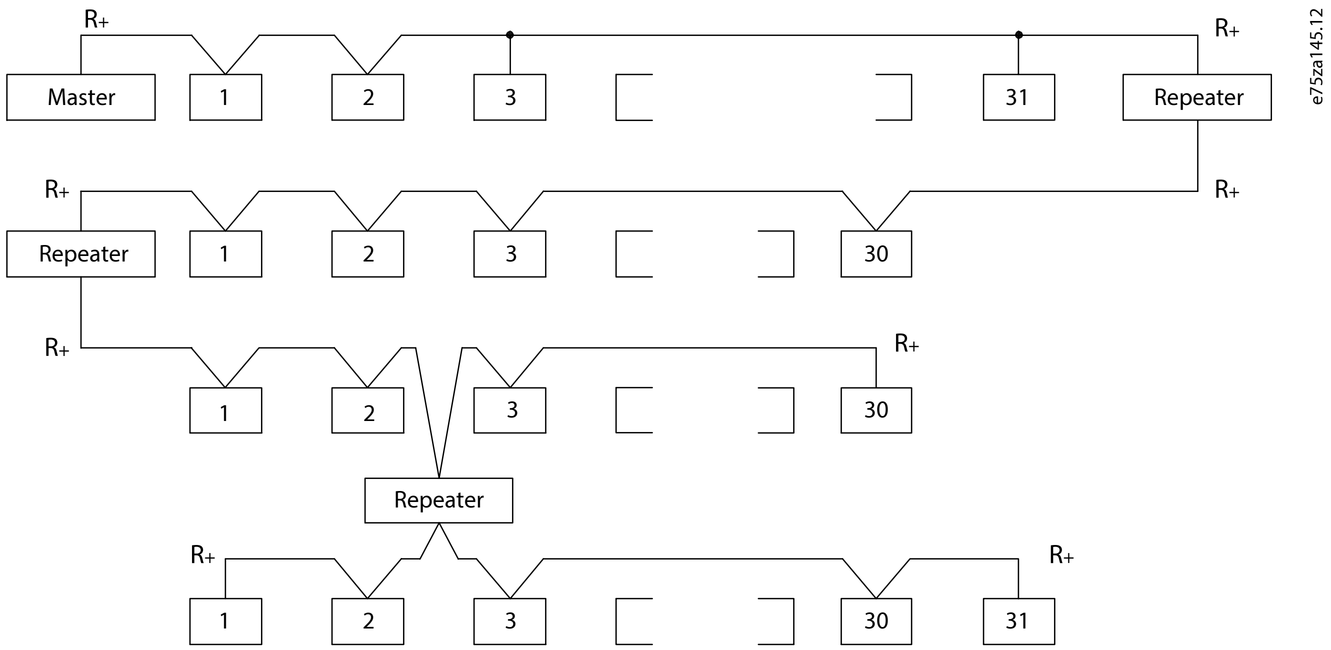

Figure 100: RS485 Bus Interface

> **NOTICE**
>
> Each repeater functions as a node within the segment in which it is installed. Each node connected within a given network must have a unique node address across all segments.

Terminate each segment at both ends, using either the termination switch (S801) of the drives or a biased termination resistor network. Always use shielded twisted pair (STP) cable for bus cabling and follow good common installation practice.

Low-impedance ground connection of the shield at every node is important, including at high frequencies. Thus, connect a large surface of the shield to ground, for example, with a cable clamp or a conductive cable gland. Sometimes, it is necessary to apply potential-equalizing cables to maintain the same ground potential throughout the network, particularly in installations with long cables.

To prevent impedance mismatch, use the same type of cable throughout the entire network. When connecting a motor to the drive, always use shielded motor cable.

Table 41: Cable Specifications

Cable	Shielded twisted pair (STP)
Impedance [Ω]	120
Cable length [m (ft)]	Maximum 1200 (3937) (including drop lines). Maximum 500 (1640) station-to-station.

10.1.2 Connecting the Drive to the RS485 Network

1. Connect signal wires to terminal 68 (P+) and terminal 69 (N-) on the main control board of the drive.

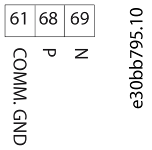

Figure 101: Network Connection

2. Connect the cable shield to the cable clamps.

NOTICE

To reduce noise between conductors, use shielded, twisted-pair cables.

10.1.3 Hardware Setup

To terminate the RS485 bus, use the terminator switch on the main control board of the drive.

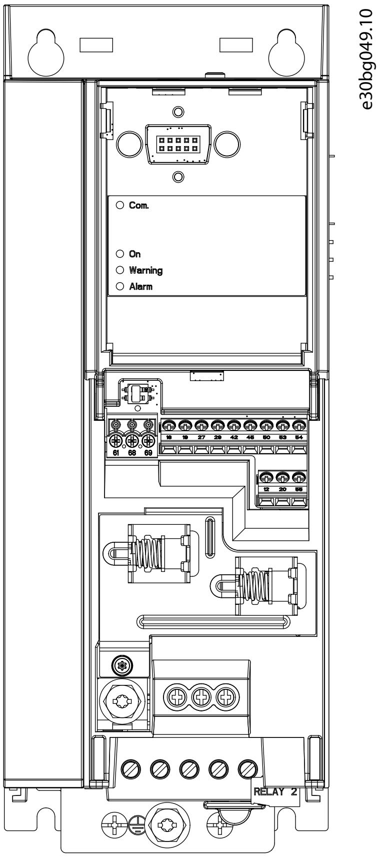

Figure 102: Terminator Switch Factory Setting

The factory setting for the switch is OFF.

10.1.4 Parameter Settings for Modbus Communication

Table 42: Modbus Communication Parameter Settings

Parameter	Function
Parameter ***8-30 Protocol***	Select the application protocol to run for the RS485 interface.
Parameter ***8-31 Address***	Set the node address. **NOTICE** The address range depends on the protocol selected in parameter ***8-30 Protocol***.
Parameter ***8-32 Baud Rate***	Set the baud rate. **NOTICE** The default baud rate depends on the protocol selected in parameter ***8-30 Protocol***.
Parameter ***8-33 Parity/Stop Bits***	Set the parity and number of stop bits. **NOTICE** The default selection depends on the protocol selected in parameter ***8-30 Protocol***.
Parameter ***8-35 Minimum Response Delay***	Specify a minimum delay time between receiving a request and transmitting a response. This function is for overcoming modem turnaround delays.
Parameter ***8-36 Maximum Response Delay***	Specify a maximum delay time between transmitting a request and receiving a response.
Parameter ***8-37 Maximum Inter-char delay***	If transmission is interrupted, specify a maximum delay time between 2 received bytes to ensure timeout. **NOTICE** The default selection depends on the protocol selected in parameter ***8-30 Protocol***.

10.1.5 EMC Precautions

To achieve interference-free operation of the RS485 network, Danfoss recommends the following EMC precautions.

NOTICE

Observe relevant national and local regulations, for example, regarding protective ground connection. To avoid coupling of high-frequency noise between the cables, keep the RS485 communication cable away from motor and brake resistor cables. Normally, a distance of 200 mm (8 in) is sufficient. Maintain the greatest possible distance between the cables, especially where cables run in parallel over long distances. When crossing is unavoidable, the RS485 cable must cross motor and brake resistor cables at an angle of 90°.

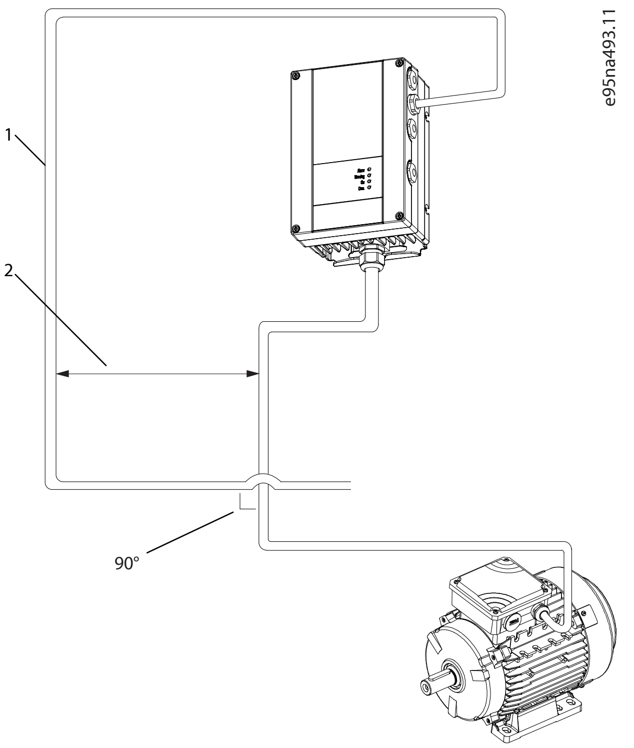

Figure 103: Minimum Distance between Communication and Power Cables

1	Fieldbus cable	**2**	Minimum 200 mm (8 in) distance

10.2 FC Protocol

10.2.1 Overview

The FC protocol, also referred to as FC bus or standard bus, is the Danfoss standard fieldbus. It defines an access technique according to the master/follower principle for communications via a fieldbus.

One master and a maximum of 126 followers can be connected to the bus. The master selects the individual followers via an address character in the telegram. A follower itself can never transmit without first being requested to do so, and direct telegram transfer between the individual followers is not possible. Communications occur in the half duplex mode.

The master function cannot be transferred to another node (single-master system).

The physical layer is RS485, thus utilizing the RS485 port built into the drive. The FC protocol supports different telegram 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.

10.2.2 FC with Modbus RTU

The FC protocol provides access to the control word and bus reference of the drive.

The control word allows the Modbus master to control several important functions of the drive:

- Start.
- Stop of the drive in various ways:
  - Coast stop.
  - Quick stop.

- DC brake stop.
- Normal (ramp) stop.

- Reset after a fault trip.
- Run at various preset speeds.
- Run in reverse.
- Change of the active setup.
- Control of the 2 relays built into the 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. Accessing the parameters offers a range of control options, including controlling the setpoint of the drive when its internal PI controller is used.

10.3 FC Protocol Network Configuration

To enable the FC protocol on the drive, set the following parameters:

Table 43: Parameters to Enable the Protocol

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

10.4 FC Protocol Message Framing Structure

10.4.1 Content of a Character (byte)

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

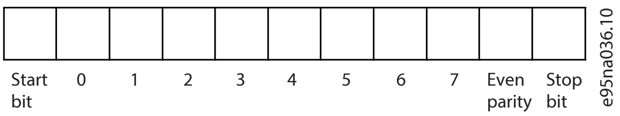

Figure 104: Content of a Character

10.4.2 Telegram Structure

Each telegram has the following structure:

- Start character (STX) = 02 hex.
- A byte denoting the telegram length (LGE).
- A byte denoting the drive address (ADR).

Several data bytes (variable, depending on the type of telegram) follow.

A data control byte (BCC) completes the telegram.

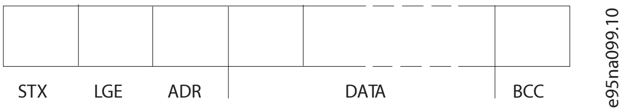

Figure 105: Telegram Structure

10.4.3 Telegram Length (LGE)

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

Table 44: Length of Telegrams

4 data bytes	LGE=4+1+1=6 bytes
12 data bytes	LGE=12+1+1=14 bytes
Telegrams containing texts	10[1]+n bytes

1) 10 represents the fixed characters, while n is variable (depending on the length of the text).

10.4.4 Drive Address (ADR)

Address format 1–126

- Bit 7 = 1 (address format 1–126 active).
- Bit 0–6 = drive address 1–126.
- Bit 0–6 = 0 broadcast.

The follower returns the address byte unchanged to the master in the response telegram.

10.4.5 Data Control Byte (BCC)

The checksum is calculated as an XOR-function. Before the 1st byte in the telegram is received, the calculated checksum is 0.

10.4.6 The Data Field

The structure of data blocks depends on the type of telegram. There are 3 telegram types, and the type applies to both control telegrams (master=>follower) and response telegrams (follower=>master).

The 3 types of telegram are:

- Process block (PCD)
- Parameter block
- Text block

Process block (PCD)

The PCD is made up of a data block of 4 bytes (2 words) and contains:

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

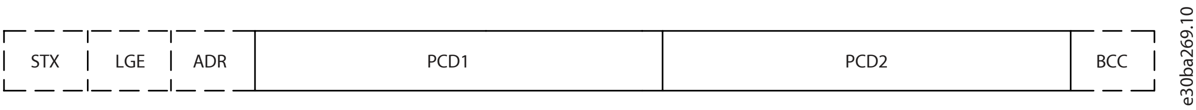

Figure 106: Process Block

Parameter block

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

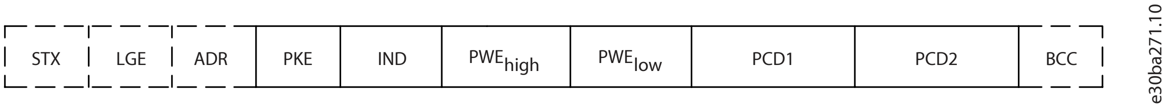

Figure 107: Parameter Block

Text block

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

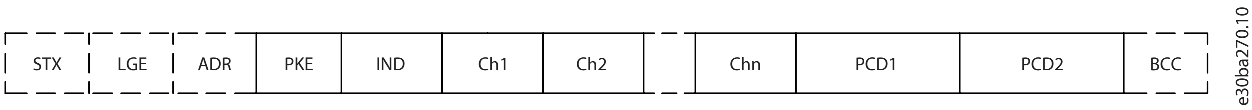

Figure 108: Text Block

10.4.7 The PKE Field

The PKE field contains 2 subfields:

- Parameter command and response (AK).
- Parameter number (PNU).

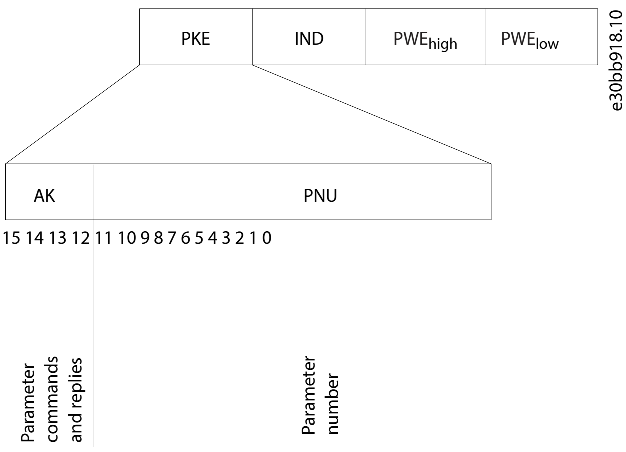

Figure 109: PKE Field

Bits 12–15 transfer parameter commands from master to follower and return processed follower responses to the master.

Table 45: Parameter Commands

Parameter commands master⇒follower				
Bit number				**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).

Table 45: Parameter Commands - (continued)

Parameter commands master⇒follower				
Bit number				**Parameter command**
1	1	1	0	Write parameter value in RAM and EEPROM (word).
1	1	1	1	Read text.

Table 46: Response

Response follower⇒master				
Bit number				**Response**
15	14	13	12	
0	0	0	0	No response.
0	0	0	1	Parameter value transferred (word).
0	0	1	0	Parameter value transferred (double word).
0	1	1	1	Command cannot be performed.
1	1	1	1	Text transferred.

If the command cannot be performed, the follower sends *0111 Command cannot be performed* response and issues the following fault reports in Table 47.

Table 47: Follower Report

Fault code	FC specification
0	Illegal parameter number.
1	Parameter cannot be changed.
2	Upper or lower limit is exceeded.
3	Sub-index is corrupted.
4	No array.
5	Wrong data type.
6	Not used.
7	Not used.
9	Description element is not available.
11	No parameter write access.
15	No text available.
17	Not applicable while running.
18	Other errors.
100	–
>100	–
130	No bus access for this parameter.
131	Write to factory setup is not possible.
132	No LCP access.
252	Unknown viewer.

Table 47: Follower Report - (continued)

Fault code	FC specification
253	Request is not supported.
254	Unknown attribute.
255	No error.

10.4.8 Parameter Number (PNU)

Bits 0–11 transfer parameter numbers. The function of the relevant parameter is defined in the parameter description in the programming guide of the drive.

10.4.9 Index (IND)

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

Only the low byte is used as an index.

10.4.10 Parameter Value (PWE)

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

When a follower responds to a parameter request (read command), the present parameter value in the PWE block is transferred and returned to the master. If a parameter contains several data options, for example, parameter ***0-01 Language***, 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).

Parameter ***15-40 FC Type*** to parameter ***15-53 Power Card Serial Number*** contain data type 9. For example, read the unit size and mains voltage range in parameter ***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 telegram length is defined in the 2nd byte of the telegram (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.

10.4.11 Data Types Supported by the Drive

Table 48: Data Types

Data types	Description
3	Integer 16
4	Integer 32
5	Unsigned 8[1]
6	Unsigned 16[1]
7	Unsigned 32[1]
9	Text string
10	Byte string
13	Time difference
33	Reserved
35	Bit sequence

1) Unsigned means that there is no operational sign in the telegram.

10.4.12 Conversion

The programming guide contains the descriptions of attributes of each parameter. Parameter values are transferred as whole numbers only. Conversion factors are used to transfer decimals.

Parameter ***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.

Table 49: Conversion

Conversion index	Conversion factor
74	3600
2	100
1	10
0	1
-1	0.1
-2	0.01
-3	0.001
-4	0.0001
-5	0.00001

10.4.13 Process Words (PCD)

The block of process words is divided into 2 blocks of 16 bits, which always occur in the defined sequence.

Table 50: Process Words (PCD)

PCD 1	PCD 2
Control telegram (master to follower control word)	Reference value
Control telegram (follower to master) status word	Present output frequency

10.5 Examples

10.5.1 Writing a Parameter Value

Change parameter ***4-14 Motor Speed High Limit [Hz]*** to 100 Hz.

Write the data in EEPROM.

PKE = E19E hex - Write single word in parameter ***4-14 Motor Speed High Limit [Hz]***:

- IND = 0000 hex.
- PWE_{HIGH} = 0000 hex.
- PWE_{LOW} = 03E8 hex.

Data value 1000, corresponding to 100 Hz, see the chapter 10.4.12 Conversion.

The telegram looks like Figure 110.

E19E H	0000 H	0000 H	03E8 H
PKE	IND	PWE$_{high}$	PWE$_{low}$

e30ba092.10

Figure 110: Telegram

> **NOTICE**
>
> Parameter ***4-14 Motor Speed High Limit [Hz]*** is a single word, and the parameter command for write in EEPROM is E. Parameter ***4-14 Motor Speed High Limit [Hz]*** is 19E in hexadecimal.

The response from the follower to the master is shown in Figure 111.

119E H	0000 H	0000 H	03E8 H
PKE	IND	PWE$_{high}$	PWE$_{low}$

e30ba093.10

Figure 111: Response from Master

10.5.2 Reading a Parameter Value

Read the value in parameter ***3-41 Ramp 1 Ramp Up Time***.

PKE = 1155 hex - Read parameter value in parameter ***3-41 Ramp 1 Ramp Up Time***:

- IND = 0000 hex.
- PWE_{HIGH} = 0000 hex.
- PWE_{LOW} = 0000 hex.

1155 H	0000 H	0000 H	0000 H
PKE	IND	PWE$_{high}$	PWE$_{low}$

e30ba094.10

Figure 112: Telegram

If the value in parameter ***3-41 Ramp 1 Ramp Up Time*** is 10 s, the response from the follower to the master is shown in Figure 113.

1155 H	0000 H	0000 H	03E8 H
PKE	IND	PWE$_{high}$	PWE$_{low}$

e30ba267.10

Figure 113: Response

3E8 hex corresponds to 1000 decimal. The conversion index for parameter ***3-41 Ramp 1 Ramp Up Time*** is -2, that is, 0.01.

Parameter ***3-41 Ramp 1 Ramp Up Time*** is of the type Unsigned 32.

10.6 Modbus RTU

10.6.1 Prerequisite Knowledge

Danfoss assumes that the installed controller supports the interfaces in this manual and strictly observes all requirements and limitations stipulated in the controller and the drive.

The built-in Modbus RTU (remote terminal unit) is designed to communicate with any controller that supports the interfaces defined in this manual. It is assumed that the user has full knowledge of the capabilities and limitations of the controller.

10.6.2 Modbus RTU Overview

Regardless of the type of physical communication networks, this section describes the process that 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 telegram fields.

During communications over a Modbus RTU network, the protocol:

- Determines how each controller learns its device address.
- Recognizes a telegram addressed to it.
- Determines which actions to take.
- Extracts any data or other information contained in the telegram.

If a reply is required, the controller constructs the reply telegram and sends it.

Controllers communicate using a master/follower technique in which only the master can initiate transactions (called queries). Followers respond by supplying the requested data to the master, or by acting as requested in the query. The master can address individual followers, or initiate a broadcast telegram to all followers. Followers return a response to queries that are addressed to them individually. No responses are returned to broadcast queries from the master.

The Modbus RTU protocol establishes the format for the master query by providing the following information:

- The device (or broadcast) address.
- A function code defining the requested action.
- Any data to be sent.
- An error-checking field.

The response telegram of the follower device 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 telegram, or if the follower is unable to perform the requested action, the follower constructs and sends an error message. Alternatively, a timeout occurs.

10.6.3 Drive with Modbus RTU

The drive communicates in Modbus RTU format over the built-in RS485 interface. Modbus RTU provides access to the control word and bus reference of the drive.

The control word allows the Modbus master to control several important functions of the drive:

- Start.
- Various stops:
  - Coast stop.
  - Quick stop.
  - DC brake stop.
  - Normal (ramp) stop.
- Reset after a fault trip.
- Run at various preset speeds.
- Run in reverse.
- Change the active setup.
- Control built-in relay of the 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. Accessing the parameters offers a range of control options, including controlling the setpoint of the drive when its internal PI controller is used.

10.7 Modbus RTU Network Configuration

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

Table 51: Parameters to Enable the Protocol

Parameter	Setting
Parameter ***8-30 Protocol***	Modbus RTU
Parameter ***8-31 Address***	1–247
Parameter ***8-32 Baud Rate***	2400–115200
Parameter ***8-33 Parity/Stop Bits***	Even parity, 1 stop bit (default)

10.8 Modbus RTU Message Framing Structure

10.8.1 Modbus RTU Message Byte Format

The controllers are set up to communicate on the Modbus network using RTU (remote terminal unit) mode, with each byte in a telegram containing 2 4-bit hexadecimal characters. The format for each byte is shown in the following table.

Table 52: Format for Each Byte

<table>
<tr><th>Start bit</th><th colspan="8">Data byte</th><th>Stop/ parity</th><th>Stop</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 53: Byte Details

Coding system	8-bit binary, hexadecimal 0–9, A–F. 2 hexadecimal characters contained in each 8-bit field of the telegram.
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	Cyclic redundancy check (CRC).

10.8.2 Modbus RTU Telegram Structure

The transmitting device places a Modbus RTU telegram into a frame with a known beginning and ending point. This allows receiving devices to begin at the start of the telegram, read the address portion, determine which device is addressed (or all devices, if the telegram is broadcast), and to recognize when the telegram is completed. Partial telegrams are detected and errors set as a result. Characters for transmission must be in hexadecimal 00–FF format in each field. The drive continuously monitors the network bus, also during silent intervals. When the 1st field (the address field) is received, each drive or device decodes it to determine which device is being addressed. Modbus RTU telegrams addressed to 0 are broadcast telegrams. No response is allowed for broadcast telegrams. A typical telegram frame is shown in the following table.

Table 54: Typical Modbus RTU Telegram Structure

Start	Address	Function	Data	CRC check	End
T1-T2-T3-T4	8 bits	8 bits	N x 8 bits	16 bits	T1-T2-T3-T4

10.8.3 Start/Stop Field

Telegrams start with a silent period of at least 3.5 character intervals. The silent period is implemented as a multiple of character intervals at the selected network baud rate (shown as Start T1-T2-T3-T4). The 1st 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 telegram. A new telegram can begin after this period.

Transmit the entire telegram frame 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 telegram and assumes that the next byte is the address field of a new telegram. Similarly, if a new telegram begins before 3.5 character intervals after a previous telegram, the receiving device considers it a continuation of the previous telegram. This behavior causes a timeout (no response from the follower), since the value in the final CRC field is not valid for the combined telegrams.

10.8.4 Address Field

The address field of a telegram frame contains 8 bits. Valid follower device addresses are in the range of 0–247 decimal. The individual follower devices are assigned addresses in the range of 1–247. 0 is reserved for broadcast mode, which all slaves recognize. A master addresses a follower by placing the follower address in the address field of the telegram. When the follower sends its response, it places its own address in this address field to let the master know which follower is responding.

10.8.5 Function Field

The function field of a telegram frame contains 8 bits. Valid codes are in the range of 1–FF. Function fields are used to send telegrams between master and follower. When a telegram is sent from a master to a follower device, the function code field tells the follower what kind of action to perform. When the follower responds to the master, it uses the function code field to indicate either a normal (error-free) response, or that some kind of error occurred (called an exception response).

For a normal response, the follower simply echoes the original function code. For an exception response, the follower returns a code that is equivalent to the original function code with its most significant bit set to logic 1. In addition, the follower places a unique code into the data field of the response telegram. This code tells the master what kind of error occurred, or the reason for the exception. Also refer to *chapter Function Codes Supported by Modbus RTU* and *chapter Modbus Exception Codes*.

10.8.6 Data Field

The data field is constructed using sets of 2 hexadecimal digits, in the range of 00–FF hexadecimal. These digits are made up of 1 RTU character. The data field of telegrams sent from a master to a follower device contains additional information which the follower must use to perform accordingly.

The information can include items such as:

- Coil or register addresses.
- The quantity of items to be handled.
- The count of actual data bytes in the field.

10.8.7 CRC Check Field

Telegrams include an error-checking field, operating based on a cyclic redundancy check (CRC) method. The CRC field checks the contents of the entire telegram. It is applied regardless of any parity check method used for the individual characters of the telegram. The transmitting device calculates the CRC value and appends the CRC as the last field in the telegram. The receiving device recalculates a CRC during receipt of the telegram and compares the calculated value to the actual value received in the CRC field. 2 unequal values result in bus timeout. The error-checking field contains a 16-bit binary value implemented as 2 8-bit bytes. After the implementation, 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 telegram.

10.8.8 Coil Register Addressing

10.8.8.1 Introduction

In Modbus, all data is organized in coils and holding registers. Coils hold a single bit, whereas holding registers hold a 2 byte word (that is 16 bits). All data addresses in Modbus telegrams are referenced to 0. The 1st occurrence of a data item is addressed as item number 0. 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 telegram. 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 telegram. 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).

10.8.8.2 Coil Register

Table 55: Coil Register

Coil number	Description	Signal direction
1–16	Drive control word.	Master to follower
17–32	Drive speed or setpoint reference range 0x0– 0xFFFF (-200% ... ~200%).	Master to follower
33–48	Drive status word.	Follower to master
49–64	Open-loop mode: Drive output frequency. Closed-loop mode: Drive feedback signal.	Follower to master
65	Parameter write control (master to follower).	Master to follower
	0 = Parameter changes are written to the RAM of the drive.	
	1 = Parameter changes are written to the RAM and EEPROM of the drive.	
66–65536	Reserved.	–

10.8.8.3 Drive Control Word (FC Profile)

Table 56: Drive Control Word (FC Profile)

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 frequency	No freeze frequency
07	Ramp stop	Start
08	No reset	Reset
09	No jog	Jog
10	Ramp 1	Ramp 2
11	Data not valid	Data valid

Table 56: Drive Control Word (FC Profile) - (continued)

Coil	0	1
12	Relay 1 off	Relay 1 on
13	Relay 2 off	Relay 2 on
14	Set up lsb	
15	–	
16	No reversing	Reversing

10.8.8.4 Drive Status Word (FC Profile)

Table 57: Drive Status Word (FC Profile)

Coil	0	1
33	Control not ready	Control ready
34	Drive not ready	Drive ready
35	Coast 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-on mode	Auto mode
43	Out of frequency 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

10.8.8.5 Address/Registers

Table 58: Address/Registers

Bus address	Bus register(1)	PLC register	Content	Access	Description
0	1	40001	Reserved	–	Reserved for legacy frequency converters VLT® 5000 and VLT® 2800.
1	2	40002	Reserved	–	Reserved for legacy frequency converters VLT® 5000 and VLT® 2800.
2	3	40003	Reserved	–	Reserved for legacy frequency converters VLT® 5000 and VLT® 2800.
3	4	40004	Free	–	–
4	5	40005	Free	–	–

Table 58: Address/Registers - (continued)

Bus address	Bus register[1]	PLC register	Content	Access	Description
5	6	40006	Modbus configuration	Read/Write	TCP only. Reserved for Modbus TCP (parameter ***12-28 Store Data Values*** and parameter ***12-29 Store*** Always - stored in, for example, EEPROM).
6	7	40007	Last fault code	Read only	Fault code received from parameter database, refer to WHAT 38295 for details.
7	8	40008	Last error register	Read only	Address of register with which last error occurred, refer to WHAT 38296 for details.
8	9	40009	Index pointer	Read/Write	Sub-index of parameter to be accessed. Refer to WHAT 38297 for details.
9	10	40010	Parameter ***0-01 Language***	Dependent on parameter access	Parameter ***0-01 Language*** (Modbus register = 10 parameter number) 20 bytes space reserved for parameter in Modbus map.
19	20	40020	Free	–	–
29	30	40030	Parameter ***0-03 Regional Settings***	Dependent on parameter access	Parameter ***0-03 Regional Settings***20 bytes space reserved for parameter in Modbus map.

1) Value written in the Modbus RTU telegram must be 1 or less than the register number. For example, Read Modbus Register 1 by writing value 0 in the telegram.

10.8.9 Access via PCD Write/Read

The advantage of using the PCD write/read configuration is that the controller can write or read more data in 1 telegram. Up to 63 registers can be read or written to via the function code read holding register or write multiple registers in 1 telegram. The structure is also flexible so that only 2 registers can be written to and 10 registers can be read from the controller.

The PCD write list is data sent from the controller to the drive, the data includes control word, reference, and application-dependent data like minimum reference and ramp times, and so on.

NOTICE

The control word and reference is always sent in the list from the controller to the drive.

The PCD write list is set up in parameter ***8-42 PCD Write Configuration***.

The PCD read list is data sent from the drive to the controller like status word, main actual value, and application dependent data like running hours, motor current, and alarm word.

NOTICE

The status word and main actual value is always sent in the list from the drive to the controller.

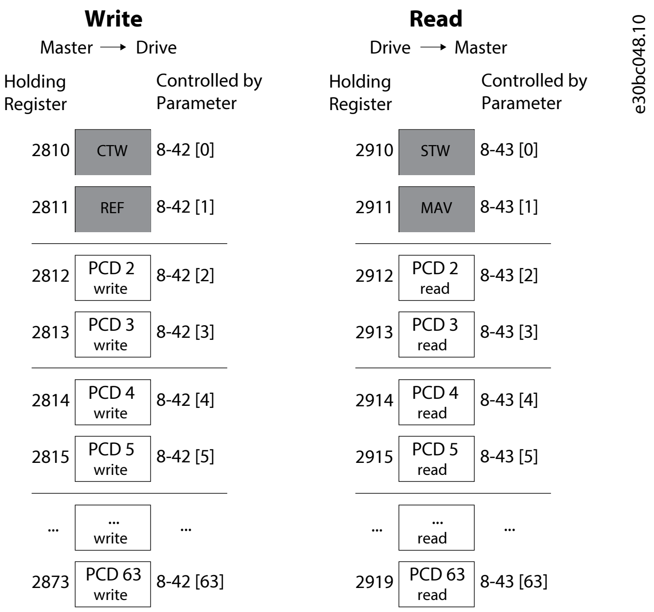

Figure 114: Accessing via PCD write/read

NOTICE

The boxes marked in gray are not changeable, they are default values.

NOTICE

The 32-bit parameters must be mapped inside the 32-bit boundaries (PCD2 and PCD3, or PCD4 and PCD5, and so on), where the number is mapped twice to parameter ***8-42 PCD Write Configuration***or parameter ***8-43 PCD Read Configuration***.

10.8.10 How to Control the Drive

10.8.10.1 Introduction

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

10.8.10.2 Function Codes Supported by Modbus RTU

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

Table 59: Function Codes

Function	Function code (hex)
Read coils	1
Read holding registers	3
Write single coil	5
Write single register	6
Diagnostics	8
Get comm. event counter	B
Write multiple coils	F
Write multiple registers	10
Report follower ID	11

Table 59: Function Codes - (continued)

Function	Function code (hex)
Read/write multiple registers	17
Encapsulated Interface Transport	2b

Table 60: Subfunction Code of Function Code 8

Function	Function code	Subfunction code	Subfunction
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 follower error count.
		14	Return follower message count.

10.8.10.3 Modbus Exception Codes

For a full explanation of the structure of an exception code response, refer to 10.8.5 Function Field.

Table 61: Modbus Exception Codes

Code	Name	Meaning
1	Illegal function	The function code received in the query is not an allowable action for the server (or follower). This may be because the function code is only applicable to newer devices and was not implemented in the unit selected. It could also indicate that the server (or follower) is in the wrong state to process a request of this type, for example, because it is not configured and is being asked to return register values.
2	Illegal data address	The data address received in the query is not an allowable address for the server (or follower). More specifically, the combination of reference number and transfer length is invalid. For a controller with 100 registers, a request with offset 96 and length 4 succeeds, while a request with offset 96 and length 5 generates exception 02.
3	Illegal data value	A value contained in the query data field is not an allowable value for server (or follower). This indicates a fault in the structure of the remainder of a complex request, such as that the implied length is incorrect. It 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 value of any register.
4	Follower device failure	An unrecoverable error occurred while the server (or follower) was attempting to perform the requested action.

10.9 How to Access Parameters

10.9.1 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.

Examples

- Reading parameter ***3-12 Catch up/slow Down Value*** (16 bit): The holding register 3120 holds the values of the parameters. A value of 1352 (decimal) means that the parameter is set to 12.52%.

- Reading parameter ***3-14 Preset Relative Reference*** (32 bit): The holding registers 3410 and 3411 hold the parameters' values. A value of 11300 (decimal) means that the parameter is set to 1113.00.

For information on the parameters, size, and conversion index, see the programming guide of the drive.

10.9.2 Storage of Data

The coil 65 decimal determines whether data written to the drive is stored in EEPROM and RAM (coil 65 = 1), or only in RAM (coil 65 = 0).

10.9.3 IND (Index)

Some parameters in the drive are array parameters, for example, parameter ***3-10 Preset Reference***. Since the Modbus does not support arrays in the holding registers, the drive has reserved the holding register 9 as pointer to the array. Before reading or writing an array parameter, set the holding register 9. Setting holding register to the value of 2 causes all following read/write to array parameters to be to the index 2.

10.9.4 Text Blocks

Parameters stored as text strings are accessed in the same way as the other parameters. The maximum text block size is 20 characters. If a read request for a parameter is for more characters than the parameter stores, the response is truncated. If the read request for a parameter is for fewer characters than the parameter stores, the response is space filled.

10.9.5 Conversion Factor

A parameter value can only be transferred as a whole number. To transfer decimals, use a conversion factor.

10.9.6 Parameter Values

Standard data types

Standard data types are int 16, int 32, uint 8, uint 16, and uint 32. They are stored as 4x registers (40001–4FFFF). The parameters are read using function 03 hex read holding registers. Parameters are written using the function 6 hex preset single register for 1 register (16 bits), and the function 10 hex preset multiple registers for 2 registers (32 bits). Readable sizes range from 1 register (16 bits) up to 10 registers (20 characters).

Non-standard data types

Non-standard data types are text strings and are stored as 4x registers (40001–4FFFF). The parameters are read using function 03 hex read holding registers and written using function 10 hex preset multiple registers. Readable sizes range from 1 register (2 characters) up to 10 registers (20 characters).

10.10 Examples

10.10.1 Introduction

The following examples show various Modbus RTU commands.

10.10.2 Read Coil Status (01 hex)

Description

This function reads the ON/OFF status of discrete outputs (coils) in the drive. Broadcast is never supported for reads.

Query

The query telegram specifies the starting coil and quantity of coils to be read. Coil addresses start at 0, that is, coil 33 is addressed as 32.

Example of a request to read coils 33–48 (status word) from follower device 01.

Table 62: Query

Field name	Example (hex)
Follower address	01 (drive address)
Function	01 (read coils)
Starting address HI	00
Starting address LO	20 (32 decimals) coil 33
Number of points HI	00
Number of points LO	10 (16 decimals)
Error check (CRC)	–

Response

The coil status in the response telegram is packed as 1 coil per bit of the data field. Status is indicated as: 1 = ON; 0 = OFF. The lsb of the 1st 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 values 0 (toward the high-order end of the byte). The byte count field specifies the number of complete bytes of data.

Table 63: Response

Field name	Example (hex)
Follower address	01 (drive address)
Function	01 (read coils)
Byte count	02 (2 bytes of data)
Data (coils 40–33)	07
Data (coils 48–41)	06 (STW = 0607hex)
Error check (CRC)	–

NOTICE

Coils and registers are addressed explicitly with an offset of -1 in Modbus. For example, coil 33 is addressed as coil 32.

10.10.3 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 followers.

Query

The query telegram specifies the coil 65 (parameter write control) to be forced. Coil addresses start at 0, that is, coil 65 is addressed as 64. Force data = 00 00 hex (OFF) or FF 00 hex (ON).

Table 64: Query

Field name	Example (hex)
Follower address	01 (drive address)
Function	05 (write single coil)
Coil address HI	00

Table 64: Query - (continued)

Field name	Example (hex)
Coil address LO	40 (64 decimal) Coil 65
Force data HI	FF
Force data LO	00 (FF 00 = ON)
Error check (CRC)	–

Response

The normal response is an echo of the query, returned after the coil state has been forced.

Table 65: Response

Field name	Example (hex)
Follower 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)	–

10.10.4 Force/Write Multiple Coils (0F hex)

Description

This function forces each coil in a sequence of coils to either on or off. When broadcasting, the function forces the same coil references in all attached followers.

Query

The query telegram specifies the coils 17–32 (speed setpoint) to be forced.

NOTICE

Coil addresses start at 0, that is, coil 17 is addressed as 16.

Table 66: Query

Field name	Example (hex)
Follower address	01 (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

Table 66: Query - (continued)

Field name	Example (hex)
Force data LO (Coils 16–9)	00 (reference = 2000 hex)
Error check (CRC)	–

Response

The normal response returns the follower address, function code, starting address, and quantity of coils forced.

Table 67: Response

Field name	Example (hex)
Follower address	01 (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)	–

10.10.5 Read Holding Registers (03 hex)

Description

This function reads the contents of holding registers in the follower.

Query

The query telegram specifies the starting register and quantity of registers to be read. Register addresses start at 0, that is, registers 1–4 are addressed as 0–3.

Example: Read parameter ***3-03 Maximum Reference***, register 03030.

Table 68: Query

Field name	Example (hex)
Follower address	01
Function	03 (Read holding registers)
Starting address HI	0B (Register address 3029)
Starting address LO	D5 (Register address 3029)
Number of points HI	00
Number of points LO	02 – (parameter ***3-03 Maximum Reference*** is 32 bits long, that is, 2 registers)
Error check (CRC)	–

Response

The register data in the response telegram is packed as 2 bytes per register, with the binary contents right justified within each byte. For each register, the 1st byte contains the high-order bits, and the 2nd contains the low-order bits.

Example: hex 000088B8 = 35.000 = 35 Hz.

Table 69: Response

Field name	Example (hex)
Follower 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)	–

10.10.6 Preset Single Register (06 hex)

Description

This function presets a value into a single holding register.

Query

The query telegram specifies the register reference to be preset. Register addresses start at 0, that is, register 1 is addressed as 0.

Example: Write to parameter ***1-00 Configuration Mode***, register 1000.

Table 70: Query

Field name	Example (hex)
Follower 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)	–

Response

The normal response is an echo of the query, returned after the register contents have been passed.

Table 71: Response

Field name	Example (hex)
Follower address	01
Function	06
Register address HI	03
Register address LO	E7
Preset data HI	00
Preset data LO	01
Error check (CRC)	–

10.10.7 Preset Multiple Registers (10 hex)

Description

This function presets values into a sequence of holding registers.

Query

The query telegram specifies the register references to be preset. Register addresses start at 0, that is, register 1 is addressed as 0.
Example of a request to preset 2 registers (set parameter ***1-24 Motor Current*** to 738 (7.38 A)):

Table 72: Query

Field name	Example (hex)
Follower address	01
Function	10
Starting address HI	04
Starting address LO	07
Number of registers HI	00
Number 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)	–

Response

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

Table 73: Response

Field name	Example (hex)
Follower address	01
Function	10
Starting address HI	04
Starting address LO	19
Number of registers HI	00
Number of registers LO	02
Error check (CRC)	–

10.10.8 Read/Write Multiple Registers (17 hex)

Description

This function code performs a combination of 1 read operation and 1 write operation in a single Modbus transaction. The write operation is performed before read.

Query

The query message specifies the starting address and number of holding registers to be read as well as the starting address, number of holding registers, and the data to be written. Holding registers are addressed starting at 0. Example of a request to set parameter ***1-24 Motor Current*** to 738 (7.38 A) and read parameter ***3-03 Maximum Reference***which has value 50000 (50,000 Hz):

Table 74: Query

Field name	Example (hex)
Follower address	01
Function	17
Reading starting address HI	0B (Register address 3029)
Reading starting address LO	D5 (Register address 3029)
Quantity to read HI	00
Quantity to read LO	02 (Parameter ***3-03 Maximum Reference*** is 32 bits long, that is, 2 registers)
Write starting address HI	04 (Register address 1239)
Write starting address LO	D7 (Register address 1239)
Quantity to write HI	00
Quantity to write LO	02
Write byte count	04
Write registers value HI	00
Write registers value LO	00
Write registers value HI	02
Write registers value LO	OE
Error check (CRC)	–

Response

The normal response contains the data from the group of registers that were read. The byte count field specifies the quantity of bytes to follow in the read data field.

Table 75: Response

Field name	Example (hex)
Follower address	01
Function	17
Byte count	04
Read registers value HI	00
Read registers value LO	00
Read registers value HI	C3
Read registers value LO	50
Error check (CRC)	–

10.11 Danfoss FC Control Profile

10.11.1 Control Word According to FC Profile (8-10 Protocol = FC Profile)

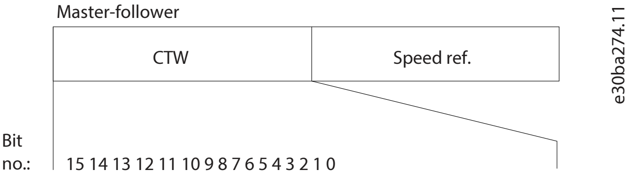

Figure 115: Control Word According to FC Profile

Table 76: Control Word According to FC Profile

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

Explanation of the control bits

Bits 00/01

Bits 00 and 01 are used to select among the 4 reference values, which are preprogrammed in parameter ***3-10 Preset Reference*** according to the following table.

Table 77: Control Bits

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

NOTICE

In parameter ***8-56 Preset Reference Select***, define how bit 00/01 gates with the corresponding function on the digital inputs.

Bit 02, DC brake

Bit 02 = 0: Leads to DC brake and stop. Set braking current and duration in parameter ***2-01 DC Brake Current*** and parameter ***2-02 DC Braking Time***.

Bit 02 = 1: Leads to ramping.

Bit 03, Coasting

Bit 03 = 0: The drive immediately releases the motor (the output transistors are shut off), and it coasts to a standstill.

Bit 03 = 1: If the other starting conditions are met, the drive starts the motor.

In parameter ***8-50 Coasting Select***, 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 parameter ***3-81 Quick Stop Ramp Time***).

Bit 05, Hold output frequency

Bit 05 = 0: The present output frequency (in Hz) freezes. Change the frozen output frequency only with the digital inputs programmed to ***[21] Speed up*** and ***[22] Speed down*** (parameter ***5-10 Terminal 18 Digital Input*** to parameter ***5-13 Terminal 29 Digital Input***).

NOTICE

If freeze output is active, the drive can only be stopped in 1 of the following ways:

- Bit 03 coast stop.
- Bit 02 DC brake
- Digital input programmed to ***[5] DC brake inverse***, ***[2] Coast inverse***, or ***[3] Coast and reset inv*** (parameter ***5-10 Terminal 18 Digital Input*** to parameter ***5-13 Terminal 29 Digital Input***).

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: If the other starting conditions are met, bit 06 allows the drive to start the motor.

In parameter ***8-53 Start Select***, define how bit 06 ramp stop/start gates with the corresponding function on a digital input.

Bit 07, Reset

Bit 07 = 0: No reset.

Bit 07 = 1: Resets a trip. Reset is activated on the leading signal edge, that is, when changing from logic 0 to logic 1.

Bit 08, Jog

Bit 08 = 1: ***Parameter 3-11 Jog Speed [Hz]*** determines the output frequency.

Bit 09, Selection of ramp 1/2

Bit 09 = 0: Ramp 1 is active (parameter ***3-41 Ramp 1 Ramp Up Time*** to parameter ***3-42 Ramp 1 Ramp Down Time***).

Bit 09 = 1: Ramp 2 is active (parameter ***3-51 Ramp 2 Ramp Up Time*** to parameter ***3-52 Ramp 2 Ramp Down Time***).

Bit 10, Data not valid/Data valid

Tell the drive whether to use or ignore the control word.

Bit 10 = 0: The control word is ignored.

Bit 10 = 1: The control word is used. This function is relevant because the telegram always contains the control word, regardless of the telegram type. If the control word is not needed when updating or reading parameter, turn it off.

Bit 11, Relay 01

Bit 11 = 0: Relay not activated.

Bit 11 = 1: Relay 01 activated if ***[36] Control word bit 11*** is selected in parameter ***5-40 Function Relay***.

Bit 12, Relay 02

Bit 12 = 0: Relay 02 is not activated.

Bit 12 = 1: Relay 02 is activated if ***[37] Control word bit 12*** is selected in parameter ***5-40 Function Relay***.

Bit 13, Setup selection

Use bit 13 to select from the 2 menu setups according to the following table.

Table 78: Menu Setups

Setup	Bit 13
1	0
2	1

The function is only possible when ***[9] Multi set-ups*** is selected in parameter ***0-10 Active Set-up***.

To define how bit 13 gates with the corresponding function on the digital inputs, use parameter ***8-55 Set-up Select***.

Bit 15 Reverse

Bit 15 = 0: No reversing.

Bit 15 = 1: Reversing. In the default setting, reversing is set to digital in parameter ***8-54 Reversing Select***. Bit 15 causes reversing only when serial communication ***[2] Logic OR*** or ***[3] Logic AND*** is selected.

10.11.2 Status Word According to FC Profile (STW)

Set parameter ***8-30 Protocol*** to ***[0] FC***.

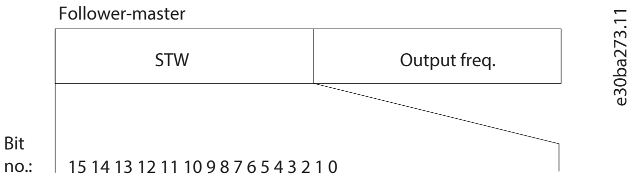

Figure 116: Status Word

Table 79: Status Word According to FC Profile

Bit	Bit value=0	Bit value=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

Table 79: Status Word According to FC Profile - (continued)

Bit	Bit value=0	Bit value=1
07	No warning	Warning
08	Speed≠reference	Speed=reference
09	Local operation	Bus control
10	Out of frequency limit	Frequency limit OK
11	No operation	In operation
12	Drive OK	Stopped, auto start
13	Voltage OK	Voltage exceeded
14	Torque OK	Torque exceeded
15	Timer OK	Timer exceeded

Explanation of the status bits

Bit 00, Control not ready/ready

Bit 00=0: The drive trips.

Bit 00=1: The drive controls are ready but the power component does not necessarily receive any supply (if there is 24 V external supply to controls).

Bit 01, Drive ready

Bit 01=0: The drive is not ready.

Bit 01=1: The drive is ready for operation, but the coasting command is active via the digital inputs or via serial communication.

Bit 02, Coast stop

Bit 02=0: The drive releases the motor.

Bit 02=1: The drive starts the motor with a start command.

Bit 03, No error/trip

Bit 03=0: The drive is not in fault mode.

Bit 03=1: The drive trips. To re-establish operation, press *[Reset]*.

Bit 04, No error/error (no trip)

Bit 04=0: The drive is not in fault mode.

Bit 04=1: The drive shows an error but does not trip.

Bit 05, Not used

Bit 05 is not used in the status word.

Bit 06, No error/triplock

Bit 06=0: The drive is not in fault mode.

Bit 06=1: The 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 runs, but the present speed is different from the preset speed reference. It might happen 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: *[Off/Reset]* is activated on the control unit or *[2] Local* in parameter ***3-13 Reference Site*** is selected. It is not possible to control the drive via serial communication.

Bit 09=1: It is possible to control the drive via the fieldbus/serial communication.

Bit 10, Out of frequency limit

Bit 10=0: The output frequency has reached the value in parameter ***4-12 Motor Speed Low Limit [Hz]*** or parameter ***4-14 Motor Speed High Limit [Hz]***.

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 drive has a start signal without coast.

Bit 12, Drive OK/stopped, auto start

Bit 12=0: There is no temporary overtemperature on the drive.

Bit 12=1: The drive stops because of overtemperature, but the unit does not trip and resumes operation once the overtemperature normalizes.

Bit 13, Voltage OK/limit exceeded

Bit 13=0: There are no voltage warnings.

Bit 13=1: The DC voltage in the drive's DC link is too low or too high.

Bit 14, Torque OK/limit exceeded

Bit 14=0: The motor current is lower than the current limit selected in parameter ***4-18 Current Limit***.

Bit 14=1: The current limit in parameter ***4-18 Current Limit*** is exceeded.

Bit 15, Timer OK/limit exceeded

Bit 15=0: The timers for motor thermal protection and thermal protection are not exceeded 100%.

Bit 15=1: 1 of the timers exceeds 100%.

10.11.3 Bus Speed Reference Value

Speed reference value is transmitted to the drive in a relative value in %. The value is transmitted in the form of a 16-bit word. The integer value 16384 (4000 hex) corresponds to 100%. Negative figures are formatted using 2's complement. The actual output frequency (MAV) is scaled in the same way as the bus reference.

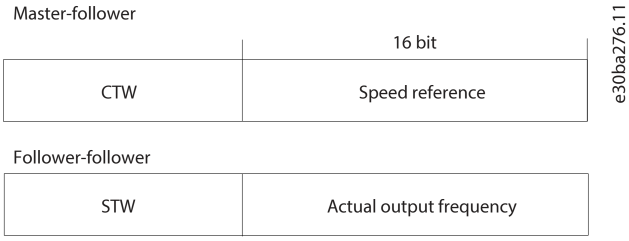

Figure 117: Actual Output Frequency (MAV)

The reference and MAV are scaled as follows:

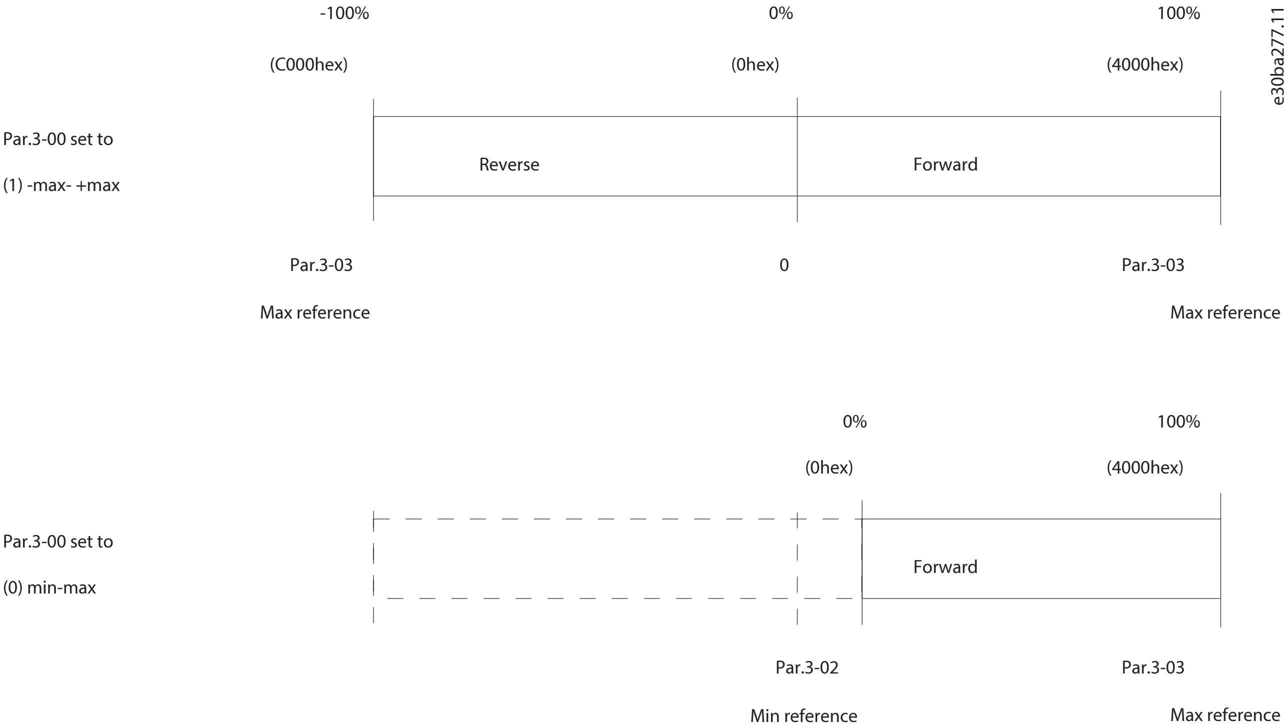

Figure 118: Reference and MAV

11 How to Order

11.1 Type Code

A type code defines a specific configuration of the drive. Use the Figure 119 to create a type code string for the desired configuration.

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

e30bb899.10

Figure 119: Type Code

Table 80: Type Code Description

Description	Position	Possible option
Product group & FC series	1–6	FC 101
Power rating	7–10	0.25–90 kW (0.34–120 hp) (PK25-P90K)
Number of phases	11	3-phases (T)
Mains voltage	11–12	T2: 3x200–240 V AC T2: 3x200Y/115–240Y/139 V AC(1) T4: 3x380–480 V AC T4: 3x380Y/220–480Y/277 V AC(1) T6: 3x525–600 V AC(2)
Enclosure	13–15	E20: IP20/chassis E20: IP20/Open type(1) P20: IP20/chassis with back plate P20: IP20/Open type with back plate(1) E5A: IP54 P5A: IP54 with back plate
RFI filter	16–17	H1: RFI filter class A1/B H2: RFI filter class A2 H3: RFI filter class A1/B (reduced cable length) H4: RFI filter class A1 HX: no RFI filter(3)
Brake	18	X: No brake chopper included
Display	19	A: Alphanumeric local control panel X: No local control panel
Coating PCB	20	X: No coated PCB C: Coated PCB
Mains option	21	X: No mains option
Adaptation	22	X: No adaptation
Adaptation	23	X: No adaptation 6: UL 61800-5-1 type(4), (5), (6)
Software release	24–27	SXXX: Latest release - standard software S600: UL61800-5-1 type
Software language	28	X: Standard
A option	29–30	AX: No A option

Table 80: Type Code Description - (continued)

Description	Position	Possible option
B option	31–32	BX: No B option
C0 options MCO	33–34	CX: No C option
C1 option	35	X: No C1 option
C option software	36–37	XX: No option
D option	38–39	DX: No D0 option

1) Applies if position 23 in the type code = 6: UL 61800-5-1.

2) UL 61800-5-1 is not available for 3x525–600 V AC.

3) HX is only available for enclosure sizes H1–H5.

4) UL 61800-5-1 is only available for T2 and T4 of enclosure sizes H1–H8.

5) Factory installed load share terminal cover for enclosure sizes H1–H5 must not be removed.

6) UL 61800-5-1 is not valid for IT and delta grounded grids.

11.2 Ordering Options and Accessories

11.2.1 Ordering Local Control Panel (LCP)

Table 81: Code number of LCP

Description	Code number
VLT® Control Panel LCP 31(1)	132B0200
VLT® Control Panel LCP 32(2)	132B9221
LCP mounting kit IP55 including 3 m (9.8 ft) cable	132B0201
LCP RJ45 Plug Converter	132B0203
LCP mounting kit IP55 without 3 m (9.8 ft) cable	132B0206

1) Supports 8 languages.

2) Supports 9 languages including Chinese.

NOTE:

- For IP20/Open type units, LCP is ordered separately.
- For IP54 units, LCP is included in the standard configuration and mounted on the drive.

Table 82: Technical Data of LCP

Enclosure	IP55 Front-mounted
Maximum cable length to unit	3 m (10 ft)
Communication standard	RS485

11.2.2 Mounting of LCP in Front Panel

1. Fit gasket on LCP.

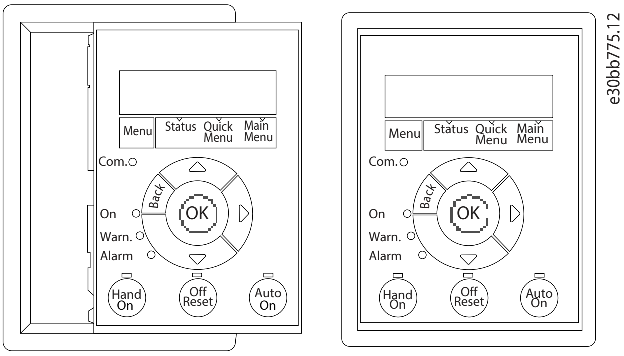

Figure 120: Fit Gasket

2. Place LCP on panel, see dimensions of hole in Figure 121.

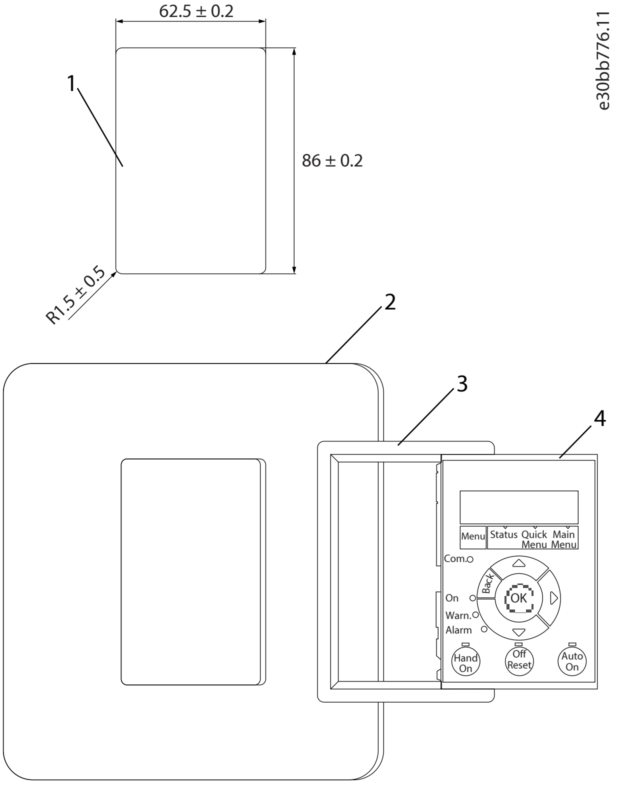

Figure 121: Place LCP on Panel (Front-mounted)

1	Panel cut out. Panel thickness 1–3 mm (0.04–0.12 in)	2	Panel
3	Gasket	4	LCP

3. Place the bracket on the back of the LCP, then slide down. Tighten screws and connect cable female side to LCP.

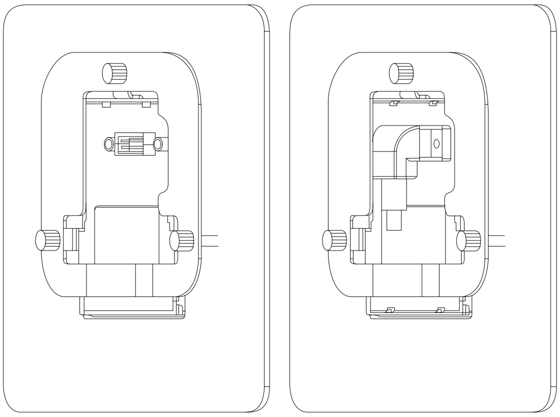

Figure 122: Place Bracket on LCP

4. Connect the cable to the drive.

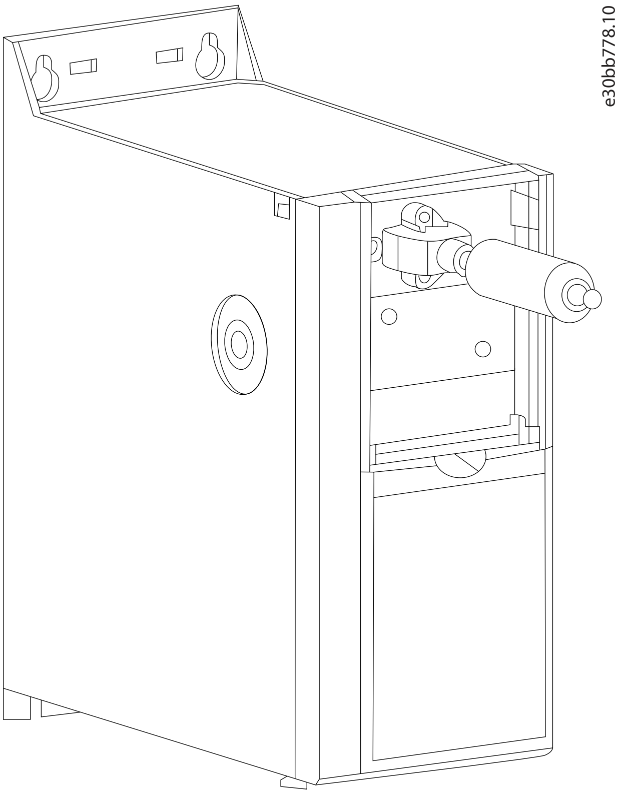

Figure 123: Connect Cable

> **NOTICE**
>
> Use the provided thread-cutting screws to fasten the connector to the drive. The tightening torque is 1.3 Nm (11.5 in-lb).

11.2.3 Ordering IP21/NEMA Type 1 Enclosure Kit

IP21/NEMA Type 1 is an optional enclosure element available for IP20/Open type units. If the enclosure kit is used, an IP20/Open type unit is upgraded to comply with enclosure IP21/NEMA Type 1.

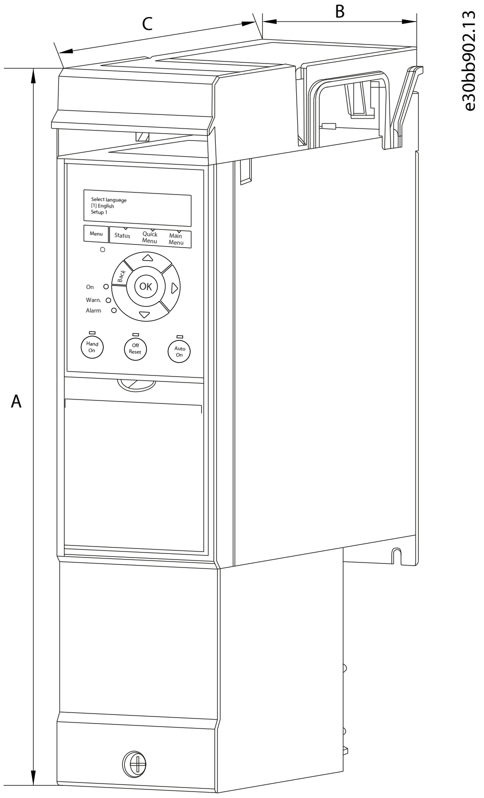

Figure 124: H1–H5

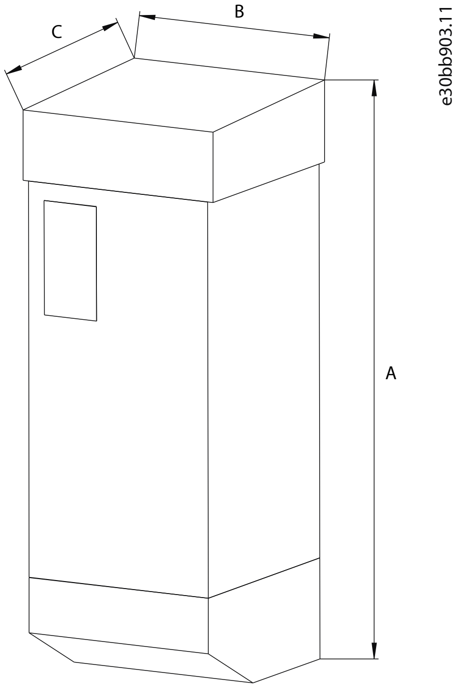

Figure 125: Dimensions

Table 83: Code Number of IP21/NEMA Type 1 Enclosure Kit

Enclosure size	Protection rating	Power [kW (hp)]			Height [mm (in)] A	Width [mm (in)] B	Depth [mm (in)] C	IP21 conversion kit code number	NEMA Type 1 kit code number
		3x200-240 V [kW (hp)]	3x380-480 V [kW (hp)]	3x525-600 V [kW (hp)]					
H1	IP20/Open type	0.25–1.5 (0.34–2.0)	0.37–1.5 (0.5–2.0)	–	293 (11.5)	81 (3.2)	173 (6.8)	132B0212	132B0222
H2	IP20/Open type	2.2 (3.0)	2.2–4.0 (3.0–5.5)	–	322 (12.7)	96 (3.8)	195 (7.7)	132B0213	132B0223
H3	IP20/Open type	3.7 (5.0)	5.5–7.5 (7.5–10)	–	346 (13.6)	106 (4.2)	210 (8.3)	132B0214	132B0224
H4	IP20/Open type	5.5–7.5 (7.5–10)	11–15 (15–20)	–	374 (14.7)	141 (5.6)	245 (9.6)	132B0215	132B0225
H5	IP20/Open type	11 (15)	18.5–22 (25–30)	–	418 (16.5)	161 (6.3)	260 (10.2)	132B0216	132B0226
H6	IP20/Open type	15–18.5 (20–25)	30–45 (40–60)	18.5–30 (25–40)	663 (26.1)	260 (10.2)	242 (9.5)	132B0217	132B0217
H7	IP20/Open type	22–30 (30–40)	55–75 (74–100)	37–55 (50–74)	807 (31.8)	329 (13.0)	335 (13.2)	132B0218	132B0218
H8	IP20/Open type	37–45 (50–60)	90 (120)	75–90 (100–120)	943 (37.1)	390 (15.3)	335 (13.2)	132B0219	132B0219
H9	IP20/Open type	–	–	2.2–7.5 (3.0–10)	372 (14.6)	130 (5.1)	205 (8.1)	132B0220	132B0220
H10	IP20/Open type	–	–	11–15 (15–20)	475 (18.7)	165 (6.5)	249 (9.8)	132B0221	132B0221

11.2.4 Ordering Decoupling Plate

Use the decoupling plate for EMC-correct installation.

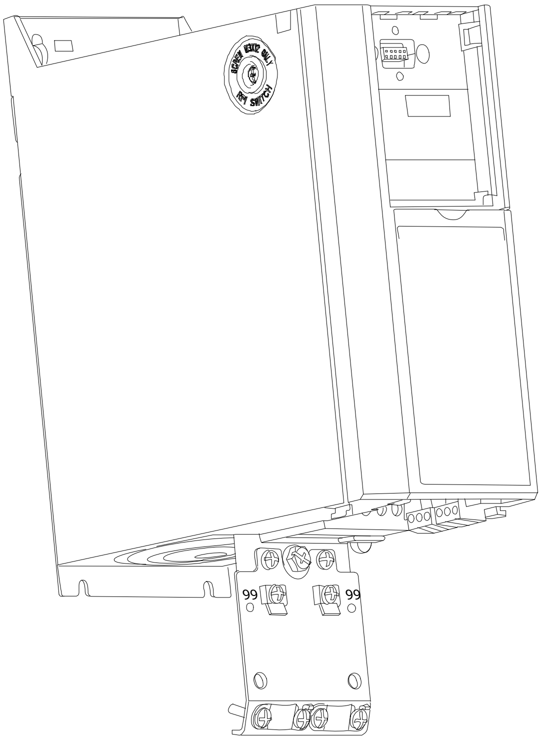

Figure 126: Decoupling Plate on H3 Enclosure Size

Table 84: Code Numbers of Decoupling Plate

Enclosure size	Protection rating	Power [kW(hp)]			Decoupling plate code numbers
		3x200–240 V	3x380–480 V	3x525–600 V	
H1	IP20/Open type	0.25–1.5 (0.33–2.0)	0.37–1.5 (0.5–2.0)	–	132B0202
H2	IP20/Open type	2.2 (3.0)	2.2–4.0 (3.0–5.5)	–	132B0202
H3	IP20/Open type	3.7 (5.0)	5.5–7.5 (7.5–10)	–	132B0204
H4	IP20/Open type	5.5–7.5 (7.5–10)	11–15 (15–20)	–	132B0205
H5	IP20/Open type	11 (15)	18.5–22 (25–30)	–	132B0205
H6	IP20/Open type	15–18.5 (20–25)	30 (40)	18.5–30 (25–40)	132B0207
H6	IP20/Open type	–	37–45 (50–60)	–	132B0242
H7	IP20/Open type	22–30 (30–40)	55 (75)	37–55 (50–75)	132B0208
H7	IP20/Open type	–	75 (100)	–	132B0243
H8	IP20/Open type	37–45 (50–60)	90 (125)	75–90 (100–125)	132B0209

NOTICE

For enclosure sizes H9 and H10, the decoupling plates are included in the accessory bag.

11.2.5 Ordering Harmonic Filters

Table 85: AHF Filters (10% Current Distortion), 3x380–480 V 50 Hz

Power [kW (hp)]	Drive input current continuous [A]	Default switching frequency [kHz]	THDi level [%]	Code number filter IP00	Code number filter IP20/Open type
22 (30)	41.5	4	6	130B1274	130B1111
30 (40)	57	4	6	130B1275	130B1176
37 (50)	70	4	9	130B1291	130B1201
45 (60)	84	3	9	130B1291	130B1201
55 (74)	103	3	9	130B1292	130B1204
75 (100)	140	3	8	130B1294	130B1213
90 (120)	176	3	8	130B1294	130B1213

Table 86: AHF Filters (10% Current Distortion), 3x440–480 V 60 Hz

Power [kW (hp)]	Drive input current continuous [A]	Default switching frequency [kHz]	THDi level [%]	Code number filter IP00	Code number filter IP20/Open type
22 (30)	34.6	4	6	130B1775	130B1487
30 (40)	49	4	8	130B1776	130B1488
37 (50)	61	4	7	130B1777	130B1491
45 (60)	73	3	9	130B1778	130B1492
55 (74)	89	3	8	130B1779	130B1493
75 (100)	121	3	9	130B1780	130B1494
90 (120)	143	3	10	130B1781	130B1495

11.2.6 Ordering External RFI Filter

With external filters listed in Table 87, the maximum shielded cable length of 50 m (164 ft) according to EN/IEC 61800-3 C2 (EN 55011 A1), or 20 m (65.6 ft) according to EN/IEC 61800-3 C1(EN 55011 B) can be achieved.

Table 87: Code Numbers of RFI Filters

Power [kW (hp)] 380–480 V	0.37–2.2 (0.5–3.0)	3.0–7.5 (4.0–10)	11–15 (15–20)	18.5–22 (25–30)
Type	FN3258-7-45	FN3258-16-45	FN3258-30-47	FN3258-42-47
A [mm (in)]	190 (7.5)	250 (9.8)	270 (10.6)	310 (12.2)
B [mm (in)]	40 (1.57)	45 (1.77)	50 (1.97)	50 (1.97)
C [mm (in)]	70 (2.76)	70 (2.76)	85 (3.35)	85 (3.35)
D [mm (in)]	160 (6.3)	220 (8.7)	240 (9.5)	280 (11)
E [mm (in)]	180 (7.1)	235 (9.3)	255 (10)	295 (11.6)
F [mm (in)]	20 (0.79)	25 (0.98)	30 (1.18)	30 (1.18)
G [mm (in)]	4.5 (0.18)	4.5 (0.18)	5.4 (0.21)	5.4 (0.21)
H [mm (in)]	1 (0.04)	1 (0.04)	1 (0.04)	1 (0.04)
I [mm (in)]	10.6 (0.42)	10.6 (0.42)	10.6 (0.42)	10.6 (0.42)
J	M5	M5	M5	M5

Table 87: Code Numbers of RFI Filters - (continued)

K [mm (in)]	20 (0.79)	22.5 (0.89)	25 (0.98)	25 (0.98)
L1 [mm (in)]	31 (1.22)	31 (1.22)	40 (1.57)	40 (1.57)
Torque [Nm (in-lb)]	0.7–0.8 (6.2–7.1)	0.7–0.8 (6.2–7.1)	1.9–2.2 (16.8–19.5)	1.9–2.2 (16.8–19.5)
Weight [kg (lb)]	0.5 (1.1)	0.8 (1.8)	1.2 (2.6)	1.4 (3.1)
Code number	132B0244	132B0245	132B0246	132B0247

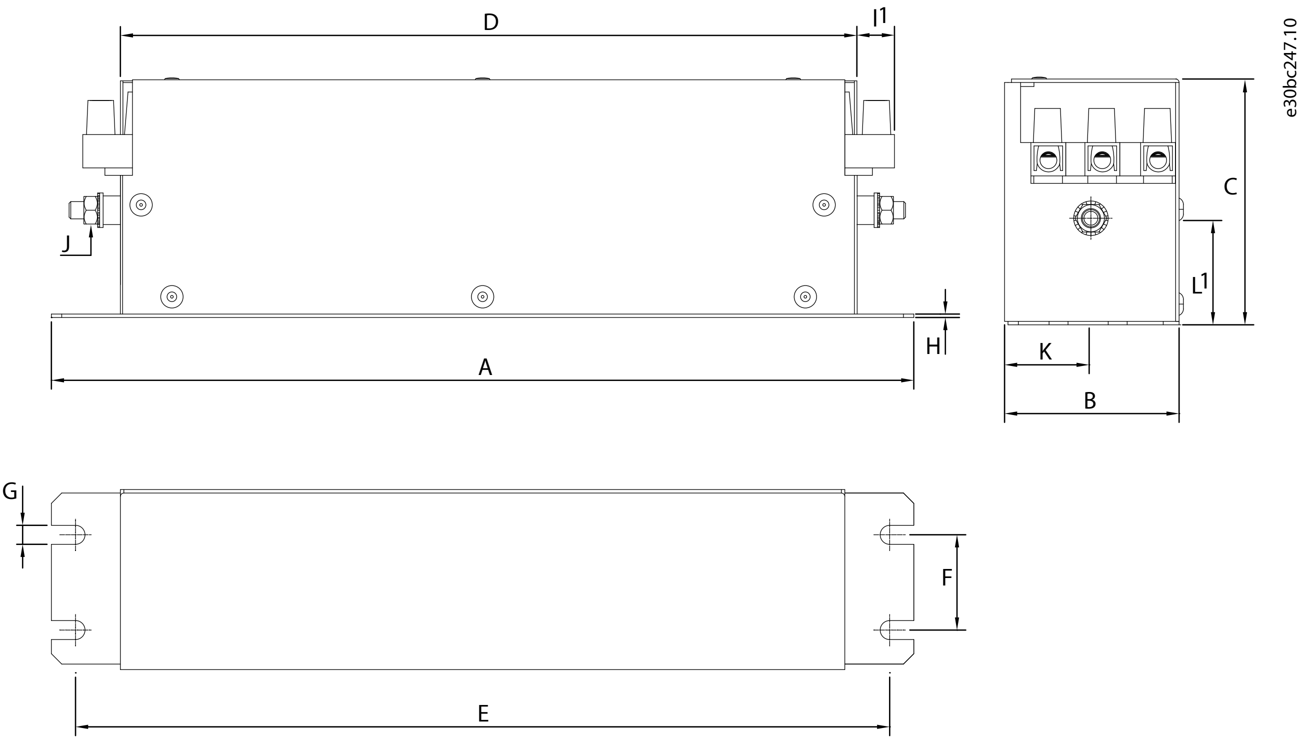

Figure 127: RFI Filter Dimensions

12 Appendix

12.1 Abbreviations and Symbols

Table 88: Abbreviations and Symbols

°C	Degrees Celsius
°F	Degrees Fahrenheit
A	Ampere/AMP
AC	Alternating current
AWG	American wire gauge
AMA	Automatic motor adaptation
DC	Direct current
D-TYPE	Drive dependent
EMC	Electro-magnetic compatibility
ETR	Electronic thermal relay
$f_{M,N}$	Nominal motor frequency
g	Gram
Hz	Hertz
hp	Horsepower
I_{LIM}	Current limit
I_{INV}	Rated inverter output current
$I_{M,N}$	Nominal motor current
$I_{VLT,MAX}$	Maximum output current
$I_{VLT,N}$	Rated output current supplied by the drive
kg	Kilogram
kHz	Kilohertz
LCP	Local control panel
m	Meter
mH	Millihenry inductance
mA	Milliampere
ms	Millisecond
min	Minute
MCT	Motion control tool
nF	Nanofarad
Nm	Newton meter
n_s	Synchronous motor speed
$P_{M,N}$	Nominal motor power
PELV	Protective extra low voltage
PCB	Printed circuit board
PM motor	Permanent magnet motor

Table 88: Abbreviations and Symbols - (continued)

Regen	Regenerative terminals
RPM	Revolutions per minute
s	Second
T_{LIM}	Torque limit
$U_{M,N}$	Nominal motor voltage
V	Volts

12.2 Definitions

12.2.1 AC Drive

Coast

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

$I_{VLT, MAX}$

Maximum output current.

$I_{VLT, N}$

Rated output current supplied by the drive.

$U_{VLT, MAX}$

Maximum output voltage.

12.2.2 Input

Control commands

Start and stop the connected motor with the LCP and digital inputs.

Functions are divided into 2 groups. Functions in group 1 have higher priority than functions in group 2.

Table 89: Function Groups

Group 1	Reset, coast stop, reset and coast stop, quick stop, DC brake, stop, and [*Off*].
Group 2	Start, pulse start, reversing, start reversing, jog, and freeze output.

12.2.3 Motor

Motor running

Torque generated on the output shaft and speed from 0 RPM to maximum speed on the motor.

f_{JOG}

Motor frequency when the jog function is activated (via digital terminals or bus).

f_M

Motor frequency.

f_{MAX}

Maximum motor frequency.

f_{MIN}

Minimum motor frequency.

$f_{M, N}$

Rated motor frequency (nameplate data).

I_M

Motor current (actual).

$I_{M, N}$

Nominal motor current (nameplate data).

$n_{M, N}$

Nominal motor speed (nameplate data).

n_s

Synchronous motor speed. $n_S = \frac{2 \times \text{Parameter1} - 23 \times 60s}{\text{Parameter1} - 39}$

n_{slip}

Motor slip.

$P_{M, N}$

Rated motor power (nameplate data in kW or hp).

$T_{M, N}$

Rated torque (motor).

U_M

Instantaneous motor voltage.

$U_{M, N}$

Rated motor voltage (nameplate data).

Break-away torque

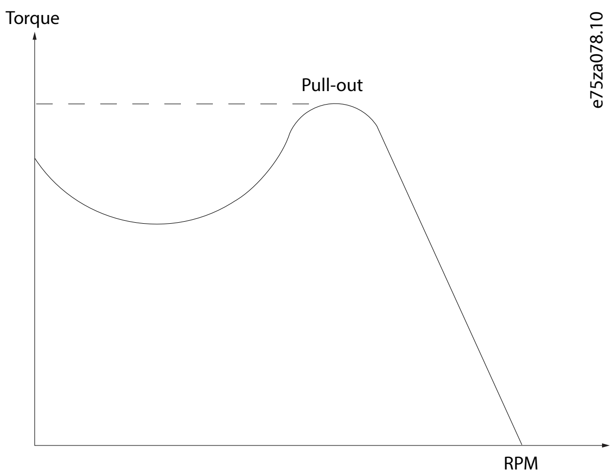

Figure 128: Break-away Torque

η_{VLT}

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

Start-disable command

A start-disable command belonging to the control commands in group 1. See the table in the *chapter Input* for more details.

Stop command

A stop command belonging to the control commands in group 1. See the table in the *chapter Input* for more details.

12.2.4 References

Analog reference

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

- Current input: 0–20 mA and 4–20 mA
- Voltage input: 0–10 V DC

Bus reference

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

Binary reference

A signal transmitted via the serial communication port.

Preset reference

A defined preset reference to be set from -100% to +100% of the reference range. Selection of 8 preset references via the digital terminals. Selection of 4 preset references via the bus.

Ref_{MAX}

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

Ref_{MIN}

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

12.2.5 Miscellaneous

Analog inputs

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

There are 2 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

The AMA algorithm determines the electrical parameters for the connected motor at standstill and compensates for the resistance based on the length of the motor cable.

Digital inputs

The digital inputs can be used for controlling various functions of the drive.

Digital outputs

Terminals 42 and 45 can be programmed as digital outputs.

DSP

Digital signal processor.

Relay outputs

The drive provides 2 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 and prevent overheating of the motor.

Initializing

If initializing is carried out (parameter ***14-22 Operation Mode***), the drive returns to the default setting. Parameter ***14-22 Operation Mode*** does not initialize communication parameters, fault log, or fire mode log.

Intermittent duty cycle

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

LCP

The local control panel makes up a complete interface for control and programming of the drive. The LCP is detachable. With the installation kit option, the LCP can be installed up to 3 m (9.8 ft) from the drive in a front panel.

GLCP

The graphical local control panel interface for control and programming of the drive. The display is graphical and the panel is used to show process values. The GLCP has storing and copy functions.

NLCP

The numerical local control panel interface for control and programming of the drive. The display is numerical and the panel is used to show process values. The NLCP has storing and copy functions.

lsb

Least significant bit.

msb

Most significant bit.

MCM

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

On-line/off-line parameters

Changes to on-line parameters are activated immediately after the data value is changed. To activate changes to offline parameters, press [*OK*].

PI controller

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

Process PID

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

PCD

Process control data.

PFC

Power factor correction.

Power cycle

Switch off the mains until the display (LCP) is dark, then turn power on again.

Power factor

The power factor is the relation between I_1 and I_{RMS}, where I_1 is the fundamental current, and I_{RMS} is the total RMS current including harmonic currents.

$$\text{Powerfactor} = \frac{\sqrt{3} \times U \times I_1 \cos\varphi 1}{\sqrt{3} \times U \times I_{RMS}}$$

For this drive, $\cos\varphi 1 = 1$, therefore: $\text{Powerfactor} = \frac{I_1 \times \cos\varphi 1}{I_{RMS}} = \frac{I_1}{I_{RMS}}$

The power factor indicates to which extent the drive imposes a load on the mains supply.

The lower the power factor, the higher the I_{RMS} for the same kW performance.

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

In addition, a high power factor indicates that the different harmonic currents are low.

The built-in DC coils produce a high power factor, minimizing the imposed load on the mains supply.

Pulse input/incremental encoder

An external, digital pulse transmitter used for feeding back information on motor speed. The encoder is used in applications where great accuracy in speed control is required.

RCD

Residual current device.

Setup

Save parameter settings in 2 setups. Change between the 2 parameter setups and edit 1 setup while the other setup is active.

SFAVM

Acronym describing the switching pattern stator flux-oriented asynchronous vector modulation.

Slip compensation

The 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. (Parameter group ***13-** Smart Logic***).

STW

Status word.

THD

Total harmonic distortion states the total contribution of harmonic distortion.

Thermistor

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

Trip

A state entered in fault situations, for example if the drive is subject to overvoltage 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, sometimes, by being programmed to reset automatically. Do not use trip for personal safety.

Trip lock

Trip lock is a state entered in fault situations when the drive is protecting itself and requiring physical intervention. An example causing a trip lock is the drive being subject to a short circuit on the output. A locked trip can only be canceled by cutting off mains, removing the cause of the fault, and reconnecting the drive. Restart is prevented until the trip state is canceled by activating reset or, sometimes, by being programmed to reset automatically. Do not use trip lock for personal safety.

VT characteristics

Variable torque characteristics for pumps and fans.

VVC+

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

60° AVM

Refers to the switching pattern 60° asynchronous vector modulation.

12.3 Conventions

- Numbered lists indicate procedures.
- Bulleted and dashed lists indicate listings of other information where the order of the information is not relevant.
- Bolded text indicates important information and section headings.
- Italicized text indicates the following:
  - Cross-reference.
  - Link.
  - Footnote.
  - Alarms/warnings
- Bolded and italicized text indicates the following:
  - Parameter name.
  - Parameter option.
  - Parameter group name.
- All dimensions in drawings are in metric values (imperial values in brackets).
- An asterisk (*) indicates the default setting of a parameter.

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