

Design Guide

VLT® HVAC Drive FC 131



VLT®
HVAC Drive

Contents

1	Introduction	9
1.1	Purpose of this Design Guide	9
1.2	Additional Resources	9
1.2.1	Other Resources	9
1.2.2	MCT 10 Setup Software Support	9
1.3	Document and Software Version	9
1.4	Regulatory Compliance	9
1.4.1	Introduction	9
1.4.2	CE Mark	9
1.4.3	RCM Mark Compliance	10
1.4.4	EAC	10
1.4.5	UkrSEPRO	11
2	Safety	12
2.1	Safety Symbols	12
2.2	Qualified Personnel	12
2.3	Safety Precautions	12
3	Product Overview	15
3.1	Advantages	15
3.1.1	Why Use a Drive for Controlling Fans and Pumps?	15
3.1.1.1	The Clear Advantage - Energy Savings	15
3.1.1.2	Example of Energy Savings	16
3.1.1.3	Comparison of Energy Savings	16
3.1.1.4	Example with Varying Flow over 1 Year	18
3.1.1.5	Better Control	19
3.1.1.6	Star/Delta Starter or Soft Starter not Required	19
3.1.1.7	Using a Drive Saves Money	19
3.1.1.8	Traditional Fan System without a Drive	20
3.1.1.9	Fan System Controlled by Drives	21
3.1.2	Application Examples	21
3.1.2.1	Variable Air Volume	21
3.1.2.2	Constant Air Volume	22
3.1.2.3	Cooling Tower Fan	23
3.1.2.4	Condenser Pumps	24
3.1.2.5	Primary Pumps	25
3.1.2.6	Secondary Pumps	26

3.2	Control Structures	27
3.2.1	Introduction	27
3.2.2	Control Structure Open Loop	27
3.2.3	PM/EC+ Motor Control	27
3.2.4	Local (Hand On) and Remote (Auto On) Control	28
3.2.5	Control Structure Closed Loop	28
3.2.6	Feedback Conversion	29
3.2.7	Reference Handling	29
3.2.8	Tuning the Drive Closed-loop	30
3.2.9	Adjusting the Manual PI	30
3.3	Ambient Running Conditions	30
3.3.1	Air Humidity	30
3.3.2	Derating	30
3.3.3	Acoustic Noise or Vibration	32
3.3.3.1	Acoustic Noise	32
3.3.3.2	Vibration and Shock	32
3.3.4	Aggressive Environments	33
3.4	General Aspects of EMC	33
3.4.1	Overview of EMC Emissions	33
3.4.2	Emission Requirements	34
3.4.3	EMC Emission Test Results	35
3.4.4	Harmonics Emission	36
3.4.4.1	Harmonics Emission Requirements	36
3.4.4.2	Harmonics Test Results (Emission)	36
3.4.5	Immunity Requirements	37
3.5	Galvanic Isolation (PELV)	37
3.6	Ground Leakage Current	38
3.6.1	Using a Residual Current Device (RCD)	40
3.7	Extreme Running Conditions	41
3.7.1	Introduction	41
3.7.2	Motor Thermal Protection (ETR)	42
3.7.3	Thermistor Inputs	42
3.7.3.1	Example with Digital Input and 10 V Power Supply	43
3.7.3.2	Example with Analog Input and 10 V Power Supply	43
4	Selection and Ordering	45
4.1	Type Code	45
4.2	Options and Accessories	46

4.2.1	Local Control Panel (LCP)	46
<hr/>		
5	Installation	47
<hr/>		
5.1	Mechanical Installation	47
5.1.1	Side-by-side Installation	47
5.1.2	Drive Dimensions	47
5.1.3	Shipping Dimensions	48
5.2	Electrical Installation	48
5.2.1	Electrical Wiring	48
5.2.2	Electrical Installation in General	49
5.2.3	IT Mains	50
5.2.4	Mains and Motor Connection	51
5.2.4.1	Introduction	51
5.2.4.2	Connecting to Mains and Motor	52
5.2.4.3	Enclosure Size I2	52
5.2.4.4	Enclosure Size I3	53
5.2.4.5	Enclosure Size I4	54
5.2.4.6	IP54 Enclosure Sizes I2, I3, I4	55
5.2.4.7	Enclosure size I6	55
5.2.4.8	Enclosure size I7, I8	57
5.2.5	EMC-compliant Electrical Installation	57
5.2.6	Control Terminals	58
<hr/>		
6	RS485 Installation and Set-up	60
<hr/>		
6.1	RS485	60
6.1.1	Overview	60
6.1.2	Connecting the Drive to the RS485 Network	60
6.1.3	Hardware Setup	61
6.1.4	Parameter Settings for Modbus Communication	62
6.1.5	EMC Precautions	62
6.2	FC Protocol	63
6.2.1	Overview	63
6.2.2	FC with Modbus RTU	63
6.3	Network Configuration	64
6.4	FC Protocol Message Framing Structure	64
6.4.1	Content of a Character (byte)	64
6.4.2	Telegram Structure	64
6.4.3	Telegram Length (LGE)	64
6.4.4	Drive Address (ADR)	65

6.4.5	Data Control Byte (BCC)	65
6.4.6	The Data Field	65
6.4.7	The PKE Field	66
6.4.8	Parameter Number (PNU)	67
6.4.9	Index (IND)	68
6.4.10	Parameter Value (PWE)	68
6.4.11	Data Types Supported by the Drive	68
6.4.12	Conversion	68
6.4.13	Process Words (PCD)	69
6.5	Examples	69
6.5.1	Writing a Parameter Value	69
6.5.2	Reading a Parameter Value	70
6.6	Modbus RTU	70
6.6.1	Prerequisite Knowledge	70
6.6.2	Modbus RTU Overview	70
6.6.3	Drive with Modbus RTU	71
6.7	Network Configuration	71
6.8	Modbus RTU Message Framing Structure	71
6.8.1	Modbus RTU Message Byte Format	71
6.8.2	Modbus RTU Telegram Structure	72
6.8.3	Start/Stop Field	72
6.8.4	Address Field	72
6.8.5	Function Field	72
6.8.6	Data Field	72
6.8.7	CRC Check Field	73
6.8.8	Coil Register Addressing	73
6.8.8.1	Introduction	73
6.8.8.2	Coil Register	73
6.8.8.3	Drive Control Word (FC Profile)	73
6.8.8.4	Drive Status Word (FC Profile)	74
6.8.8.5	Address/Registers	75
6.8.9	Access via PCD Write/read	75
6.8.10	How to Control the Drive	76
6.8.10.1	Introduction	76
6.8.10.2	Function Codes Supported by Modbus RTU	76
6.8.10.3	Modbus Exception Codes	77
6.9	How to Access Parameters	77
6.9.1	Parameter Handling	77

6.9.2	Storage of Data	77
6.9.3	IND (Index)	78
6.9.4	Text Blocks	78
6.9.5	Conversion Factor	78
6.9.6	Parameter Values	78
6.10	Examples	78
6.10.1	Introduction	78
6.10.2	Read Coil Status (01 hex)	78
6.10.3	Force/Write Single Coil (05 hex)	79
6.10.4	Force/Write Multiple Coils (0F hex)	80
6.10.5	Read Holding Registers (03 hex)	81
6.10.6	Preset Single Register (06 hex)	81
6.10.7	Preset Multiple Registers (10 hex)	82
6.10.8	Read/Write Multiple Registers (17 hex)	83
6.11	Danfoss FC Control Profile	84
6.11.1	Control Word According to FC Profile (8-10 Protocol = FC Profile)	84
6.11.2	Explanation of Each Control Bit	85
6.11.3	Status Word According to FC Profile (STW)	87
6.11.4	Explanation of Each Status Bit	88
6.11.5	Bus Speed Reference Value	89
7	General Specifications	91
7.1	Mains Supply	91
7.1.1	3x380–480 V AC	91
7.2	Fuses and Circuit Breakers	93
7.2.1	Branch Circuit Protection	93
7.2.2	Short-circuit Protection	93
7.2.3	Overcurrent Protection	93
7.2.4	UL/Non-UL Compliance	93
7.2.5	Recommendation of Fuses and Circuit Breakers	93
7.3	General Technical Data	94
7.3.1	Protection and Features	94
7.3.2	Mains Supply (L1, L2, L3)	94
7.3.3	Motor Output (U, V, W)	94
7.3.4	Cable Length and Cross-section	95
7.3.5	Digital Inputs	95
7.3.6	Analog Inputs	95
7.3.7	Analog Outputs	95

7.3.8	Digital Output	96
7.3.9	Control Card, RS485 Serial Communication	96
7.3.10	Control Card, 24 V DC Output	96
7.3.11	Relay Output	96
7.3.12	Control Card, 10 V DC Output	97
7.3.13	Ambient Conditions	97
7.4	dU/Dt	98
8 Appendix		101
8.1	Abbreviations	101
8.2	Definitions	102
8.2.1	AC Drive	102
8.2.2	Input	102
8.2.3	Motor	102
8.2.4	References	103
8.2.5	Miscellaneous	104

1 Introduction

1.1 Purpose of this 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 VLT® HVAC Drive FC 131 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 Drive FC 131 Operating Guide provides basic information on mechanical dimensions, installation, and basic commissioning.
- VLT® HVAC Drive FC 131 Programming Guide provides information on how to program, and includes complete parameter descriptions.
- Danfoss VLT® Energy Box software. Select PC Software Download 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 manuals are available from 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 Drive FC 131 functionality. A license key is not required for using the VLT® HVAC Drive FC 131 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 Document and Software Version

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

The original language of this manual is English.

Table 1: Document and Software Version

Edition	Remarks	Software version
AJ370727701888, version 0101	First edition.	4.60

1.4 Regulatory Compliance

1.4.1 Introduction

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

1.4.2 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.

N O T I C E

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

N O T I C E

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	

Declarations of conformity are available on request.

1.4.2.1 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 75–1500 V DC voltage ranges.

1.4.2.2 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.

1.4.2.3 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.

1.4.3 RCM Mark Compliance



Illustration 1: 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.

1.4.4 EAC



Illustration 2: 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.

1.4.5 UkrSEPRO



Illustration 3: 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.

2 Safety

2.1 Safety Symbols

The following symbols are used in this guide:

⚠ D A N G E R ⚠

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

⚠ W A R N I N G ⚠

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

⚠ C A U T I O N ⚠

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

N O T I C E

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

2.2 Qualified Personnel

To allow trouble-free and safe operation of the unit, only qualified personnel with proven skills are allowed to transport, store, assemble, install, program, commission, maintain, and decommission this equipment.

Persons with proven skills:

- Are qualified electrical engineers, or persons who have received training from qualified electrical engineers and are suitably experienced to operate devices, systems, plant, and machinery in accordance with pertinent laws and regulations.
- Are familiar with the basic regulations concerning health and safety/accident prevention.
- Have read and understood the safety guidelines given in all guides provided with the unit, especially the instructions given in the installation guide and safety guide.
- Have good knowledge of the generic and specialist standards applicable to the specific application.

2.3 Safety Precautions

⚠ W A R N I N G ⚠

HAZARDOUS VOLTAGE

AC drives contain hazardous voltage when connected to the AC mains or connected on the DC terminals. Failure to perform installation, start-up, and maintenance by skilled personnel can result in death or serious injury.

- Only skilled personnel must perform installation, start-up, and maintenance.

⚠ W A R N I N G ⚠

UNINTENDED START

When the drive is connected to AC mains, DC supply, or load sharing, the motor may start at any time. Unintended start during programming, service, or repair work can result in death, serious injury, or property damage. Start the motor with an external switch, a fieldbus command, an input reference signal from the local control panel (LCP), via remote operation using MCT 10 software, or after a cleared fault condition.

- Disconnect the drive from the mains.
- Press [Off/Reset] on the LCP before programming parameters.
- Ensure that the drive is fully wired and assembled when it is connected to AC mains, DC supply, or load sharing.

⚠ W A R N I N G ⚠

DISCHARGE TIME

The drive contains DC-link capacitors, which can remain charged even when the drive is not powered. High voltage can be present even when the warning indicator lights are off.

Failure to wait the specified time after power has been removed before performing service or repair work could result in death or serious injury.

- Stop the motor.
- Disconnect AC mains, permanent magnet type motors, and remote DC-link supplies, including battery back-ups, UPS, and DC-link connections to other drives.
- Wait for the capacitors to discharge fully. The minimum waiting time is specified in the table *Discharge time* and is also visible on the nameplate on the top of the drive.
- Before performing any service or repair work, use an appropriate voltage measuring device to make sure that the capacitors are fully discharged.

Table 3: Discharge Time

Voltage [V]	Power range [kW (hp)]	Minimum waiting time (minutes)
3x400	0.75–7.5 (1.0–10)	4
3x400	11–90 (15–125)	15

⚠ W A R N I N G ⚠

ELECTRICAL SHOCK HAZARD - LEAKAGE CURRENT HAZARD

Leakage currents exceed 3.5 mA. Failure to connect the drive properly to protective earth (PE) can result in death or serious injury.

- Ensure reinforced protective earthing conductor according to IEC 60364-5-54 cl. 543.7 or according to local safety regulations for high touch current equipment. The reinforced protective earthing of the drive can be done with:
 - a PE conductor with a cross-section of at least 10 mm² (8 AWG) Cu or 16 mm² (6 AWG) Al.
 - an extra PE conductor of the same cross-sectional area as the original PE conductor as specified by IEC 60364-5-54 with a minimum cross-sectional area of 2.5 mm² (14 AWG) (mechanical protected) or 4 mm² (12 AWG) (not mechanical protected).
 - a PE conductor completely enclosed with an enclosure or otherwise protected throughout its length against mechanical damage.
 - a PE conductor part of a multi-conductor power cable with a minimum PE conductor cross-section of 2.5 mm² (14 AWG) (permanently connected or pluggable by an industrial connector. The multi-conductor power cable shall be installed with an appropriate strain relief).
- NOTE: In IEC/EN 60364-5-54 cl. 543.7 and some application standards (for example IEC/EN 60204-1), the limit for requiring reinforced protective earthing conductor is 10 mA leakage current.

⚠ W A R N I N G ⚠

EQUIPMENT HAZARD

Contact with rotating shafts and electrical equipment can result in death or serious injury.

- Ensure that only trained and qualified personnel perform installation, start-up, and maintenance.
- Ensure that electrical work conforms to national and local electrical codes.
- Follow the procedures in this manual.

▲ C A U T I O N ▲**INTERNAL FAILURE HAZARD**

An internal failure in the drive can result in serious injury when the drive is not properly closed.

- Ensure that all safety covers are in place and securely fastened before applying power.

3 Product Overview

3.1 Advantages

3.1.1 Why Use a Drive for Controlling Fans and Pumps?

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 [3.1.1.2 Example of Energy Savings](#).

3.1.1.1 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.

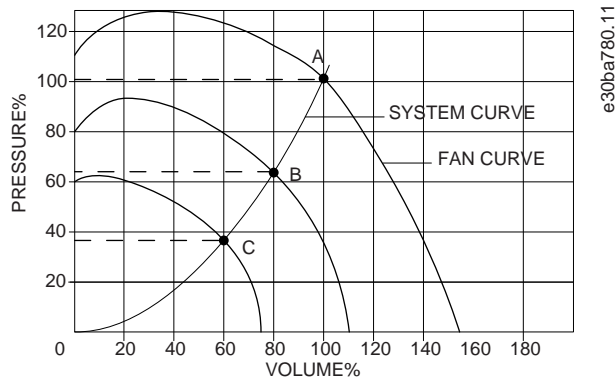


Illustration 4: Fan Curves (A, B, and C) for Reduced Fan Volumes

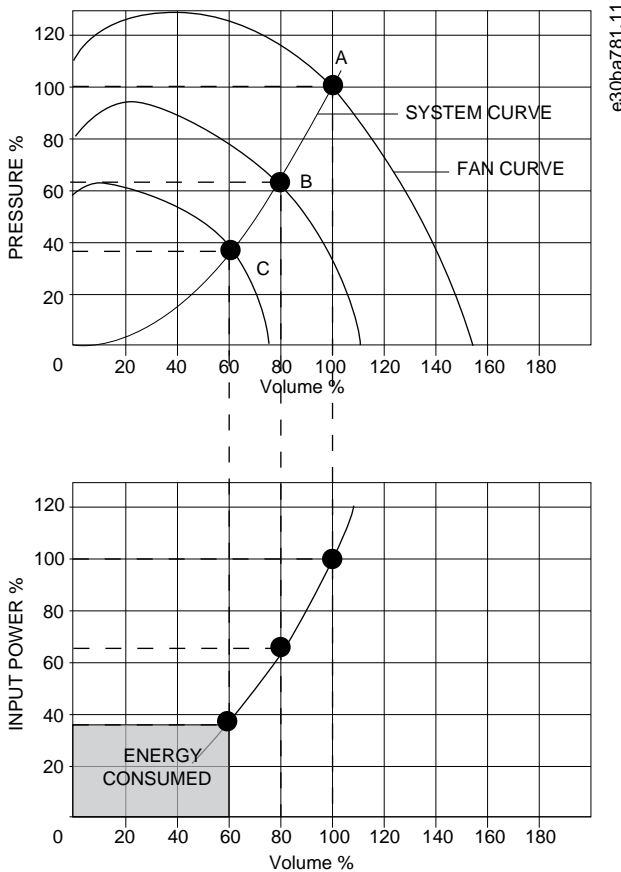


Illustration 5: Energy Savings with Drive Solution

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

3.1.1.2 Example of Energy Savings

As shown in the following illustration, 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%.

The following illustration describes the dependence of flow, pressure, and power consumption on RPM.

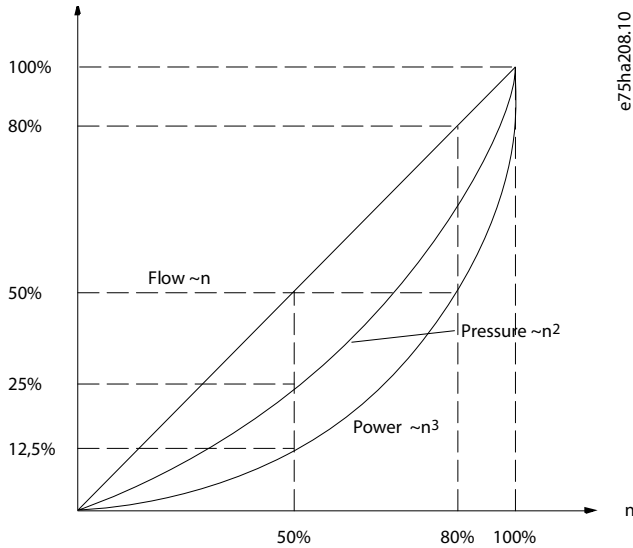


Illustration 6: Laws of Proportionality

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

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

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

Table 4: 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

3.1.1.3 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 illustration in [3.1.1.2 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.

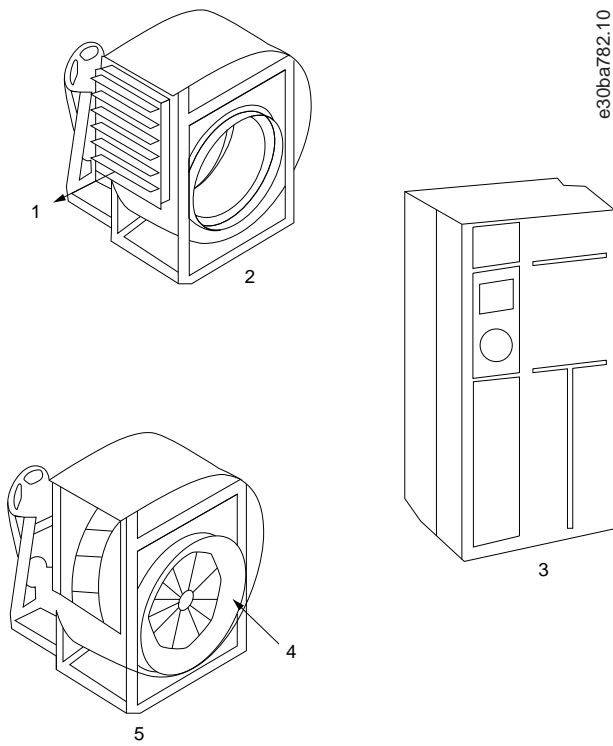


Illustration 7: The 3 Common Energy Saving Systems

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

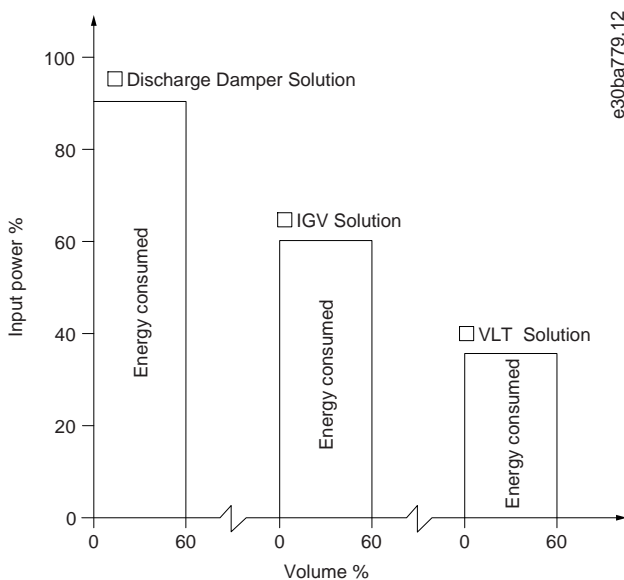


Illustration 8: Energy Savings

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.

3.1.1.4 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

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

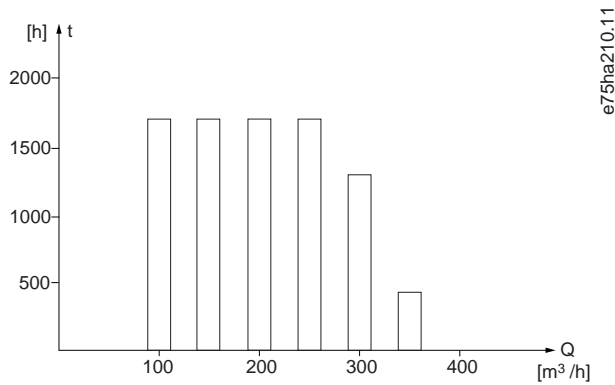


Illustration 9: Flow Distribution over 1 Year

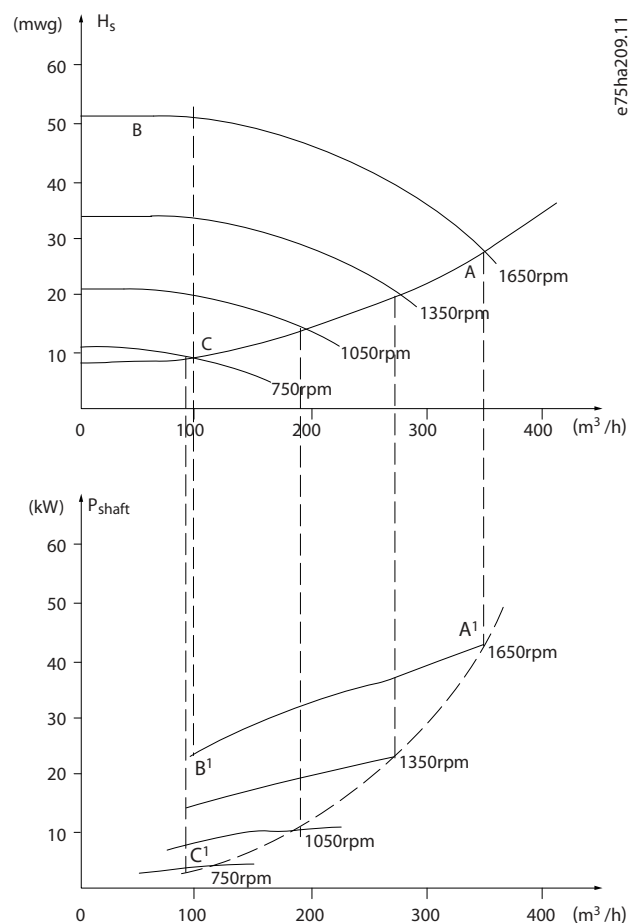


Illustration 10: Energy

Table 5: 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

3.1.1.5 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.

3.1.1.6 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 the following illustration, a drive does not consume more than rated current.

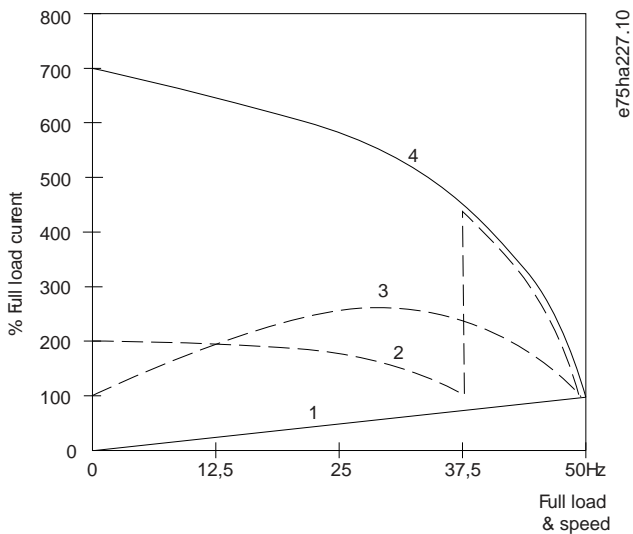


Illustration 11: Start-up Current

1	VLT® HVAC Drive FC 131	3	Soft starter
2	Star/delta starter	4	Start directly on mains

3.1.1.7 Using a Drive Saves Money

The example in [3.1.1.8 Traditional Fan System without a Drive](#) and [3.1.1.9 Fan System Controlled by Drives](#) shows 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.

3.1.1.8 Traditional Fan System without a Drive

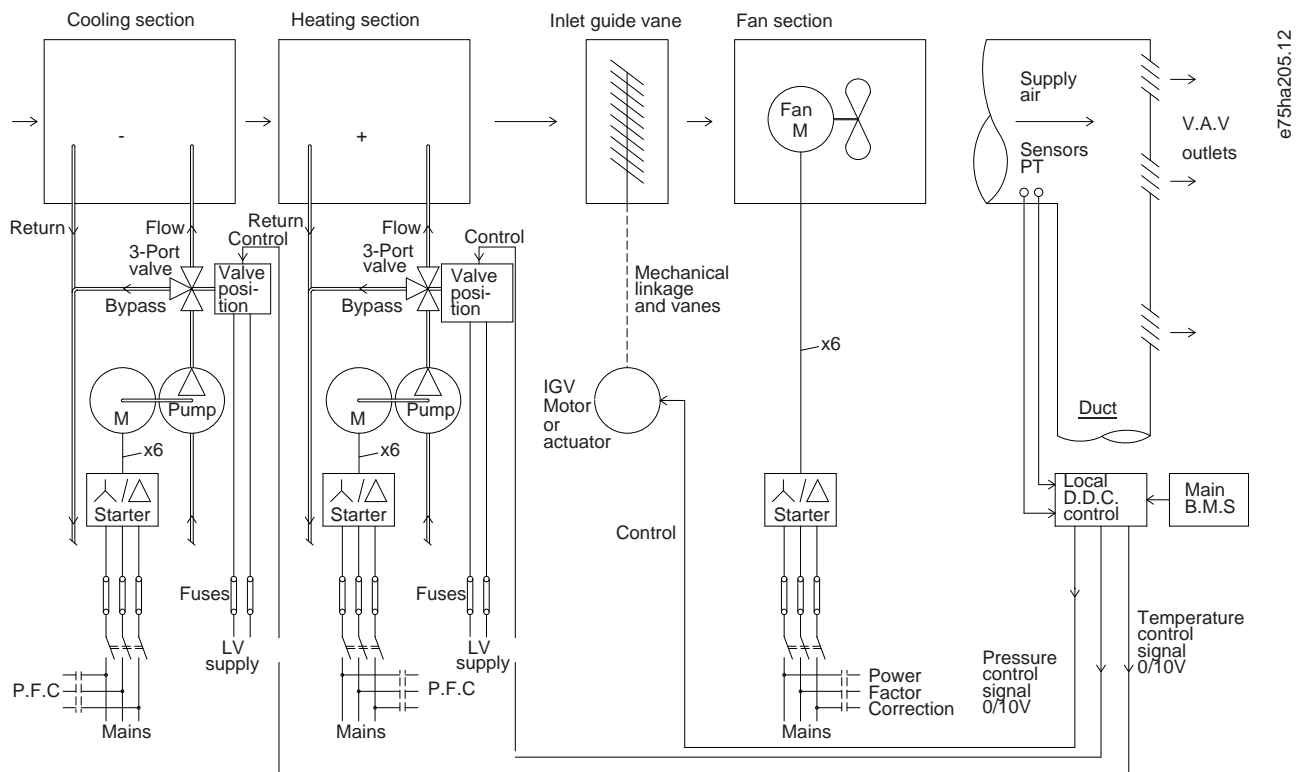
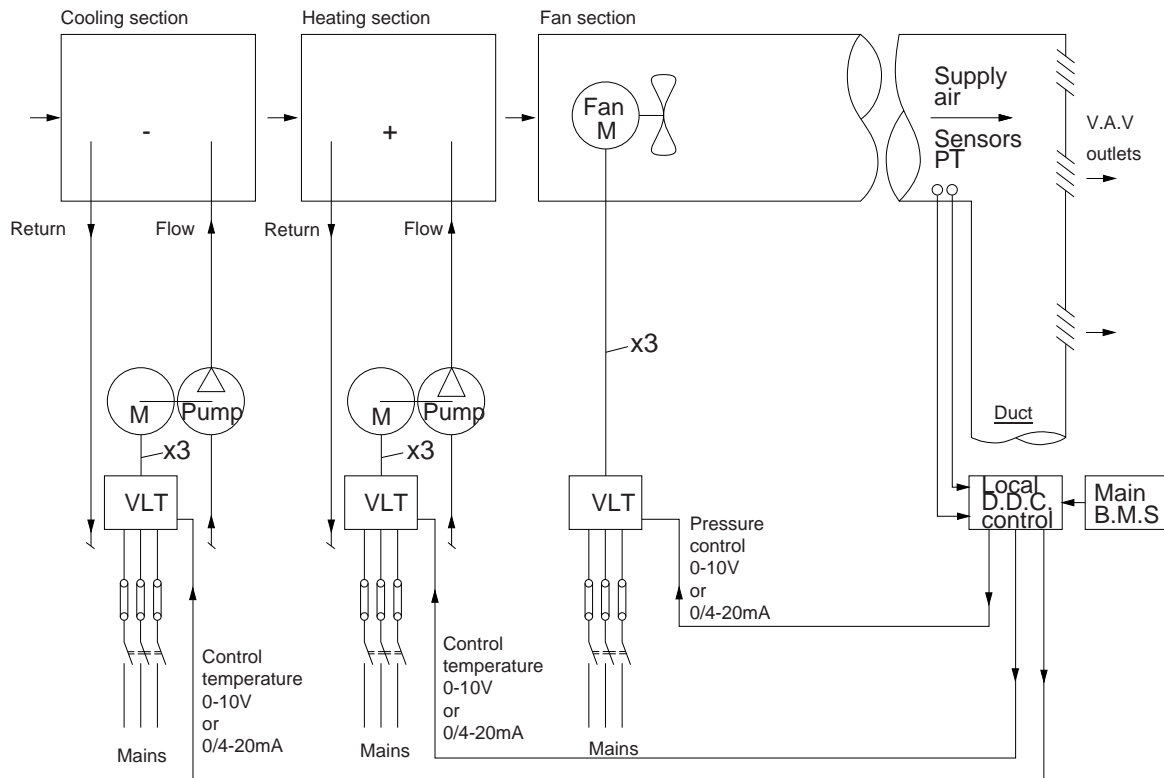


Illustration 12: Traditional Fan System without a Drive

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

3.1.1.9 Fan System Controlled by Drives



e75ha206.11

Illustration 13: Fan System Controlled by Drives

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

3.1.2 Application Examples

The following sections give typical examples of applications.

3.1.2.1 Variable Air Volume

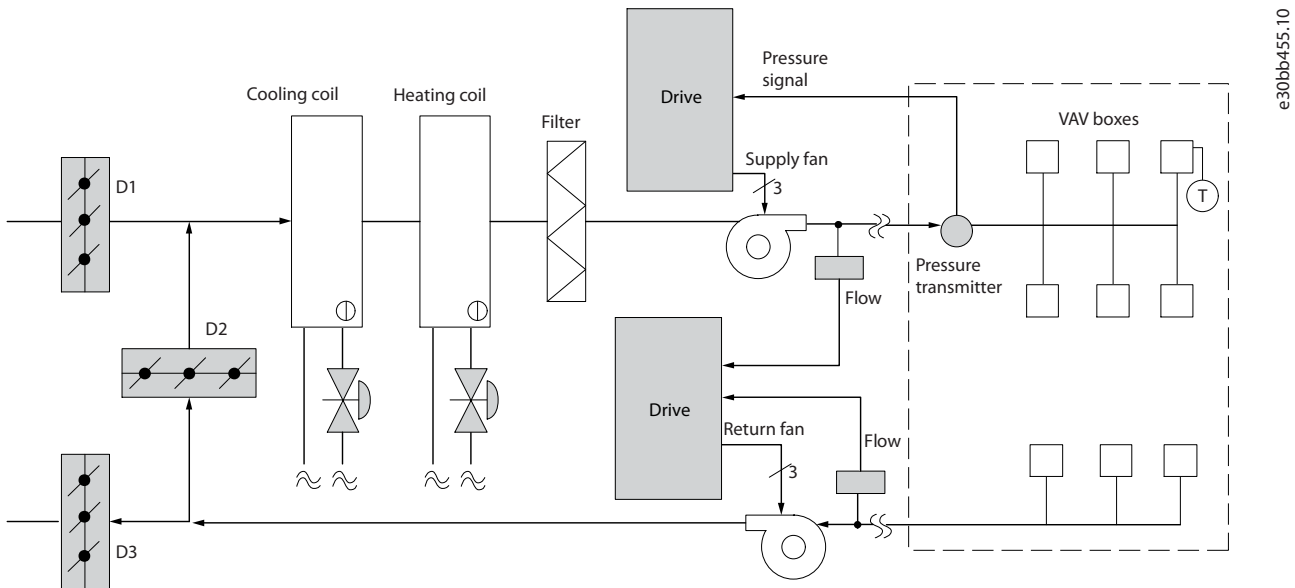
VAV, or variable air volume systems, control both the ventilation and temperature to satisfy the requirements of a building. Central VAV systems are considered to be the most energy-efficient method to air condition buildings. By designing central systems instead of distributed systems, a greater efficiency 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.



e30bb455.10

Illustration 14: Variable Air Volume

3.1.2.2 Constant Air Volume

CAV, or constant air volume systems, are central ventilation systems usually 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 utilizing 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 CO₂ 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 CO₂ 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.

With temperature control, especially used in air conditioning systems, as the outside temperature varies as well as 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 air flow, energy used to heat or cool the fresh air is also reduced, adding further savings.

Several features of the Danfoss dedicated drive can be utilized 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 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 is capable of monitoring and comparing 2 feedback signals to control the return fan by maintaining a fixed differential airflow between the supply and return ducts as well.

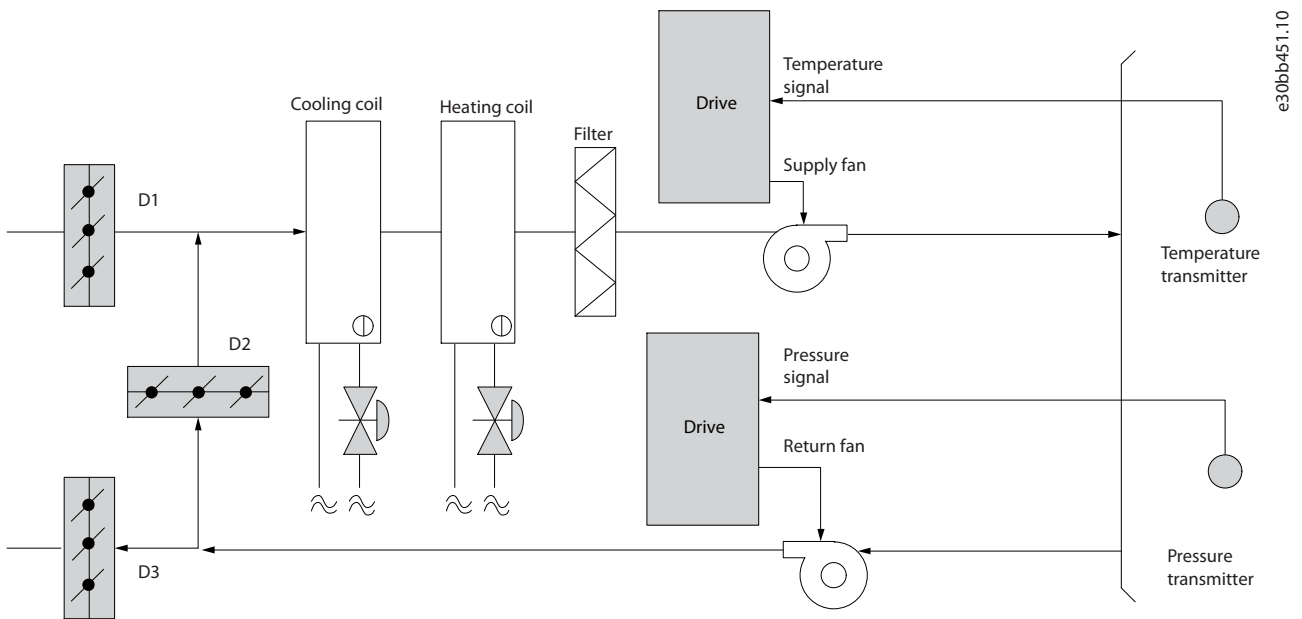


Illustration 15: Constant Air Volume

3.1.2.3 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 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 utilized 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 utilizing 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. Additionally, 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.

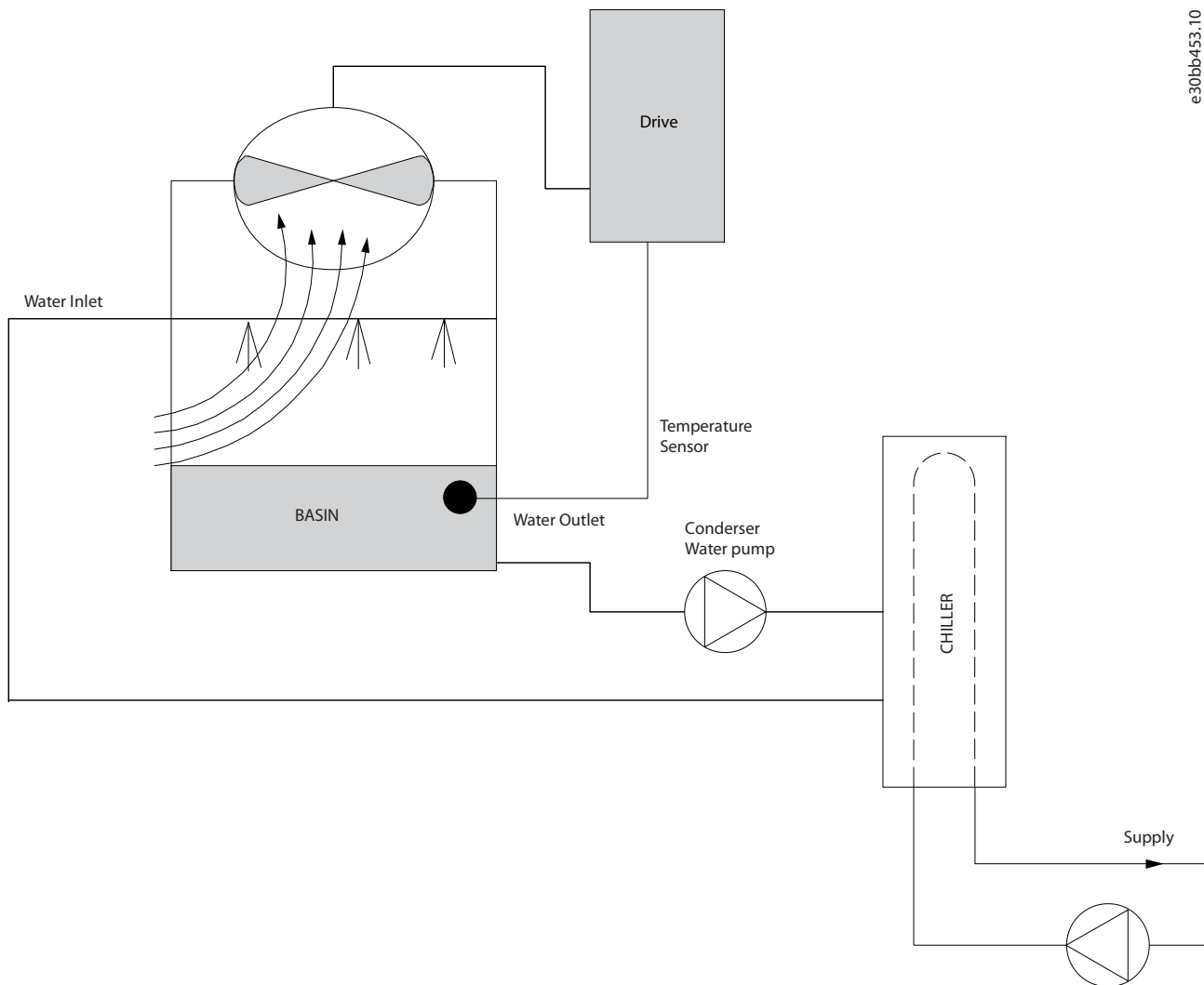


Illustration 16: Cooling Tower Fan

3.1.2.4 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.

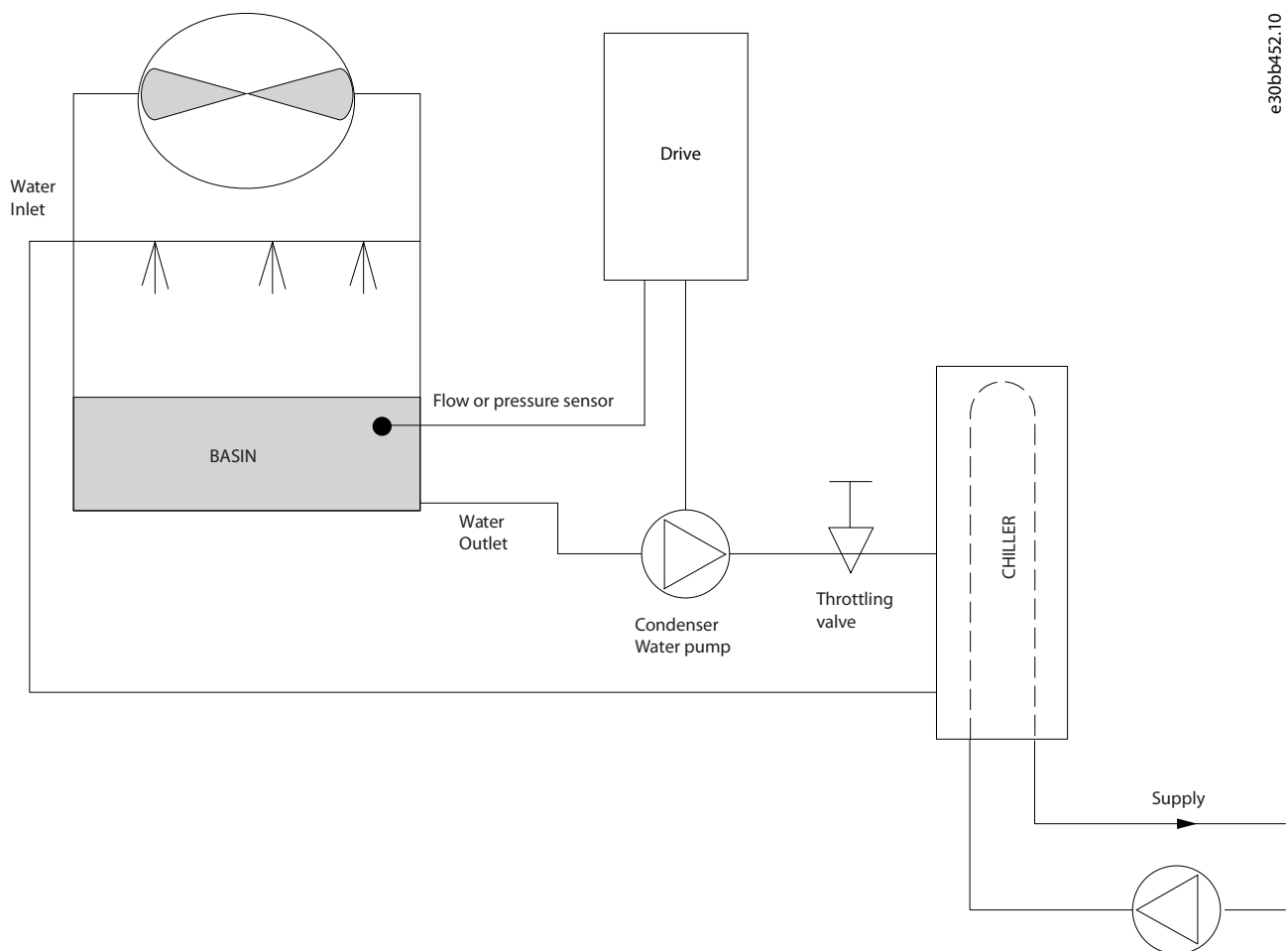


Illustration 17: Condenser Pumps

3.1.2.5 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 utilized.

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 very 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 any time 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 usually 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.

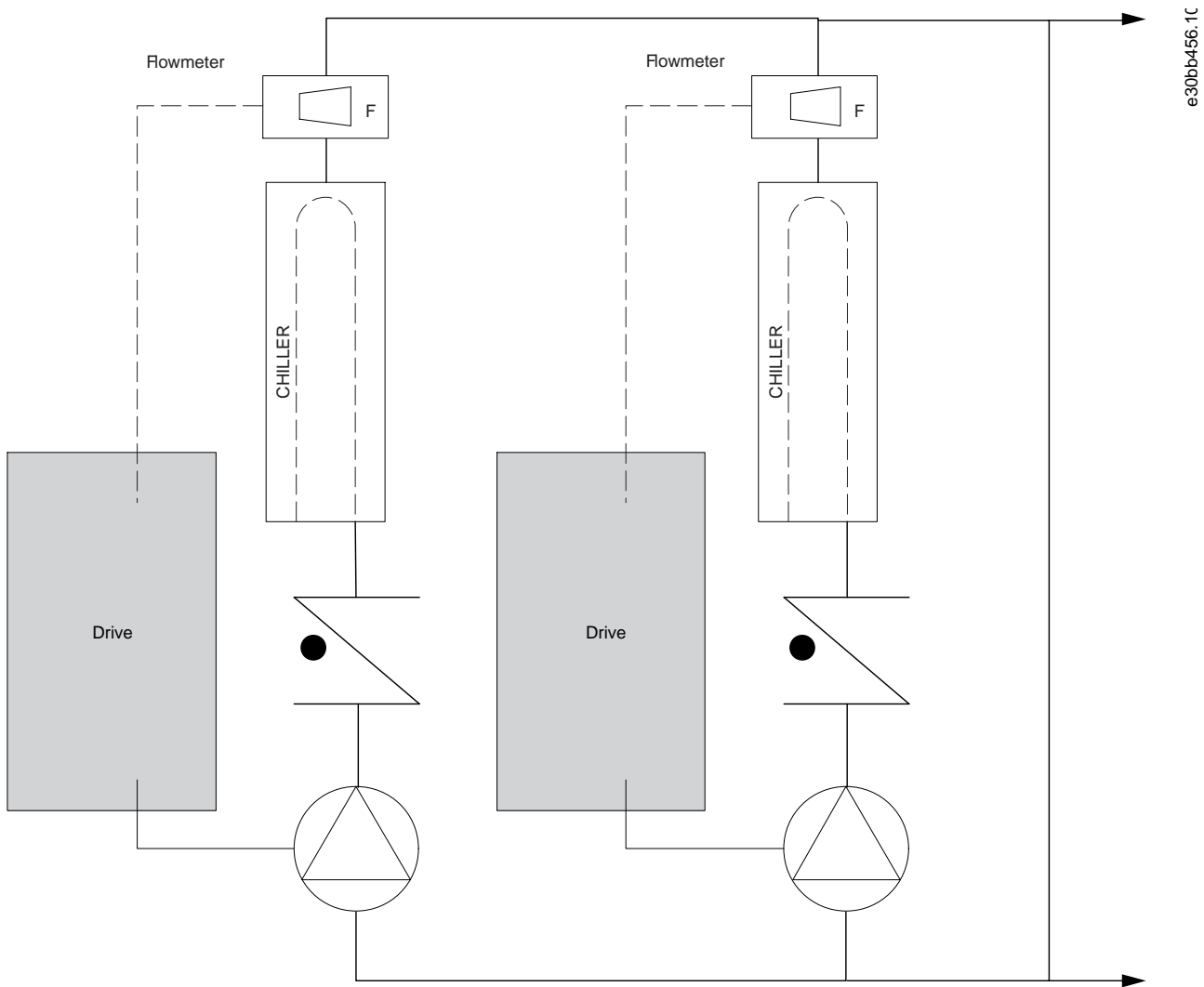


Illustration 18: Primary Pumps

3.1.2.6 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 hydraulically 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.

N O T I C E

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.

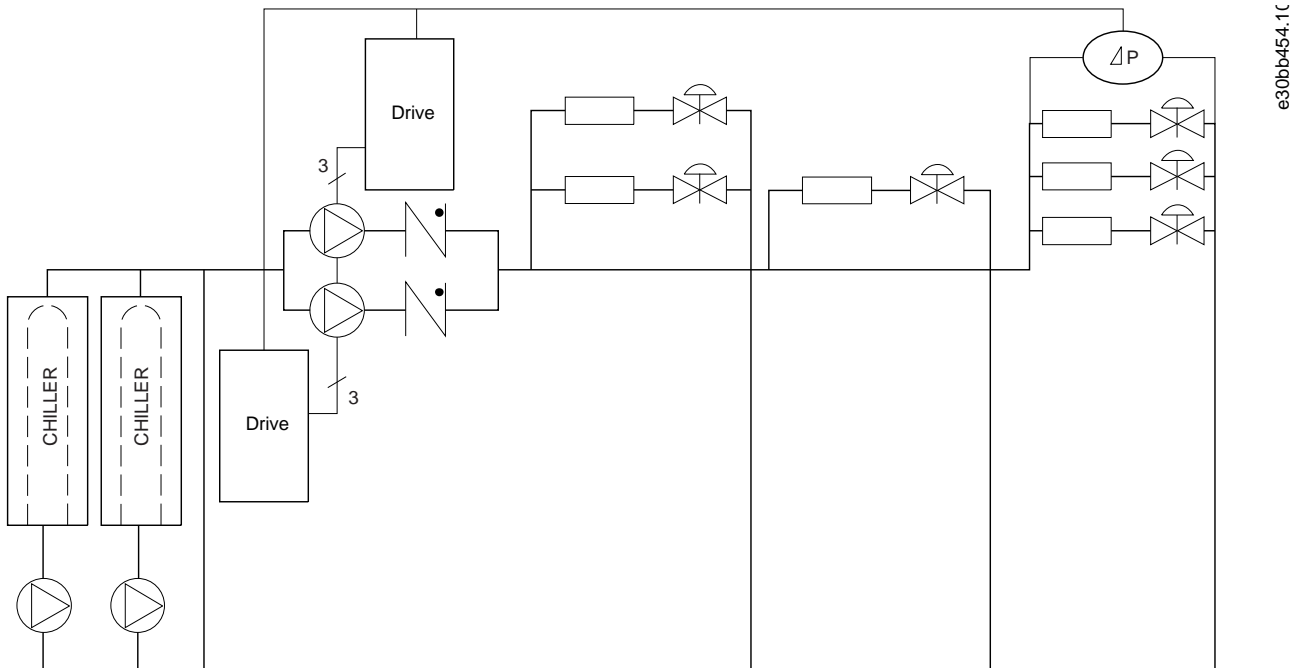


Illustration 19: Secondary Pumps

3.2 Control Structures

3.2.1 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.

3.2.2 Control Structure Open Loop

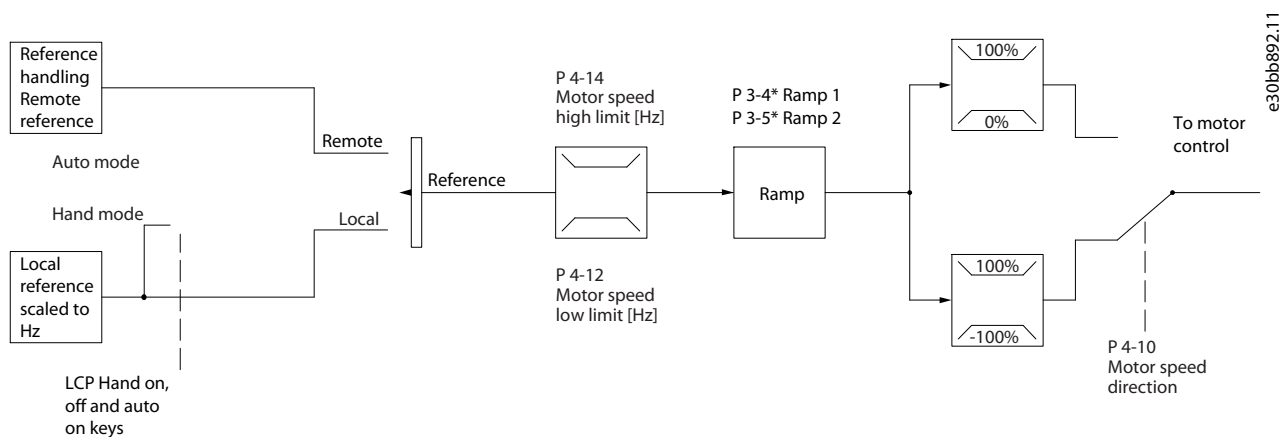


Illustration 20: Open-loop Structure

In the configuration shown in the above illustration, *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.

3.2.3 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 utilizing the Danfoss VVC+ PM control strategy.

Customer advantages:

- Free choice of motor technology (permanent magnet or induction motor).
- Installation and operation as know on induction motors.
- Manufacturer independent when selecting system components (for example, motors).
- Best system efficiency by selecting best components.
- Possible retrofit of existing installations.
- Power range: 0.75–90 kW (1.0–125 hp) (400 V) for induction motors and 0.75–22 kW (1.0–30 hp) (400 V) for PM motors.

Current limitations for PM motors:

- Currently only supported up to 90 kW (125 hp).
- LC filters are not supported with PM motors.
- Kinetic back-up algorithm is not supported with PM motors.
- Support only complete AMA of the stator resistance R_s in the system.
- No stall detection (supported from software version 2.80).

3.2.4 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.

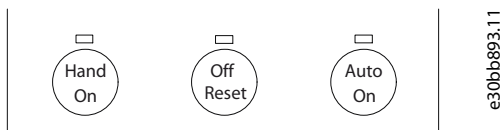


Illustration 21: LCP Keys

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.

3.2.5 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 compressor application where the speed of the compressor is to be controlled to ensure a constant suction pressure in an evaporator. The suction pressure value is supplied to the drive as the setpoint reference. A pressure sensor measures the actual suction pressure in the evaporator and supplies the data to the drive as a feedback signal. If the feedback signal is greater than the setpoint reference, the drive speeds up the compressor to reduce the pressure. In a similar way, if the suction pressure is lower than the setpoint reference, the drive automatically slows down the compressor to increase the pressure.

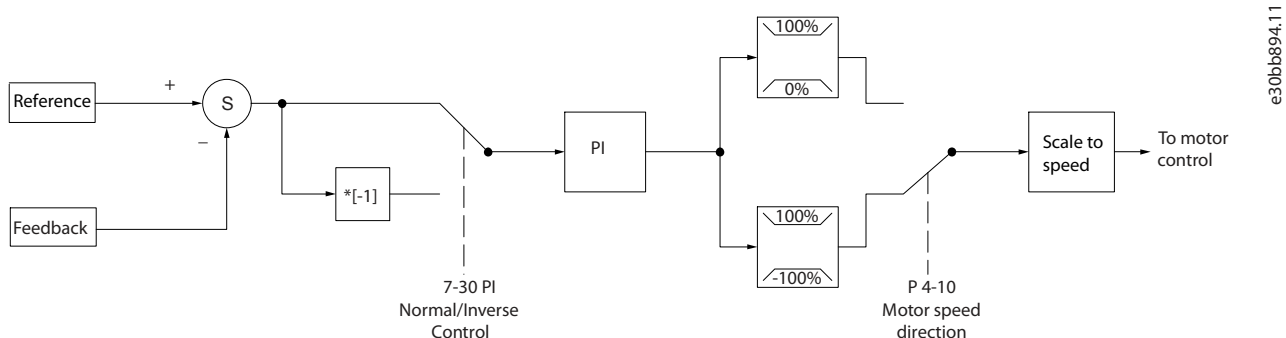


Illustration 22: Control Structure Closed Loop

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.

3.2.6 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 following illustration.

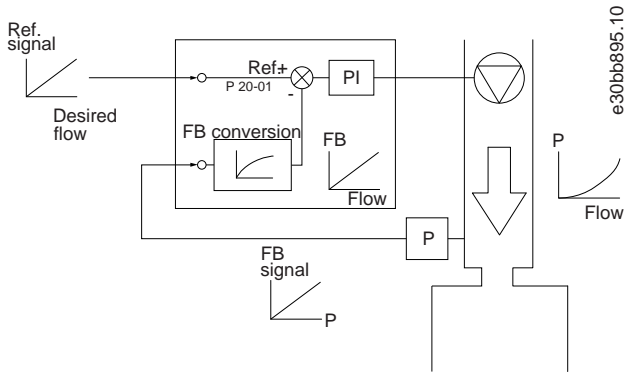


Illustration 23: Feedback Signal Conversion

3.2.7 Reference Handling

Details for open-loop and closed-loop operation.

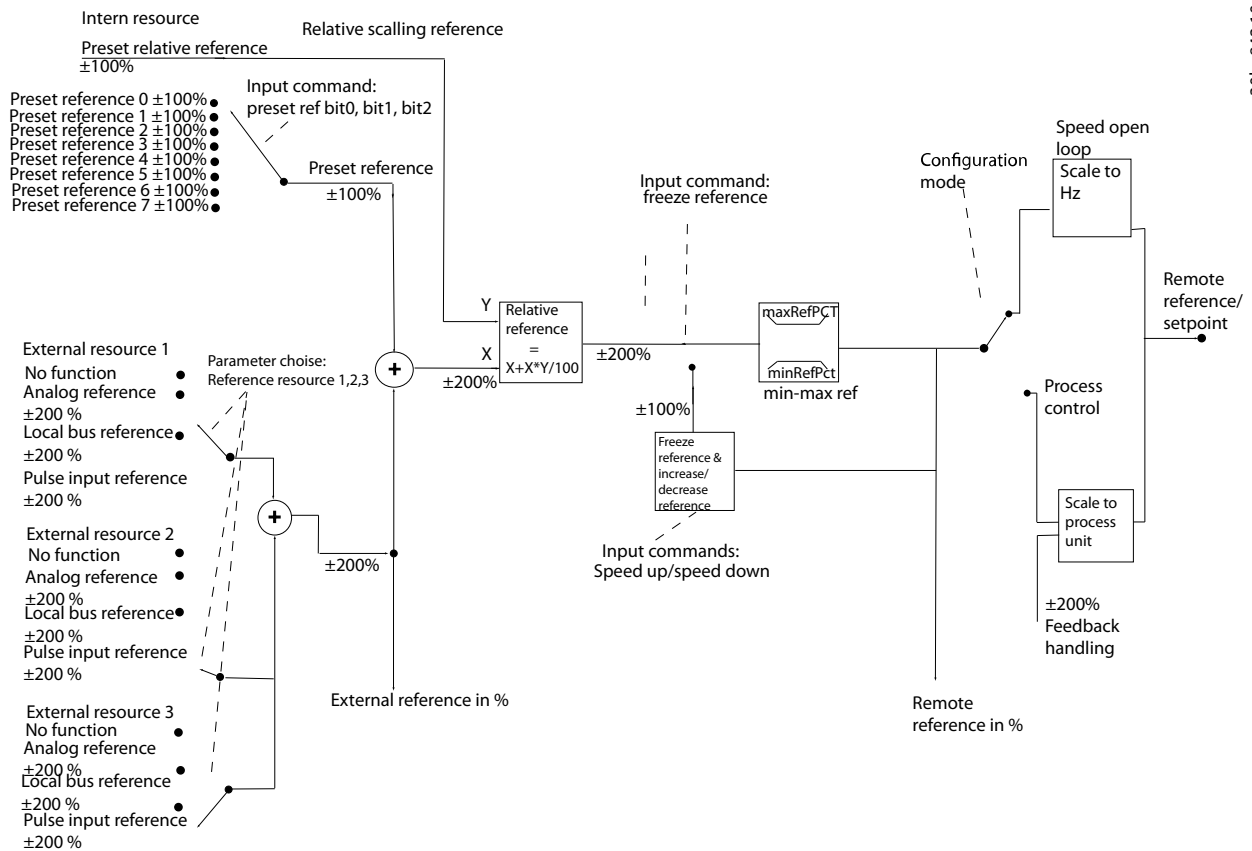


Illustration 24: Block Diagram Showing Remote Reference

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 be scaled using *parameter 3-14 Preset Relative Reference*.

The scaled reference is calculated as follows:

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

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.

3.2.8 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.

3.2.9 Adjusting the Manual PI

Procedure

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%.

3.3 Ambient Running Conditions

3.3.1 Air Humidity

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).

3.3.2 Derating

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.

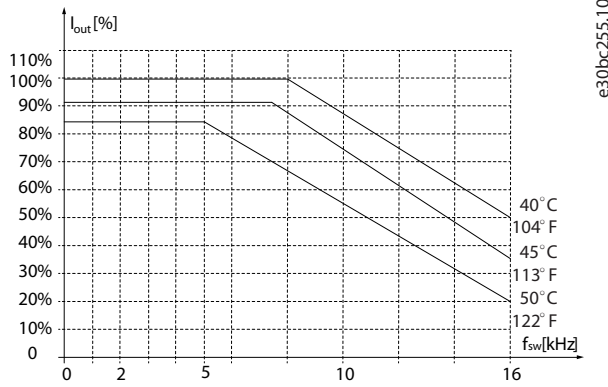


Illustration 25: 0.75–4.0 kW (1.0–5.4 hp), 400 V, Enclosure Size I2, IP54

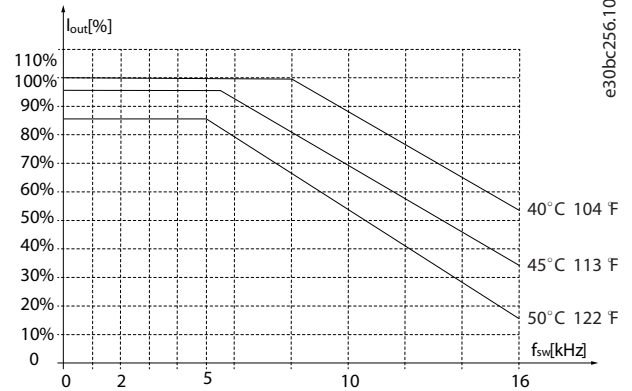


Illustration 26: 5.5–7.5 kW (7.4–10 hp), 400 V, Enclosure Size I3, IP54

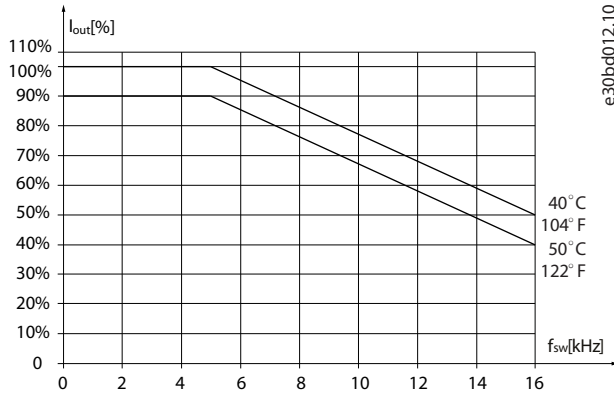


Illustration 27: 11–18.5 kW (15–25 hp), 400 V, Enclosure Size I4, IP54

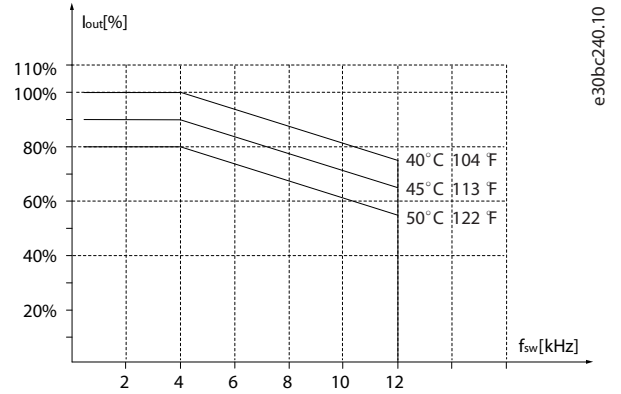


Illustration 28: 22–30 kW (30–40 hp), 400 V, Enclosure Size I6, IP54

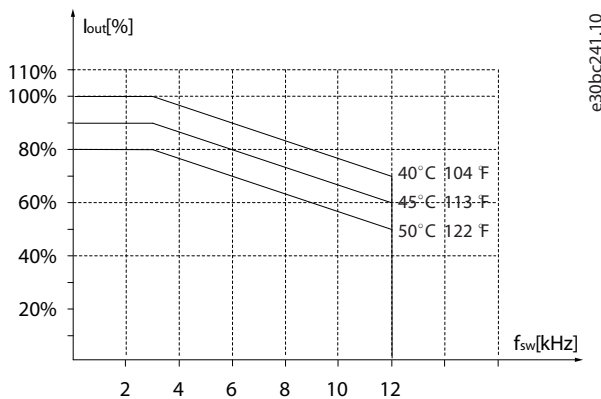


Illustration 29: 37 kW (50 hp), 400 V, Enclosure Size I6, IP54

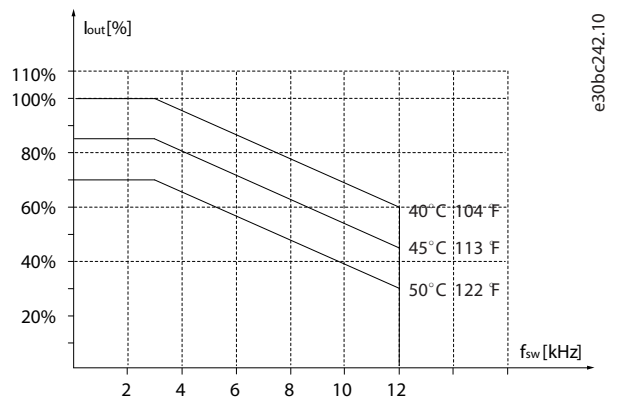


Illustration 30: 45–55 kW (60–74 hp), 400 V, Enclosure Size I7, IP54

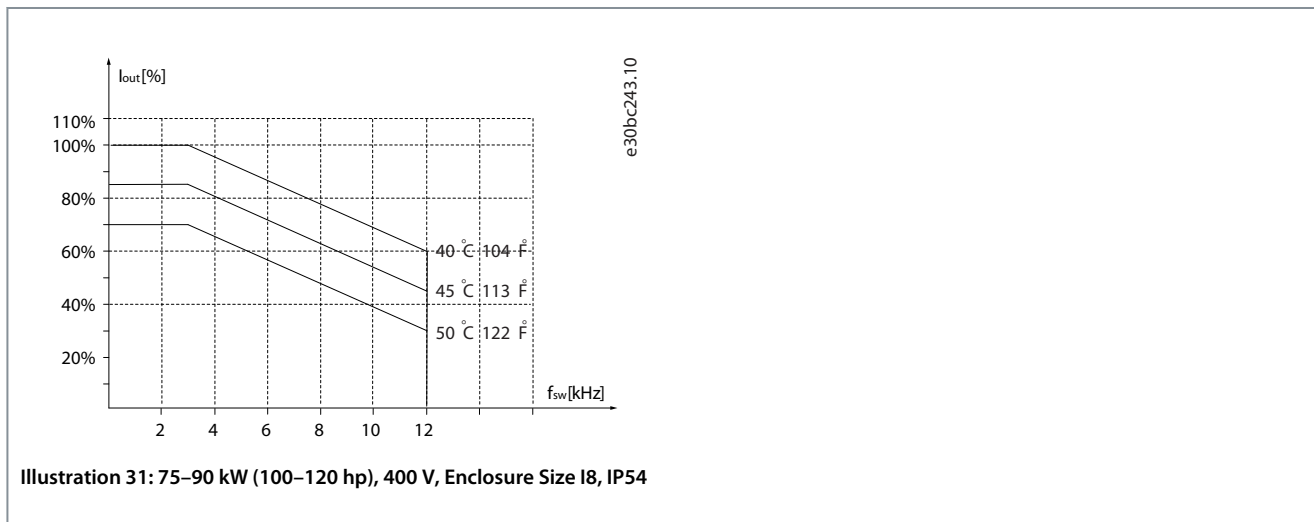


Illustration 31: 75–90 kW (100–120 hp), 400 V, Enclosure Size I8, IP54

3.3.3 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.

3.3.3.1 Acoustic Noise

The acoustic noise from the drive comes from 3 sources:

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

Table 6: Typical Values Measured at a Distance of 1 m (3.28 ft) from the Unit

Enclosure size	Level [dBA] ⁽¹⁾
I2	50.2
I3	54
I4	67.4
I6	70
I7	62
I8	65.6

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

3.3.3.2 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.

3.3.4 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.

3.4 General Aspects of EMC

3.4.1 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 interference usually occurs 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 following illustration.

The use of a shielded motor cable increases the leakage current (see the following illustration) 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 the following illustration.

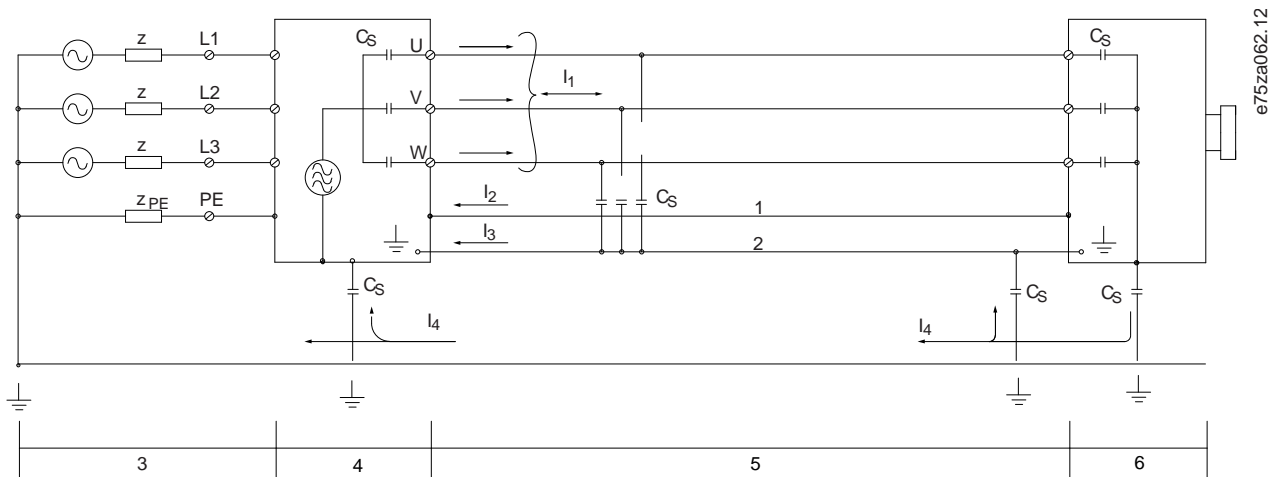


Illustration 32: Generation of Leakage Currents

1	Ground wire	4	Drive
2	Shield	5	Shielded motor cable
3	AC mains supply	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 (pigtailed). Pigtailed 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.

3.4.2 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 7: 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 1 st environment (home and office) with a supply voltage less than 1000 V.	Class B
C2	Drives installed in the 1 st environment (home and office) with a supply voltage less than 1000 V, which are neither plug-in nor movable and are intended to be installed and commissioned by a professional.	Class A Group 1
C3	Drives installed in the 2 nd environment (industrial) with a supply voltage lower than 1000 V.	Class A Group 2
C4	Drives installed in the 2 nd 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 8: 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

3.4.3 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 9: 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
H2 RFI filter (EN 55011 A2, EN/IEC 61800-3 C3)										
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)										
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	–

3.4.4 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 10: 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.

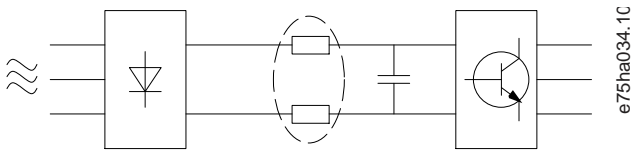


Illustration 33: DC-link Coils

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:

$$THD\% = \sqrt{U_{\frac{2}{5}}^2 + U_{\frac{2}{7}}^2 + \dots + U_{\frac{2}{N}}^2}$$

(U_N % of U)

3.4.4.1 Harmonics Emission Requirements

Equipment is connected to the public supply network.

Table 11: 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.

3.4.4.2 Harmonics Test Results (Emission)

Power sizes up to PK75 in T4 complies with IEC/EN 61000-3-2 Class A. Power sizes from P1K1 and up to P90K in T4 complies with IEC/EN 61000-3-12, Table 4.

Table 12: 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 $R_{SCE} \geq 120$	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 $R_{SCE} \geq 120$	48		46	

Table 13: 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 $R_{SCE} \geq 120$	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 $R_{SCE} \geq 120$	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 with reference to 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.

3.4.5 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.

3.5 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 [Illustration 35](#).

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

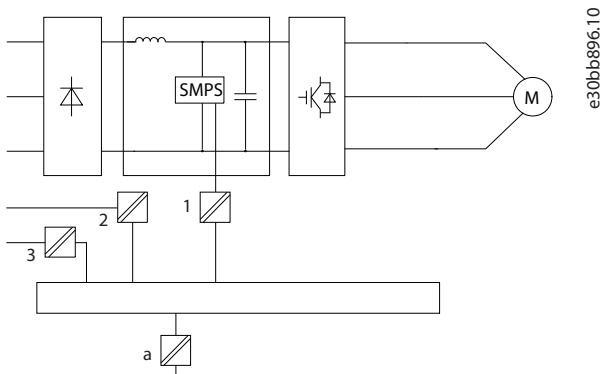


Illustration 34: Galvanic Isolation 0.75–22 kW (1.0–30 hp)

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

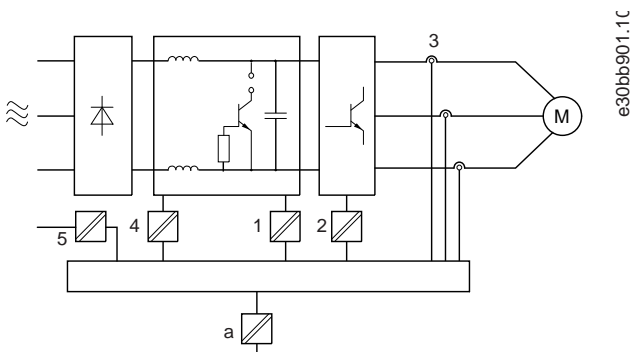


Illustration 35: Galvanic Isolation 30–90 kW (40–125 hp)

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

The functional galvanic isolation (see [Illustration 34](#)) is for the RS485 standard bus interface.

! C A U T I O N !

INSTALLATION AT HIGH ALTITUDE

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

3.6 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.

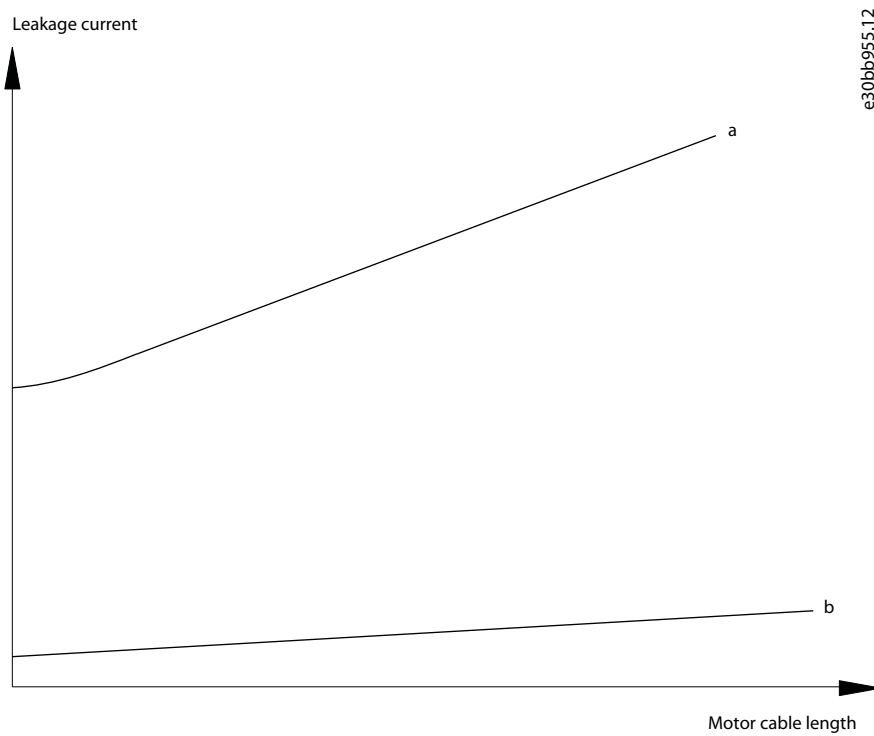


Illustration 36: Influence of the Cable Length and Power Size on Leakage Current, Power Size a > Power Size B

The leakage current also depends on the line distortion.

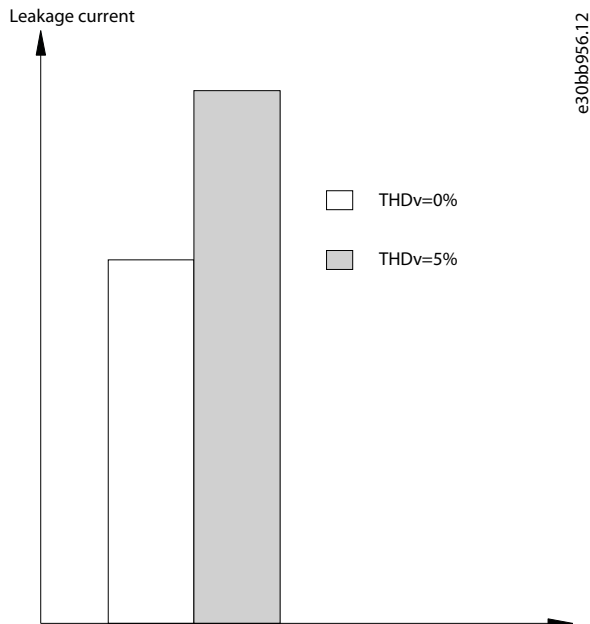


Illustration 37: Influence of Line Distortion on Leakage Current

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 mm² (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 back-up.
- 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.

3.6.1 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.

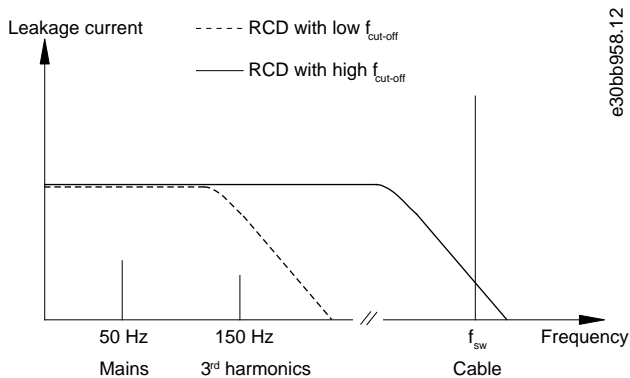


Illustration 38: Mains Contributions to Leakage Current

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

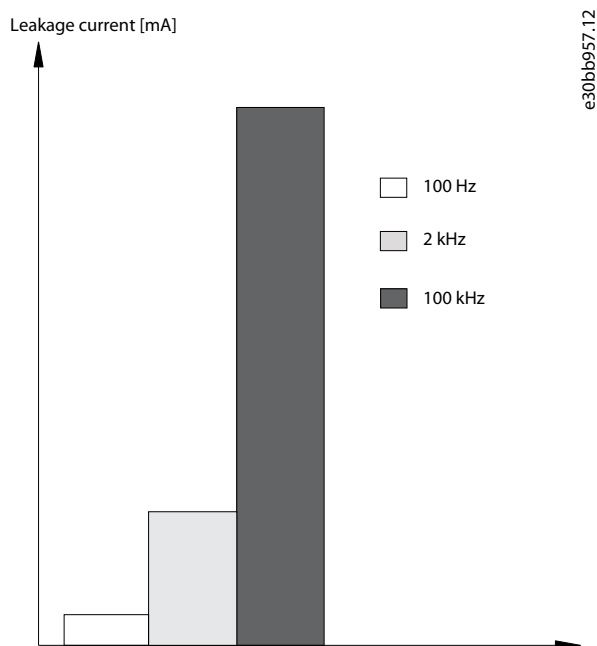


Illustration 39: Influence of Cut-off Frequency of the RCD on what is Responded to/Measured

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.

3.7 Extreme Running Conditions

3.7.1 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 drop-out

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 drop-out and the motor load determines how long it takes for the drive to coast.

3.7.2 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 following illustration.

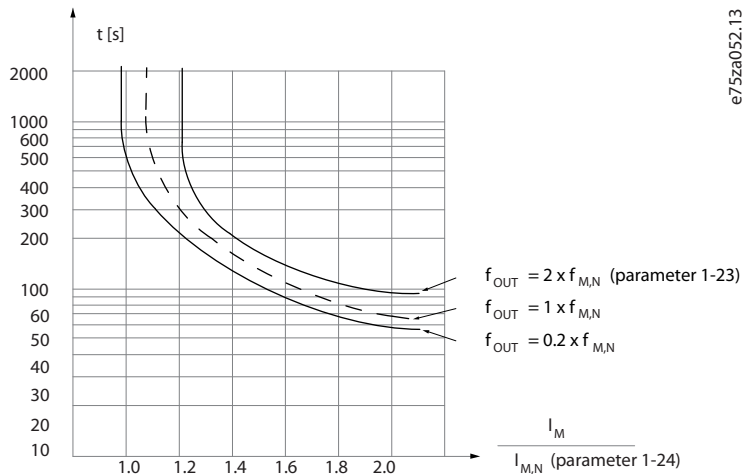


Illustration 40: Motor Thermal Protection Characteristic

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.

3.7.3 Thermistor Inputs

The thermistor cutout value is $>3 \text{ k}\Omega$.

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).

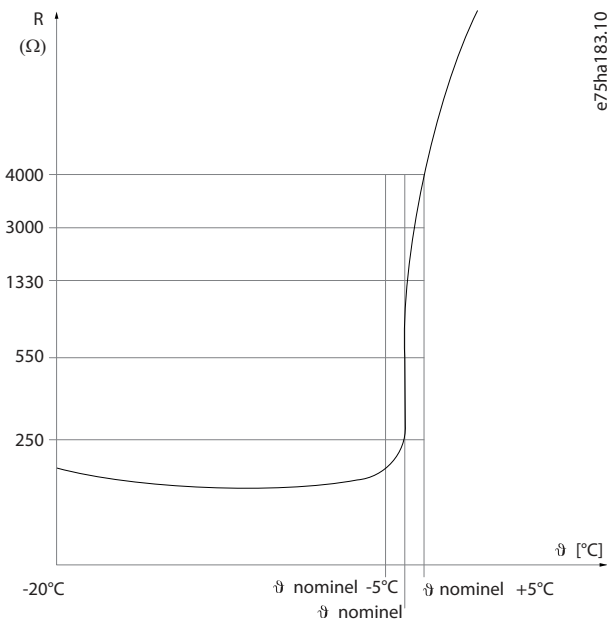


Illustration 41: Trip due to High Motor Temperature

3.7.3.1 Example with Digital Input and 10 V Power Supply

The drive trips when the motor temperature is too high.

Parameter set-up:

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

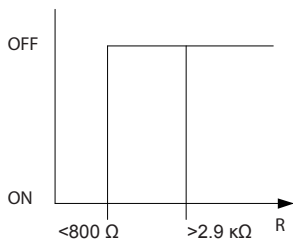
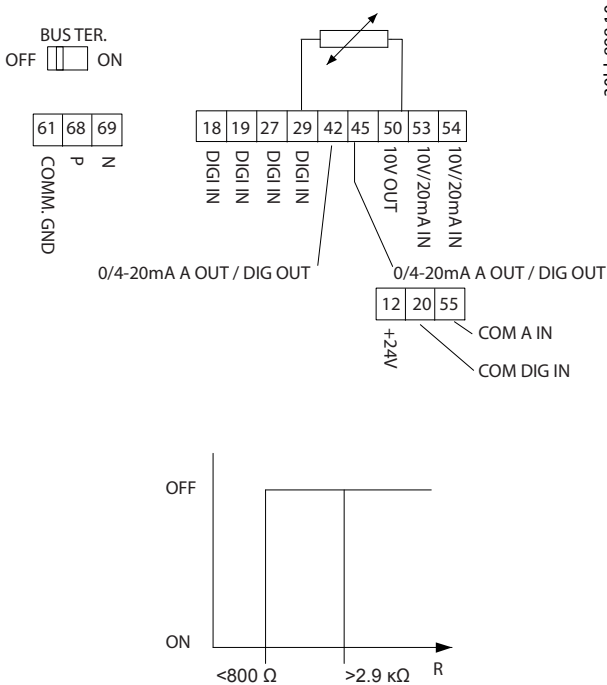


Illustration 42: Digital Input/10 V Power Supply

3.7.3.2 Example with Analog Input and 10 V Power Supply

The drive trips when the motor temperature is too high.

Parameter set-up:

- 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.

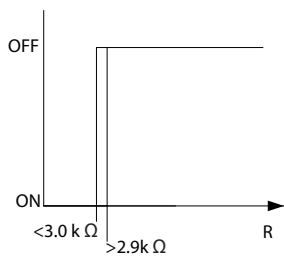
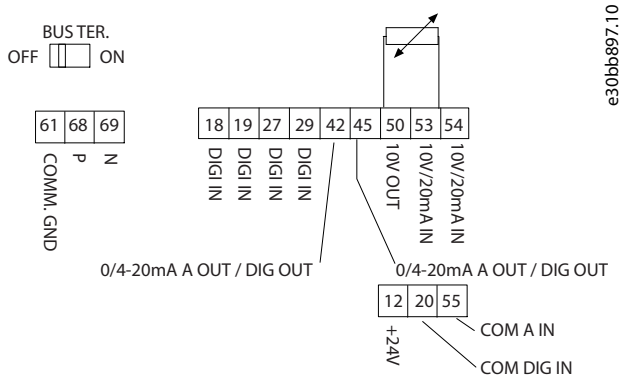


Illustration 43: Analog Input/10 V Power Supply

Table 14: 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*.

4 Selection and Ordering

4.1 Type Code

A type code defines a specific configuration of the drive. Use the following illustration 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	3	1	P				T					H	X			X	X	X	S	X	X	X	X	A	X	B	X	C	X	X	X	X	X	D	X

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Illustration 44: Type Code

Table 15: Type Code Description

Description	Position	Possible choice
Product group & FC series	1–6	FC 131
Power rating	7–10	0.75–90 kW (1.0–125 hp) (PK75-P90K)
Number of phases	11	3 phases (T)
Mains voltage	11–12	T4: 380-480 V AC
Enclosure	13–15	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
Brake	18	X: No brake chopper included
Display	19	A: Alpha numeric 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
Software release	24–27	SXXXX: Latest release - standard software
Software language	28	X: Standard
A options	29–30	AX: No A options
B options	31–32	BX: No B options
C0 options MCO	33–34	CX: No C options

C1 options	35	X: No C1 options
C option software	36–37	XX: No options
D options	38–39	DX: No D0 options

4.2 Options and Accessories

4.2.1 Local Control Panel (LCP)

Table 16: Ordering Number of LCP

Ordering number	Description
132B9221	LCP 32

Table 17: Technical Data of LCP

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

5 Installation

5.1 Mechanical Installation

5.1.1 Side-by-side Installation

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

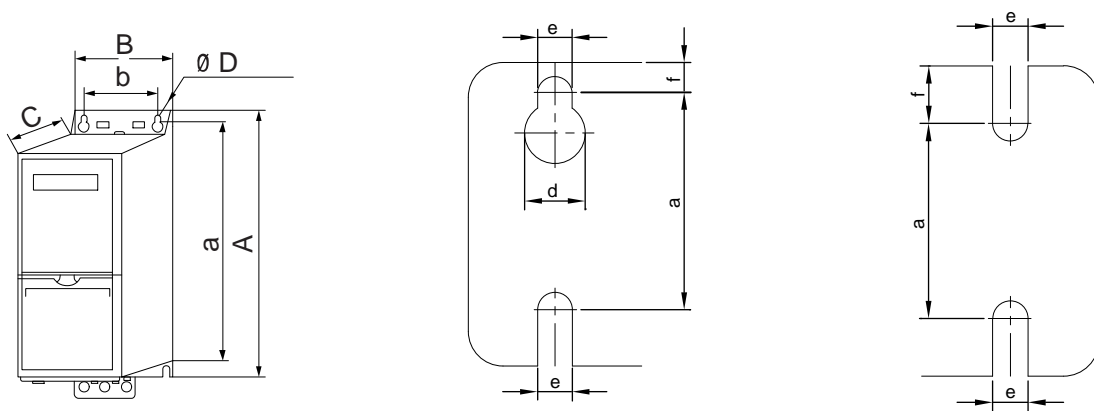
Table 18: Clearance Required for Cooling

Size	IP class	Power [kW (hp)]	Clearance above/below [mm (in)]
I2	IP54	0.75–4.0 (1.0–5.0)	100 (4.0)
I3	IP54	5.5–7.5 (7.5–10)	100 (4.0)
I4	IP54	11–18.5 (15–25)	100 (4.0)
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)

NOTICE

The drives are not suitable for outdoor mounting.

5.1.2 Drive Dimensions



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Illustration 45: Dimensions

Table 19: 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)

Enclosure Size		I2	I3	I4	I6	I7	I8
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 [5.1.1 Side-by-side Installation](#).

5.1.3 Shipping Dimensions

Table 20: Shipping Dimensions

Enclosure frame size	T4 (380–480 V AC) [kW (hp)]	IP frame	Maximum weight [kg (lb)]	Height [mm (in)]	Width [mm (in)]	Depth [mm (in)]
I2	0.75–4.0 (1–5)	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 (25.0)
I5	11–18.5 (15–25)	IP54	23.3 (51.4)	850 (33.5)	370 (15.6)	460 (18.1)
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)

5.2 Electrical Installation

5.2.1 Electrical Wiring

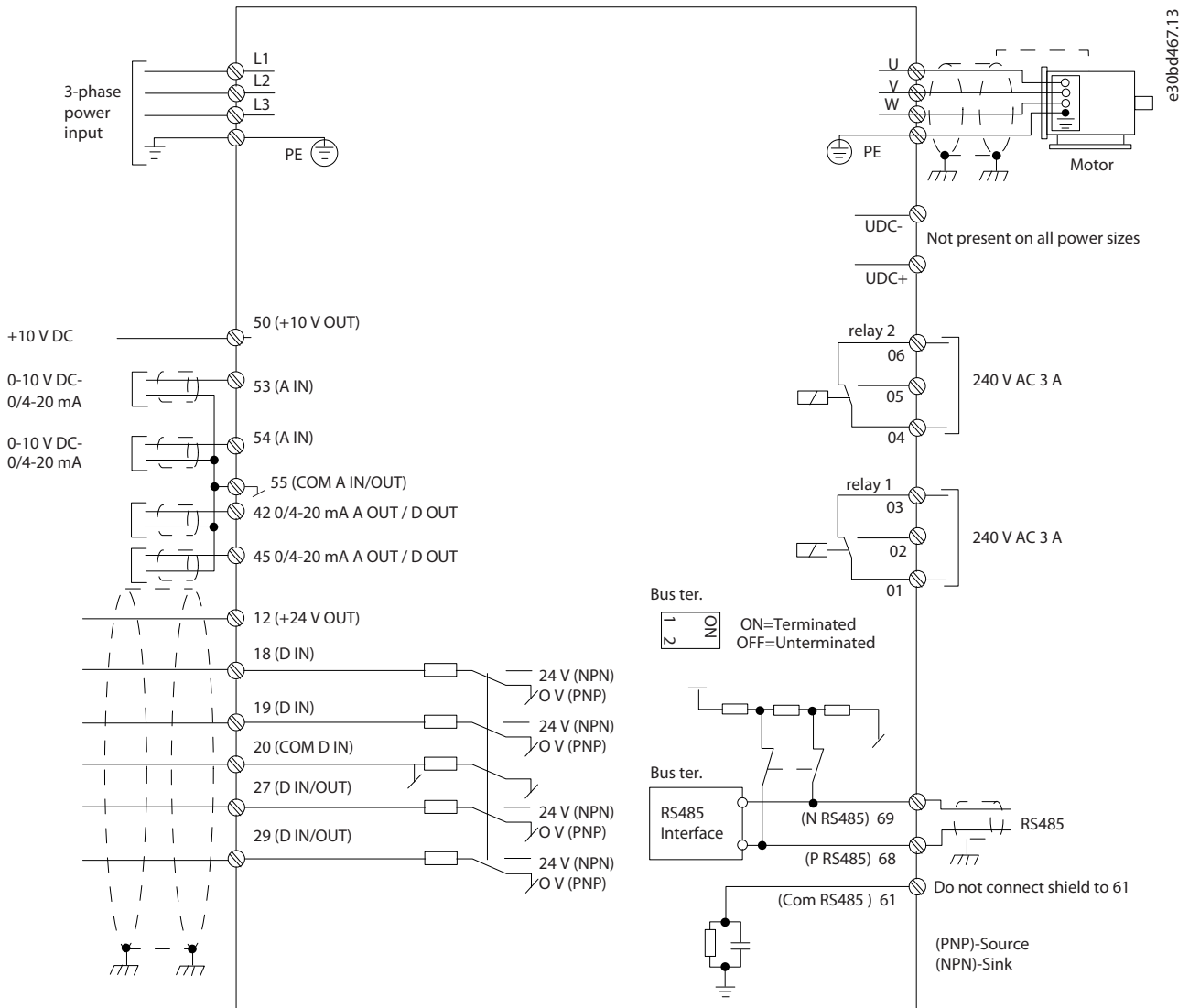


Illustration 46: Basic Wiring Schematic Drawing

NOTICE

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

- IP54, 380–480 V, 22–90 kW (30–125 hp)

5.2.2 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 21: Tightening Torques for Enclosure Sizes I2–I8

Power [kW (hp)]			Torque [Nm (in-lb)]					
Enclosure size	IP class	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)	0.8 (7.0)	0.8 (7.0)	0.5 (4.0)	0.8 (7.0)	0.5 (4.0)
I3	IP54	5.5–7.5 (7.5–10)	0.8 (7.0)	0.8 (7.0)	0.8 (7.0)	0.5 (4.0)	0.8 (7.0)	0.5 (4.0)
I4	IP54	11–18.5 (15–25)	1.2 (11)	1.2 (11)	0.8 (7.0)	0.5 (4.0)	0.8 (7.0)	0.5 (4.0)

Power [kW (hp)]			Torque [Nm (in-lb)]					
16	IP54	22–37 (30–50)	4.5 (40)	4.5 (40)	–	0.5 (4.0)	3 (27)	0.6 (5.0)
17	IP54	45–55 (60–70)	10 (89)	10 (89)	–	0.5 (4.0)	3 (27)	0.6 (5.0)
18	IP54	75–90 (100–125)	14 (124)/24 (212) ⁽¹⁾	14 (124)/24 (212) ⁽¹⁾	–	0.5 (4.0)	3 (27)	0.6 (5.0)

¹ Cable dimensions ≤95 mm².

5.2.3 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.

For IP54, 400 V, 0.75–18.5 kW (1.0–25 hp) units, open the RFI switch by removing the EMC screw inside the drive when at IT grid. The EMC screw is shown in the the following illustration.

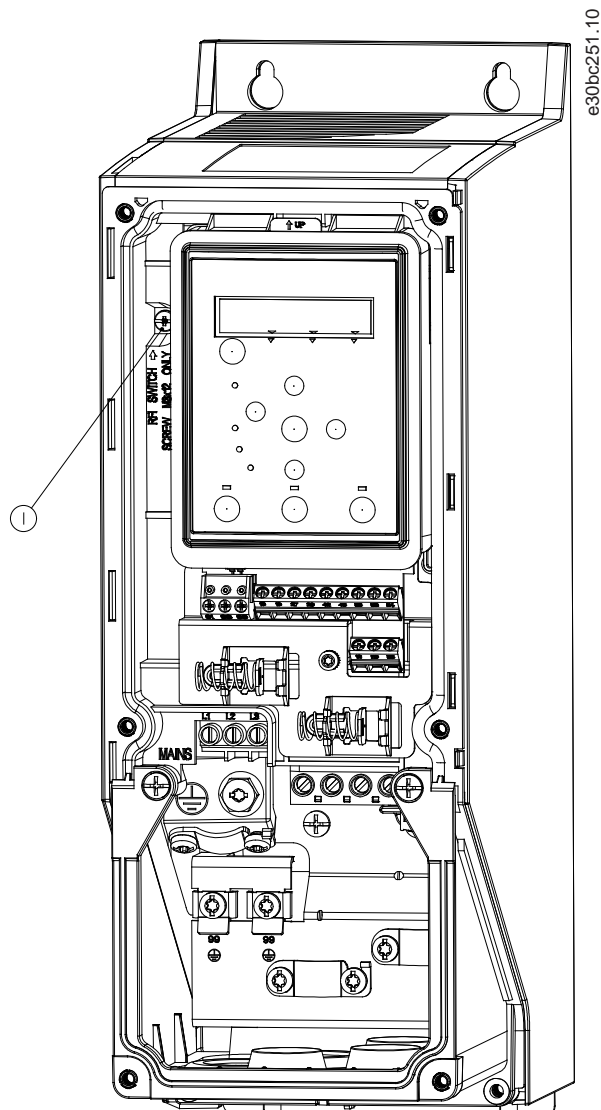


Illustration 47: IP54, 400 V, 0.75–18.5 kW (1–25 hp)

1	EMC screw
---	-----------

For IP54, 400 V, 22-90 kW (30–125 hp) units, the RFI switch can be opened in *parameter 14-50 RFI Filter*. Select [1] On to turn the RFI filter on. The RFI filter ensures that the drive complies with EMC standards. Select [0] Off only when the drive is connected to IT mains.

NOTICE

If reinserted, use only M3x12 screw.

5.2.4 Mains and Motor Connection

5.2.4.1 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 the motor.
- Keep the motor cable as short as possible to reduce the noise level and leakage currents.
- Also see EMC-Correct Installation in the [5.2.5 EMC-compliant Electrical Installation](#).

5.2.4.2 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 [5.2.2 Electrical Installation in General](#).

5.2.4.3 Enclosure Size I2

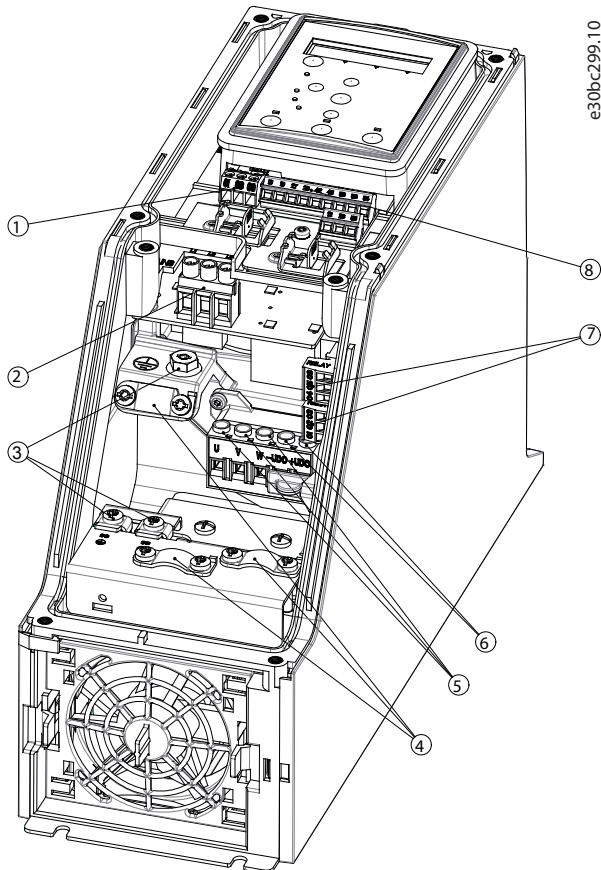


Illustration 48: Enclosure Size I2, IP54, 380–480 V, 0.75–4.0 kW (1.0–5.0 hp)

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

5.2.4.4 Enclosure Size I3

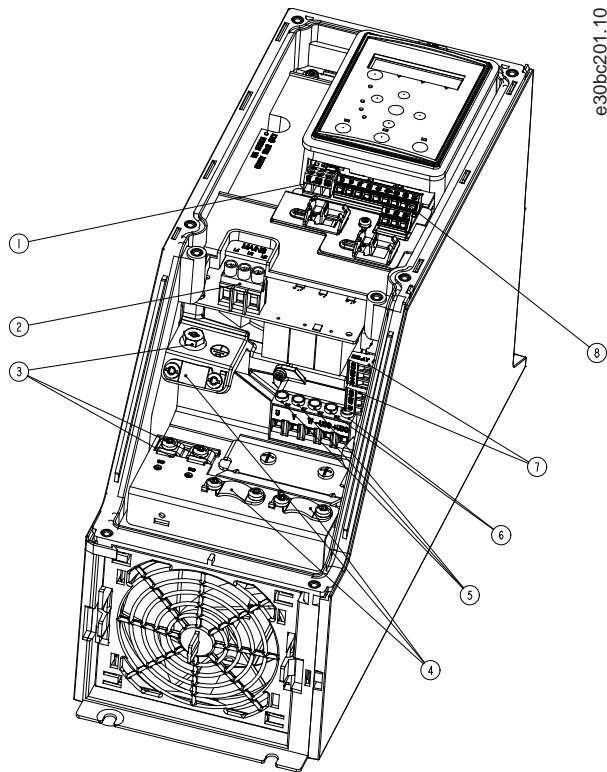


Illustration 49: Enclosure Size I3, IP54, 380–480 V, 5.5–7.5 kW (7.5–10 hp)

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

5.2.4.5 Enclosure Size I4

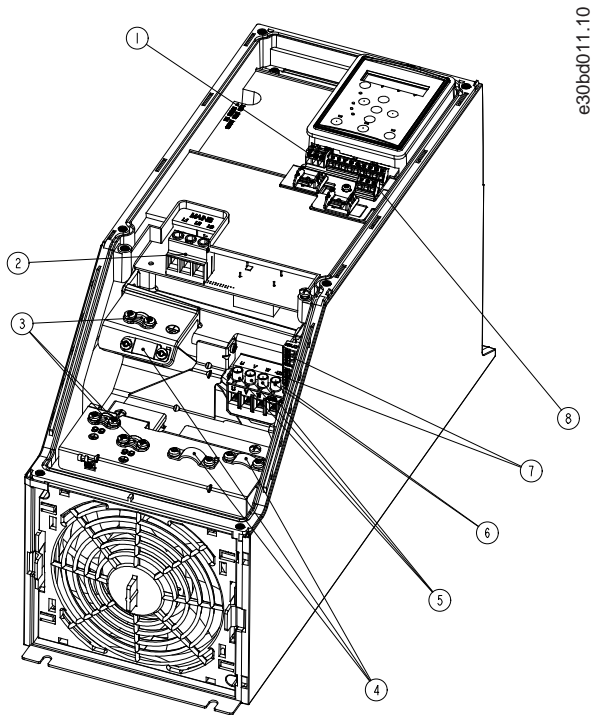
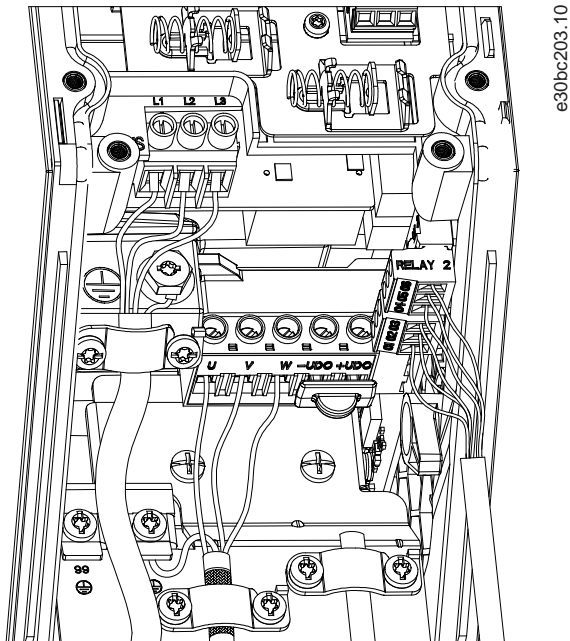


Illustration 50: Enclosure Size I4, IP54, 380–480 V, 11–18.5 kW (15–25 hp)

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

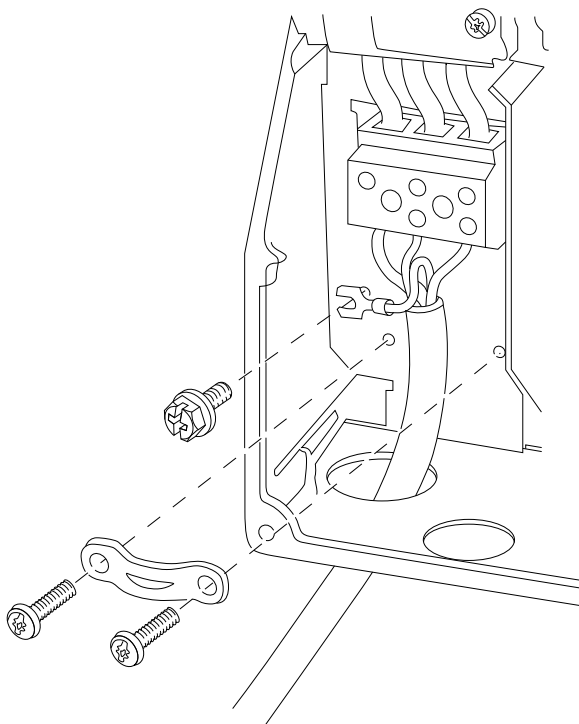
5.2.4.6 IP54 Enclosure Sizes I2, I3, I4



e30bc203.10

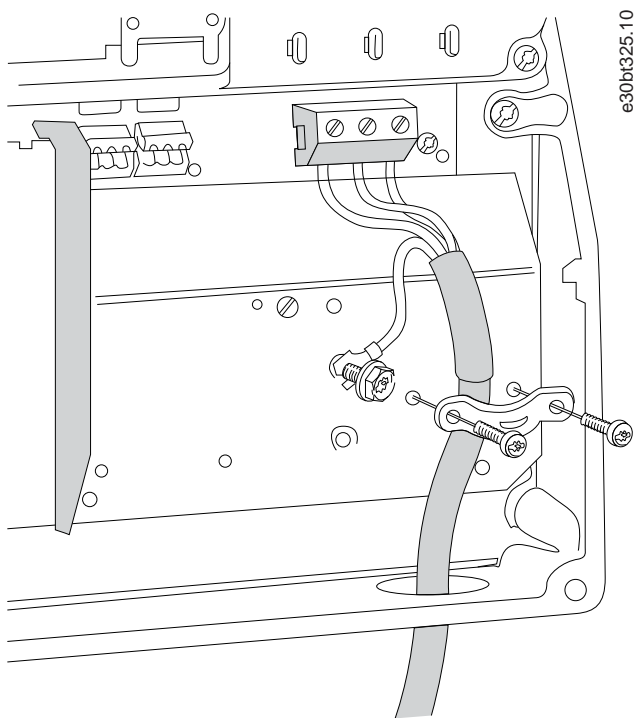
Illustration 51: IP54 Enclosure Sizes I2, I3, I4

5.2.4.7 Enclosure size I6



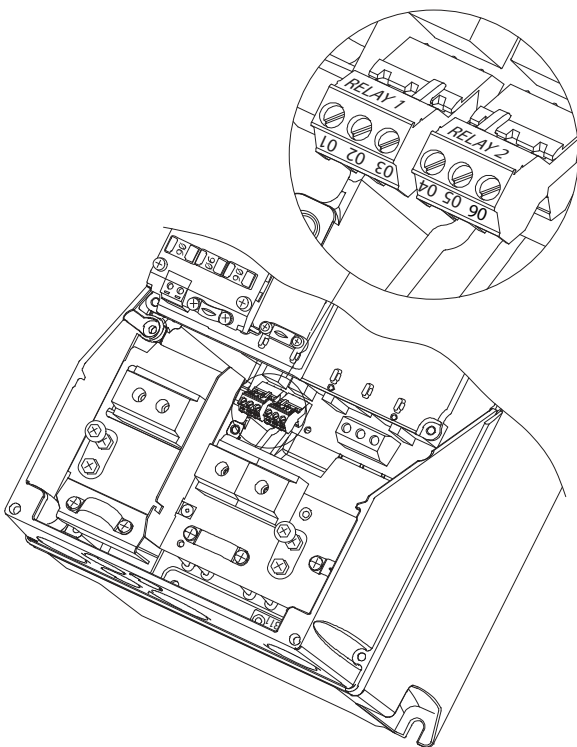
e30bt326.10

Illustration 52: Connecting to Mains for Enclosure Size I6, IP54, 380–480 V, 22–37 kW (30–50 hp)



e30bt325.10

Illustration 53: Connecting to Motor for Enclosure Size I6, IP54, 380–480 V, 22–37 kW (30–50 hp)



e30ba215.10

Illustration 54: Relays on Enclosure Size I6, IP54, 380–480 V, 22–37 kW (30–50 hp)

5.2.4.8 Enclosure size I7, I8

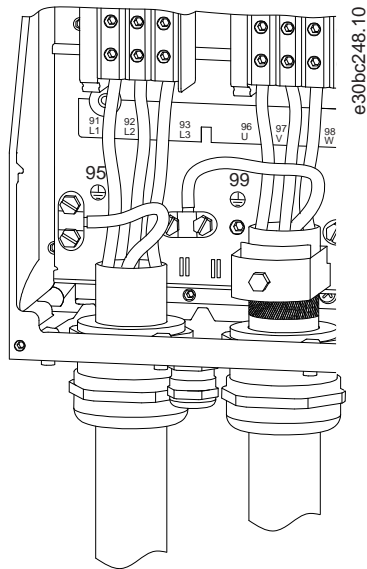


Illustration 55: Enclosure Sizes I7, I8, IP54, 380–480 V, 45–55 kW (60–70 hp), IP54, 380–480 V, 75–90 kW (100–125 hp)

5.2.5 EMC-compliant Electrical Installation

To ensure EMC-correct electrical installation, observe the following:

- Use only shielded/armored motor cables and shielded/armored control cables.
- Ground the shield at both ends.
- Avoid installation with twisted shield ends (pigtailed), 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.
- Use star washers and galvanically conductive installation plates.

e30bb761.13

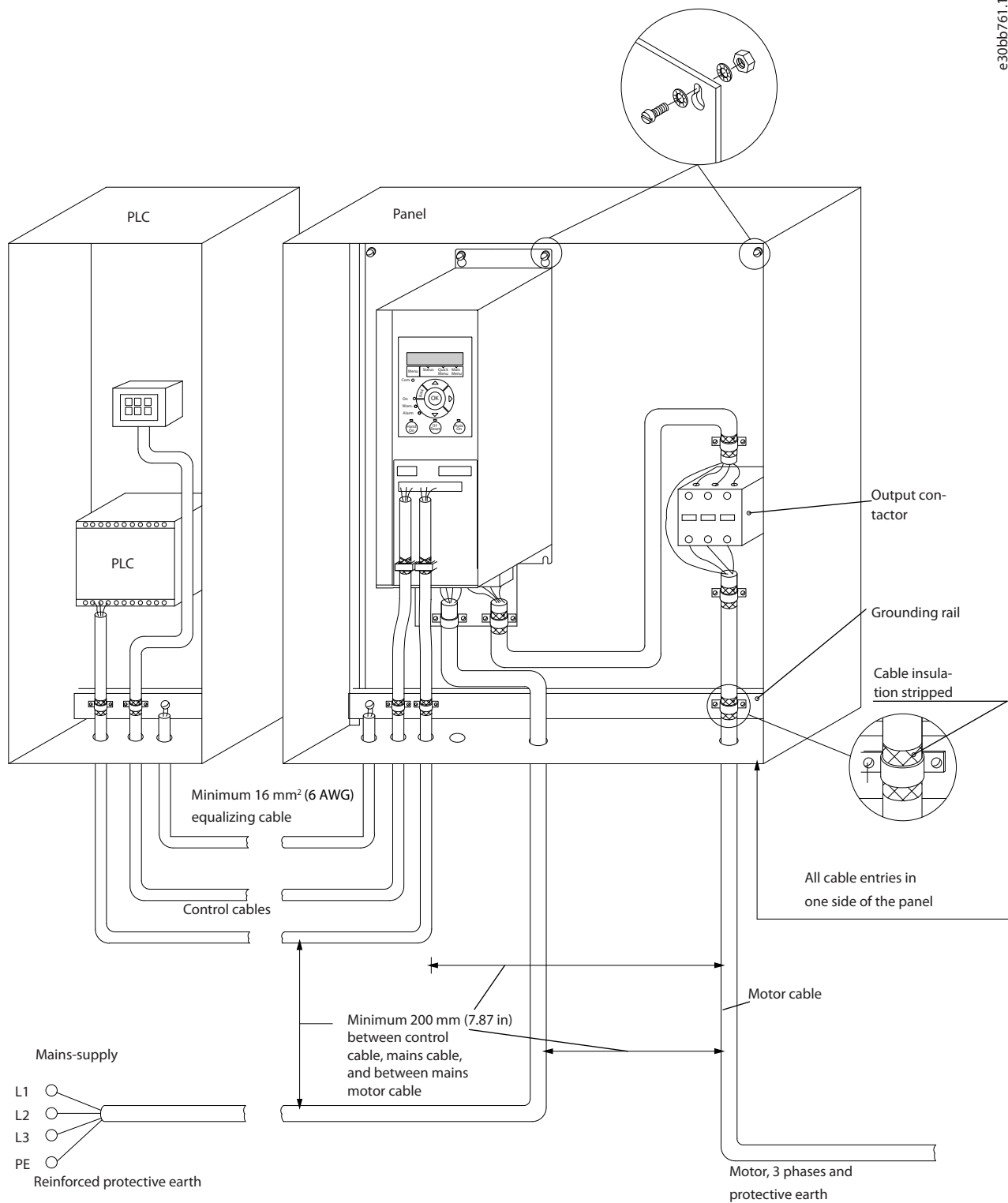


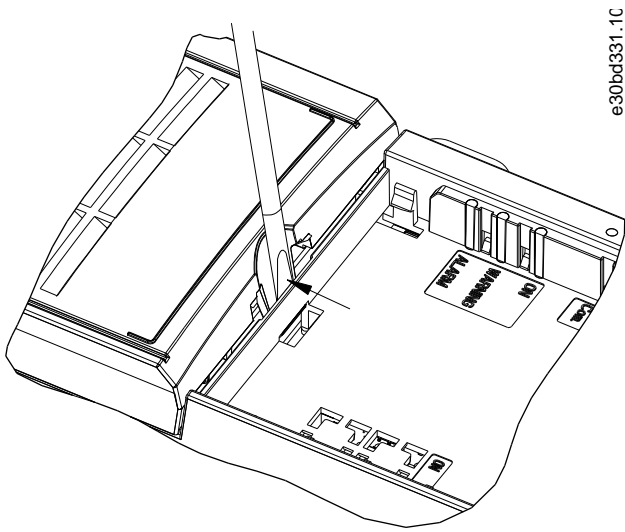
Illustration 56: EMC-compliant Installation

5.2.6 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 the following illustration.

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

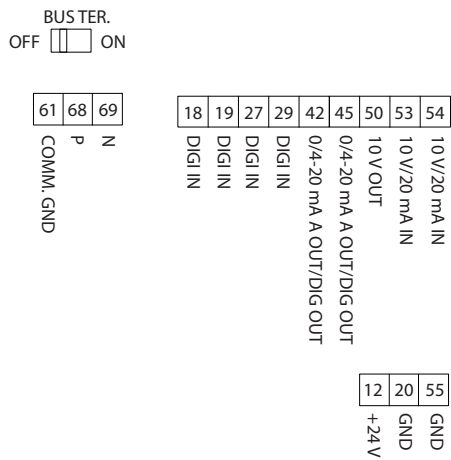


e30bd331.1C

Illustration 57: Removing the Terminal Cover

The following illustration 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).



e30bf892.10

Illustration 58: Control Terminals

6 RS485 Installation and Set-up

6.1 RS485

6.1.1 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 the following illustration.

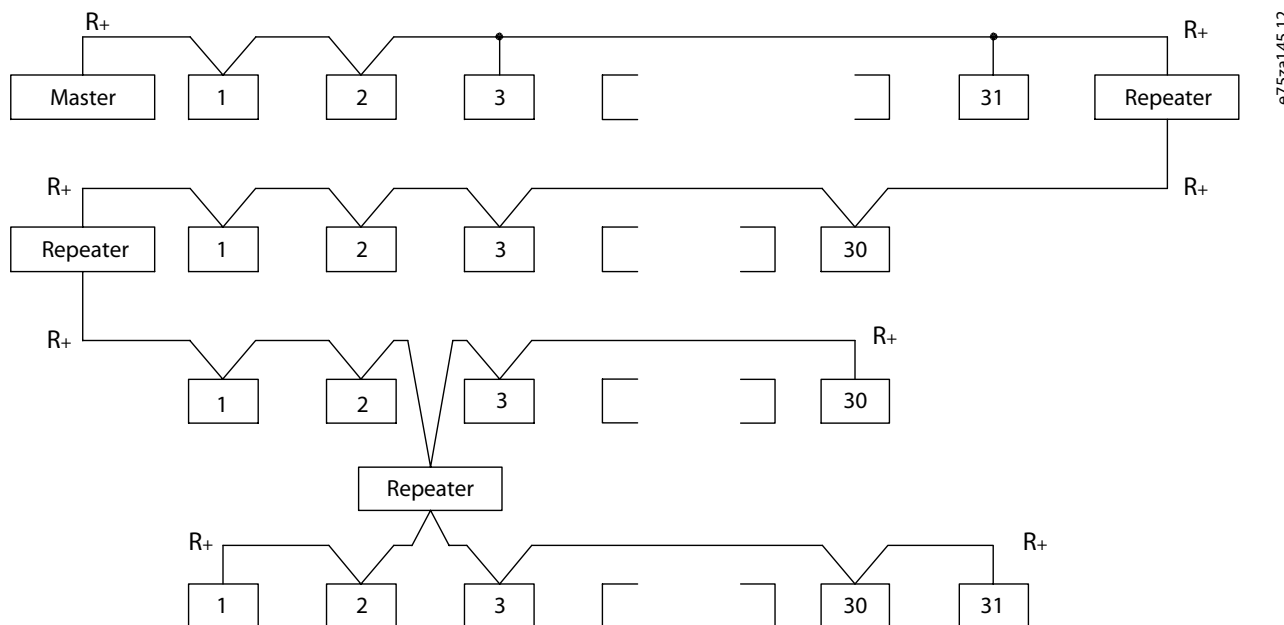


Illustration 59: RS485 Bus Interface

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.

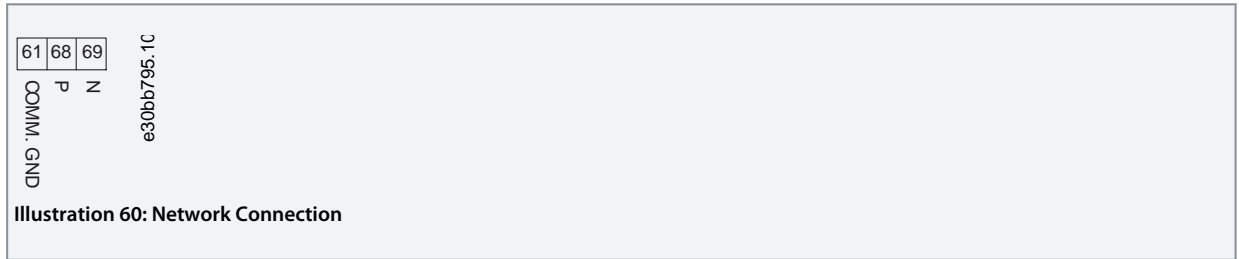
Table 22: Cable Specifications

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

6.1.2 Connecting the Drive to the RS485 Network

Procedure

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



2. Connect the cable shield to the cable clamps.

NOTICE

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

6.1.3 Hardware Setup

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

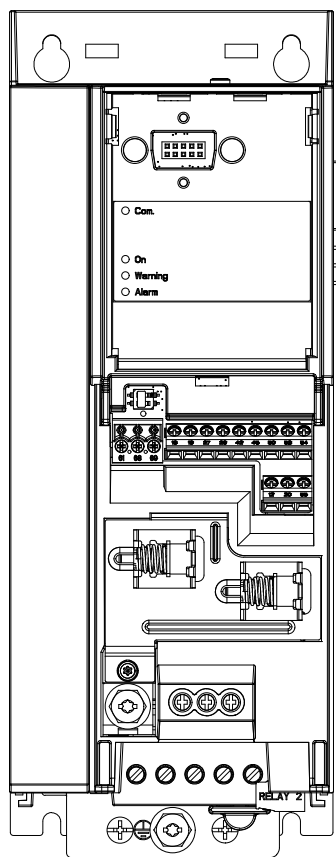


Illustration 61: Terminator Switch Factory Setting

The factory setting for the switch is OFF.

6.1.4 Parameter Settings for Modbus Communication

Table 23: Modbus Communication Parameter Settings

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

6.1.5 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 earth connection. Failure to ground the cables properly can result in communication degradation and equipment damage. 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°.

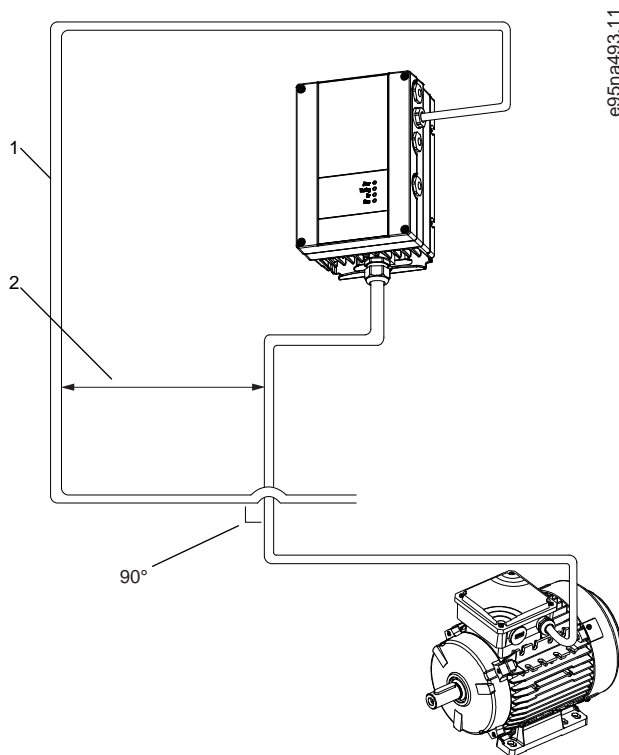


Illustration 62: Minimum Distance between Communication and Power Cables

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

6.2 FC Protocol

6.2.1 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 halfduplex 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.

6.2.2 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 set-up.
- 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.

6.3 Network Configuration

To enable the FC protocol for the drive, set the following parameters.

Table 24: 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)

6.4 FC Protocol Message Framing Structure

6.4.1 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 are 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.

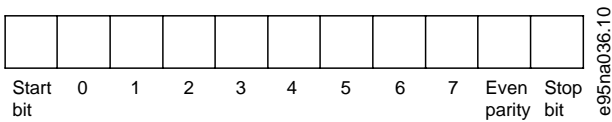


Illustration 63: Content of a Character

6.4.2 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.

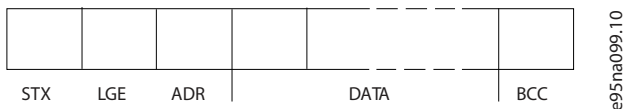


Illustration 64: Telegram Structure

6.4.3 Telegram Length (LGE)

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

Table 25: Length of Telegrams

4 data bytes	LGE=4+1+1=6 bytes
12 data bytes	LGE=12+1+1=14 bytes
Telegram containing texts	10 ⁽¹⁾ +n bytes

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

6.4.4 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.

6.4.5 Data Control Byte (BCC)

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

6.4.6 The Data Field

The structure of data blocks depends on the type of telegram. There are 3 telegram types, and the type applies for 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).

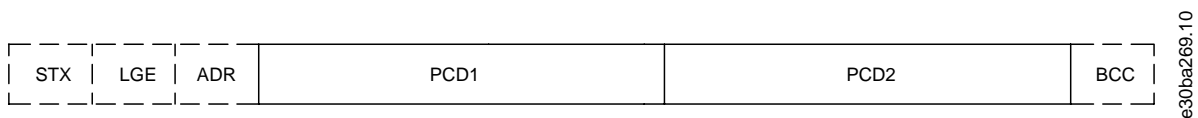


Illustration 65: Process Block

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.

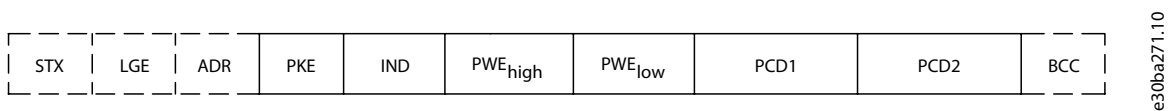
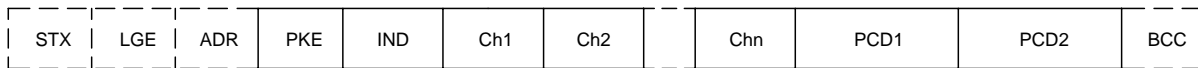


Illustration 66: Parameter Block

Text block

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



e30ba270.10

Illustration 67: Text Block

6.4.7 The PKE Field

The PKE field contains 2 subfields:

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

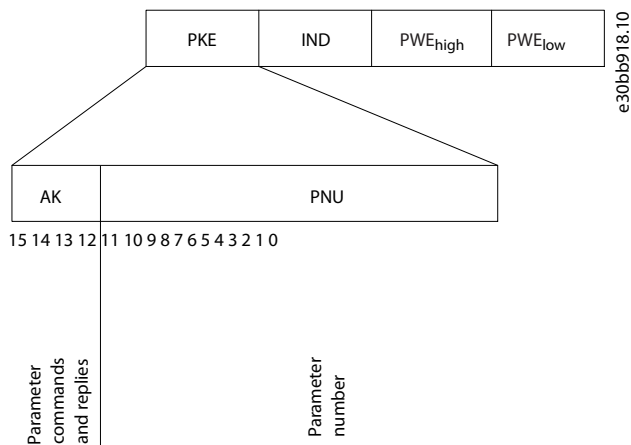


Illustration 68: PKE Field

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

Table 26: 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).
1	1	1	0	Write parameter value in RAM and EEPROM (word).
1	1	1	1	Read text.

Table 27: 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 the following table.

Table 28: Follower Report

Fault code	FC specification
0	Illegal parameter number.
1	Parameter cannot be changed
2	Upper or lower limit is exceeded.
3	Subindex 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 set-up is not possible.
132	No LCP access.
252	Unknown viewer.
253	Request is not supported.
254	Unknown attribute.
255	No error.

6.4.8 Parameter Number (PNU)

Bits 0–11 transfer parameter numbers. The function of the relevant parameter is defined in the parameter description in the VLT® HVAC Drive FC 131 Programming Guide.

6.4.9 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.

6.4.10 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.

6.4.11 Data Types Supported by the Drive

Table 29: 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.

6.4.12 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 30: Conversion

Conversion index	Conversion factor
74	3600
2	100
1	10

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

6.4.13 Process Words (PCD)

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

Table 31: Process Words (PCD)

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

6.5 Examples

6.5.1 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 [6.4.12 Conversion](#).

The telegram looks like the following illustration.

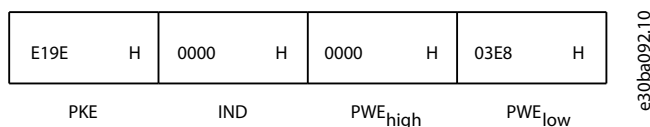


Illustration 69: Telegram

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 the following illustration.

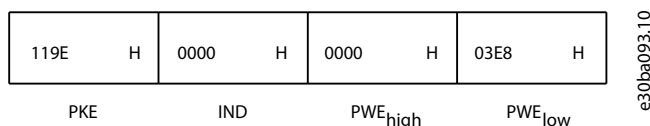


Illustration 70: Response from Master

6.5.2 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.

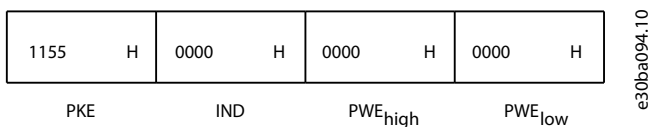


Illustration 71: Telegram

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 the following illustration.

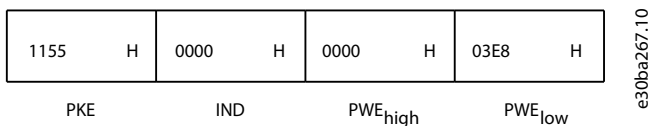


Illustration 72: Response

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.

6.6 Modbus RTU

6.6.1 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 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.

6.6.2 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.

6.6.3 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 set-up.
- 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.

6.7 Network Configuration

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

Table 32: Network Configuration

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

6.8 Modbus RTU Message Framing Structure

6.8.1 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 tables.

Table 33: Format for Each Byte

Start bit	Data byte	Stop/ parity	Stop

Table 34: 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	<ul style="list-style-type: none"> • 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).

6.8.2 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 35: 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

6.8.3 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.

6.8.4 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 followers 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.

6.8.5 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 (errorfree) 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 [6.8.10.2 Function Codes Supported by Modbus RTU](#) and [6.8.10.3 Modbus Exception Codes](#).

6.8.6 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.

6.8.7 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.

6.8.8 Coil Register Addressing

6.8.8.1 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).

6.8.8.2 Coil Register

Table 36: 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.	–

6.8.8.3 Drive Control Word (FC Profile)

Table 37: 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

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

6.8.8.4 Drive Status Word (FC Profile)

Table 38: 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 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

6.8.8.5 Address/Registers

Table 39: Address/Registers

Bus address	Bus register ⁽¹⁾	PLC register	Content	Access	Description
0	1	40001	Reserved	–	Reserved for legacy drives VLT® 5000 and VLT® 2800.
1	2	40002	Reserved	–	Reserved for legacy drives VLT® 5000 and VLT® 2800.
2	3	40003	Reserved	–	Reserved for legacy drives VLT® 5000 and VLT® 2800.
3	4	40004	Free	–	–
4	5	40005	Free	–	–
5	6	40006	Modbus configuration	Read/Write	TCP only. Reserved for Modbus TCP (<i>parameter 12-28 Store Data Values</i> and <i>parameter 12-29 Store Always - stored in</i> , 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	Subindex of parameter to be accessed. Refer to WHAT 38297 for details.
9	10	40010	<i>Parameter 0-01 Language</i>	Dependent on parameter access	<i>Parameter 0-01 Language</i> (Modbus register = 10 parameter number) 20 bytes space reserved for parameter in Modbus map.
19	20	40020	Free	–	–
29	30	40030	<i>Parameter 0-03 Regional Settings</i>	Dependent on parameter access	<i>Parameter 0-03 Regional Settings</i> 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.

6.8.9 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.

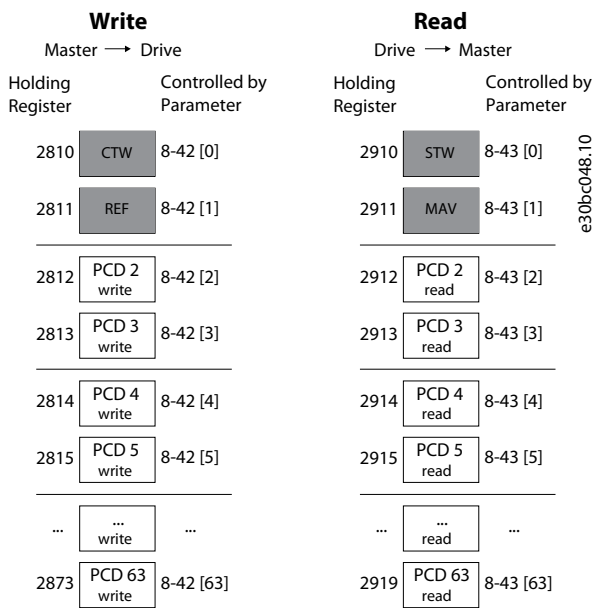


Illustration 73: Accessing via PCD write/read

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 & PCD3 or PCD4 & PCD5, and so on), where the parameter number is mapped twice to *parameter 8-42 PCD Write Configuration* or *parameter 8-43 PCD Read Configuration*.

6.8.10 How to Control the Drive

6.8.10.1 Introduction

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

6.8.10.2 Function Codes Supported by Modbus RTU

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

Table 40: Function Codes

Function	Function code (hex)
Read coils	1
Read holding registers	3
Write single coil	5
Write single register	6
Write multiple coils	F
Write multiple registers	10
Get comm. event counter	B
Report follower ID	11
Read write multiple registers	17

Table 41: Function Codes

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.

6.8.10.3 Modbus Exception Codes

For a full explanation of the structure of an exception code response, refer to [6.8.5 Function Field](#).

Table 42: 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.

6.9 How to Access Parameters

6.9.1 Parameter Handling

The PNU (parameter number) is translated from the register address contained in the Modbus read or write telegram. 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 parameter's value. 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 parameter's 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 drive's programming guide.

6.9.2 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).

6.9.3 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.

6.9.4 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.

6.9.5 Conversion Factor

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

6.9.6 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).

6.10 Examples

6.10.1 Introduction

The following examples show various Modbus RTU commands.

6.10.2 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 43: 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 44: 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)	–

N O T I C E

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

6.10.3 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 45: Query

Field name	Example (hex)
Follower address	01 (drive address)
Function	05 (write single coil)
Coil address HI	00
Coil address LO	40 (64 decimal) Coil 65
Force data HI	FF
Force data LO	00 (FF 00 = ON)
Error check (CRC)	–

Response

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

Table 46: Response

Field name	Example (hex)
Follower address	01
Function	05
Force data HI	FF
Force data LO	00

Field name	Example (hex)
Quantity of coils HI	00
Quantity of coils LO	01
Error check (CRC)	–

6.10.4 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.

N O T I C E

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

Table 47: 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
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 48: 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)

Field name	Example (hex)
Quantity of coils HI	00
Quantity of coils LO	10 (16 coils)
Error check (CRC)	–

6.10.5 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 49: 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 – (<i>parameter 3-03 Maximum Reference</i> 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 50: 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)	–

6.10.6 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 51: Query

Field name	Example (hex)
Follower address	01
Function	06
Starting address HI	03 (register address 999)
Starting 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 52: 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)	–

6.10.7 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 53: Query

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

Field name	Example (hex)
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 54: 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)	–

6.10.8 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 55: Query

Field name	Example (hex)
Follower address	01
Function	17
Reading starting address HI	0B (Register address 3029)
Read starting address LO	D5 (Register address 3029)
Quantity to read HI	00
Quantity to read LO	02 (<i>Parameter 3-03 Maximum Reference</i> is 32 bits long, that is, 2 registers)
Write starting address HI	04 (Register address 1239)

Field name	Example (hex)
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	0E
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 56: 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)	-

6.11 Danfoss FC Control Profile

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

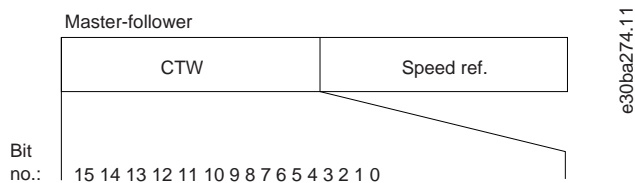


Illustration 74: Control Word According to FC Profile

Table 57: 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

Bit	Bit value = 0	Bit value = 1
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 set-up	Selection lsb
14	Parameter set-up	Selection msb
15	No function	Reverse

6.11.2 Explanation of Each Control Bit

6.11.2.1 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 58: Control Bits

Programmed reference value	Parameter	Bit 01	Bit 00
1	<i>Parameter 3-10 Preset Reference</i> [0]	0	0
2	<i>Parameter 3-10 Preset Reference</i> [1]	0	1
3	<i>Parameter 3-10 Preset Reference</i> [2]	1	0
4	<i>Parameter 3-10 Preset Reference</i> [3]	1	1

N O T I C E

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

6.11.2.2 Bit 02, DC Brake

Bit 02 = 0: Leads to DC braking 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.

6.11.2.3 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.

6.11.2.4 Bit 04, Quick Stop

Bit 04 = 0: Makes the motor speed ramp down to stop (set in *parameter 3-81 Quick Stop Ramp Time*).

6.11.2.5 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*).

N O T I C E

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*).

6.11.2.6 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: Allows the drive to start the motor if the other starting conditions are met.

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

6.11.2.7 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.

6.11.2.8 Bit 08, Jog

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

6.11.2.9 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 (*parameter 3-51 Ramp 2 Ramp Up Time* to *parameter 3-52 Ramp 2 Ramp Down Time*) is active.

6.11.2.10 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.

6.11.2.11 Bit 11, Relay 01

Bit 11 = 0: Relay 01 not activated.

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

6.11.2.12 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*.

6.11.2.13 Bit 13, Set-up Selection

Use bit 13 to select from the 2 set-ups according to the following table.

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

Table 59: Set-up selection

Setup	Bit 13
1	0
2	1

NOTICE

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

6.11.2.14 Bit 15, Reverse

Bit 15 = 0: No reversing.

Bit 15 = 1: Reversing. In the default setting, reversing is set to [0] Digital input in *parameter 8-54 Reversing Select*. Bit 15 causes reversing only when [1] Bus, [2] Logic AND or [3] Logic OR is selected.

6.11.3 Status Word According to FC Profile (STW)

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

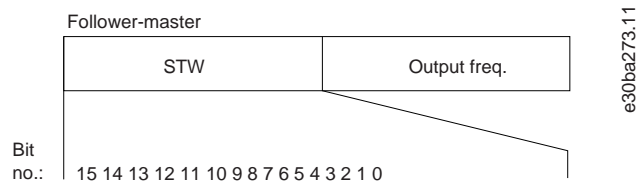


Illustration 75: Status Word

Table 60: Status Word According to FC Profile

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

Bit	Bit = 0	Bit = 1
13	Voltage OK	Voltage exceeded
14	Torque OK	Torque exceeded
15	Timer OK	Timer exceeded

6.11.4 Explanation of Each Status Bit

6.11.4.1 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).

6.11.4.2 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.

6.11.4.3 Bit 02, Coast Stop

Bit 02=0: The drive releases the motor.

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

6.11.4.4 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].

6.11.4.5 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.

6.11.4.6 Bit 05, Not Used

Bit 05 is not used in the status word.

6.11.4.7 Bit 06, No Error/Triplock

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

Bit 06=1: The drive is tripped and locked.

6.11.4.8 Bit 07, No Warning/Warning

Bit 07=0: There are no warnings.

Bit 07=1: A warning has occurred.

6.11.4.9 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.

6.11.4.10 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.

6.11.4.11 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.

6.11.4.12 Bit 11, No Operation/In Operation

Bit 11=0: The motor is not running.

Bit 11=1: The drive has a start signal or the output frequency is greater than 0 Hz.

6.11.4.13 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.

6.11.4.14 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.

6.11.4.15 Bit 14, Current 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.

6.11.4.16 Bit 15, Thermal Level 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%.

6.11.5 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.

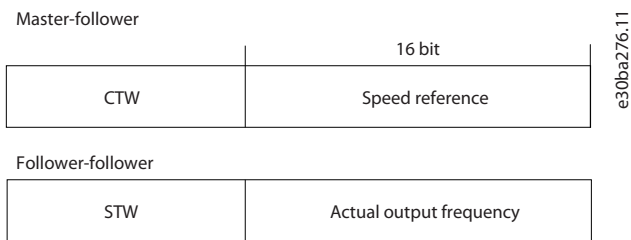


Illustration 76: Actual Output Frequency (MAV)

The reference and MAV are scaled as follows:

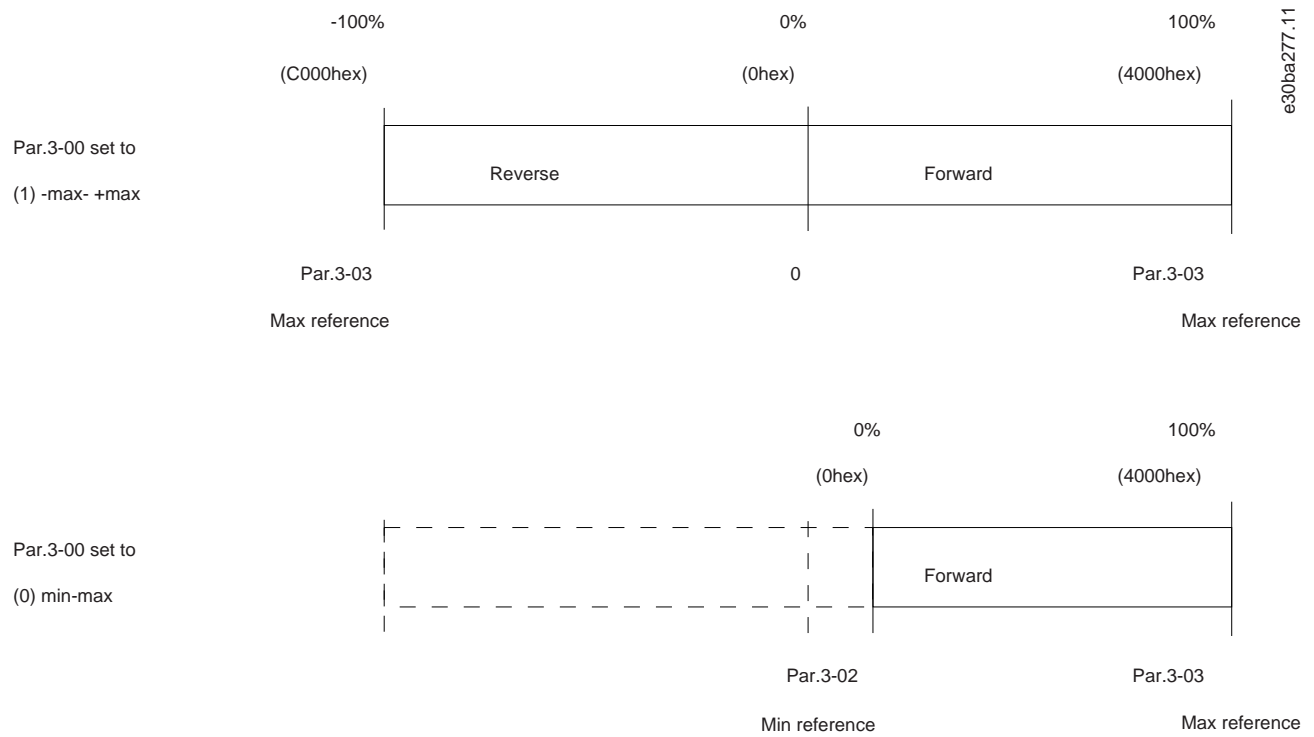


Illustration 77: Reference and MAV

7 General Specifications

7.1 Mains Supply

7.1.1 3x380–480 V AC

Table 61: 3x380–480 V AC, 0.75–18.5 kW (1.0–25 hp), Enclosure Sizes I2–I4

Drive	PK75	P1K5	P2K2	P3K0	P4K0	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	10.0	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 at 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
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 7.2.5 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 at 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

Drive	PK75	P1K5	P2K2	P3K0	P4K0	P5K5	P7K5	P11K	P15K	P18K
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 Danfoss [MyDrive® ecoSmart](#) website.

² Efficiency measured at nominal current. For energy efficiency class, see [7.3.13 Ambient Conditions](#). For part load losses, see Danfoss [MyDrive® ecoSmart](#) website.

Table 62: 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 at 40 °C (104 °F) ambient temperature							
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 7.2.5 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 at 50 °C (122 °F) ambient temperature							
Continuous (3x380–440 V) [A]	35.2	48.8	58.4	63	74.2	102.9	123.9

Drive	P22K	P30K	P37K	P45K	P55K	P75K	P90K
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 Danfoss [MyDrive® ecoSmart](#) website.

² Efficiency measured at nominal current. For energy efficiency class, see [7.3.13 Ambient Conditions](#). For part load losses, see Danfoss [MyDrive® ecoSmart](#) website.

7.2 Fuses and Circuit Breakers

7.2.1 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.

7.2.2 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.

7.2.3 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.

7.2.4 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 A_{rms} (symmetrical), 480 V maximum.

7.2.5 Recommendation of Fuses and Circuit Breakers

NOTICE

If a malfunction occurs, failure to follow the protection recommendation may result in damage to the drive.

Table 63: Fuses and Circuit Breakers

	Circuit breaker		Fuse				
	UL	Non-UL	UL				Non-UL
			Bussmann	Bussmann	Bussmann	Bussmann	Maximum fuse
Power [kW (hp)]			Type RK5	Type RK1	Type J	Type T	Type G
3x380–480 V IP54							
0.75 (1.0)	–	PKZM0-16	FRS-R-10	KTS-R-10	JKS-10	JJS-10	16
1.5 (2.0)		PKZM0-16	FRS-R-10	KTS-R-10	JKS-10	JJS-10	16
2.2 (3.0)		PKZM0-16	FRS-R-15	KTS-R-15	JKS-15	JJS-15	16
3.0 (4.0)		PKZM0-16	FRS-R-15	KTS-R-15	JKS-15	JJS-15	16
4.0 (5.0)		PKZM0-16	FRS-R-15	KTS-R-15	JKS-15	JJS-15	16

5.5 (7.5)			PKZM0-25	FRS-R-25	KTS-R-25	JKS-25	JJS-25	25
7.5 (10)			PKZM0-25	FRS-R-25	KTS-R-25	JKS-25	JJS-25	25
11 (15)			PKZM4-63	FRS-R-50	KTS-R-50	JKS-50	JJS-50	63
15 (20)			PKZM4-63	FRS-R-50	KTS-R-50	JKS-50	JJS-50	63
18.5 (25)			PKZM4-63	FRS-R-80	KTS-R-80	JKS-80	JJS-80	63
22 (30)	Moeller NZMB1-A125	-		FRS-R-80	KTS-R-80	JKS-80	JJS-80	125
30 (40)				FRS-R-125	KTS-R-125	JKS-125	JJS-125	125
37 (50)				FRS-R-125	KTS-R-125	JKS-125	JJS-125	125
45 (60)	Moeller NZMB2-A160	-		FRS-R-125	KTS-R-125	JKS-125	JJS-125	160
55 (70)				FRS-R-200	KTS-R-200	JKS-200	JJS-200	160
75 (100)	Moeller NZMB2-A250	-		FRS-R-200	KTS-R-200	JKS-200	JJS-200	200
90 (125)				FRS-R-250	KTS-R-250	JKS-200	JJS-200	200

7.3 General Technical Data

7.3.1 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.

7.3.2 Mains Supply (L1, L2, L3)

Supply voltage	380–480 V ±10%
Supply frequency	50/60 Hz
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 ($\cos\phi$) near unity	(>0.98)
Switching on the input supply L1, L2, L3 (power-ups) enclosure sizes I2–I4	Maximum 1 time/30 s
Switching on the input supply L1, L2, L3 (power-ups) enclosure sizes I6–I8	Maximum 1 time/minute
Environment according to EN 60664-1	Overtoltage 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, 480 V maximum.

7.3.3 Motor Output (U, V, W)

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

7.3.4 Cable Length and Cross-section

Maximum motor cable length, shielded/armored (EMC-correct installation)	See 3.4.3 EMC Emission Test Results .
Maximum motor cable length, unshielded/unarmoured	50 m (164 ft)
Maximum cross-section to motor, mains	See 7.1.1 3x380–480 V AC for more information
Cross-section DC terminals for filter feedback on enclosure sizes I2–I4	4 mm ² /11 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

7.3.5 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.

7.3.6 Analog Inputs

Number of analog inputs	2
Terminal number	53, 54
Terminal 53 mode	<i>Parameter 16-61 Terminal 53 Setting: 1 = voltage, 0 = current</i>
Terminal 54 mode	<i>Parameter 16-63 Terminal 54 Setting: 1 = voltage, 0 = current</i>
Voltage level	0–10 V
Input resistance, R _i	Approximately 10 kΩ
Maximum voltage	20 V
Current level	0/4–20 mA (scalable)
Input resistance, R _i	<500 Ω
Maximum current	29 mA
Resolution on analog input	10 bit

7.3.7 Analog Outputs

Number of programmable analog outputs	2
Terminal number	42, 45 ⁽¹⁾
Current range at analog output	0/4–20 mA
Maximum load to common at analog output	500 Ω
Maximum voltage at analog output	17 V
Accuracy on analog output	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.

7.3.8 Digital Output

Number of digital outputs	4
---------------------------	---

Terminals 27 and 29

Terminal number	27, 29 ⁽¹⁾
Voltage level at digital output	0–24 V
Maximum output current (sink and source)	40 mA

Terminals 42 and 45

Terminal number	42, 45 ⁽²⁾
Voltage level at digital output	17 V
Maximum output current at digital output	20 mA
Maximum load at digital output	1 kΩ

¹ Terminals 27 and 29 can also be programmed as input.

² 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.

7.3.9 Control Card, RS485 Serial Communication

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

7.3.10 Control Card, 24 V DC Output

Terminal number	12
Maximum load	80 mA

7.3.11 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

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.

Programmable relay outputs

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 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
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.

7.3.12 Control Card, 10 V DC Output

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

7.3.13 Ambient Conditions

Enclosure protection rating	IP54 (not for outdoor installation)
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), non-coated enclosure sizes I2–I8	Class 3C2
Test method according to IEC 60068-2-43 H2S (10 days)	
Ambient temperature ⁽¹⁾	See maximum output current at 40/50 °C (104/122 °F) in 7.1.1 3x380–480 V AC .
Minimum ambient temperature during full-scale operation	0 °C (32 °F)
Minimum ambient temperature at reduced performance, enclosure sizes I2–I4	-20 °C (-4 °F)
Minimum ambient temperature at reduced performance, enclosure sizes 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)

Safety standards	EN/IEC 61800-5-1
EMC standards, Emission	EN 61800-3, EN 61000-6-3/4, EN 55011, IEC 61800-3
EMC standards, Immunity	EN 61800-3, EN 61000-3-12, EN 61000-6-1/2, EN 61000-4-2, EN 61000-4-3, EN 61000-4-4, EN 61000-4-5, EN 61000-4-6
Energy efficiency class ⁽²⁾	IE2

¹ Refer to chapter Special Conditions in the operating guide for:

- Derating for high ambient temperature.
- Derating for high altitude.

² Determined according to EN 50598-2 at:

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

7.4 dU/Dt

Table 64: dU/Dt Data

	Cable length [m (ft)]	AC line voltage [V]	Rise time [μsec]	V _{peak} [kV]	dU/dt [kV/μsec]
400 V 0.75 kW (1 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 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 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 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 (5.4 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 5.5 kW (7.4 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

	Cable length [m (ft)]	AC line voltage [V]	Rise time [μ sec]	V _{peak} [kV]	dU/dt [kV/ μ sec]
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
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

	Cable length [m (ft)]	AC line voltage [V]	Rise time [μsec]	V_{peak} [kV]	dU/dt [kV/ μsec]
	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 (74 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 (125 hp)	10 (33)	400	0.402	1.108	2.155
		400	0.408	1.288	2.529
		400	0.424	1.368	2.585

8 Appendix

8.1 Abbreviations

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

8.2 Definitions

8.2.1 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.

8.2.2 Input

Control commands

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

Functions are divided into 2 groups.

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

Table 65: 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.

8.2.3 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.

$$n_s = \frac{2 \times \text{Parameter 1-23} \times 60 \text{ s}}{\text{Parameter 1-39}}$$

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

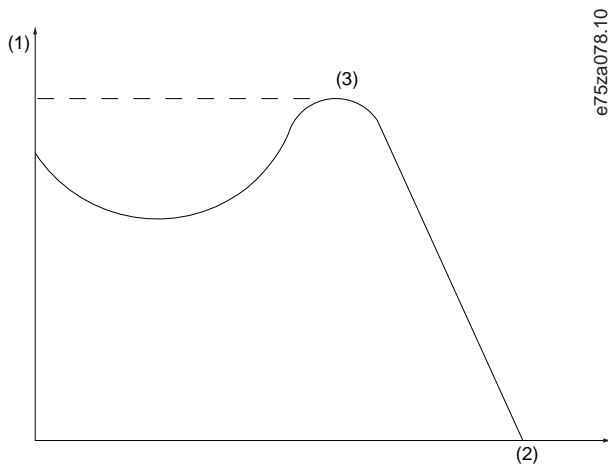


Illustration 78: Break-away Torque

1	Torque	3	Pull-out
2	RPM		

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 chapter Input for more details.

Stop command

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

8.2.4 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*.

8.2.5 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

The drive features 2 solid-state outputs that can supply a 24 V DC (maximum 40 mA) signal.

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 nonperiodic 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.

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.

GLCP

The graphic local control panel interface for control and programming of the drive. The display is graphic and the panel is used to show process values. The GLCP 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 mm².

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.

$$\text{Power factor} = \frac{\sqrt{3} \times U \times I_1 \cos\phi_1}{\sqrt{3} \times U \times I_{RMS}}$$

For VLT® HVAC Drive FC 131 drives, $\cos\phi_1 = 1$, therefore:

$$\text{Power factor} = \frac{I_1 \times \cos\phi_1}{I_{RMS}} = \frac{I_1}{I_{RMS}}$$

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.

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

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 another setup is active.

SFAVM

Acronym describing the switching pattern stator fluxoriented 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 smart logic controller evaluates the associated user-defined events as true.

STW

Status word.

THD

Total harmonic distortion states the total contribution of harmonic distortion.

Thermistor

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

Trip

Trip is a state entered in fault situations. Examples of fault situations:

- The drive is subject to an over voltage.
- The drive protects the motor, process, or mechanism.

Restart is prevented until the cause of the fault has disappeared, and the trip state is canceled by activating reset or, in some cases, by being programmed to reset automatically. Do not use trip for personal safety.

Trip lock

Trip lock is a state entered in fault situations when the drive is protecting itself and requiring physical intervention. For example, a short circuit on the output triggers a trip lock. 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 used 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

Refer to the switching pattern 60° asynchronous vector modulation.

Index

1		Data field.....	65
10 V DC output.....	97	Data types.....	68
2		DC brake.....	85
24 V DC output.....	96	DC link.....	41
A		Definition of EMC categories.....	34
Abbreviations.....	101	Derating.....	30
Acoustic noise.....	32	Differential pressure.....	26
Additional resource.....	9	Digital input.....	95
ADR.....	65	Digital output.....	96
Aggressive environments.....	33	Document version.....	9
Air humidity.....	30	Drive address.....	65
AK.....	66, 68	Drive closed-loop controller, tuning.....	30
AMA.....	104	E	
Ambient condition.....	97	EAC.....	10
Analog input.....	95, 103, 104	Earth leakage circuit breaker.....	40
Analog output.....	104	See Residual current device	
Application examples.....	21	Electrical installation.....	49
B		Electronic thermal relay.....	104
Balancing contractor.....	25	EMC	
BCC.....	65	Directive.....	10
Better control.....	19	EMC plan.....	34
Branch circuit protection.....	93	EMC-compliant installation.....	57
Break-away torque.....	103	Emission.....	33
Building management system, BMS.....	16	Emission requirement.....	34, 34
Bypass frequency range.....	23	Energy efficiency class.....	98
C		Energy saving.....	15, 16, 18
Cables		Environment	
Leakage current.....	38	Industrial.....	34
CAV.....	22	Residential.....	34
CE mark.....	9	ErP directive.....	10
Central VAV system.....	21	ETR.....	42, 104
Circuit breaker.....	93	Evaporator flow rate.....	25
Coast.....	85, 102	Extreme running condition.....	41
Comparison, energy saving.....	16	F	
Condenser pump.....	24	Feedback conversion.....	29
Constant air volume.....	22	Flow meter.....	25
Control card.....	96, 96, 97	Force/write multiple coil (0F hex).....	80
Control potential.....	26	Force/write single coil (05 hex).....	79
Control structure closed loop.....	28	Freeze output.....	102
Control structure open loop.....	27	Function Codes.....	76
Control word.....	84	Fuse.....	93
Controlling fan.....	15	G	
Controlling pump.....	15	Galvanic isolation.....	37
Conversion.....	68	GLCP.....	104
Conversion factor.....	68	Ground	
Conversion index.....	68	Leakage protection.....	33
Cooling tower fan.....	23	Leakage current.....	39
Current		H	
Leakage current.....	38	Hardware setup.....	61
Transient ground.....	40	Harmonic current.....	36
Current loop.....	34	Harmonics distortion.....	33
D		Harmonics emission.....	36
Damper.....	21	Harmonics emission requirement.....	36
Data control byte.....	65	Harmonics test result (emission).....	36
		Hold output frequency.....	86

I	
IGV.....	21
Immunity requirement.....	34, 37
IND.....	68
Index.....	68
Industrial environment.....	34, 35
Installation	
Qualified personnel.....	12
Intermittent duty cycle.....	104
J	
Jog.....	86, 102
L	
LCP.....	28, 102, 104
Leakage current.....	13, 33, 38
LGE.....	64
Local (hand on) control.....	28
Local speed determination.....	25
Low evaporator temperature.....	25
Low voltage directive.....	10
M	
Mains drop-out.....	41
Mains supply (L1, L2, L3).....	94
Manual PI adjustment.....	30
MCT 10 setup software.....	9
Modbus communication.....	62
Modbus exception codes.....	77
Modbus RTU.....	63, 70, 71, 76
Modbus RTU commands.....	78
Modbus RTU protocol.....	70
Moment of inertia.....	41
Motor	
Cable.....	33
Leakage current.....	38
Thermal protection.....	42, 89
Motor output (U, V, W).....	94
Motor-generated overvoltage.....	41
Multiple pump.....	26
N	
Network configuration.....	71
Network connection.....	61
NLCP.....	104
Nominal motor current.....	103
Nominal motor speed.....	103
O	
Overcurrent protection.....	93
Overload protection.....	94
P	
Parameter block.....	65
Parameter number.....	67
Parameter value.....	68
Payback period.....	18
PCD.....	65, 69
PELV.....	37
PKE field.....	66
PNU.....	66, 67, 77
Power cycle.....	105
Preset multiple register (10 hex).....	82
Preset single register (06 hex).....	81
Primary pump.....	25
Process block.....	65
Process words.....	69
Programmable minimum frequency setting.....	23
Protective extra low voltage.....	37
Public supply network.....	36
Pump impeller.....	24
Purpose of the manual.....	9
PWE.....	68
Q	
Qualified personnel.....	12
R	
Rated current.....	34
RCD.....	105
RCM mark compliance.....	10
Read coil status (01 hex).....	78
Read holding registers (03 hex).....	81
Read/write multiple registers (17 hex).....	83
Reference handling.....	29
Relay output.....	96
Remote (auto on) control.....	28
Remote terminal unit.....	70
Residential environment.....	34, 35
Residual current device.....	40
RS485.....	60, 63
RS485 serial communication.....	96
S	
Secondary pump.....	26
Serial communication.....	104
Shock.....	32
Short circuit (motor phase-phase).....	41
Short-circuit protection.....	93
Side-by-side installation.....	47
Slip compensation.....	105
Soft starter.....	19
Software version.....	9
Star/delta starter.....	19
Status word.....	87
Switching frequency	
Use with RCDs.....	40
Switching on the output.....	41
Symbols.....	12
Synchronous motor speed.....	103
T	
Telegram length.....	64
Telegram structure.....	64
Text block.....	65
THD.....	36
Throttling valve.....	24
Total voltage distortion.....	36
Trip.....	106
Trip lock.....	106
Type code.....	45

U		VAV.....	21
UkrSEPRO certificate.....	11	Vibration.....	23, 32
UL/Non-UL compliance.....	93	Voltage	
		Safety warning.....	12
		Voltage distortion.....	36
V		W	
Variable air volume.....	21	Wiring schematic.....	48
Variable control, flow and pressure.....	19		
Varying flow (1 year).....	18		

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