ENGINEERING TOMORROW

Danfoss

Design Guide

# VLT® Flow Drive FC 111

# Contents

# 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® Flow Drive FC 111 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.

VLTÆis 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® Flow Drive FC 111 Operating Guide provides basic information on mechanical dimensions, installation, and basic commissioning.
- VLT® Flow Drive FC 111 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 Set-up 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 81462700 to activate the VLT® Flow Drive FC 111 functionality. A license key is not required for using the VLT® Flow Drive FC 111 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 *.OSS files).

## 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 |
|---|---|---|
| AJ363928382091, version 0201 | Update the manual for 30–90 kW (40–125 hp) drives. | • V76.xx for 0.37–22 kW (0.5–125 hp).<br>• V65.xx for 110–315 kW (150–450 hp). |

## 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.

**NOTICE**

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

**NOTICE**

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

**Table 2: EU Directives Applicable to Drives**

| EU directive | Version |
|---|---|
| Low Voltage Directive | 2014/35/EU |
| EMC Directive | 2014/30/EU |
| ErP Directive | |

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.

# 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 manuals provided with the unit, especially the instructions given in the Operating 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 | 0.37–7.5 (0.5–10) | 4 |
| 3x400 | 11–90 (15–125) | 15 |
| 3x400 | 110–315 (150–450) | 20 |

**⚠ W A R N I N G ⚠**

**LEAKAGE CURRENT HAZARD**

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

- Ensure that the minimum size of the ground conductor complies with the local safety regulations for high touch current equipment.

**⚠ 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.

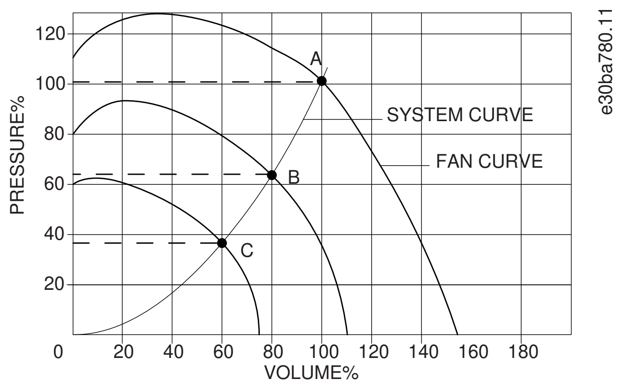



**Illustration 1: Fan Curves (A, B, and C) for Reduced Fan Volumes**

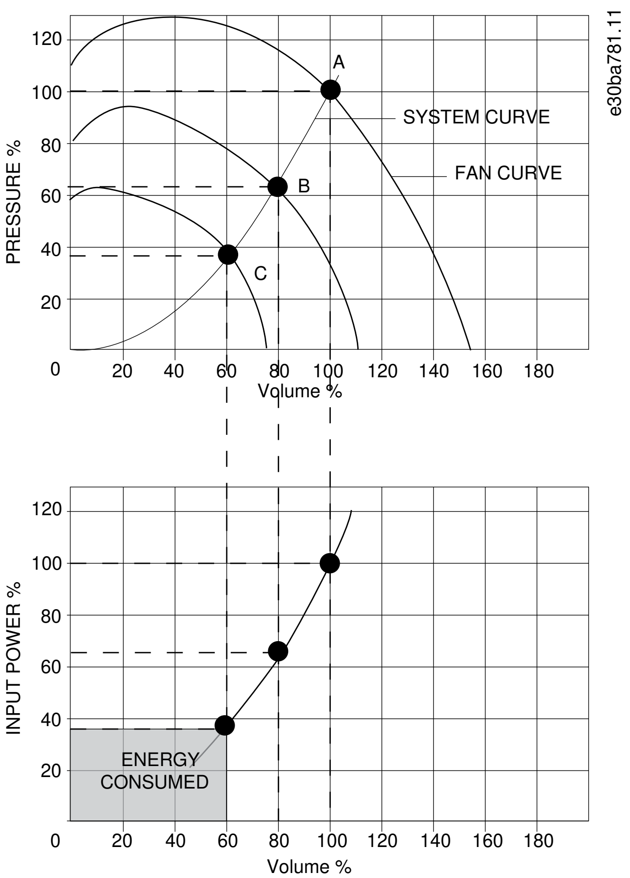



**Illustration 2: Energy Savings with Drive Solution**

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.

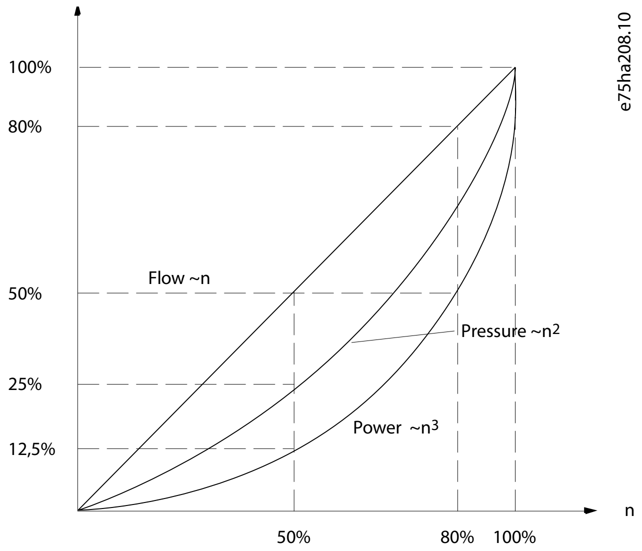



**Illustration 3: Laws of Proportionally**

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

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

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

**Table 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.

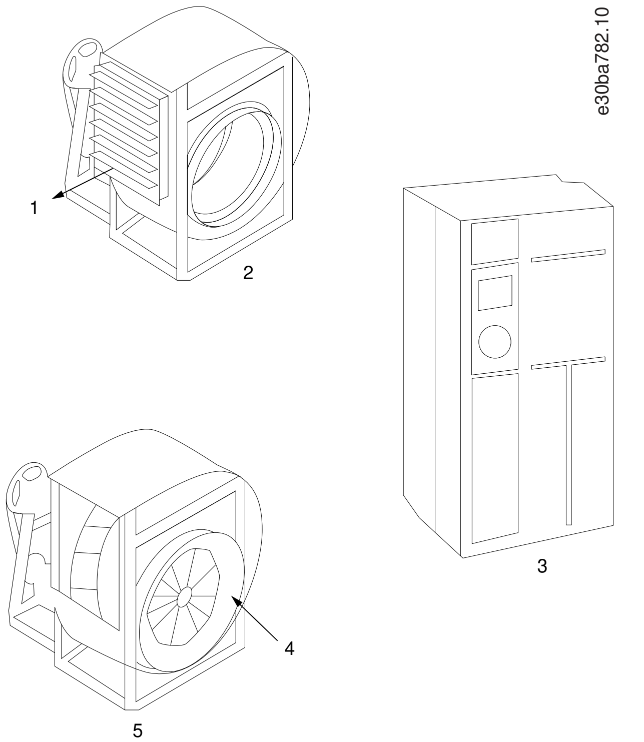



**Illustration 4: The 3 Common Energy Saving Systems**

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

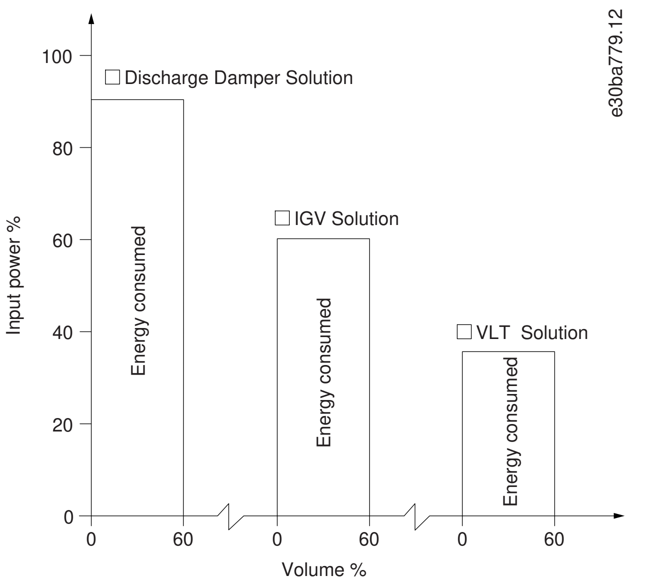



**Illustration 5: Energy Savings**

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**

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

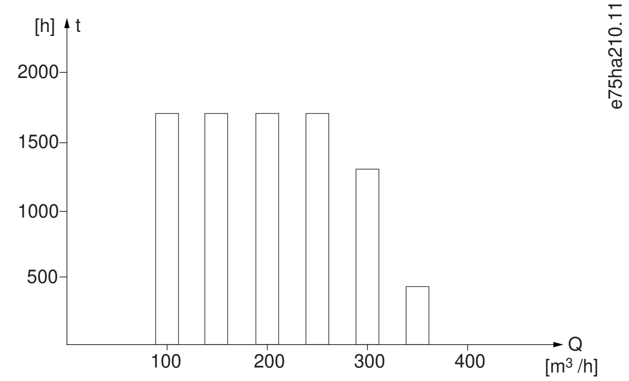



**Illustration 6: Flow Distribution over 1 Year**

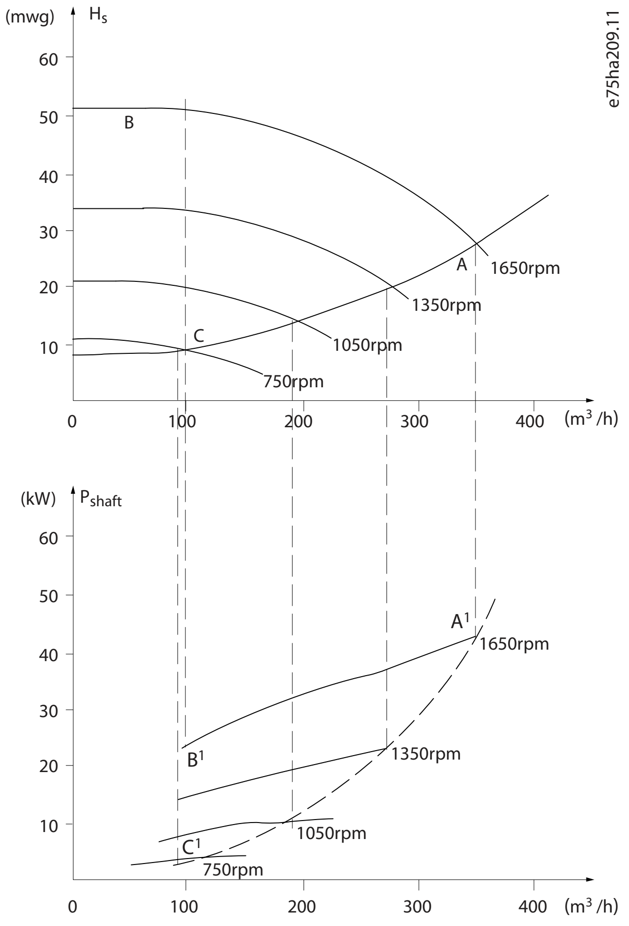



**Illustration 7: Energy**

**Table 5: Result**

| m³/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.

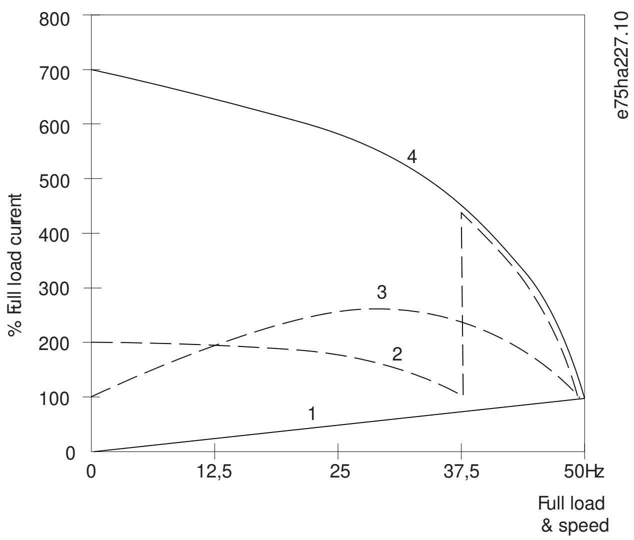



**Illustration 8: Start-up Current**

| | | | |
|---|---|---|---|
| 1 | VLT® Flow Drive FC 111 | 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

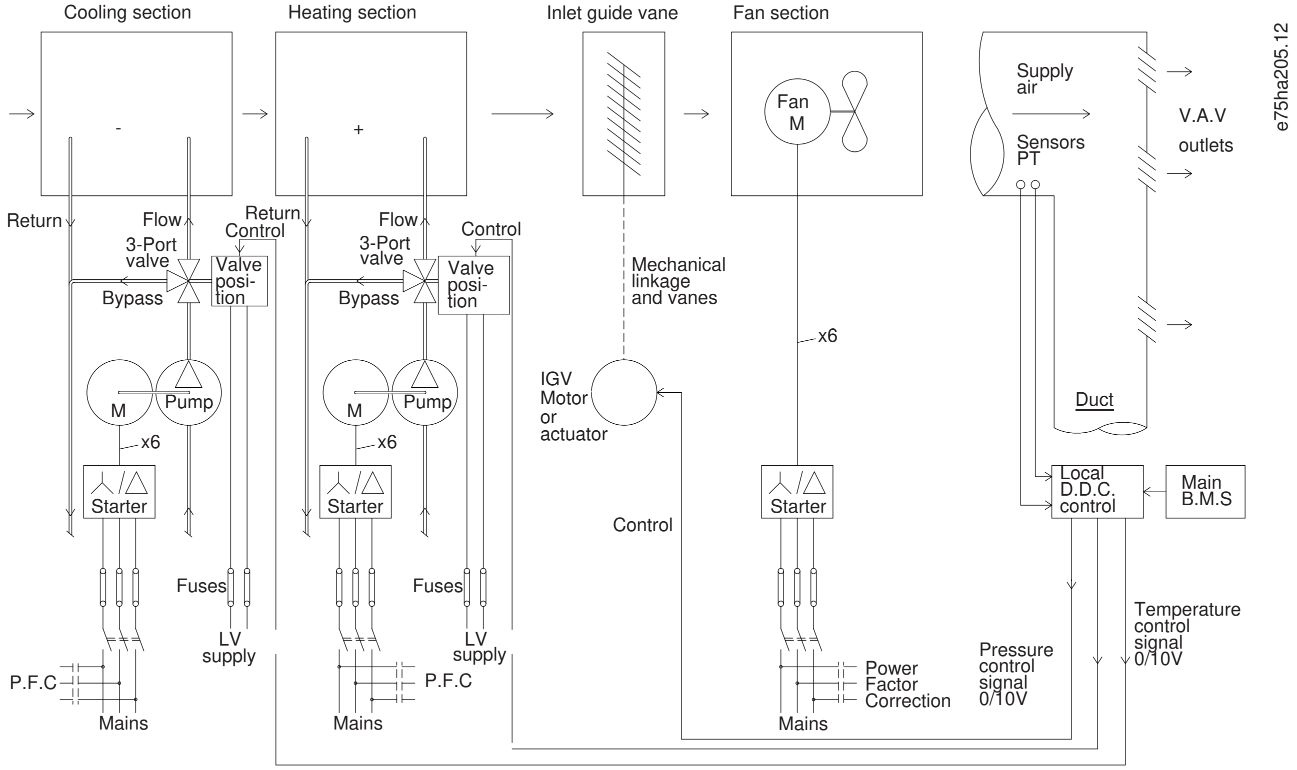



**Illustration 9: Traditional Fan System without a Drive**

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

### 3.1.1.9 Fan System Controlled by Drives

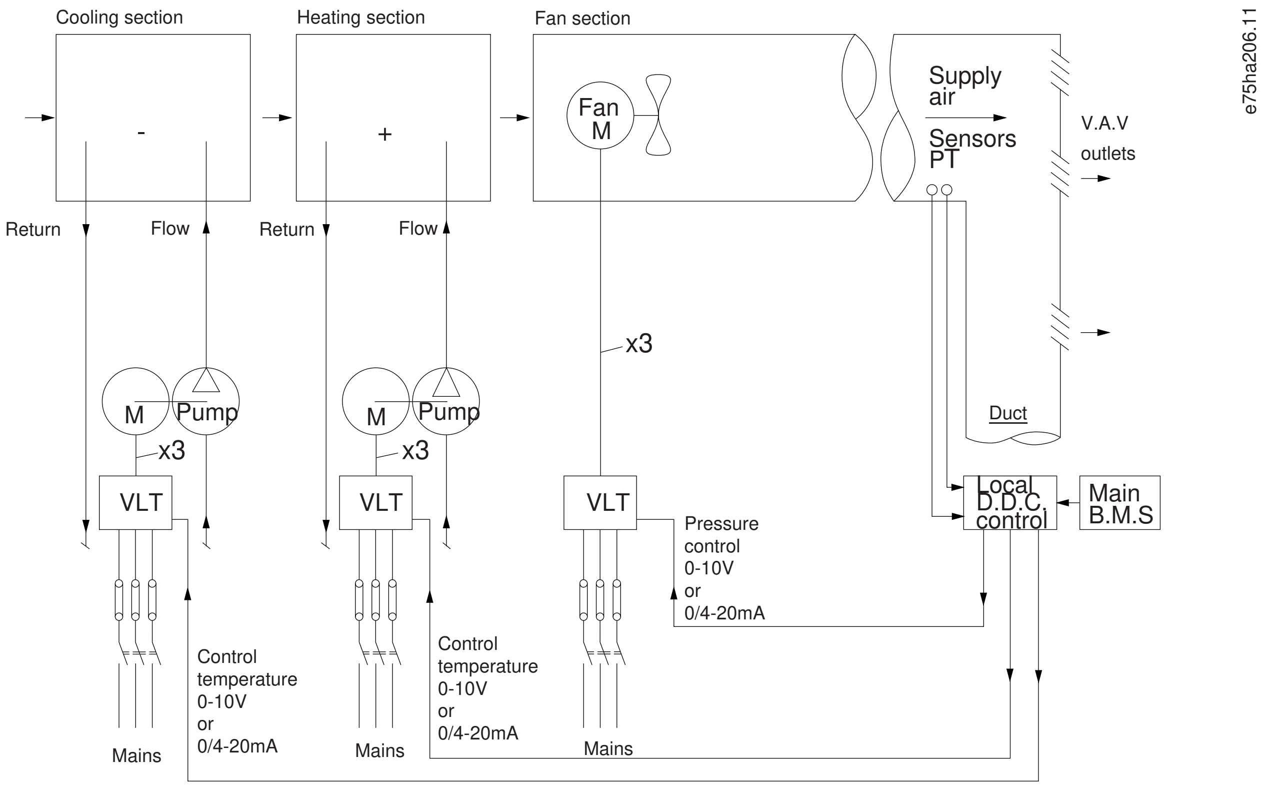



**Illustration 10: Fan System Controlled by Drives**

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

## 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.

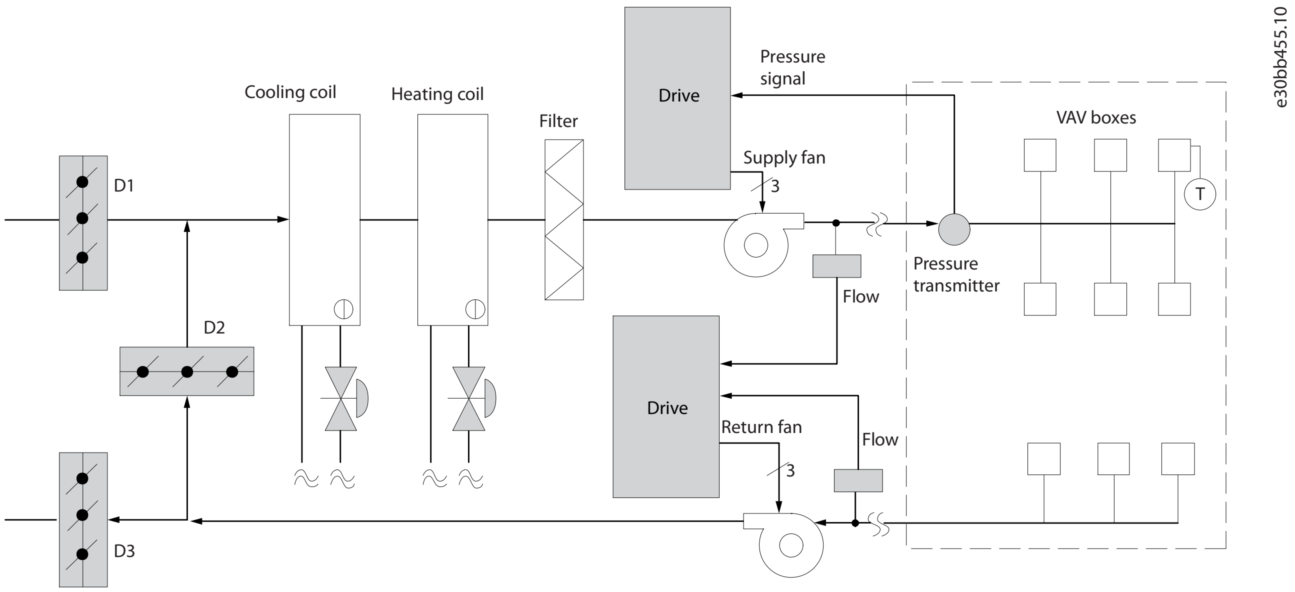



**Illustration 11: Variable Air Volume**

## 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 $CO_2$ sensors can be used as feedback signals to drives. Whether controlling temperature, air quality, or both, a CAV system can be controlled to operate based on actual building conditions. As the number of people in the controlled area decreases, the need for fresh air decreases. The $CO_2$ sensor detects lower levels and decreases the supply fans speed. The return fan modulates to maintain a static pressure setpoint or fixed difference between the supply and return airflows.

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.

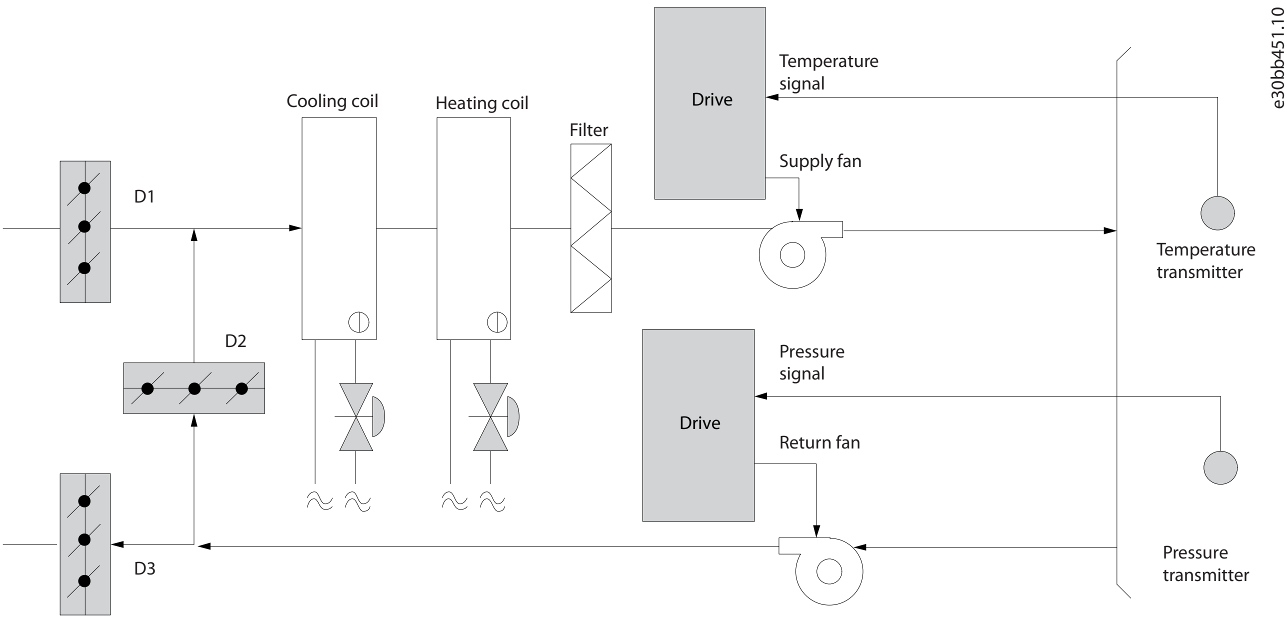



**Illustration 12: Constant Air Volume**

### 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.

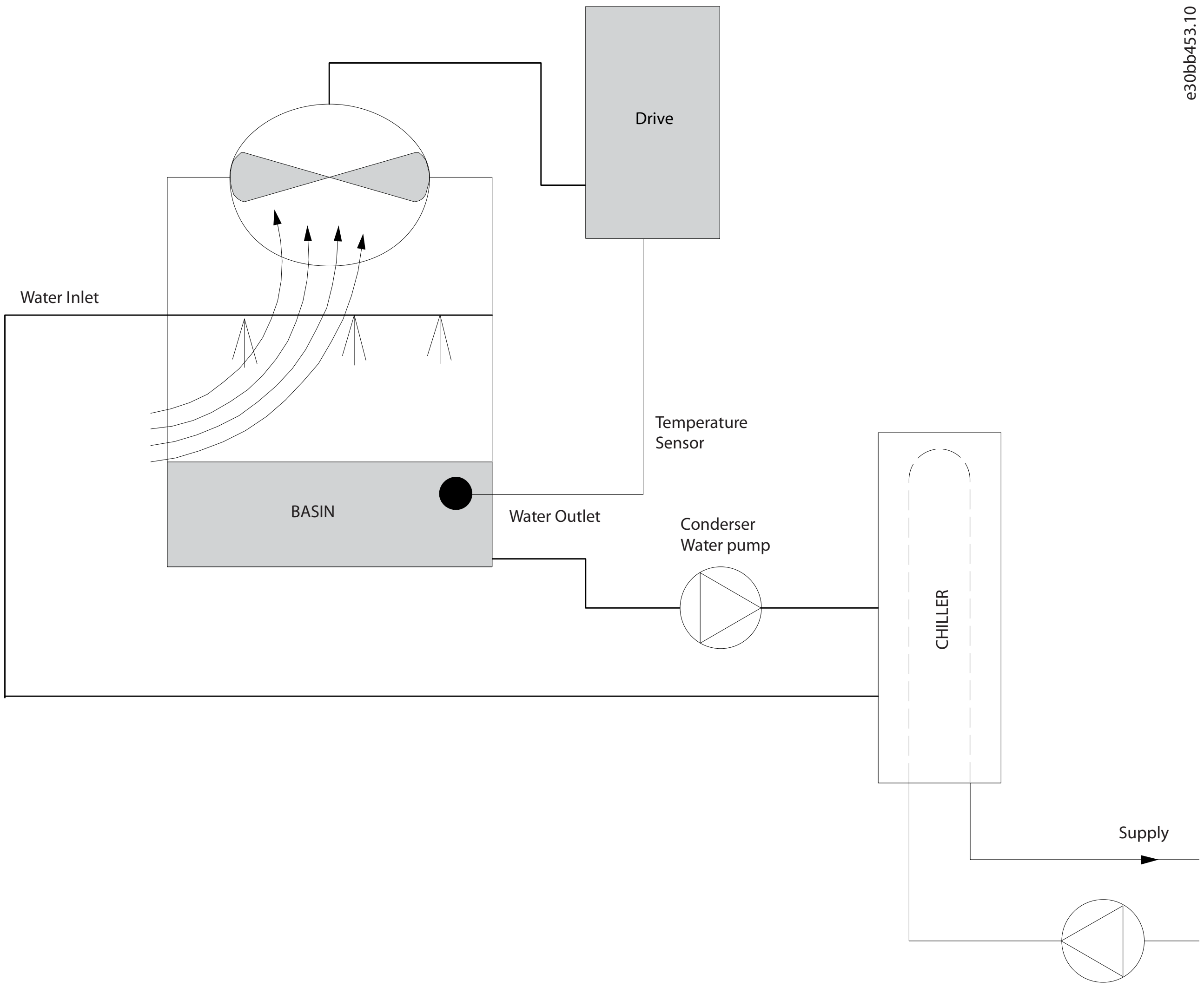



**Illustration 13: Cooling Tower Fan**

### 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.

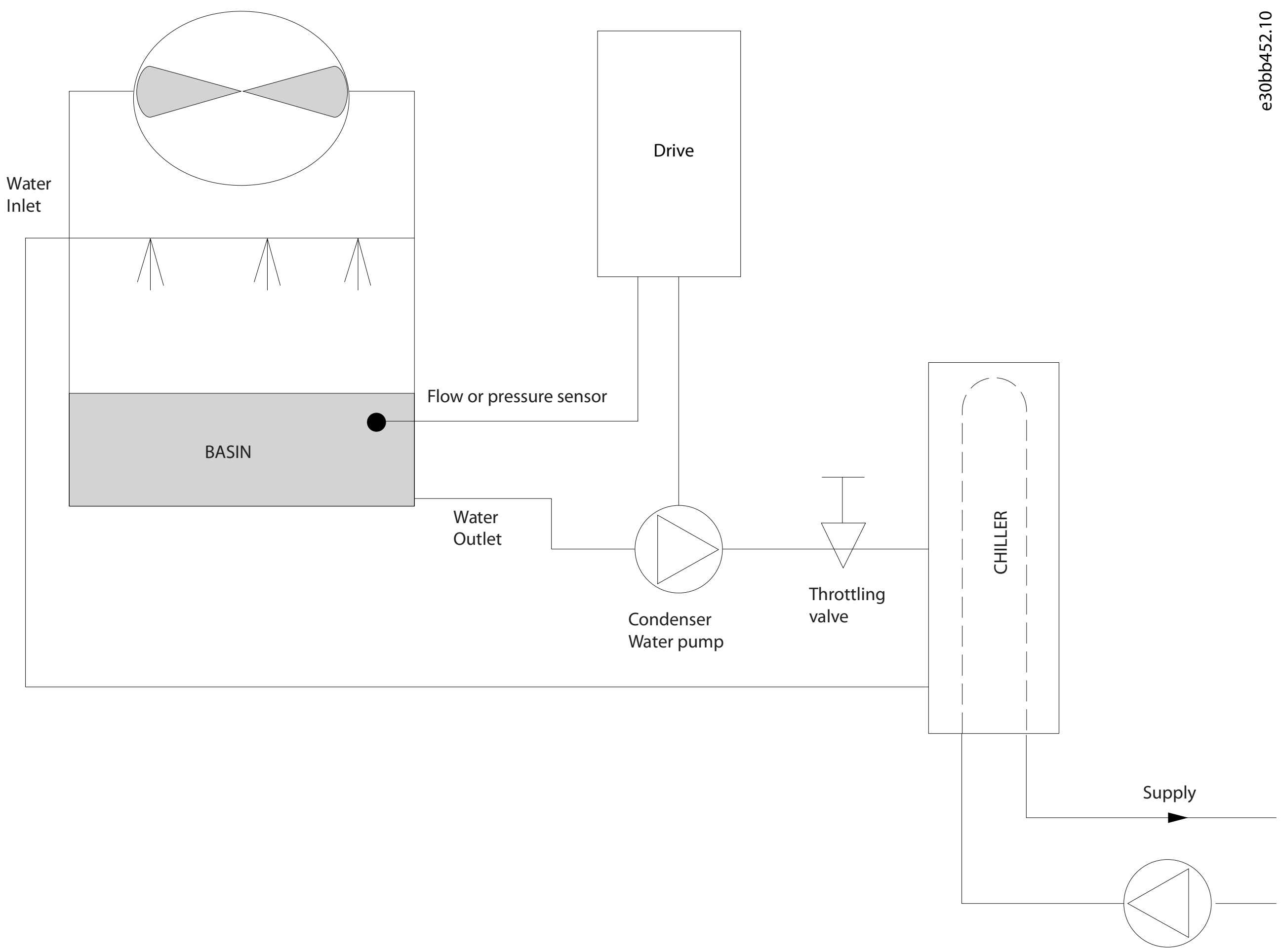



**Illustration 14: Condenser Pumps**

## 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.

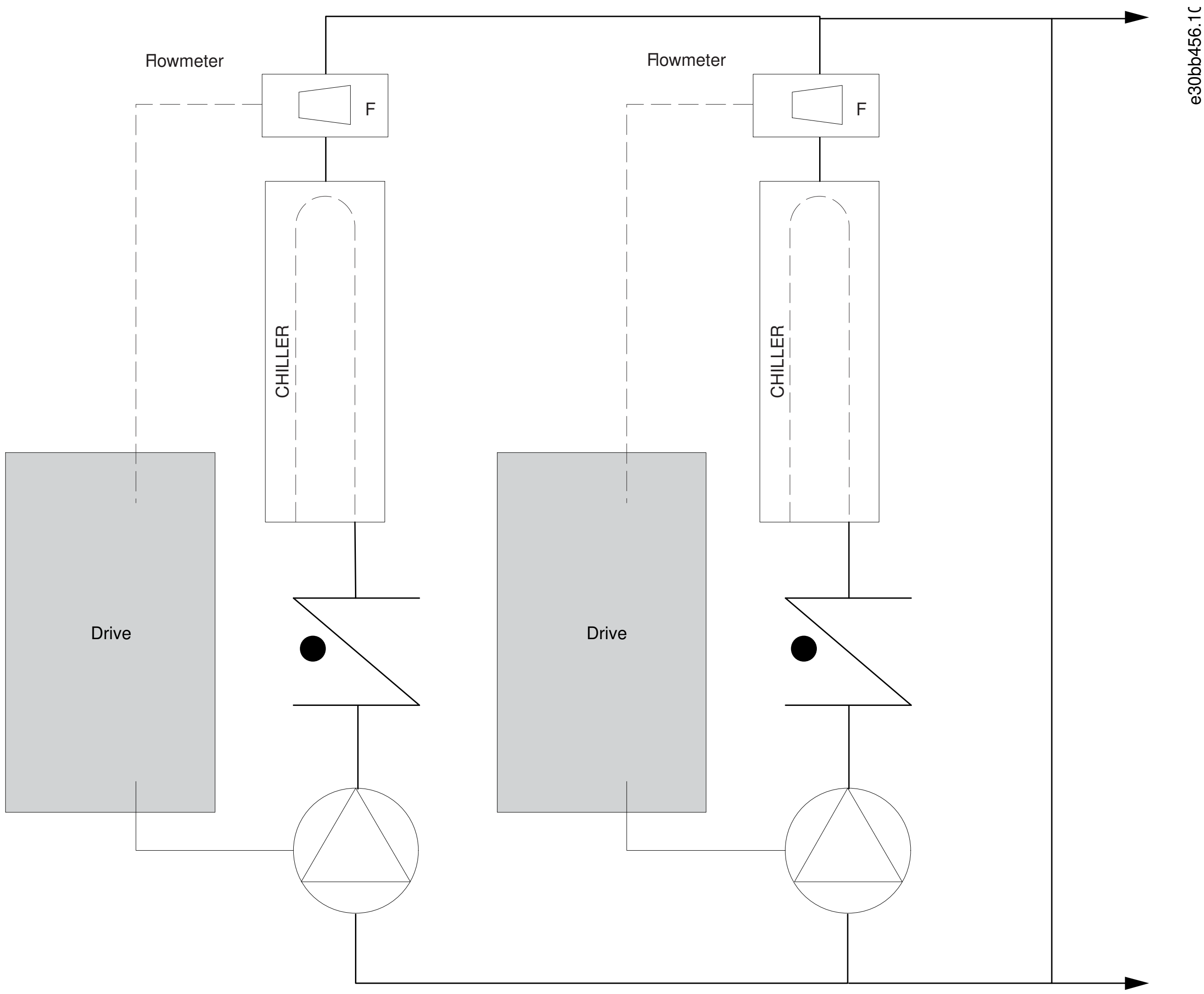



**Illustration 15: Primary Pumps**

### 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 hydronically de-couple 1 piping loop from another. In this case, the primary pump is used to maintain a constant flow through the chillers while allowing the secondary pumps to vary in flow, increase control and save energy.

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

**The VLT Solution**

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

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

As the monitored loads are reached, the 2-way valves close down. This increases the differential pressure measured across the load and the 2-way valve. As this differential pressure starts to rise, the pump is slowed to maintain the control head also called setpoint value. This setpoint value is calculated by summing the pressure drop of the load and the 2-way valve together under design conditions.

**NOTICE**

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

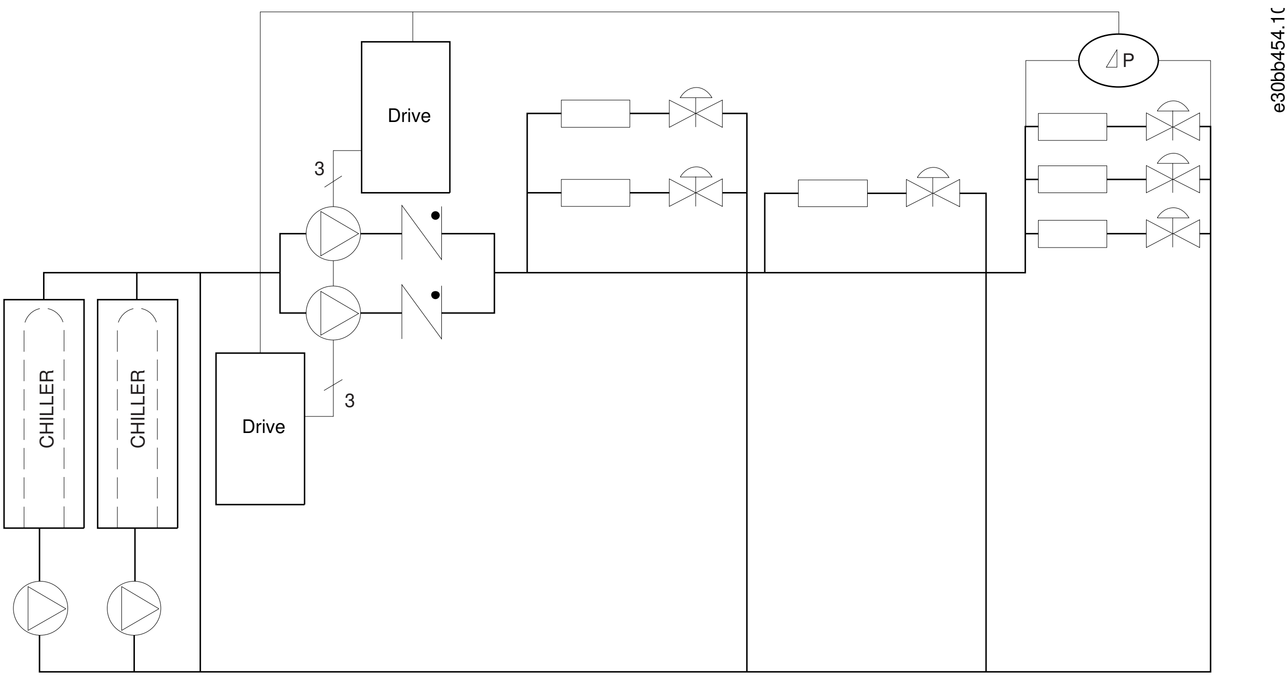



**Illustration 16: Secondary Pumps**

## 3.1.3 Check Valve Monitoring

In the pump application system, a damaged check valve is hard to detect, which therefore causes low efficiency of the whole system. VLT® Flow Drive FC 111 can monitor the status of check valves in the system. After enabling the check valve monitoring function via setting *parameter 22-04 Check Valve Monitor* to *[1] Enabled*, the drive trips *warning 159, Check Valve Failure* if a damaged check valve is detected.

## 3.1.4 Dry Pump Detection

In the pump application system, the drive monitors the operation status of the system to detect whether there is water on the pump's suction side. If the pump runs at maximum speed and consumes little power, then it can be assumed that there is no water on the pump's suction side. Via setting *parameter 22-26 Dry Pump Function* to warning or alarm, the drive trips *warning/alarm 93, dry pump* if the dry-pump condition is detected.

## 3.1.5 End of Curve Detection

In the pump application system, the drive monitors the operation status of the system to detect whether the pressure side of pump is subject to a major leakage. If the pump runs at maximum speed for a defined time period, but the pressure is below the set point, then it can be considered to reflect the end-of-curve situation. Via setting *parameter 22-50 End of Curve Function* to warning or alarm, the drive trips *warning/alarm 94, end of curve* if the end-of-curve condition is detected.

## 3.1.6 Time-based Functions

In some application scenarios, there are requirements to control the motor running for a specific time, in a specific direction and a specific speed within a specific time interval. For example, checking the motor status in fire mode or exercising pumps, fans, and compressors.

For detailed parameter settings, refer to the *parameter group 23-** Time-based Functions* in the drive's Programming Guide.

# 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

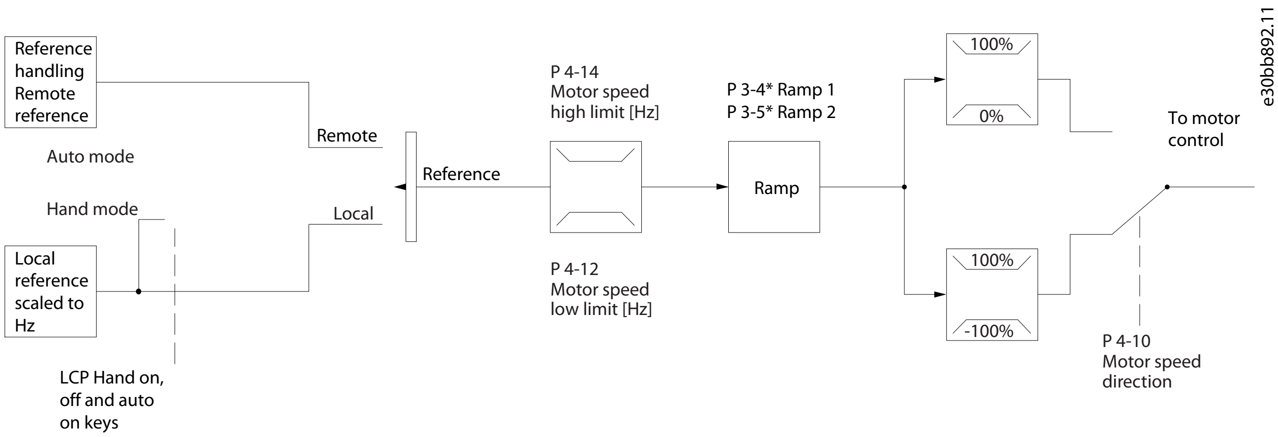



**Illustration 17: Open-loop Structure**

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: 0.37–315 kW (0.5–450 hp) (400 V) for induction motors and 0.37–90 kW (0.5–125 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 Rs in the system.
- No stall detection (supported from software version 62.80).

### 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.

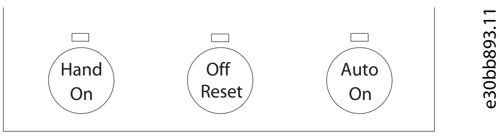



**Illustration 18: LCP Keys**

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.

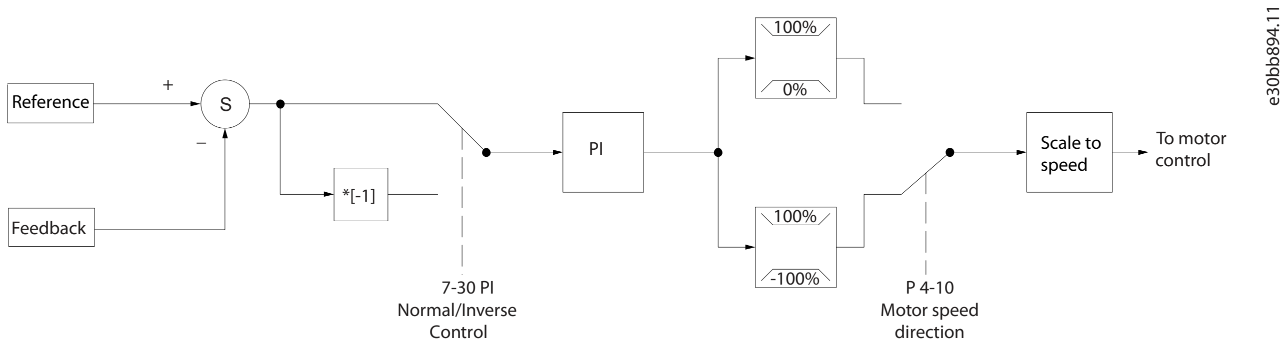



**Illustration 19: Control Structure Closed Loop**

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.

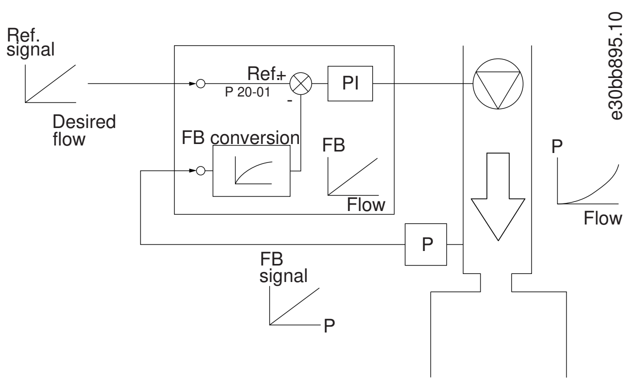



**Illustration 20: Feedback Signal Conversion**

## 3.2.7 Reference Handling

Details for open-loop and closed-loop operation.

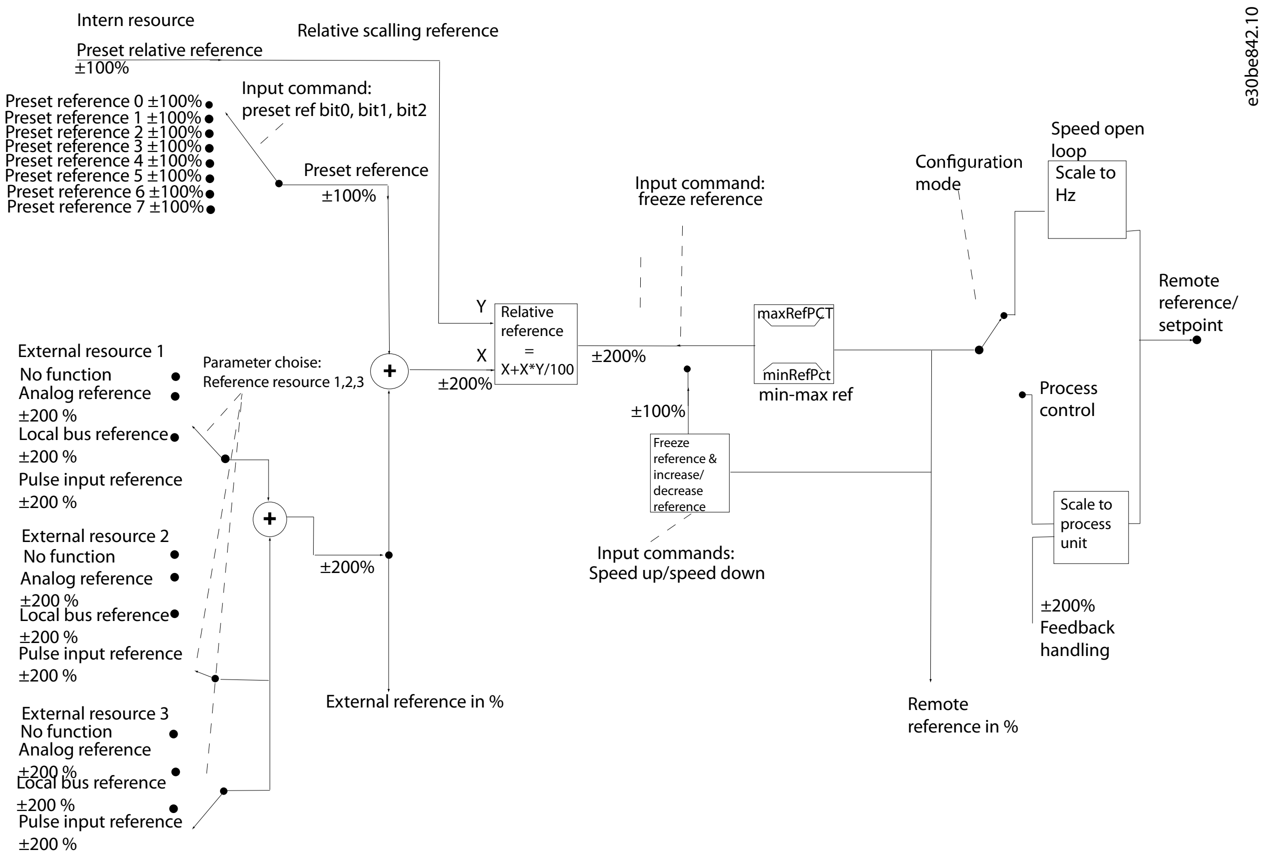



**Illustration 21: Block Diagram Showing Remote Reference**

The remote reference consists of:

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

Up to 8 preset references can be programmed in the drive. The active preset reference can be selected using digital inputs or the serial communications bus. The reference can also be supplied externally, most commonly from an analog input. This external source is selected by 1 of the 3 reference source parameters (*parameter 3-15 Reference 1 Source*, *parameter 3-16 Reference 2 Source*, and *parameter 3-17 Reference 3 Source*). All reference resources and the bus reference are added to produce the total external reference. The external reference, the preset reference, or the sum of the 2 can be selected to be the active reference. Finally, this reference can by be scaled using *parameter 3-14 Preset Relative Reference*.

The scaled reference is calculated as follows:

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

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

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

## 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 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*.

#### 3.3.2.1 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] |
|---|---|
| H1 | 43.6 |
| H2 | 50.2 |
| H3 | 53.8 |
| H4 | 64 |
| H5 | 63.7 |
| H11 | 71 |
| H12 | 72 |
| H13 | 73 |
| H14 | 75 |

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

#### 3.3.2.2 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.

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

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

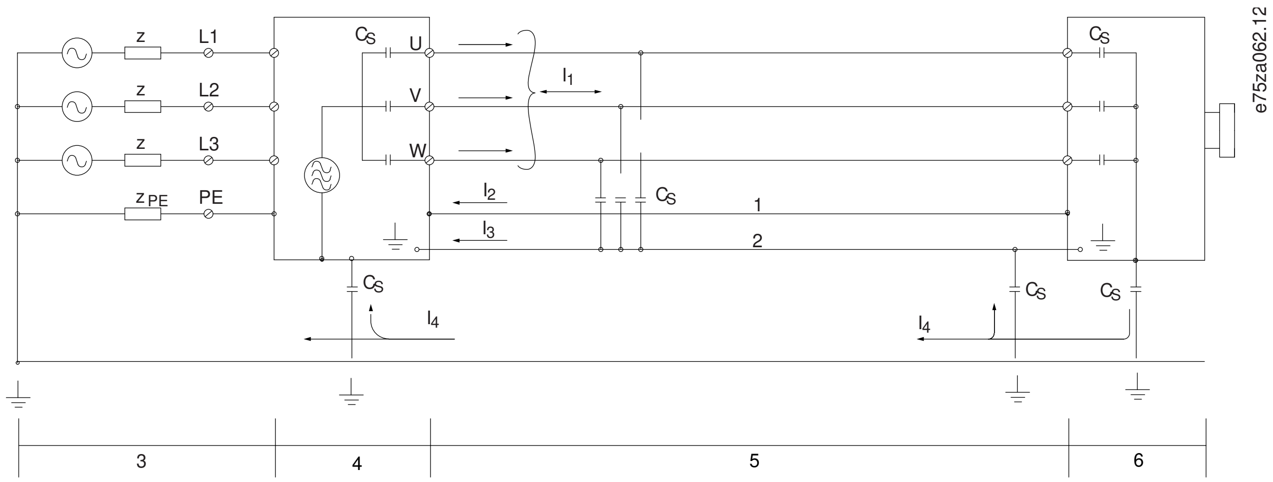



**Illustration 22: Generation of Leakage Currents**

| | | | |
|---|---|---|---|
| 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 (pigtails). Pigtails increase the shield impedance at higher frequencies, which reduces the shield effect and increases the leakage current ($I_4$).

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

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

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

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

## 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, H1–H5 & H11–H14**

| RFI filter type | Conduct emission. Maximum shielded cable length [m (ft)] | | | Radiated emission | | |
|---|---|---|---|---|---|---|
| EN 55011 | **Class B Housing, trades and light industries** | **Class A Group 1 Industrial environment** | **Class A Group 2 Industrial environment** | **Class B Housing, trades and light industries** | **Class A Group 1 Industrial environment** | **Class A Group 2 Industrial environment** |
| EN/IEC 61800-3 | **Category C1** First environment home and office | **Category C2** First environment home and office | **Category C3** Second environment industrial | **Category C1** First environment home and office | **Category C2** First environment home and office | **Category C3** First environment home and office |
| **H2 RFI filter (EN55011 A2, EN/IEC61800-3 C3)** | | | | | | |
| 0.37–22 kW (0.5–30 hp) 3x380–480 V IP20 | – | – | 25 (82) | – | – | Yes |
| 30–90 kW (40–125 hp) 3x380–480 V IP20 | – | – | 25 (82) | – | – | Yes |
| 110–315 kW (150–450 hp) 3x380–480 V IP20 | – | – | 150 (492) | – | – | Yes |

## 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.

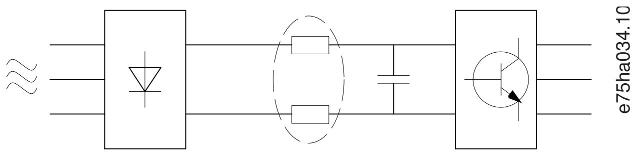



**Illustration 23: DC-link Coils**

| N O T I C E |
| --- |
| Some of the harmonic currents might disturb communication equipment connected to the same transformer or cause resonance with power factor correction batteries. |

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

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

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

($U_N$% of U)

## 3.4.5 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. |

## 3.4.6 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 0.37–22 kW (0.5–30 hp), 380-480 V**

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

**Table 13: Harmonic Current 30 kW (40 hp), 380-480 V**

| | Individual harmonic current $I_n/I_1$ (%) | | | |
| --- | --- | --- | --- | --- |
| | $I_5$ | $I_7$ | $I_{11}$ | $I_{13}$ |

| | | | | |
|---|---|---|---|---|
| **Actual 30 kW (40 hp), IP20, 380-480 V (typical)** | 16.6 | 8.4 | 3.9 | 2.7 |
| **Limit for $R_{sce}$≥120** | 40 | 25 | 15 | 10 |
| | **Harmonic current distortion factor (%)** | | | |
| | **THDi** | | **PWHD** | |
| **Actual 30 kW (40 hp), 380-480 V (typical)** | 40.4 | | 39.8 | |
| **Limit for $R_{sce}$≥120** | 48 | | 46 | |

**Table 14: Harmonic Current 37 kW (50 hp), 380-480 V**

| | **Individual harmonic current $I_n/I_1$ (%)** | | | |
|---|---|---|---|---|
| | **$I_5$** | **$I_7$** | **$I_{11}$** | **$I_{13}$** |
| **Actual 37 kW (50 hp), IP20, 380-480 V (typical)** | 19.1 | 9.6 | 4 | 2.7 |
| **Limit for $R_{sce}$≥120** | 40 | 25 | 15 | 10 |
| | **Harmonic current distortion factor (%)** | | | |
| | **THDi** | | **PWHD** | |
| **Actual 37 kW (50 hp), 380-480 V (typical)** | 44.1 | | 37.9 | |
| **Limit for $R_{sce}$≥120** | 48 | | 46 | |

**Table 15: Harmonic Current 45 kW (60 hp), 380-480 V**

| | **Individual harmonic current $I_n/I_1$ (%)** | | | |
|---|---|---|---|---|
| | **$I_5$** | **$I_7$** | **$I_{11}$** | **$I_{13}$** |
| **Actual 45 kW (60 hp), IP20, 380-480 V (typical)** | 25.5 | 12.8 | 5.1 | 3.3 |
| **Limit for $R_{sce}$≥120** | 40 | 25 | 15 | 10 |
| | **Harmonic current distortion factor (%)** | | | |
| | **THDi** | | **PWHD** | |
| **Actual 45 kW (60 hp), 380-480 V (typical)** | 45.5 | | 36.1 | |
| **Limit for $R_{sce}$≥120** | 48 | | 46 | |

**N O T I C E**

The following harmonic current data for 55-315 kW (70-450 hp), 380-480 V are simulation results. For units with phase currents above 75 A, there is no requirement regarding harmonic currents.

**Table 16: Harmonic Current 55 kW (70 hp), 380-480 V**

| | **Individual harmonic current $I_n/I_1$ (%)** | | | |
|---|---|---|---|---|
| | **$I_5$** | **$I_7$** | **$I_{11}$** | **$I_{13}$** |
| **Actual 55 kW (70 hp), IP20, 380-480 V (typical)** | 39.5 | 21.8 | 8.1 | 5.8 |
| **Limit for $R_{sce}$≥120** | 40 | 25 | 15 | 10 |
| | **Harmonic current distortion factor (%)** | | | |

| | THDi | PWHD |
|---|---|---|
| **Actual 55 kW (70 hp), 380-480 V (typical)** | 46.8 | 37.6 |
| **Limit for $R_{sce}$≥120** | 48 | 46 |

**Table 17: Harmonic Current 75 kW (100 hp), 380-480 V**

| | Individual harmonic current $I_n/I_1$ (%) | | | |
|---|---|---|---|---|
| | $I_5$ | $I_7$ | $I_{11}$ | $I_{13}$ |
| **Actual 75 kW (100 hp), IP20, 380-480 V (typical)** | 40 | 22.2 | 8.1 | 5.8 |
| **Limit for $R_{sce}$≥120** | 40 | 25 | 15 | 10 |
| | **Harmonic current distortion factor (%)** | | | |
| | **THDi** | | **PWHD** | |
| **Actual 75 kW (100 hp), 380-480 V (typical)** | 47.5 | | 37.4 | |
| **Limit for $R_{sce}$≥120** | 48 | | 46 | |

**Table 18: Harmonic Current 90 kW (125 hp), 380-480 V**

| | Individual harmonic current $I_n/I_1$ (%) | | | |
|---|---|---|---|---|
| | $I_5$ | $I_7$ | $I_{11}$ | $I_{13}$ |
| **Actual 90 kW (125 hp), IP20, 380-480 V (typical)** | 37.7 | 18.9 | 8.6 | 3.8 |
| **Limit for $R_{sce}$≥120** | 40 | 25 | 15 | 10 |
| | **Harmonic current distortion factor (%)** | | | |
| | **THDi** | | **PWHD** | |
| **Actual 90 kW (125 hp), 380-480 V (typical)** | 43.7 | | 30.6 | |
| **Limit for $R_{sce}$≥120** | 48 | | 46 | |

**Table 19: Harmonic Current 110 kW (150 hp), 380-480 V**

| | Individual harmonic current $I_n/I_1$ (%) | | | |
|---|---|---|---|---|
| | $I_5$ | $I_7$ | $I_{11}$ | $I_{13}$ |
| **Actual 110 kW (150 hp), IP20, 380-480 V (typical)** | 32.3 | 7.6 | 6.2 | 3.2 |
| **Limit for $R_{sce}$≥120** | 40 | 25 | 15 | 10 |
| | **Harmonic current distortion factor (%)** | | | |
| | **THDi** | | **PWHD** | |
| **Actual 110 kW (150 hp), 380-480 V (typical)** | 34.2 | | 15.9 | |
| **Limit for $R_{sce}$≥120** | 48 | | 46 | |

Table 20: Harmonic Current 132 kW (175 hp), 380-480 V

| | Individual harmonic current $I_n/I_1$ (%) | | | |
|---|---|---|---|---|
| | $I_5$ | $I_7$ | $I_{11}$ | $I_{13}$ |
| **Actual 132 kW (175 hp), IP20, 380-480 V (typical)** | 31.6 | 6.8 | 6.2 | 2.6 |
| **Limit for $R_{sce}$≥120** | 40 | 25 | 15 | 10 |
| | **Harmonic current distortion factor (%)** | | | |
| | **THDi** | | **PWHD** | |
| **Actual 132 kW (175 hp), 380-480 V (typical)** | 33.2 | | 14.7 | |
| **Limit for $R_{sce}$≥120** | 48 | | 46 | |

Table 21: Harmonic Current 160 kW (250 hp), 380-480 V

| | Individual harmonic current $I_n/I_1$ (%) | | | |
|---|---|---|---|---|
| | $I_5$ | $I_7$ | $I_{11}$ | $I_{13}$ |
| **Actual 160 kW (250 hp), IP20, 380-480 V (typical)** | 31.6 | 7.1 | 6.2 | 3.1 |
| **Limit for $R_{sce}$≥120** | 40 | 25 | 15 | 10 |
| | **Harmonic current distortion factor (%)** | | | |
| | **THDi** | | **PWHD** | |
| **Actual 160 kW (250 hp), 380-480 V (typical)** | 33.3 | | 15.8 | |
| **Limit for $R_{sce}$≥120** | 48 | | 46 | |

Table 22: Harmonic Current 200 kW (300 hp), 380-480 V

| | Individual harmonic current $I_n/I_1$ (%) | | | |
|---|---|---|---|---|
| | $I_5$ | $I_7$ | $I_{11}$ | $I_{13}$ |
| **Actual 200 kW (300 hp), IP20, 380-480 V (typical)** | 31.3 | 6.7 | 6.1 | 2.7 |
| **Limit for $R_{sce}$≥120** | 40 | 25 | 15 | 10 |
| | **Harmonic current distortion factor (%)** | | | |
| | **THDi** | | **PWHD** | |
| **Actual 200 kW (300 hp), 380-480 V (typical)** | 32.9 | | 14.6 | |
| **Limit for $R_{sce}$≥120** | 48 | | 46 | |

Table 23: Harmonic Current 250 kW (350 hp), 380-480 V

| | Individual harmonic current $I_n/I_1$ (%) | | | |
|---|---|---|---|---|
| | $I_5$ | $I_7$ | $I_{11}$ | $I_{13}$ |
| **Actual 250 kW (350 hp), IP20, 380-480 V (typical)** | 31.9 | 6.7 | 6.7 | 2.7 |
| **Limit for $R_{sce}$≥120** | 40 | 25 | 15 | 10 |
| | **Harmonic current distortion factor (%)** | | | |

| | THDi | PWHD |
|---|---|---|
| **Actual 250 kW (350 hp), 380-480 V (typical)** | 33.5 | 15.6 |
| **Limit for $R_{sce}$≥120** | 48 | 46 |

**Table 24: Harmonic Current 315 kW (450 hp), 380-480 V**

| | Individual harmonic current $I_n/I_1$ (%) | | | |
|---|---|---|---|---|
| | $I_5$ | $I_7$ | $I_{11}$ | $I_{13}$ |
| **Actual 315 kW (450 hp), IP20, 380-480 V (typical)** | 31.2 | 7.1 | 6.1 | 3.1 |
| **Limit for $R_{sce}$≥120** | 40 | 25 | 15 | 10 |
| | **Harmonic current distortion factor (%)** | | | |
| | **THDi** | | **PWHD** | |
| **Actual 315 kW (450 hp), 380-480 V (typical)** | 32.9 | | 15.7 | |
| **Limit for $R_{sce}$≥120** | 48 | | 46 | |

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

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

at the interface point between the user's supply and the public system ($R_{sce}$).

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

Compliance with various system level guidelines: The harmonic current data in the tables above 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.

### 3.4.7 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 the following illustrations.

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

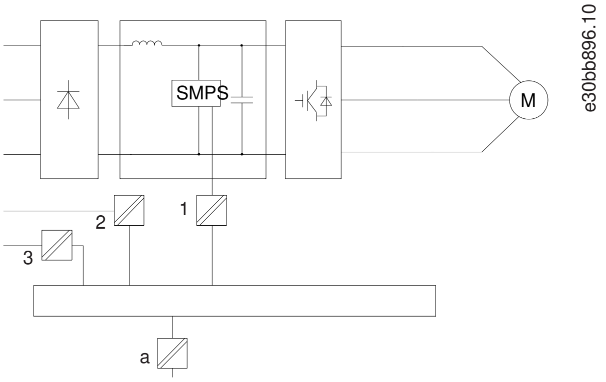



**Illustration 24: Galvanic Isolation 0.37–22 kW (0.5–30 hp)**

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

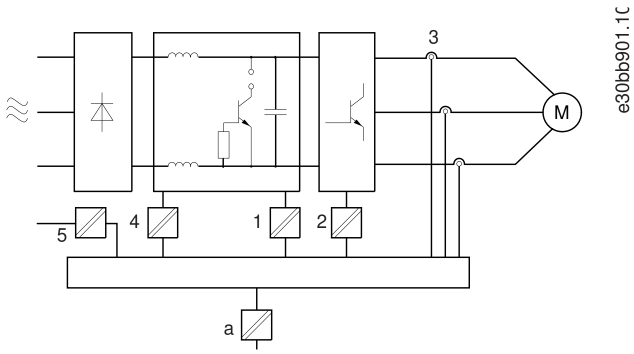



**Illustration 25: Galvanic Isolation 30–90 kW (40–120 hp)**

| | | | |
|---|---|---|---|
| 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 |

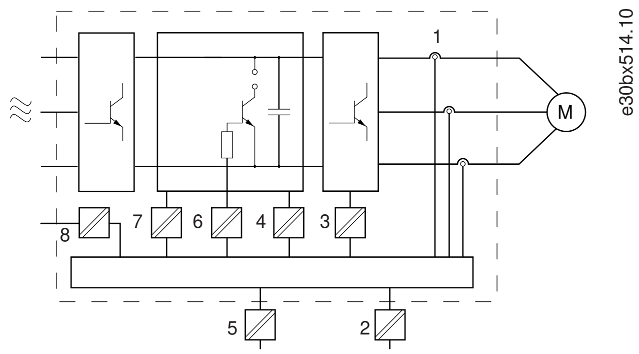



**Illustration 26: Galvanic Isolation 110–315 kW (150–450 hp)**

| | | | |
|---|---|---|---|
| 1 | Current transducers | 5 | Galvanic isolation for the 24 V back-up option |
| 2 | Galvanic isolation for the RS485 standard bus interface | 6 | Opto-coupler, brake module (optional) |
| 3 | Gate drive for the IGBTs | 7 | Internal inrush, RFI, and temperature measurement circuits |
| 4 | Supply (SMPS) including signal isolation of V DC, indicating the intermediate current voltage | 8 | Customer relays |

The functional galvanic isolation (see Illustration 24) is for the RS485 standard bus interface.

**CAUTION**

**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.

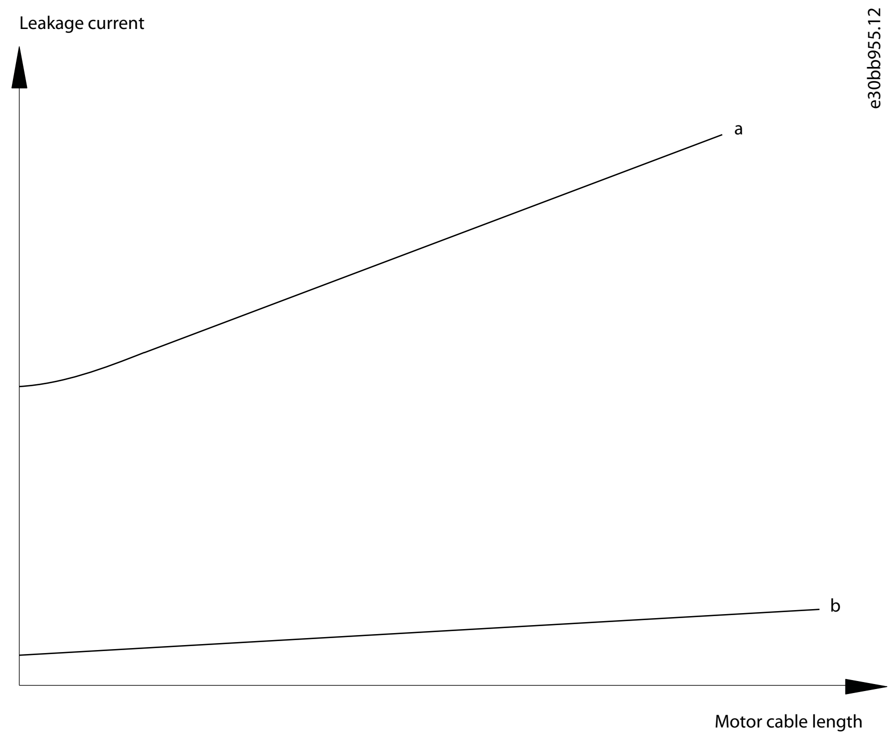



**Illustration 27: Influence of the Cable Length and Power Size on Leakage Current, Power Size a > Power Size B**

The leakage current also depends on the line distortion.

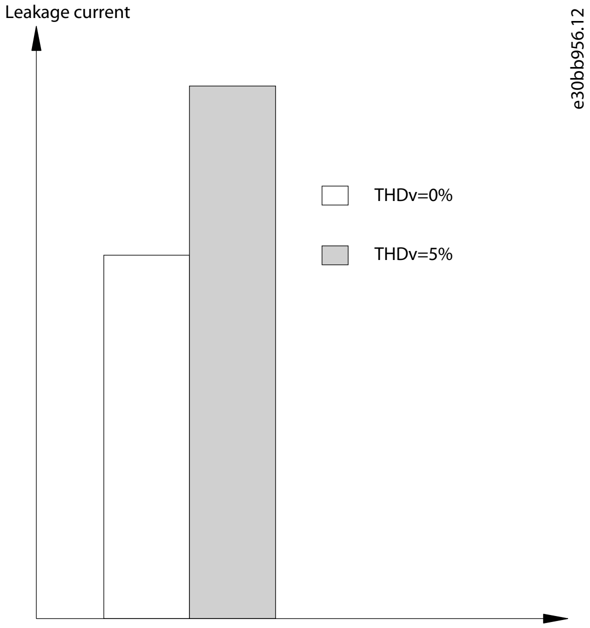



**Illustration 28: Influence of Line Distortion on Leakage Current**

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

Reinforce grounding with the following protective earth connection requirements:

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

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

**W A R N I N G**

**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.

**W A R N I N G**

**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.

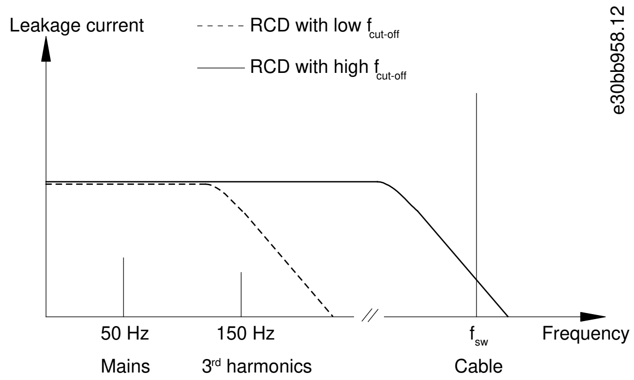



**Illustration 29: Mains Contributions to Leakage Current**

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

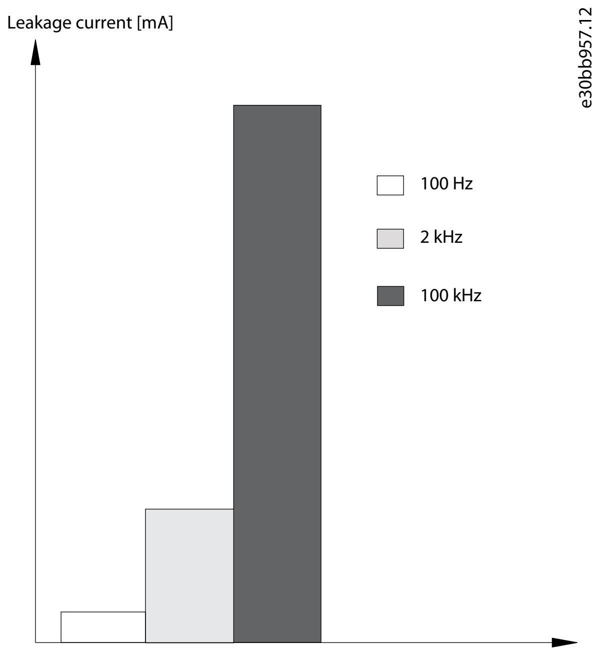



**Illustration 30: Influence of Cut-off Frequency of the RCD on what is Responded to/Measured**

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.

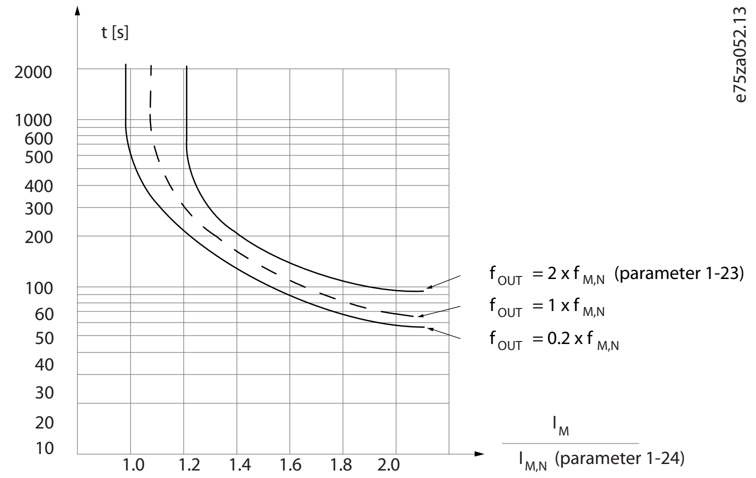



**Illustration 31: Motor Thermal Protection Characteristic**

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 kΩ.

Integrate a thermistor (PTC sensor) in the motor for winding protection.

Motor protection can be implemented using a range of techniques:

- PTC sensor in motor windings.
- Mechanical thermal switch (Klixon type).
- Electronic thermal relay (ETR).

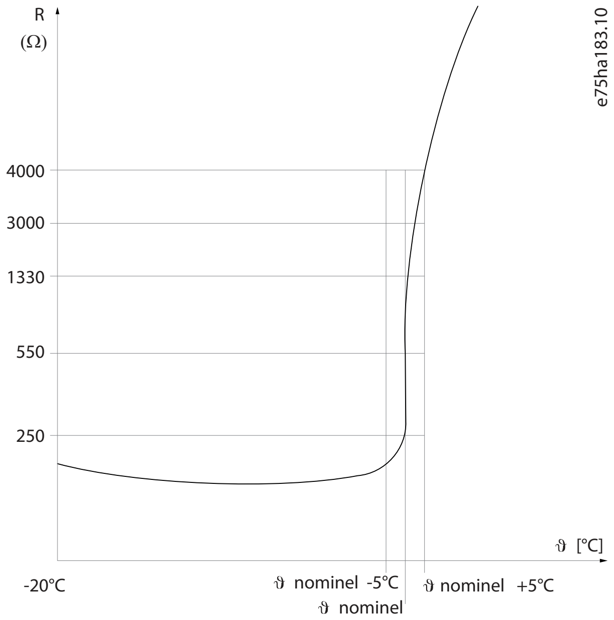



**Illustration 32: Trip due to High Motor Temperature**

## 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*.

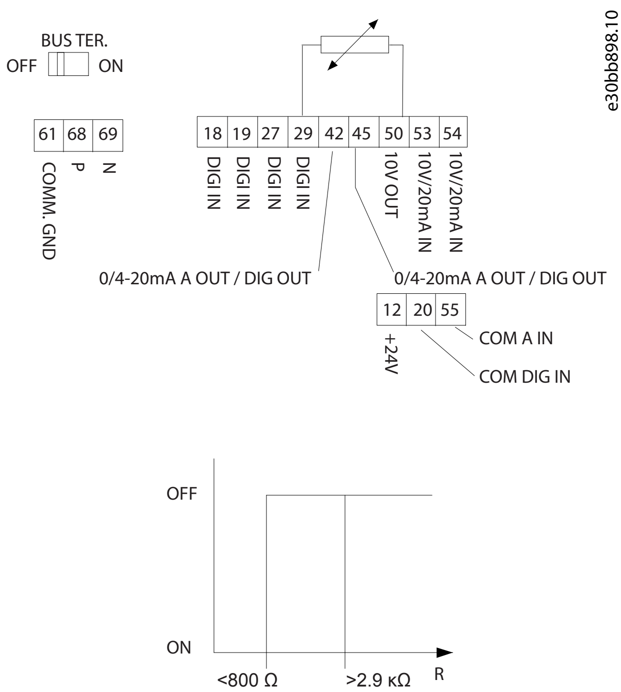



**Illustration 33: Digital Input/10 V Power Supply**

## 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. |

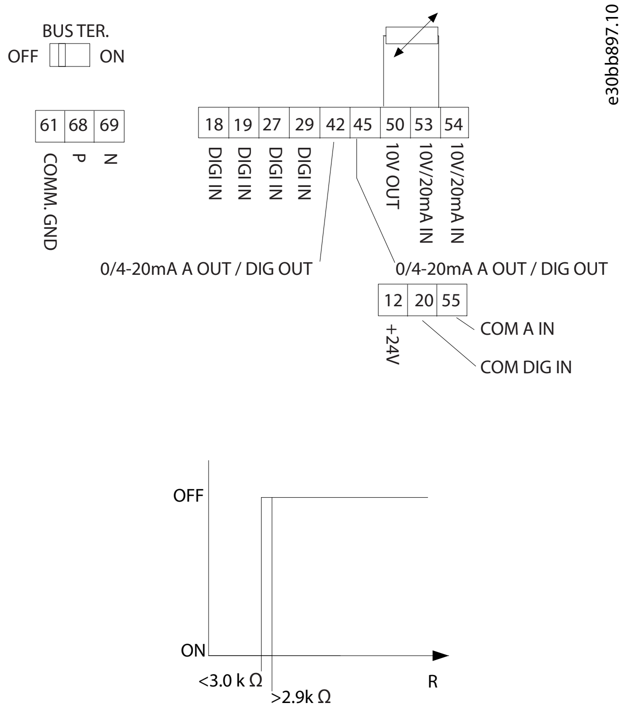



**Illustration 34: Analog Input/10 V Power Supply**

**Table 25: 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 | 1 | 1 | P | | | | T | | | | | H | | X | | | X | X | X | S | X | X | X | X | A | X | B | X | C | X | X | X | X | D | X |

e30bu797.10

**Illustration 35: Type Code**

**Table 26: Type Code Description**

| Description | Position | Possible choice |
|---|---|---|
| Product group & FC series | 1–6 | FC 111 |
| Power rating | 7–10 | 0.37–315 kW (0.5–450 hp) (PK37-P315) |
| Number of phases | 11 | 3 phases (T) |
| Mains voltage | 11–12 | T4: 380-480 V AC |
| Enclosure | 13–15 | E20: IP20/chassis<br>P20: IP20/chassis with back plate |
| RFI filter | 16–17 | H2: RFI filter class A2 |
| Brake | 18 | X: No brake chopper included |
| Display | 19 | X: No local control panel |
| Coating PCB | 20 | 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

**Table 27: Options and Accessories**

| Enclosure size | 3x380–480 V [kW (hp)] | LCP(1) | LCP mounting kit including 3 m (9.8 ft) cable | Decoupling plate(2) | IP21/Type 1 conversion kit(3) |
|---|---|---|---|---|---|
| **H1** | 0.37–1.5 (0.5–2.0) | LCP 31: 132B0200<br>LCP 32: 132B9221 | 132B0201 | 132B0202 | 132B0212 |
| **H2** | 2.2–4.0 (3.0–5.4) | | | | 132B0213 |
| **H3** | 5.5–7.5 (7.5–10) | | | 132B0204 | 132B0214 |
| **H4** | 11–15 (15–20) | | | 132B0205 | 132B0215 |
| **H5** | 18.5–22 (25–30) | | | | 132B0216 |
| **H11** | 30–45 (40–60) | | | 132B0284 | 132B0376 |
| **H12** | 55–90 (75–125) | | | 132B0285 | 132B0377 |
| **H13** | 110–160 (150–250) | | | – | – |
| **H14** | 200–315 (300–450) | | | | |

[1] For IP20 units, LCP is ordered separately.

[2] Use the decoupling plate for EMC functionality.

[3] IP21/Type 1 conversion kit is an optional enclosure element available for IP20 units. When using the IP21/Type 1 conversion kit, the IP20 unit is upgraded to IP21 protection rating.

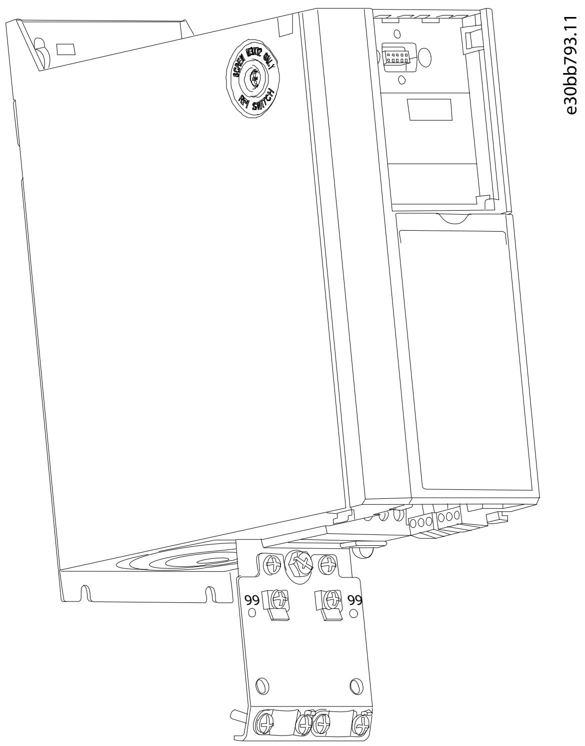



**Illustration 36: Decoupling Plate**

# 5 Mechanical Installation Considerations

## 5.1 Power Ratings, Weights, and Dimensions

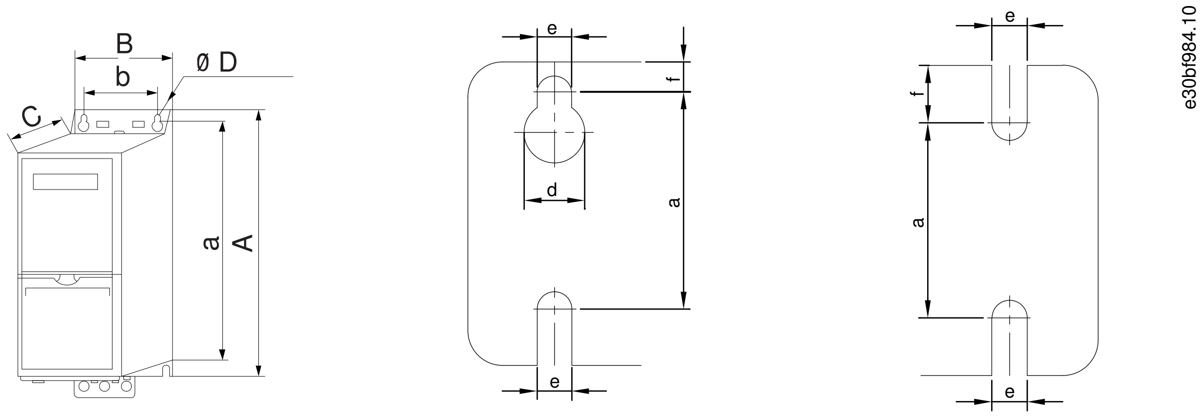



**Illustration 37: Dimensions, Enclosure Sizes H1–H5 & H11–H12**

**Table 28: Power Ratings, Weights, and Dimensions, Enclosure Sizes H1–H5 & H11–H12**

| Enclosure Size | | H1 | H2 | H3 | H4 | H5 | H11 | H12 |
|---|---|---|---|---|---|---|---|---|
| Protection rating | | IP20 | IP20 | IP20 | IP20 | IP20 | IP20 | IP20[(1)] |
| 3x380–480 V [kW (hp)] | | 0.37–1.5 (0.5–2.0) | 2.2–4.0 (3.0–5.0) | 5.5–7.5 (7.5–10) | 11–15 (15–20) | 18.5–22 (25–30) | 30–45 (40–60) | 55–90 (70–125) |
| Height [mm (in)] | A | 195 (7.7) | 227 (8.9) | 255 (10.0) | 296 (11.7) | 334 (13.1) | 515 (20.3) | 550 (21.7) |
| | A[(2)] | 273 (10.7) | 303 (11.9) | 329 (13.0) | 359 (14.1) | 402 (15.8) | 545 (21.5) | 610.5 (24) |
| | a | 183 (7.2) | 212 (8.3) | 240 (9.4) | 275 (10.8) | 314 (12.4) | 495 (19.5) | 521 (20.5) |
| Width [mm (in)] | B | 75 (3.0) | 90 (3.5) | 100 (3.9) | 135 (5.3) | 150 (5.9) | 233 (9.2) | 308 (12.1) |
| | b | 56 (2.2) | 65 (2.6) | 74 (2.9) | 105 (4.1) | 120 (4.7) | 200 (7.9) | 270 (10.6) |
| Depth [mm (in)] | C | 168 (6.6) | 190 (7.5) | 206 (8.1) | 241 (9.5) | 255 (10) | 241 (9.5) | 323 (12.7) |
| Mounting hole [mm (in)] | d | 9 (0.35) | 11 (0.43) | 11 (0.43) | 12.6 (0.50) | 12.6 (0.50) | – | – |
| | e | 4.5 (0.18) | 5.5 (0.22) | 5.5 (0.22) | 7 (0.28) | 7 (0.28) | 8.5 (0.33) | 8.5 (0.33) |
| | f | 5.3 (0.21) | 7.4 (0.29) | 8.1 (0.32) | 8.4 (0.33) | 8.5 (0.33) | 13 (0.5) | 17 (0.67) |
| Maximum weight [kg (lb)] | | 2.1 (4.6) | 3.4 (7.5) | 4.5 (9.9) | 7.9 (17.4) | 9.5 (20.9) | 22.6 (49.8) | 37.3 (82.2) |

[1] Install the protective cover on the mains and motor terminals after connecting the stripped wire. See Illustration 38.

[2] Including decoupling plate.

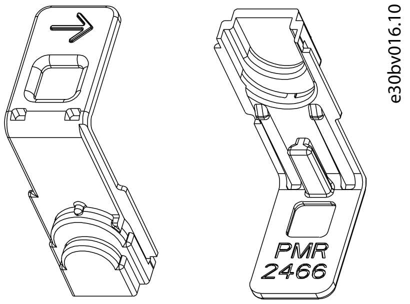



**Illustration 38: Protective Cover**

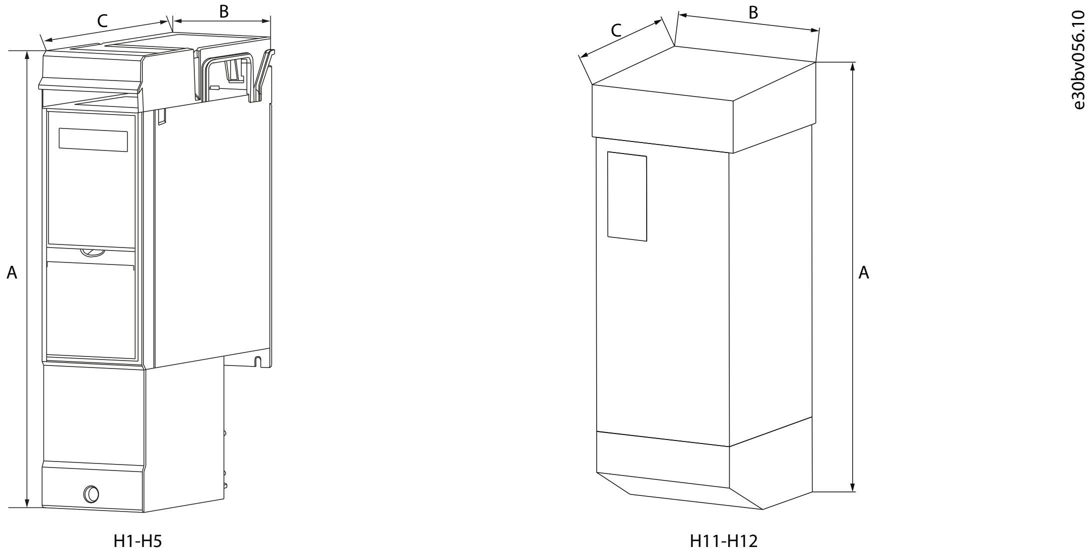



**Illustration 39: Dimensions, Enclosure Sizes H1–H5 & H11–H12 with IP21/Type 1 Conversion Kit**

**Table 29: Power Ratings and Dimensions, Enclosure Sizes H1–H5 & H11–H12 with IP21/Type 1 Conversion Kit**

| Enclosure Size | | H1 | H2 | H3 | H4 | H5 | H11 | H12 |
|---|---|---|---|---|---|---|---|---|
| Protection rating | | IP21 | IP21 | IP21 | IP21 | IP21 | IP21 | IP21 |
| 3x380–480 V [kW (hp)] | | 0.37–1.5 (0.5–2.0) | 2.2–4.0 (3.0–5.0) | 5.5–7.5 (7.5–10) | 11–15 (15–20) | 18.5–22 (25–30) | 30–45 (40–60) | 55–90 (70–125) |
| Height [mm (in)] | A | 293 (11.5) | 322 (12.7) | 346 (13.6) | 374 (14.7) | 418 (16.5) | 770 (30.3) | 807 (31.8) |
| Width [mm (in)] | B | 81 (3.2) | 96 (3.8) | 106 (4.2) | 141 (5.6) | 161 (6.3) | 254 (10) | 329 (13.0) |
| Depth [mm (in)] | C | 173 (6.8) | 195 (7.7) | 210 (8.3) | 245 (9.6) | 260 (10.2) | 262 (10.3) | 340 (13.4) |

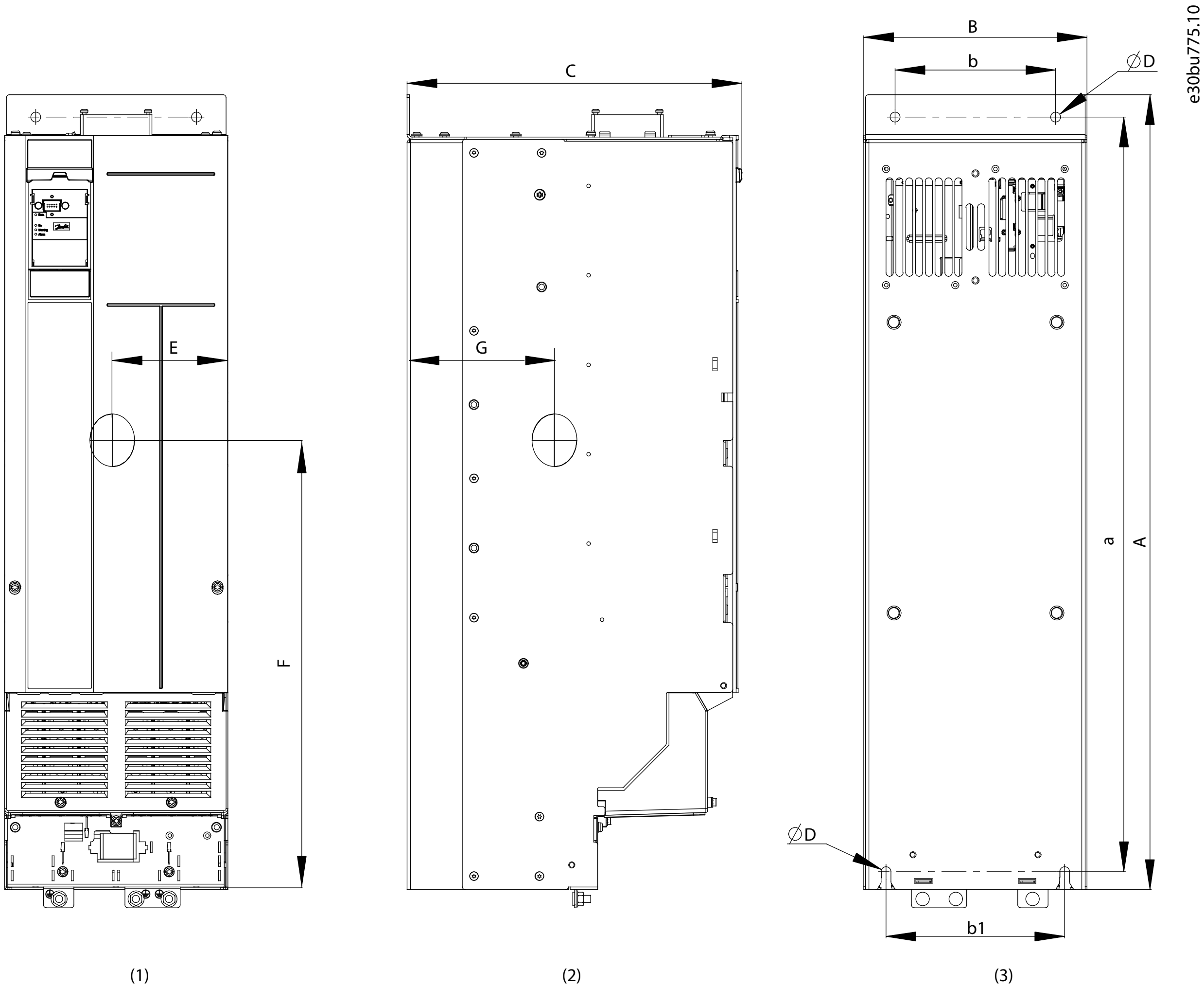



**Illustration 40: Dimensions, Enclosure Sizes H13–H14**

| | | | |
|---|---|---|---|
| 1 | Front view | 3 | Back view |
| 2 | Side view | | |

**Table 30: Power Ratings, Weights, and Dimensions, Enclosure Sizes H13–H14**

| Enclosure Size | | H13 | H14 |
|---|---|---|---|
| **Protection rating** | | IP20 | IP20 |
| **3x380–480 V [kW (hp)]** | | 110–160 (150–250) | 200–315 (300–450) |
| **Height [mm (in)]** | **A** | 889 (35.0) | 1096 (43.1) |
| | **A(1)** | 909 (35.8) | 1122 (44.2) |
| | **a** | 844 (33.2) | 1051 (41.4) |
| **Width [mm (in)]** | **B** | 250 (9.8) | 350 (13.8) |
| | **b** | 180 (7.1) | 280 (11.0) |
| | **b1** | 200 (7.9) | 271 (10.7) |
| **Depth [mm (in)]** | **C** | 375 (14.8) | 375 (14.8) |

| Enclosure Size | | H13 | H14 |
|---|---|---|---|
| **Mounting hole [mm (in)]** | **D** | 11 (0.4) | 11 (0.4) |
| **Center of gravity [mm (in)]** | **E** | 128 (5.0) | 176 (6.9) |
| | **F** | 495 (19.5) | 611 (24.1) |
| | **G** | 148 (5.8) | 148 (5.8) |
| **Maximum weight [kg (lb)]** | | 98 (216) | 164 (362) |

[1] Including decoupling plate.

The dimensions are only for the physical units.

## 5.2 Storage and Operating Environment

**Storage**

Store the drive in a dry location. Keep the equipment sealed in its packaging until installation. Refer to the *Ambient Conditions* section for recommended ambient temperature.

Periodic forming (capacitor charging) is not necessary during storage unless storage exceeds 12 months.

**Operating Environment**

**N O T I C E**

**OPERATING ENVIRONMENT**

In environments with airborne liquids, particles, or corrosive gases, failure to meet requirements for ambient conditions can reduce the lifetime of the drive.

- Ensure that the IP/Type rating of the equipment matches the installation environment.
- Ensure that requirements for air humidity, temperature, and altitude are met.

**Table 31: Installation at High Altitudes**

| Voltage [V] | Altitude restrictions |
|---|---|
| 380–480 | At altitudes above 3000 m (9842 ft), contact Danfoss regarding PELV. |

**N O T I C E**

**CONDENSATION**

Moisture can condense on the electronic components and cause short circuits.

- Avoid installation in areas subject to frost.
- Install an optional space heater when the drive is colder than the ambient air.
- Operating in standby mode reduces the risk of condensation as long as the power dissipation keeps the circuitry free of moisture.

**N O T I C E**

**EXTREME AMBIENT CONDITIONS**

Hot or cold temperatures compromise unit performance and longevity.

- Do not operate in environments where the ambient temperature exceeds 55 °C (131 °F).
- The drive can operate at temperatures down to -15 °C (5 °F). However, proper operation at rated load is only guaranteed at 0 °C (32 °F) or higher.
- Extra air conditioning of the cabinet or installation site is required if temperature exceeds ambient temperature limits.

**⚠ WARNING ⚠**

**EXPLOSIVE ATMOSPHERE**

Do not install the drive in a potentially explosive atmosphere.

- Install the unit in a cabinet outside of this area.
- Failure to follow this guideline increases risk of death or serious injury.

**NOTICE**

**GASES**

Aggressive gases, such as hydrogen sulfide, chlorine, or ammonia can damage the electrical and mechanical components.

- The unit uses conformal-coated circuit boards to reduce the effects of aggressive gases.

When installing the drive in dusty environments, pay attention to the following:

**Periodic maintenance**

When dust accumulates on electronic components, it acts as a layer of insulation. This layer reduces the cooling capacity of the components, and the components become warmer. The hotter environment decreases the life of the electronic components. Keep the heat sink and fans free from dust build-up.

**Cooling fans**

Fans provide airflow to cool the drive. When fans are exposed to dusty environments, the dust can damage the fan bearings and cause premature fan failure. Also, dust can accumulate on fan blades causing an imbalance which prevents the fans from properly cooling the unit.

## 5.3 Side-by-side Installation

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

**Table 32: Clearance Required for Cooling**

| Size | IP class | Power [kW (hp)] | Clearance above/below [mm (in)] |
|---|---|---|---|
| | | 3x380–480 V | |
| H1 | IP20 | 0.37–1.5 (0.5–2.0) | 100 (4) |
| H2 | IP20 | 2.2–4.0 (3.0–5.4) | 100 (4) |
| H3 | IP20 | 5.5–7.5 (7.5–10) | 100 (4) |
| H4 | IP20 | 11–15 (15–20) | 100 (4) |
| H5 | IP20 | 18.5–22 (25–30) | 100 (4) |
| H11 | IP20 | 30–45 (40–60) | 200 (7.9) |
| H12 | IP20 | 55–90 (70–125) | 200 (7.9) |
| H13 | IP20/Chassis | 110–160 (150–250) | 225 (9) |
| H14 | IP20/Chassis | 200–315 (300–450) | 225 (9) |

**NOTICE**

With IP21 option kit mounted (available for H1–H5 & H11–H12), a distance of 50 mm (2 in) between the units is required.

## 5.4 Tools Needed

**Table 33: Tools Needed**

| Tools Needed | Receiving/unloading | Installation |
|---|---|---|
| H1–H5 | – | • 3 mm flat-edged screwdriver for terminals.<br>• T20 torx head screwdriver for M5 grounding screw. |
| H11–H12 | • I-beam and hooks rated to lift the weight of the drive. Refer to 5.1 Power Ratings, Weights, and Dimensions.<br>• Crane or other lifting aid to place the unit into position. | • Allen key 6# (for M8).<br>• T30 torx head screwdriver for terminals.<br>• T25 torx head screwdriver for M6 grounding screw. |
| H13–H14 | | • Drill with a 12 mm (1/2 in) drill bit.<br>• Tape measurer.<br>• Phillips and flat bladed screwdrivers.<br>• Wrench with 7–17 mm metric sockets.<br>• Wrench extensions.<br>• T25 and T50 torx drives.<br>• Sheet metal punch and/or pliers for cable entry plate. |

## 5.5 Installation and Cooling Requirements

**NOTICE**

**OVERHEATING**

Improper mounting can result in overheating and reduced performance.

– Install the drive according to the installation and cooling requirements.

### Installation requirements

- Ensure drive stability by mounting the drive vertically to a solid flat surface.
- Ensure that the strength of the mounting location supports the drive weight. Ensure that the mounting location allows access to open the enclosure door. Refer to 5.1 Power Ratings, Weights, and Dimensions.
- Ensure that there is enough space around the drive for cooling airflow.
- Place the drive as near to the motor as possible. Keep the motor cables as short as possible. See 8.2.4 Cable Length and Cross-section.
- Ensure the location allows for cable entry at the bottom of the drive.

### Cooling and airflow requirements

- Ensure that top and bottom clearance for air cooling is provided, see 5.3 Side-by-side Installation.
- Consider derating for temperatures starting between 40 °C (104 °F) and 55 °C (131 °F) and elevation 1000 m (3300 ft) above sea level. See *chapter Derating* for detailed information.
- The drive's maximum heating value could be estimated via the following equation:

  Maximum heating value ≈ Power × (1 – Efficiency)

  For example, the heating value of 110 kW (150 hp) drive could be 2.2 kW. Refer to 8.1.1 3x380–480 V AC for the drive's efficiency at rated load.
- If multiple drives are installed in 1 cabinet at the same time, the heating value and ventilation volume shall be accumulated.

- If there are other heating devices, increase the ventilation according to the instructions.
- If the dust screen needs to be installed, the air volume needs to be appropriately increased according to the wind resistance coefficient of the dust screen. For the wind resistance coefficient of dust screen, contact the dust screen supplier.

**Table 34: Ventilation Volume Reference Value of the Cabinet**

| Power kW (hp) | Ventilation volume reference value of the cabinet | |
|---|---|---|
| | CFM | $m^3$/hr |
| 0.37 (0.5) | 2 | 4 |
| 0.75 (1.0) | 4 | 7 |
| 1.5 (2.0) | 8 | 14 |
| 2.2 (3.0) | 9 | 15 |
| 3 (4.0) | 13 | 22 |
| 4 (5.0) | 19 | 32 |
| 5.5 (7.5) | 22 | 37 |
| 7.5 (10) | 40 | 68 |
| 11 (15) | 73 | 125 |
| 15 (20) | 100 | 170 |
| 18.5 (25) | 135 | 229 |
| 22 (30) | 160 | 272 |
| 30 (40) | 178 | 303 |
| 37 (50) | 220 | 374 |
| 45 (60) | 240 | 408 |
| 55 (70) | 257 | 436 |
| 75 (100) | 350 | 595 |
| 90 (125) | 370 | 629 |
| 110 (150) | 414 | 704 |
| 132 (175) | 499 | 849 |
| 160 (250) | 605 | 1029 |
| 200 (300) | 757 | 1286 |
| 250 (350) | 887 | 1507 |
| 315 (450) | 1118 | 1900 |

## 5.6 Lifting the Drive

**⚠ W A R N I N G ⚠**

**HEAVY LOAD**

Unbalanced loads can fall or tip over. Failure to take proper lifting precautions increases risk of death, serious injury, or equipment damage.

- Move the unit using a hoist, crane, forklift, or other lifting device with the appropriate weight rating. See 5.1 Power Ratings, Weights, and Dimensions for the weight of the drive.
- Failure to locate the center of gravity and correctly position the load can cause unexpected shifting during lifting and transport. For measurements and center of gravity, see 5.1 Power Ratings, Weights, and Dimensions.
- The angle from the top of the drive module to the lifting cables affects the maximum load force on the cable. This angle must be 65° or greater. Refer to the following illustration. Attach and dimension the lifting cables properly.
- Never walk under suspended loads.
- To guard against injury, wear personal protective equipment such as gloves, safety glasses, and safety shoes.

Always lift the drive using the dedicated eye bolts at the top of the drive. See the following illustration.

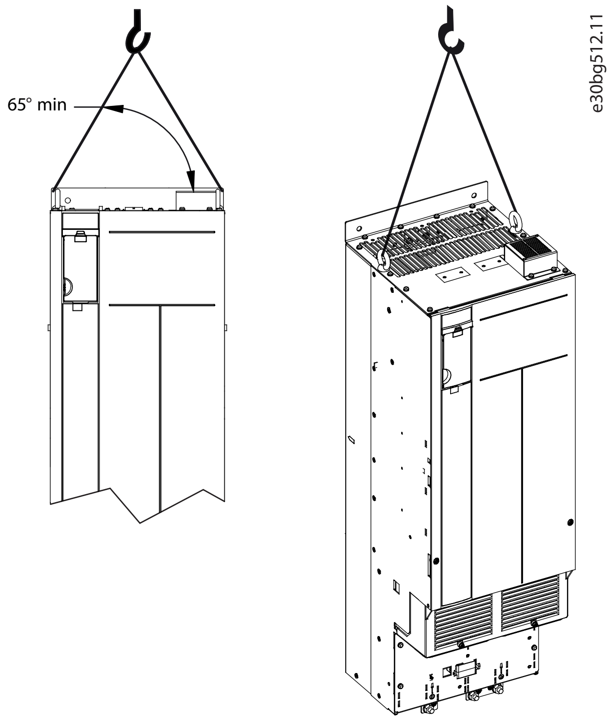



**Illustration 41: Lifting the Drive**

## 5.7 Wall Mounting the Drive

H13 and H14 are chassis drives intended to be mounted on a wall or on a mounting plate within an enclosure. To wall mount the drive, use the following steps.

**Procedure**

1. Fasten 2 M10 bolts in the wall to align with the fastener slots at the bottom of drive.
2. Slide the lower fastener slots in the drive over the M10 bolts.

3. Tip the drive against the wall, and secure the top with 2 M10 bolts in the mounting holes.

**Example**

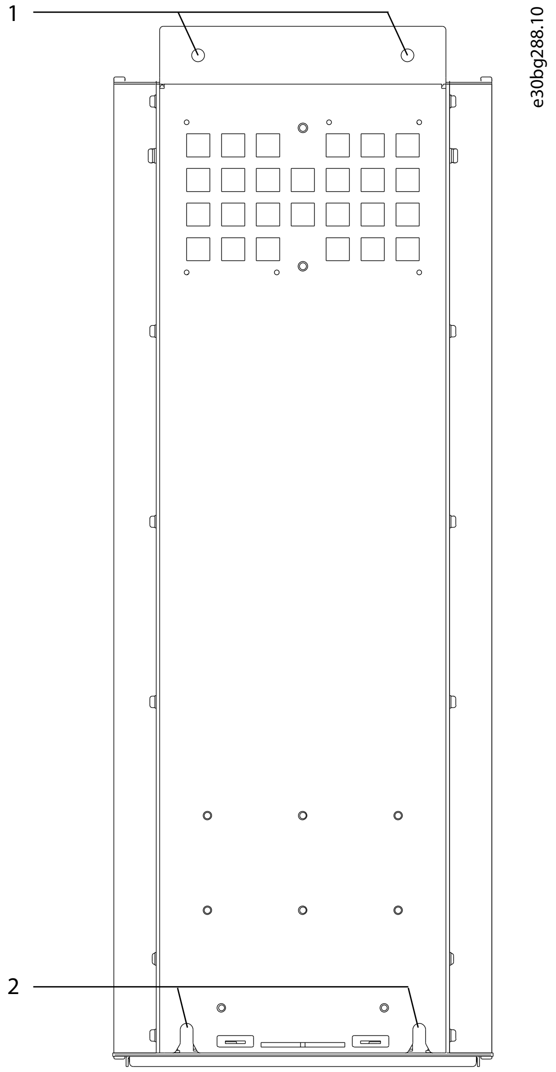



**Illustration 42: Drive-to-wall Mounting Holes**

| | |
|---|---|
| 1 | Top mounting holes |
| 2 | Lower fastener slots |

## 5.8 Creating Cable Openings

After installing H13-H14 drive, create cable openings in the gland plate to accommodate the mains and motor cables. The gland plate is required to maintain the drive protection rating.

**Procedure**

1. Punch out plastic tabs to accommodate the cables.

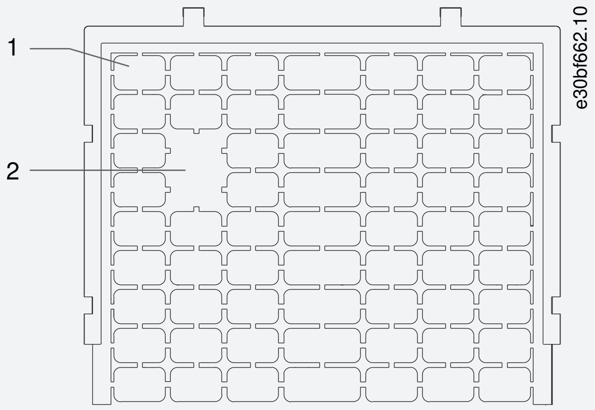



**Illustration 43: Cable Openings in Plastic Gland Plate**

| | |
|---|---|
| 1 | Plastic tabs |
| 2 | Tabs removed for cable access |

## 5.9 Derating

### 5.9.1 Manual Derating and Automatic Derating

Derating is a method used to reduce output current to avoid tripping the drive when high temperatures are reached within the enclosure. If certain extreme operating conditions are expected, a higher-powered drive can be selected to eliminate the need for derating. This is called manual derating. Otherwise, the drive automatically derates the output current to eliminate the excessive heat generated by extreme conditions.

**Manual derating**

When the following conditions are present, Danfoss recommends selecting a drive 1 power size higher (for example P132 instead of P110):

- Low-speed – continuous operation at low RPM in constant torque applications.
- Low air pressure – operating at altitudes above 1000 m (3281 ft).
- High ambient temperature – operating at ambient temperatures of 10 °C (50 °F).
- High switching frequency.
- Long motor cables.
- Cables with a large cross-section.

**Automatic derating**

If the following operating conditions are found, the drive automatically changes switching frequency or switching pattern (PWM to SFAVM) to reduce excessive heat within the enclosure:

- High temperature on the control card or heat sink.
- High motor load or low motor speed.
- High DC-link voltage.

### 5.9.2 Derating for Low-speed Operation

When a motor is connected to a drive, it is necessary to ensure that the cooling of the motor is adequate. The level of cooling required depends on the following:

- Load on the motor.
- Operating speed.
- Length of operating time.

#### Constant torque applications (CT mode)

In a constant torque application, a motor may overheat at low speeds because the fan within the motor is providing less cooling air.

Therefore, if the motor is to be run continuously at an RPM value lower than half of the rated value, the motor must be supplied with extra air cooling. If extra air cooling is not available, use a motor designed for low RPM/constant torque applications, or select a larger motor to reduce the load level.

Variable (quadratic) torque applications (VT)

In variable torque applications where the torque is proportional to the square of the speed and the power is proportional to the cube of the speed, there is no need for extra cooling or derating of the motor. Common variable torque applications are centrifugal pumps and fans.

## 5.9.3 Derating for Low Air Pressure and High Altitudes

The cooling capability of air is decreased at low air pressure. For altitudes above 2000 m (6562 ft), contact Danfoss regarding PELV. Below 1000 m (3281 ft) altitude, derating is not necessary. For altitudes above 1000 m (3281 ft), decrease the ambient temperature or the maximum output current. Decrease the output by 1% per 100 m (328 ft) altitude above 1000 m (3281 ft) or reduce the maximum ambient cooling air temperature by 1 °C (1.8 °F) per 200 m (656 ft).

## 5.9.4 Derating for Ambient Temperature and Switching Frequency

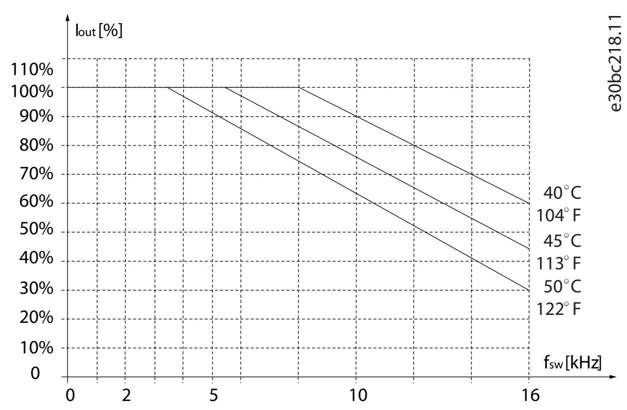
Ensure that the ambient temperature measured over 24 hours is at least 5 °C (9 °F) lower than the maximum ambient temperature that is specified for the drive. If the drive is operated at a high ambient temperature, decrease the constant output current.

**N O T I C E**

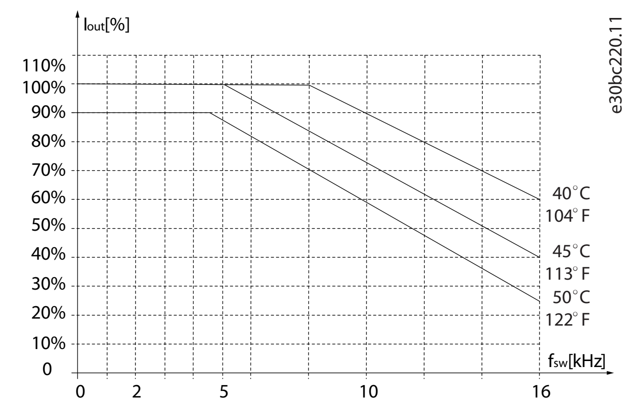
**FACTORY DERATING**

Danfoss drives have already derated for operational temperature (55 °C (131 °F) $T_{AMB,MAX}$ and 50 °C (122 °F) $T_{AMB,AVG}$).

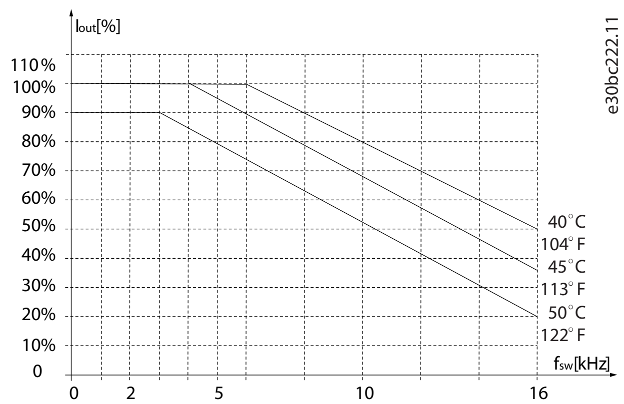
Use the following graphs to determine if the output current must be derated based on switching frequency and ambient temperature. When referring to the graphs, $I_{out}$ indicates the percentage of rated output current, and $f_{sw}$ indicates the switching frequency.



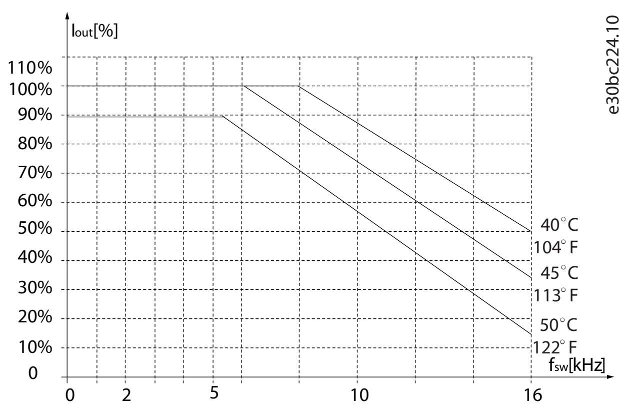

0.37–1.5 kW (0.5–2.0 hp), 400 V, Enclosure Size H1, IP20



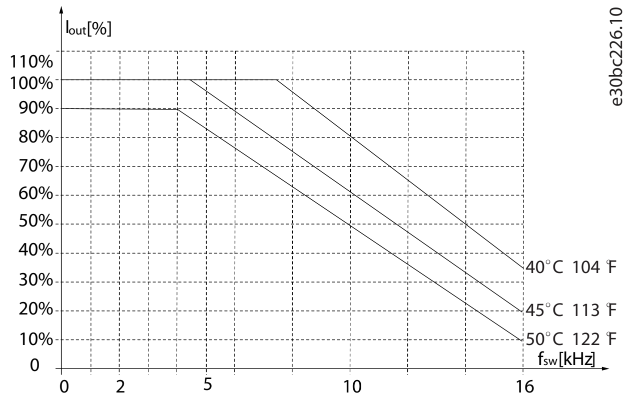

2.2–4.0 kW (3.0–5.4 hp), 400 V, Enclosure Size H2, IP20



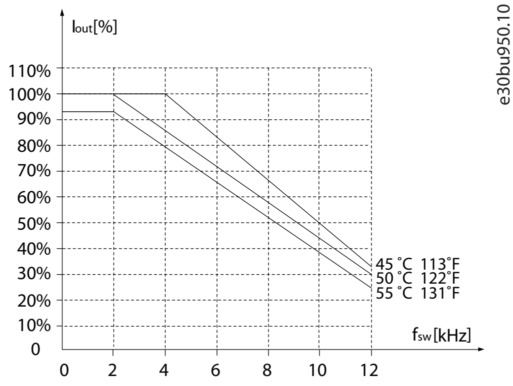

5.5–7.5 kW (7.4–10 hp), 400 V, Enclosure Size H3, IP20



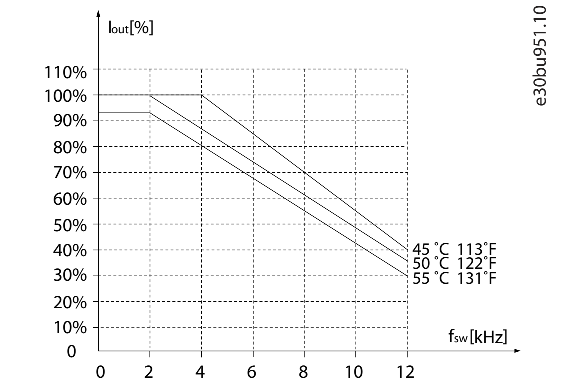

11–15 kW (15–20 hp), 400 V, Enclosure Size H4, IP20



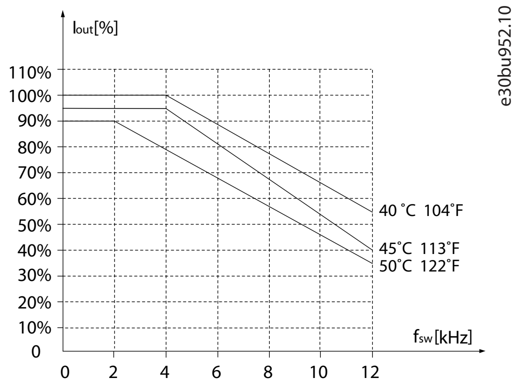

18.5–22 kW (25–30 hp), 400 V, Enclosure Size H5, IP20



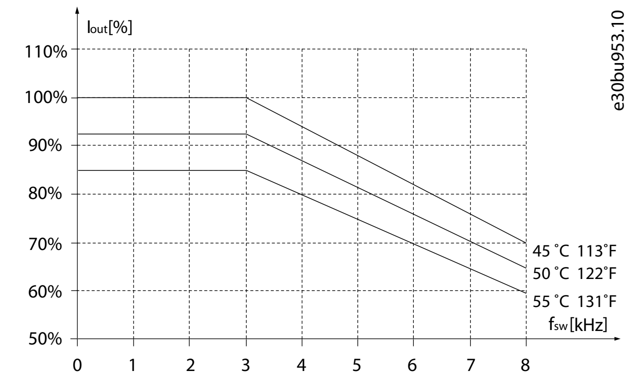

30–45 kW (40–60 hp), 400 V, Enclosure Size H11, IP20



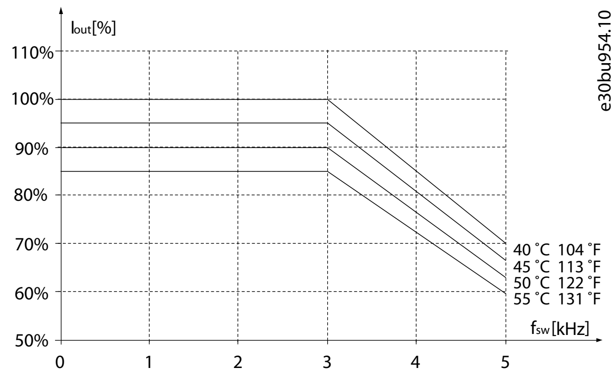

55–75 kW (70–100 hp), 400 V, Enclosure Size H12, IP20




90 kW (125 hp), 400 V, Enclosure Size H12, IP20




110–315 kW (150–450 hp), 400 V, Enclosure Size H13–H14, IP20, Switching Pattern 60 AVM




110–315 kW (150–450 hp), 400 V, Enclosure Size H13–H14, IP20, Switching Pattern SFAVM

# 6 Electrical Installation Considerations

## 6.1 Safety Instructions

See *chapter Safety* for general safety instructions.

**⚠ W A R N I N G ⚠**

**INDUCED VOLTAGE**

Induced voltage from output motor cables from different drives that are run together can charge equipment capacitors even with the equipment turned off and locked out. Failure to run output motor cables separately or use shielded cables could result in death or serious injury.

- Run output motor cables separately or use shielded cables.
- Simultaneously lock out all the drives.

**⚠ W A R N I N G ⚠**

**SHOCK HAZARD**

The drive can cause a DC current in the ground conductor and thus result in death or serious injury. Failure to follow the recommendation means that the residual current-operated protective device (RCD) cannot provide the intended protection.

- When a residual current-operated protective device (RCD) is used for protection against electrical shock, only an RCD of Type B is allowed on the supply side.

**Overcurrent protection**

- Additional protective equipment such as short-circuit protection or motor thermal protection between drive and motor is required for applications with multiple motors.
- Input fusing is required to provide short circuit and overcurrent protection. If fuses are not factory-supplied, the installer must provide them. See maximum fuse ratings in *chapter Fuses and Circuit Breakers*.

**Wire type and ratings**

- All wiring must comply with local and national regulations regarding cross-section and ambient temperature requirements.
- Power connection wire recommendation: Minimum 75 °C (167 °F) rated copper wire.

See 8.2.4 Cable Length and Cross-section for recommended wire sizes and types.

## 6.2 Electrical Wiring

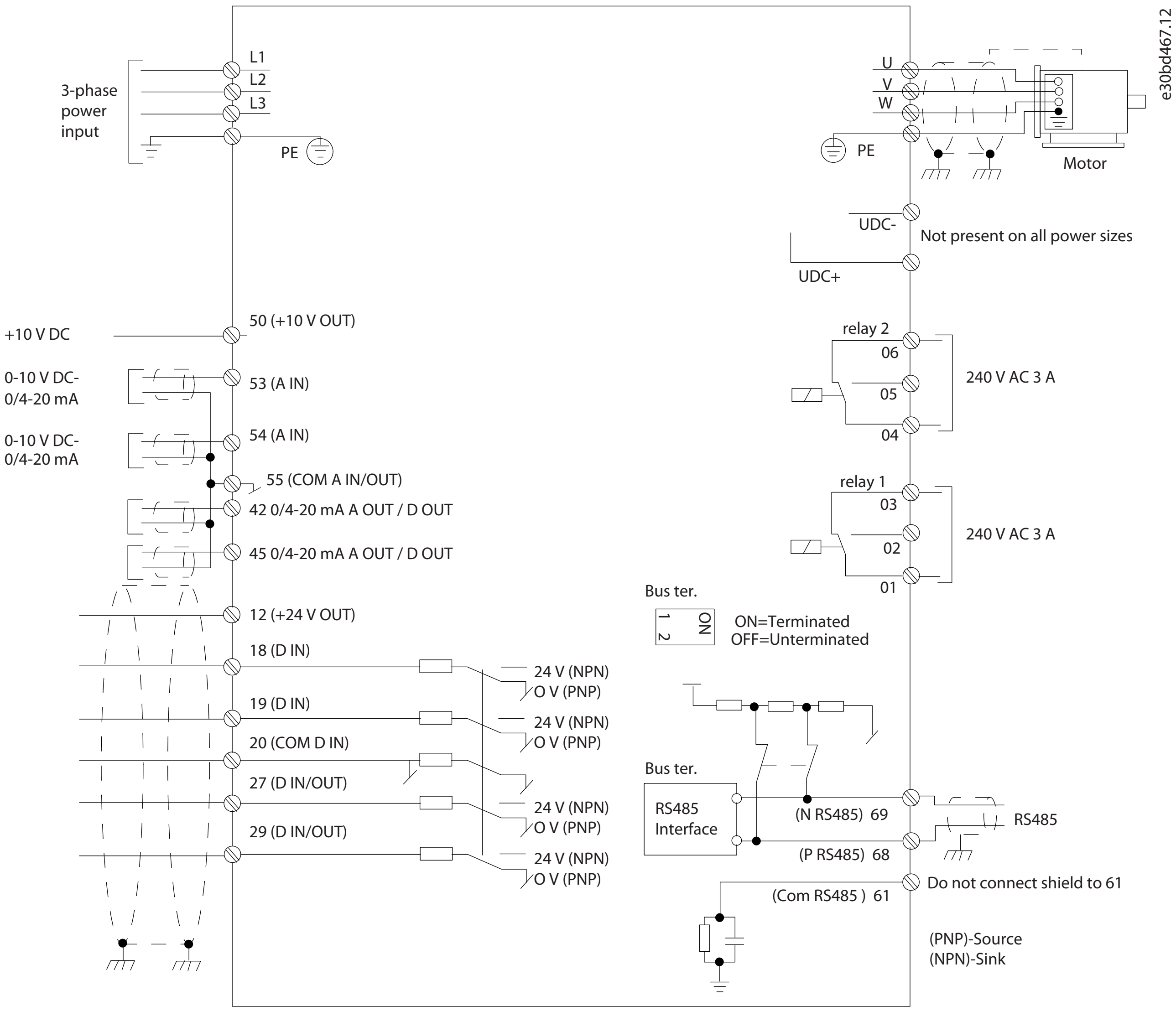



**Illustration 44: Basic Wiring Schematic Drawing**

**N O T I C E**

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

- IP20, 380–480 V, 30–315 kW (40–450 hp)

## 6.3 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 (pigtails), because it reduces the shielding effect at high frequencies. Use the cable clamps provided.
- Ensure the same potential between the drive and the ground potential of PLC.
- Use star washers and galvanically conductive installation plates.

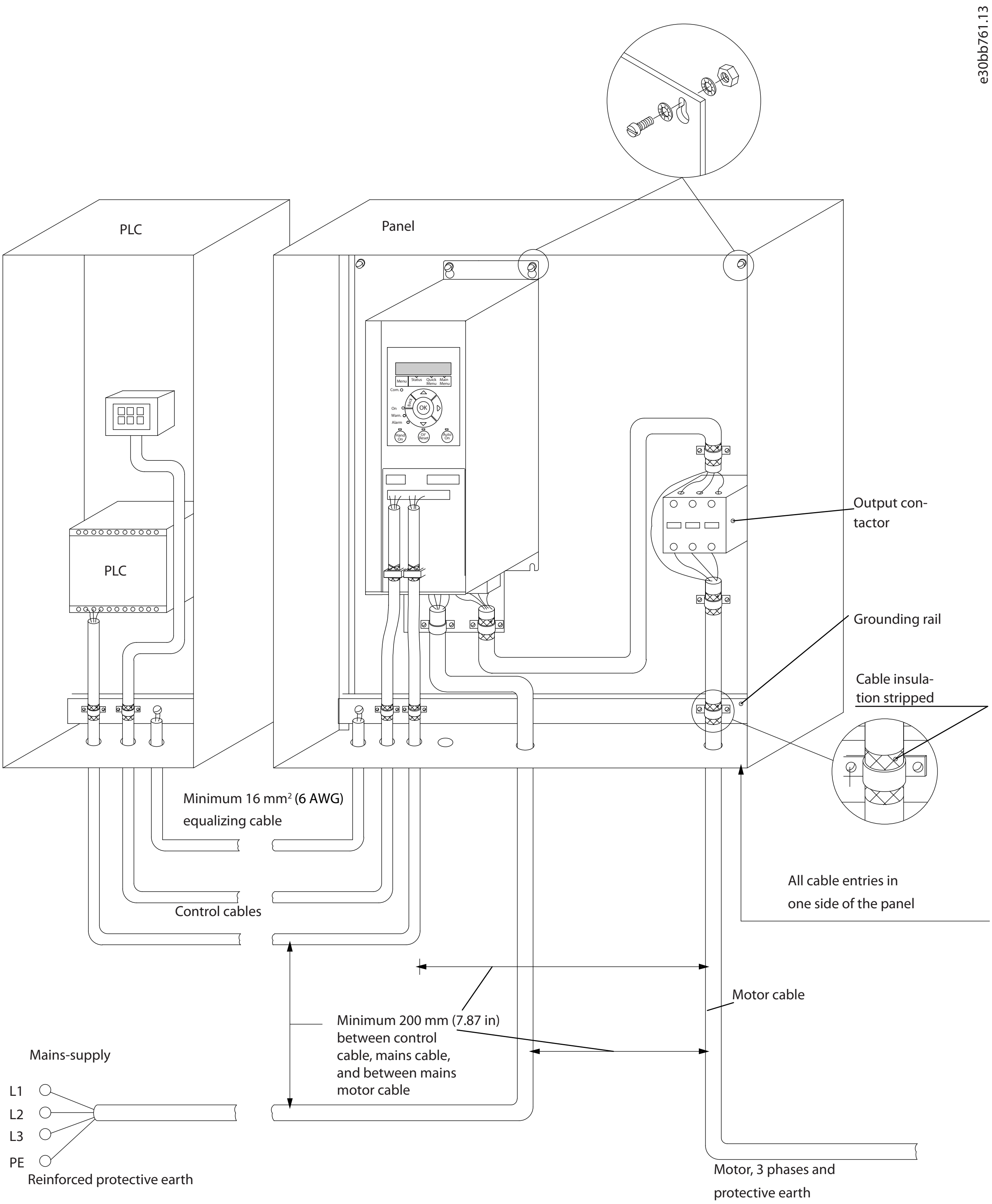



**Illustration 45: EMC-compliant Installation**

## 6.4 Relays and Terminals

### 6.4.1 Relays and Terminals on Enclosure Sizes H1–H5

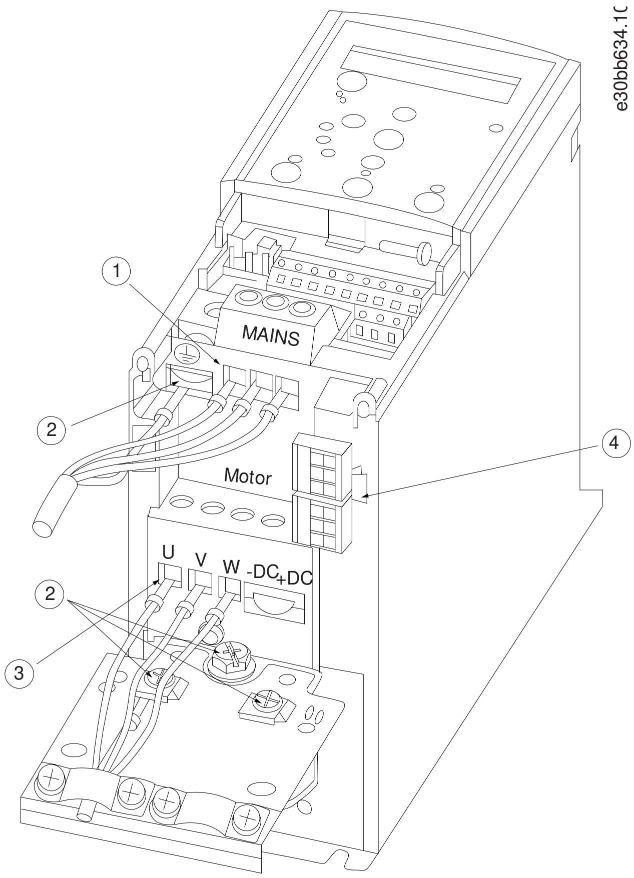



**Illustration 46: Enclosure Sizes H1–H5 IP20, 380–480 V, 0.37–22 kW (0.5–30 hp)**

| | | | |
|---|---|---|---|
| 1 | Mains | 3 | Motor |
| 2 | Ground | 4 | Relays |

## 6.4.2 Relays and Terminals on Enclosure Size H11

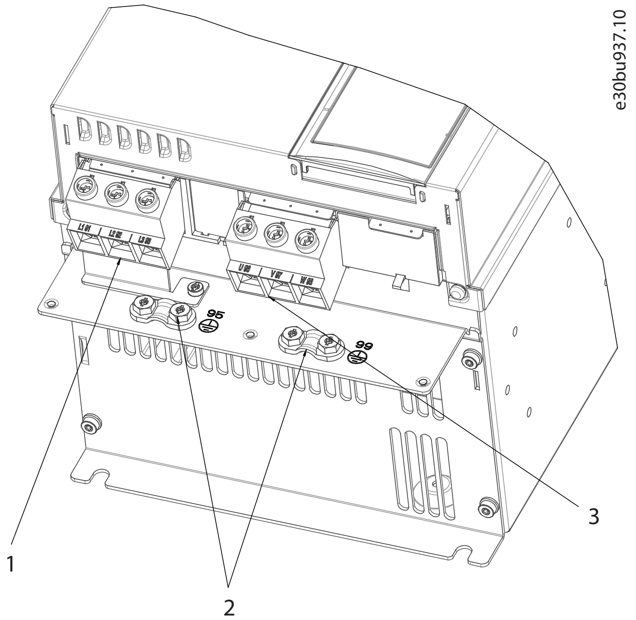



**Illustration 47: Enclosure Size H11 IP20, 380–480 V, 30–45 kW (40–60 hp)**

| | | | |
|---|---|---|---|
| 1 | Mains | 3 | Motor |
| 2 | Ground | | |

See 6.5 View of Control Shelf for the relay terminals of H11 drives.

## 6.4.3 Relays and Terminals on Enclosure Size H12

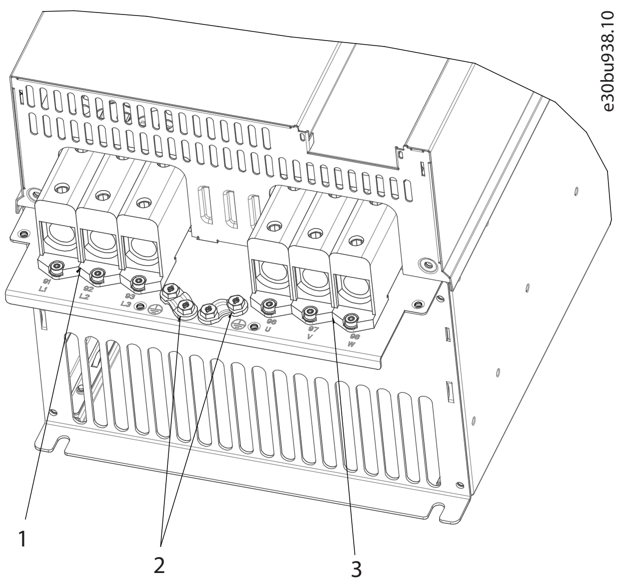



**Illustration 48: Enclosure Size H12 IP20, 380–480 V, 55–90 kW (75–125 hp)**

| | | | |
|---|---|---|---|
| 1 | Mains | 3 | Motor |
| 2 | Ground | | |

See 6.5 View of Control Shelf for the relay terminals of H12 drives.

### 6.4.4 Relays and Terminals on Enclosure Size H13–H14

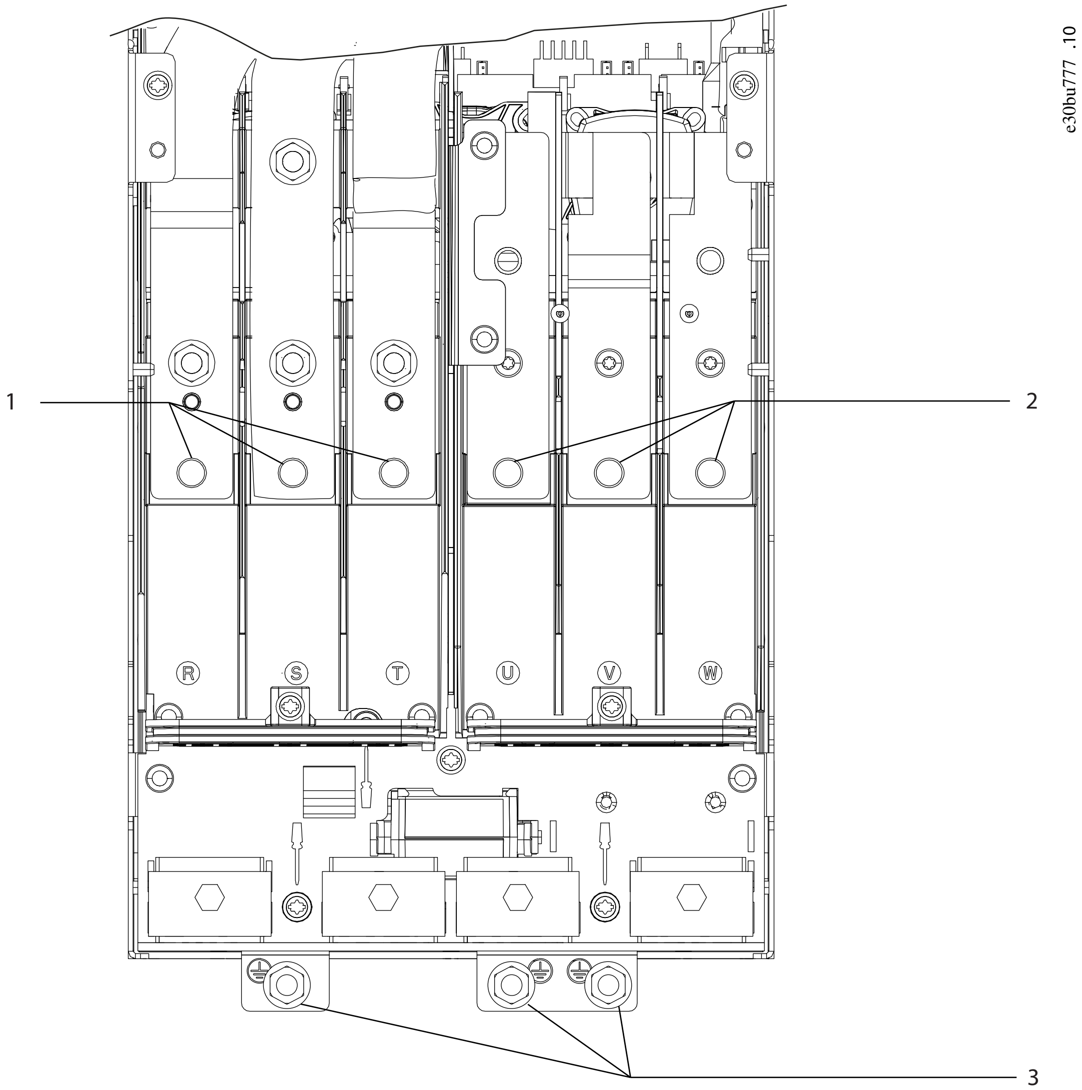



**Illustration 49: Enclosure Size H13–H14 IP20, 380–480 V, 110–315 kW (150–450 hp)**

| | | | |
|---|---|---|---|
| 1 | Mains | 3 | Ground |
| 2 | Motor | | |

See 6.5 View of Control Shelf for the relay terminals of H13–H14 drives.

## 6.5 View of Control Shelf

The control shelf of H11-H14 drives holds the LCP. The control shelf also includes the control terminals, relays, and various connectors.

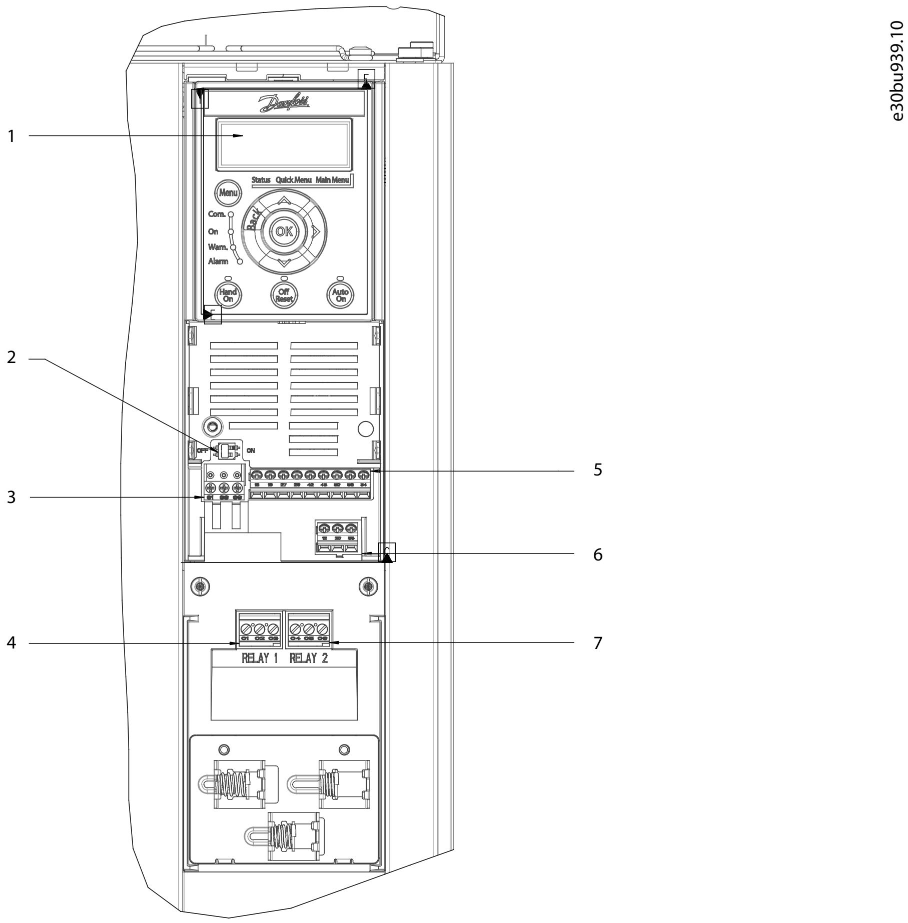



**Illustration 50: View of Control Shelf in H11–H12**

| | | | |
|---|---|---|---|
| 1 | LCP | 5 | Digital I/O and 24 V supply |
| 2 | RS485 termination switch | 6 | Analog I/O connector |
| 3 | RS485 fieldbus connector | 7 | Relay 2 on power card |
| 4 | Relay 1 on power card | | |

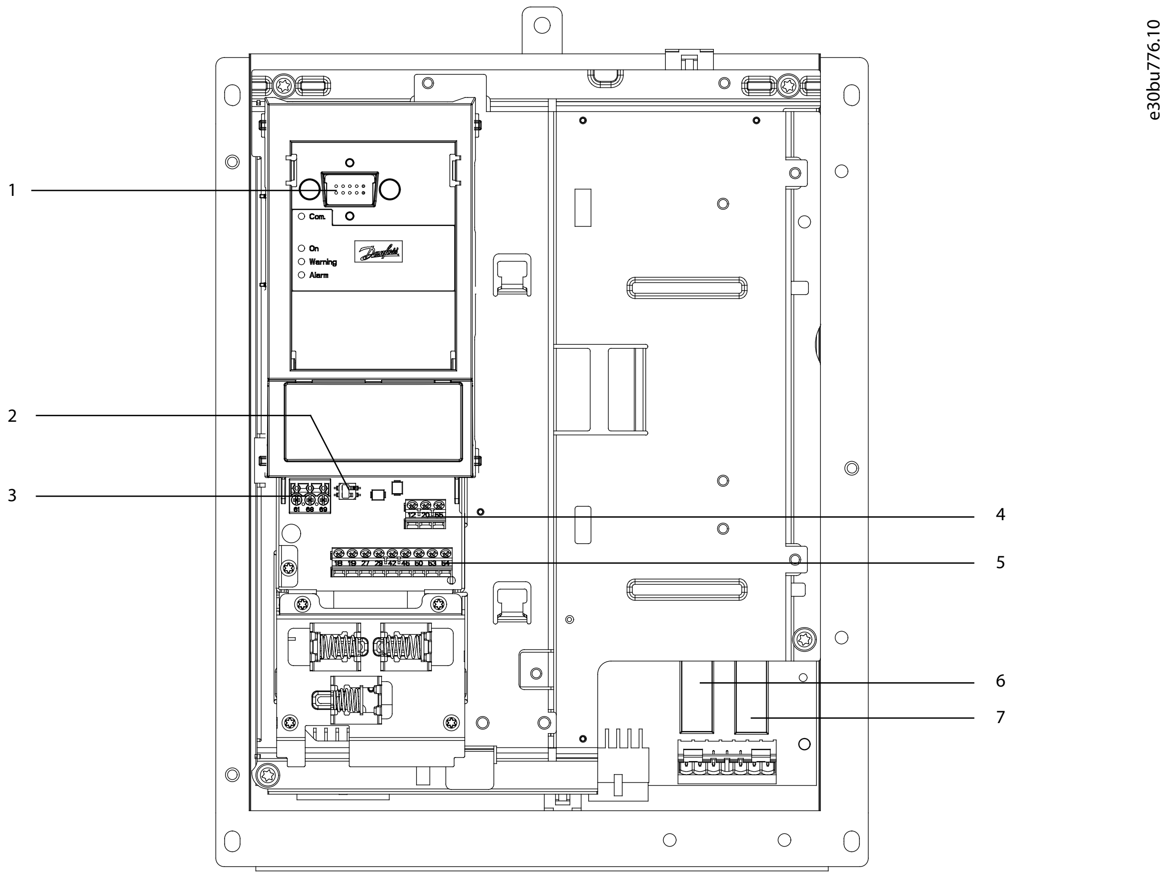



**Illustration 51: View of Control Shelf in H13–H14**

| | | | |
|---|---|---|---|
| 1 | LCP connector | 5 | Digital I/O and 24 V supply |
| 2 | RS485 termination switch | 6 | Relay 1 on power card |
| 3 | RS485 fieldbus connector | 7 | Relay 2 on power card |
| 4 | Analog I/O connector | | |

## 6.6 Fastener Tightening Torques

Apply the correct torque when tightening fasteners in the locations that are listed in the following tables. Too low or too high torque when fastening an electrical connection results in a bad electrical connection. To ensure correct torque, use a torque wrench.

**Table 35: Tightening Torques for Enclosure Sizes H1–H5 & H11–H12, 3x380–480 V**

| Power [kW (hp)] | | | Torque [Nm (in-lb)] | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Enclosure size** | **IP class** | **3x380–480 V** | **Mains** | **Motor** | **DC connection** | **Control terminals** | **Ground** | **Relay** |
| H1 | IP20 | 0.37–1.5 (0.5–2.0) | 0.8 (7) | 0.8 (7) | 0.8 (7) | 0.5 (4) | 0.8 (7) | 0.5 (4) |
| H2 | IP20 | 2.2–4.0 (3.0–5.4) | 0.8 (7) | 0.8 (7) | 0.8 (7) | 0.5 (4) | 0.8 (7) | 0.5 (4) |
| H3 | IP20 | 5.5–7.5 (7.5–10) | 0.8 (7) | 0.8 (7) | 0.8 (7) | 0.5 (4) | 0.8 (7) | 0.5 (4) |
| H4 | IP20 | 11–15 (15–20) | 1.2 (11) | 1.2 (11) | 1.2 (11) | 0.5 (4) | 0.8 (7) | 0.5 (4) |
| H5 | IP20 | 18.5–22 (25–30) | 1.2 (11) | 1.2 (11) | 1.2 (11) | 0.5 (4) | 0.8 (7) | 0.5 (4) |
| H11 | IP20 | 30–45 (40–60) | 4.5 (40) | 4.5 (40) | – | 0.5 (4) | 3 (27) | 0.5 (4) |

| Power [kW (hp)] | | | Torque [Nm (in-lb)] | | | | | |
|---|---|---|---|---|---|---|---|---|
| Enclosure size | IP class | 3x380–480 V | Mains | Motor | DC connection | Control terminals | Ground | Relay |
| H12 | IP20 | 55 (70) | 10 (89) | 10 (89) | – | 0.5 (4) | 3 (27) | 0.5 (4) |
| H12 | IP20 | 75 (100) | 14 (124) | 14 (124) | – | 0.5 (4) | 3 (27) | 0.5 (4) |
| H12 | IP20 | 90 (125) | 24 (212)[1] | 24 (212)[1] | – | 0.5 (4) | 3 (27) | 0.5 (4) |

[1] Cable dimensions >95 mm$^2$.

**Table 36: Tightening Torques for Enclosure Sizes H13–H14, 3x380–480 V**

| Location | Bolt size | Torque [Nm (in-lb)] |
|---|---|---|
| Mains terminals | M10/M12 | 19 (168)/37 (335) |
| Motor terminals | M10/M12 | 19 (168)/37 (335) |
| Ground terminals | M8/M10 | 9.6 (84)/19.1 (169) |
| Relay terminals | – | 0.5 (4) |
| Door/panel cover | M5 | 2.3 (20) |
| Gland plate | M5 | 2.3 (20) |

## 6.7 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 380–480 V, IP20, 0.37–22 kW (0.5–30 hp) units, open the RFI switch by removing the screw on the side of the drive when at IT grid.

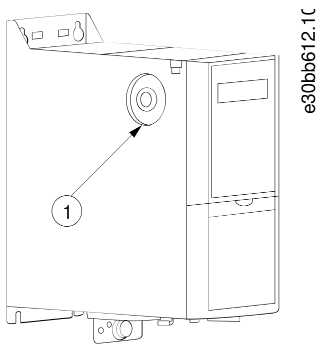



**Illustration 52: IP20, 0.37–22 kW (0.5–30 hp), 380–480 V**

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

**NOTICE**

If reinserted, use only M3x12 screw.

For 380–480 V, 30–90 kW (40–125 hp) units, set *parameter 14-50 RFI Filter* to *[0] Off* when operating in IT mains.

For 380–480 V, 110–315 kW (150–450 hp) units, if the drive is supplied from an isolated mains source (IT mains, floating delta, or grounded delta) or TT/TN-S mains with grounded leg, the RFI switch is recommended to be turned off via *parameter 14-50 RFI Filter* on the drive and *parameter 14-50 RFI Filter* on the filter. For more details, see IEC 364-3. In the *[Off]* position, the filter capacitors between the chassis and the DC link are cut off to avoid damage to the DC link and to reduce the ground capacity currents, according to IEC 61800-3.

If optimum EMC performance is needed, or parallel motors are connected, or the motor cable length is above 25 m (82 ft), Danfoss recommends setting *parameter 14-50 RFI Filter* to *[On]*. It is important to use isolation monitors that are rated for use together with power electronics (IEC 61557-8).

## 6.8 Mains and Motor Connection

### 6.8.1 Introduction

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

- Use a shielded/armored motor cable to comply with EMC emission specifications and connect this cable to both the decoupling plate and the motor.
- Keep the motor cable as short as possible to reduce the noise level and leakage currents.
- For further details on mounting the decoupling plate, see the relevant Decoupling Plate Installation Guide.
- Also see EMC-Correct Installation in the 6.3 EMC-compliant Electrical Installation.

### 6.8.2 Connecting to the Ground

**⚠ WARNING ⚠**

**LEAKAGE CURRENT HAZARD**

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

- Ensure that the minimum size of the ground conductor complies with the local safety regulations for high touch current equipment.

For electrical safety:

- Ground the drive in accordance with applicable standards and directives.
- Use a dedicated ground wire for input power, motor power, and control wiring.
- Do not ground 1 drive to another in a daisy chain fashion.
- Keep the ground wire connections as short as possible.
- Follow motor manufacturer wiring requirements.
- Minimum cable cross-section: 10 mm$^2$ (8 AWG) Cu or 16 mm$^2$ (6 AWG) Al (or 2 rated ground wires terminated separately).
- Tighten the terminals in accordance with the information provided in 6.6 Fastener Tightening Torques.

For EMC-compliant installation

- Establish electrical contact between the cable shield and the drive enclosure by using metal cable glands or by using the clamps provided on the equipment.
- Reduce burst transient by using high-strand wire.
- Do not use twisted shield ends (pigtails).

**NOTICE**

**POTENTIAL EQUALIZATION**

There is a risk of burst transient when the ground potential between the drive and the control system is different.

- Install equalizing cables between the system components. Recommended cable cross-section: 16 mm$^2$ (6 AWG).

### 6.8.3 Connecting the Motor

**WARNING**

**INDUCED VOLTAGE**

Induced voltage from output motor cables that run together can charge equipment capacitors, even with the equipment turned off and locked out/tagged out. Failure to run output motor cables separately or to use shielded cables could result in death or serious injury.

- Run output motor cables separately or use shielded cables.
- Simultaneously lock out/tag out all the drives.

- Comply with local and national electrical codes for cable sizes. For maximum wire sizes, see 8.2.4 Cable Length and Cross-section.
- Follow motor manufacturer wiring requirements.
- Motor wiring knockouts or access panels are provided at the base of IP21 and higher units.
- Do not wire a starting or pole-changing device (for example, Dahlander motor or slip ring asynchronous motor) between the drive and the motor.

**Procedure**

1. For H12 drives, remove the protective covers using a screwdriver before connecting the stripped wire.
2. For H1–H5 and H13–H14 drives, strip a section of the outer cable insulation.
3. For H11-H12 drives:
   a. If ferrule without plastic sleeve is used, strip 16–17 mm (0.63–0.67 in) section of the outer cable insulation.
   b. If ferrule with plastic sleeve is used, strip a section of the outer cable insulation.

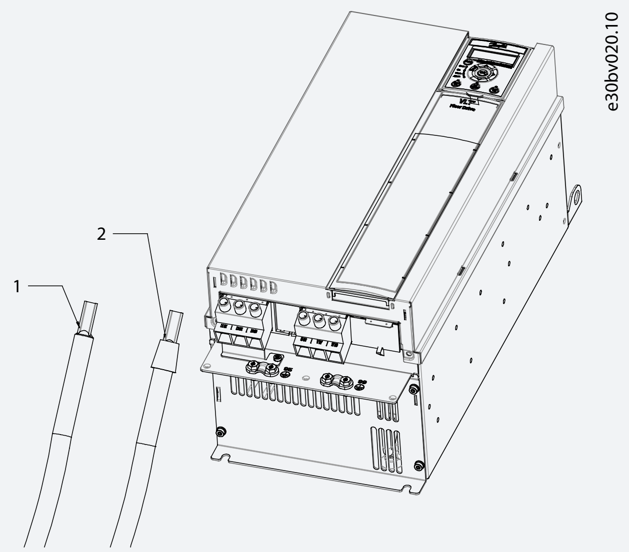



**Illustration 53: Ferrule with/without Plastic Sleeve**

| | |
|---|---|
| 1 | Ferrule without plastic sleeve |
| 2 | Ferrule with plastic sleeve |

4. Position the stripped wire under the cable clamp, establishing mechanical fixation and electrical contact between the cable shield and ground.
5. Connect the ground wire to the nearest grounding terminal in accordance with the grounding instructions provided in 6.8.2 Connecting to the Ground.
6. Connect the 3-phase motor wiring to terminals U, V, and W.
7. Tighten the terminals in accordance with the information provided in 6.6 Fastener Tightening Torques.
8. For H12 drives, install the protective cover on the terminals.

  a. Cut the cable block slice according to the wire size.
  b. Put the positioning pin to the terminal locating slot.

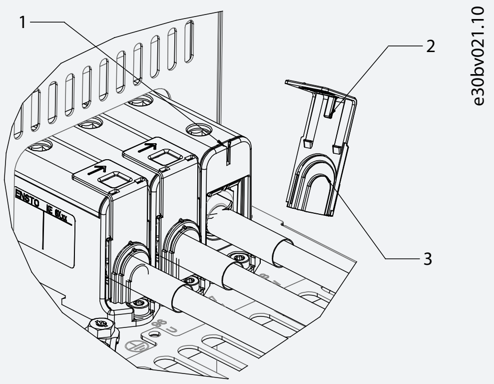



**Illustration 54: Installing Protective Covers, H12**

| | | | |
|---|---|---|---|
| 1 | Terminal locating slot | 3 | Cable block slice |
| 2 | Cover positioning pins | | |

## 6.8.4 Connecting the AC Mains

- Size the wiring according to the input current of the drive. For maximum wire sizes, see 8.1.1 3x380–480 V AC.
- Comply with local and national electrical codes for cable sizes.

**Procedure**

1. For H12 drives, remove the protective covers using a screwdriver before connecting the stripped wire.
2. For H1–H5 and H13–H14 drives, strip a section of the outer cable insulation.
3. For H11-H12 drives, see the *Illustration Ferrule with/without Plastic Sleeve* in 6.8.3 Connecting the Motor.
   a. If ferrule without plastic sleeve is used, strip 16–17 mm (0.63–0.67 in) section of the outer cable insulation.
   b. If ferrule with plastic sleeve is used, strip a section of the outer cable insulation.
4. Position the stripped wire under the cable clamp, establishing mechanical fixation and electrical contact between the cable shield and ground.
5. Connect the ground wire to the nearest grounding terminal in accordance with the grounding instructions provided in 6.8.2 Connecting to the Ground.
6. For H1-H5 & H11-H12 drives, connect the 3-phase AC input power wiring to terminals L1, L2, and L3.
7. For H13-H14 drives, connect the 3-phase AC input power wiring to terminals R, S, and T.
8. When supplied from an isolated mains source (IT mains or floating delta) or TT/TN-S mains with a grounded leg (grounded delta), ensure that *parameter 14-50 RFI Filter* is set to *[0] Off* to avoid damage to the DC link and to reduce ground capacity currents.
9. Tighten the terminals in accordance with the information provided in 6.6 Fastener Tightening Torques.
10. For H12 drives, install the protective cover on the terminals, see the *Illustration Installing Protective Covers, H12* in 6.8.3 Connecting the Motor.
    a. Cut the cable block slice according to the wire size.
    b. Put the positioning pin to the terminal locating slot.

## 6.9 Fuses and Circuit Breakers

## 6.9.1 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.

## 6.9.2 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.

## 6.9.3 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.

## 6.9.4 CE Compliance

To ensure compliance with 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.

## 6.9.5 Recommendation of Fuses

**N O T I C E**

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

**Table 37: Recommendation of Fuses**

| 3x380–480 V IP20 [kW (hp)] | Maximum fuse |
|---|---|
| 0.37 (0.5) | gG-10 |
| 0.75 (1.0) | gG-10 |
| 1.5 (2.0) | gG-10 |
| 2.2 (3.0) | gG-16 |
| 3.0 (4.0) | gG-16 |
| 4.0 (5.4) | gG-16 |
| 5.5 (7.5) | gG-25 |
| 7.5 (10) | gG-25 |
| 11 (15) | gG-50 |
| 15 (20) | gG-50 |
| 18.5 (25) | gG-63 |
| 22 (30) | gG-63 |
| 30 (40) | gG-125 |
| 37 (50) | gG-125 |
| 45 (60) | gG-125 |
| 55 (70) | aR-250 |
| 75 (100) | aR-250 |
| 90 (125) | aR-250 |
| 110 (150) | aR-315 |
| 132 (175) | aR-350 |

| | |
|---|---|
| 160 (250) | aR-400 |
| 200 (300) | aR-500 |
| 250 (350) | aR-630 |
| 315 (450) | aR-800 |

**Table 38: H13–H14 Power/semiconductor Fuse Options, 380–480 V**

| Model | Fuse Options | | | | | | |
|---|---|---|---|---|---|---|---|
| | Bussman | Littelfuse | Littelfuse | Bussman | Siba | Ferraz-Shawmut | Ferraz-Shawmut(Europe) |
| P110 | 170M2619 | LA50QS300-4 | L50S-300 | FWH-300A | 20 189 20.315 | A50QS300-4 | 6,9URD31D08A0315 |
| P132 | 170M2620 | LA50QS350-4 | L50S-350 | FWH-350A | 20 189 20.350 | A50QS350-4 | 6,9URD31D08A0350 |
| P160 | 170M2621 | LA50QS400-4 | L50S-400 | FWH-400A | 20 189 20.400 | A50QS400-4 | 6,9URD31D08A0400 |
| P200 | 170M4015 | LA50QS500-4 | L50S-500 | FWH-500A | 20 189 20.550 | A50QS500-4 | 6,9URD31D08A0550 |
| P250 | 170M4016 | LA50QS600-4 | L50S-600 | FWH-600A | 20 189 20.630 | A50QS600-4 | 6,9URD31D08A0630 |
| P315 | 170M4017 | LA50QS800-4 | L50S-800 | FWH-800A | 20 189 20.800 | A50QS800-4 | 6,9URD32D08A0800 |

## 6.10 Control Terminals

Remove the terminal cover (H1-H5 & H11-H12) or the cradle cover (H13-H14) to access the control terminals.

**H1-H5 & H11-H12**

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 Illustration 55.

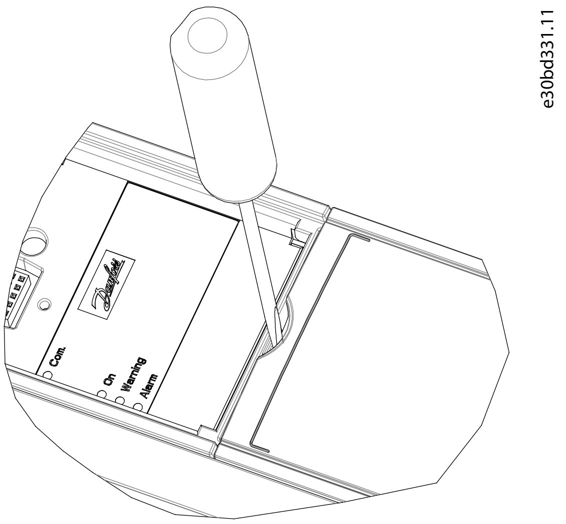



**Illustration 55: Removing the Terminal Cover**

**H13-H14**

Press the tips of the cradle cover inwards as shown in Illustration 56, and then lift the cradle cover up.

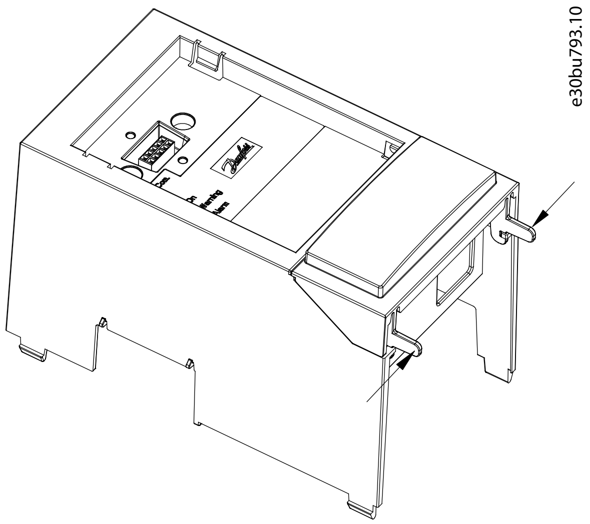



**Illustration 56: Removing the Cradle Cover**

All the drive control terminals are shown in Illustration 57. 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).

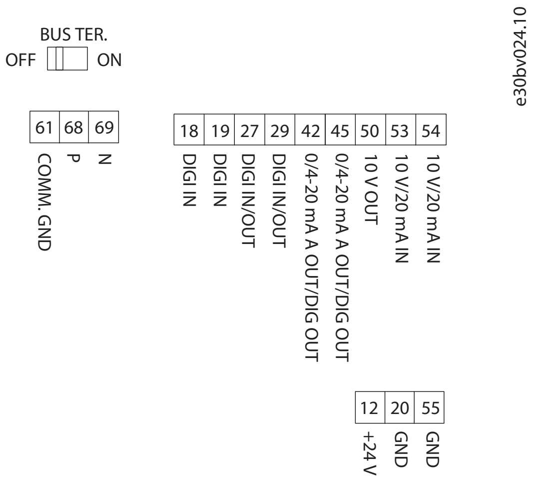



**Illustration 57: Control Terminals**

## 6.11 Efficiency

### 6.11.1 Efficiency of the Drive

The load on the drive has little effect on its efficiency. In general, the efficiency is the same at the rated motor frequency $f_{M,N}$. This rule also applies even if the motor supplies 100% of the rated shaft torque or only 75%, for example if there is part loads.

This also means that the efficiency of the drive does not change even if other U/f characteristics are selected.

However, the U/f characteristics influence the efficiency of the motor.

The efficiency declines a little when the switching frequency is set to a value above the default value. If the mains voltage is 480 V, or if the motor cable is longer than 30 m (98.4 ft), the efficiency is also slightly reduced.

Calculate the efficiency of the drive ($\eta_{VLT}$) at different loads based on the following illustration. Multiply the factor in the following illustration by the specific efficiency factor listed in the specification tables.

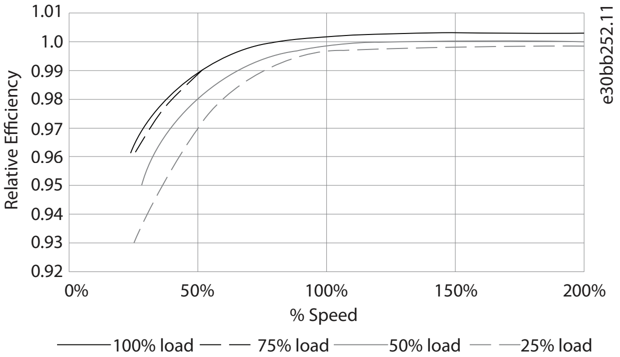



**Illustration 58: Typical Efficiency Curves**

## 6.11.2 Efficiency of the Motor

The efficiency of a motor ($\eta_{MOTOR}$) connected to the drive depends on the magnetizing level. In general, the efficiency is as good as with mains operation. The efficiency of the motor depends on the type of motor.

In the range of 75–100% of the rated torque, the efficiency of the motor is practically constant, both when controlled by the drive and when running directly on mains.

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

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

## 6.11.3 Efficiency of the System

To calculate the system efficiency ($\eta_{SYSTEM}$), the efficiency of the drive ($\eta_{VLT}$) is multiplied by the efficiency of the motor ($\eta_{MOTOR}$):

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

## 6.12 dU/dt Conditions

## 6.12.1 dU/dt Overview

**N O T I C E**

To avoid the premature aging of motors that are not designed to be used with drives, such as those motors without phase insulation paper or other insulation reinforcement, Danfoss strongly recommends a dU/dt filter or a sine-wave filter fitted on the output of the drive. For further information about dU/dt and sine-wave filters, see the *Output Filters Design Guide*.

When a transistor in the inverter bridge switches, the voltage across the motor increases by a dU/dt ratio depending on the motor cable (type, cross-section, length shielded or unshielded) and the inductance.

The natural induction causes an overshoot $U_{PEAK}$ in the motor voltage before it stabilizes itself at a level depending on the voltage in the intermediate circuit. The rise time and the peak voltage $U_{PEAK}$ affect the service life of the motor. In particular, motors without phase coil insulation are affected if the peak voltage is too high. Motor cable length affects the rise time and peak voltage. If the motor cable is short (a few meters), the rise time and peak voltage are lower. If the motor cable is long (100 m (328 ft)), the rise time and peak voltage are higher.

Peak voltage on the motor terminals is caused by the switching of the IGBTs. The drive complies with the demands of IEC 60034-25:2007 edition 2.0 regarding motors designed to be controlled by drives. The drive also complies with IEC 60034-17:2006 edition 4 regarding Norm motors controlled by drives.

## 6.12.2 dU/dt Test Results for H1–H5 & H11–H12

**Table 39: dU/dt Test Results for H1–H5 & H11–H12**

| | Cable length [m (ft)] | AC line voltage [V] | Rise time [µsec] | $V_{peak}$ [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|---|
| 400 V 0.37 kW (0.5 hp) | 5 (16) | 400 | 0.160 | 0.808 | 4.050 |
| | 25 (82) | 400 | 0.240 | 1.026 | 3.420 |

| | Cable length [m (ft)] | AC line voltage [V] | Rise time [µsec] | $V_{peak}$ [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|---|
| | 50 (164) | 400 | 0.340 | 1.056 | 2.517 |
| 400 V 0.75 kW (1.0 hp) | 5 (16) | 400 | 0.160 | 0.808 | 4.050 |
| | 25 (82) | 400 | 0.240 | 1.026 | 3.420 |
| | 50 (164) | 400 | 0.340 | 1.056 | 2.517 |
| 400 V 1.5 kW (2.0 hp) | 5 (16) | 400 | 0.160 | 0.808 | 4.050 |
| | 25 (82) | 400 | 0.240 | 1.026 | 3.420 |
| | 50 (164) | 400 | 0.340 | 1.056 | 2.517 |
| 400 V 2.2 kW (3.0 hp) | 5 (16) | 400 | 0.190 | 0.760 | 3.200 |
| | 25 (82) | 400 | 0.293 | 1.026 | 2.801 |
| | 50 (164) | 400 | 0.422 | 1.040 | 1.971 |
| 400 V 3.0 kW (4.0 hp) | 5 (16) | 400 | 0.190 | 0.760 | 3.200 |
| | 25 (82) | 400 | 0.293 | 1.026 | 2.801 |
| | 50 (164) | 400 | 0.422 | 1.040 | 1.971 |
| 400 V 4.0 kW (5.4 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 |
| 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 |

| | Cable length [m (ft)] | AC line voltage [V] | Rise time [µsec] | $V_{peak}$ [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|---|
| | 50 (164) | 400 | 0.222 | 1.00 | 3.603 |
| 400 V 30 kW (40 hp) | 5 (16.4) | 400 | 0.160 | 0.86 | 4.28 |
| | 50 (164) | 400 | 0.313 | 1.02 | 2.59 |
| | 5 (16.4) | 480 | 0.170 | 1.00 | 4.66 |
| | 50 (164) | 480 | 0.340 | 1.21 | 2.83 |
| 400 V 37 kW (50 hp) | 5 (16.4) | 400 | 0.212 | 0.81 | 3.08 |
| | 53 (174) | 400 | 0.294 | 0.94 | 2.56 |
| | 5 (16.4) | 480 | 0.228 | 0.95 | 3.37 |
| | 53 (174) | 480 | 0.274 | 1.11 | 3.24 |
| 400 V 45 kW (60 hp) | 5 (16.4) | 400 | 0.14 | 0.64 | 3.60 |
| | 50 (164) | 400 | 0.548 | 0.95 | 1.37 |
| | 5 (16.4) | 480 | 0.146 | 0.70 | 3.86 |
| | 50 (164) | 480 | 0.54 | 1.13 | 1.68 |
| 400 V 55 kW (75 hp) | 5 (16.4) | 400 | 0.206 | 0.91 | 3.52 |
| | 54 (177) | 400 | 0.616 | 1.03 | 1.34 |
| | 5 (16.4) | 480 | 0.212 | 1.06 | 3.99 |
| | 54 (177) | 480 | 0.62 | 1.23 | 1.59 |
| 400 V 75 kW (100 hp) | 5 (16.4) | 400 | 0.232 | 0.81 | 2.82 |
| | 50 (164) | 400 | 0.484 | 1.03 | 1.70 |
| | 5 (16.4) | 480 | 0.176 | 1.06 | 4.77 |
| | 50 (164) | 480 | 0.392 | 1.19 | 2.45 |
| 400 V 90 kW (125 hp) | 5 (16.4) | 400 | 0.176 | 0.91 | 4.11 |
| | 50 (164) | 400 | 0.610 | 0.96 | 1.26 |
| | 5 (16.4) | 480 | 0.184 | 1.06 | 4.60 |
| | 50 (164) | 480 | 0.576 | 1.12 | 1.56 |

## 6.12.3 High-power Range

The power sizes in the tables in 6.12.4 dU/dt Test Results for H13–H14 at the appropriate mains voltages comply with the requirements of IEC 60034-17:2006 edition 4 regarding normal motors controlled by drives, IEC 60034-25:2007 edition 2.0 regarding motors designed to be controlled by drives, and NEMA MG 1-1998 Part 31.4.4.2 for inverter-fed motors. The power sizes in the tables in 6.12.4 dU/dt Test Results for H13–H14 do not comply with NEMA MG 1-1998 Part 30.2.2.8 for general purpose motors.

## 6.12.4 dU/dt Test Results for H13–H14

**Table 40: IEC dU/dt Test Results for H13–H14 with Unshielded Cables and No Output Filter, 380–480 V**

| Power size [kW (hp)] | Cable [m (ft)] | Mains voltage [V] | Rise time [µs] | Peak voltage [V] | dU/dt [V/µs] |
|---|---|---|---|---|---|
| 90–160 (125–250) | 30 (98) | 500 | 0.71 | 1180 | 1339 |
| | 150 (492) | 500 | 0.76 | 1423 | 1497 |
| | 300 (984) | 500 | 0.91 | 1557 | 1370 |
| 200–315 (300–450) | 30 (98) | 500 | 1.10 | 1116 | 815 |
| | 150 (492) | 500 | 2.53 | 1028 | 321 |
| | 300 (984) | 500 | 1.29 | 835 | 517 |

**Table 41: IEC dU/dt Test Results for H13–H14 with Shielded Cables and No Output Filter, 380–480 V**

| Power size [kW (hp)] | Cable [m (ft)] | Mains voltage [V] | Rise time [µs] | Peak voltage [V] | dU/dt [V/µs] |
|---|---|---|---|---|---|
| 90–160 (125–250) | 30 (98) | 500 | – | – | – |
| | 150 (492) | 500 | 0.66 | 1418 | 1725 |
| | 300 (984) | 500 | 0.96 | 1530 | 1277 |
| 200–315 (300–450) | 30 (98) | 500 | – | – | – |
| | 150 (492) | 500 | 0.56 | 1261 | 1820 |
| | 300 (984) | 500 | 0.78 | 1278 | 1295 |

## 6.12.5 dU/dt Filters

dU/dt filters can suppress the output voltage peak and fast voltage change of the inverter, and reduce the pressure of the motor insulation. VLT® Flow Drive FC 111 supports dU/dt filter, for more details, contact Danfoss local sales office.

## 6.13 PHF Filters

VLT® Flow Drive FC 111 with an appropriate passive harmonic filter (PHF) can reduce the THDI to less than 10%. For more details, contact Danfoss local sales office.

# 7 RS485 Installation and Set-up

## 7.1 RS485

### 7.1.1 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.

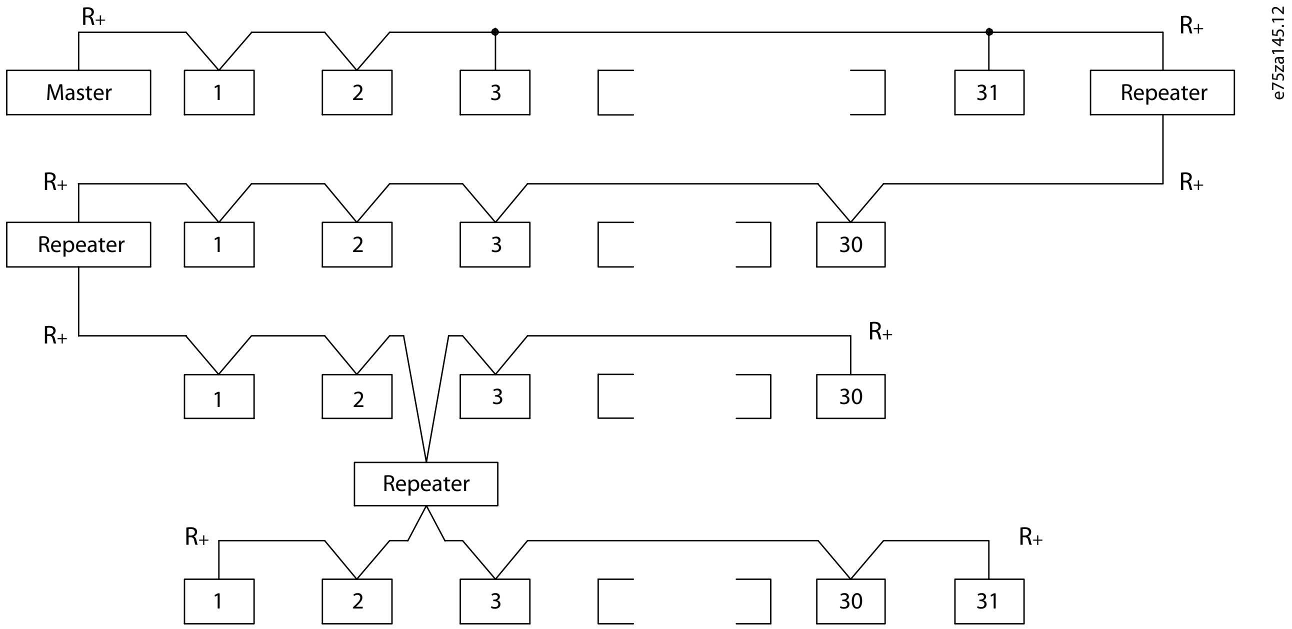



**Illustration 59: RS485 Bus Interface**

> **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 42: Cable Specifications**

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

### 7.1.2 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.

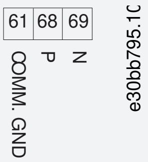



**Illustration 60: Network Connection**

2. Connect the cable shield to the cable clamps.

**N O T I C E**

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

## 7.1.3 Hardware Setup

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

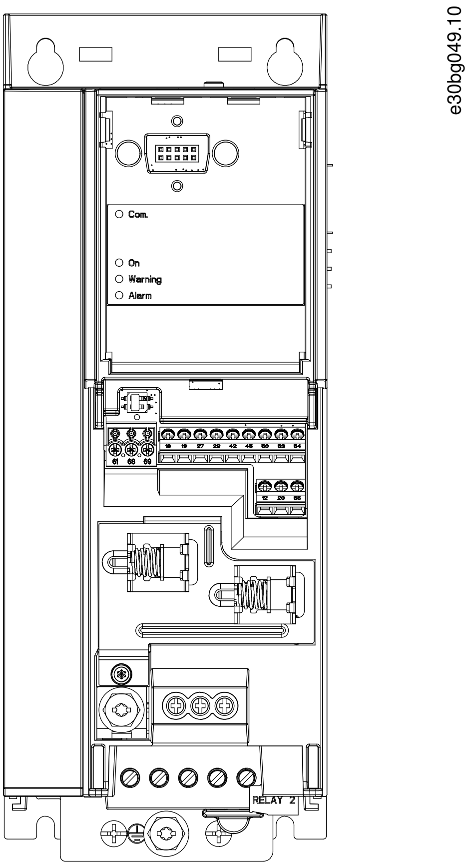



**Illustration 61: Terminator Switch Factory Setting**

The factory setting for the switch is OFF.

## 7.1.4 Parameter Settings for Modbus Communication

**Table 43: Modbus Communication Parameter Settings**

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

## 7.1.5 EMC Precautions

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

**N O T I C E**

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°.

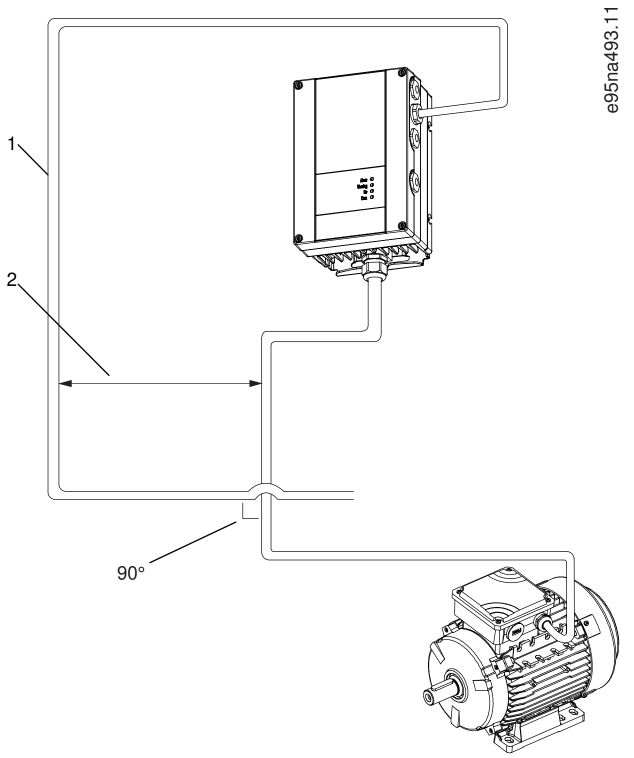



**Illustration 62: Minimum Distance between Communication and Power Cables**

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

## 7.2 FC Protocol

### 7.2.1 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.

### 7.2.2 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.

## 7.3 Network Configuration

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

**Table 44: 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) |

## 7.4 FC Protocol Message Framing Structure

### 7.4.1 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.

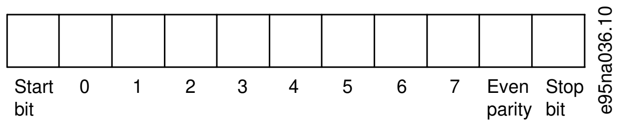



**Illustration 63: Content of a Character**

### 7.4.2 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.

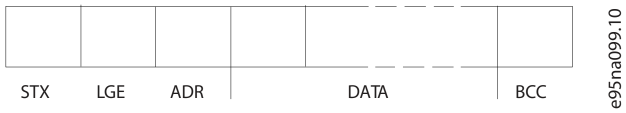



**Illustration 64: Telegram Structure**

### 7.4.3 Telegram Length (LGE)

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

**Table 45: Length of Telegrams**

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

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

## 7.4.4 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.

## 7.4.5 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.

## 7.4.6 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).

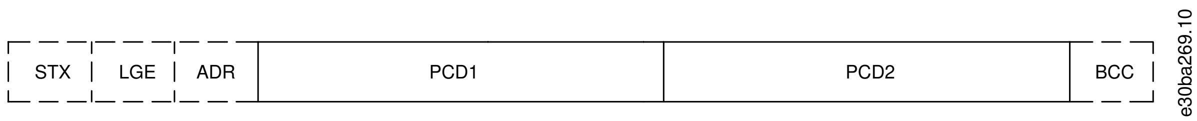



**Illustration 65: Process Block**

**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.

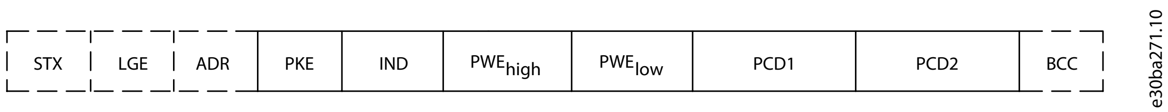



**Illustration 66: Parameter Block**

**Text block**

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

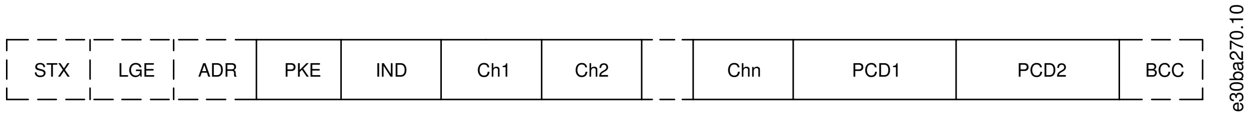



**Illustration 67: Text Block**

## 7.4.7 The PKE Field

The PKE field contains 2 subfields:

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

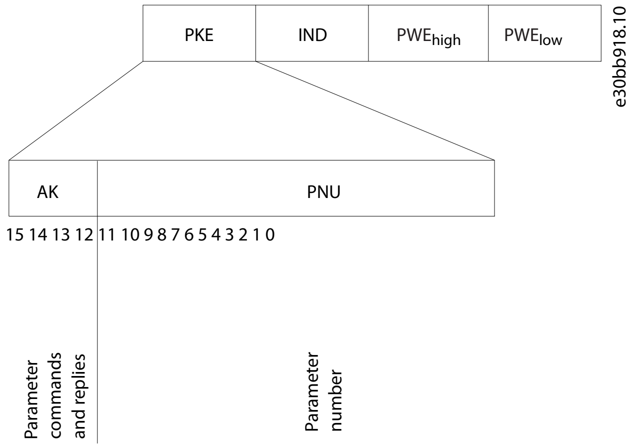



**Illustration 68: PKE Field**

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

**Table 46: 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 47: 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 48: 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. |

## 7.4.8 Parameter Number (PNU)

Bits 0–11 transfer parameter numbers. The function of the relevant parameter is defined in the parameter description in the VLT® Flow Drive FC 111 Programming Guide.

## 7.4.9 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.

## 7.4.10 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 2$^{nd}$ 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.

## 7.4.11 Data Types Supported by the Drive

**Table 49: 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.

## 7.4.12 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 50: 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 |

## 7.4.13 Process Words (PCD)

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

**Table 51: Process Words (PCD)**

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

# 7.5 Examples

## 7.5.1 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 7.4.12 Conversion.
The telegram looks like the following illustration.

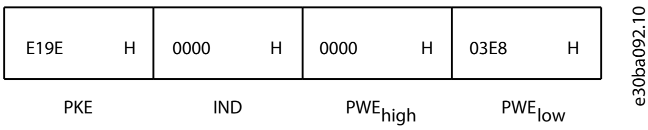



**Illustration 69: Telegram**

**N O T I C E**

*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.

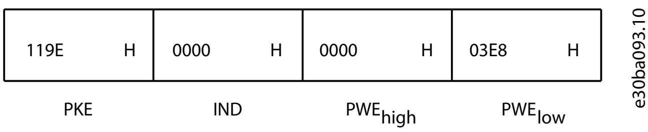



**Illustration 70: Response from Master**

## 7.5.2 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.

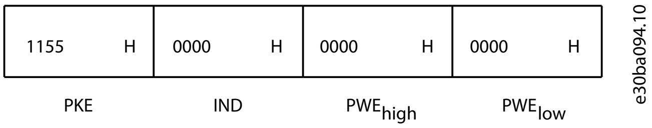



**Illustration 71: Telegram**

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.

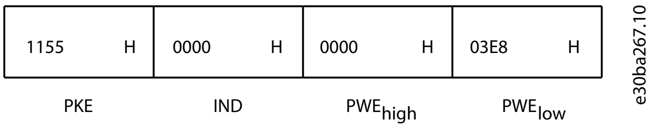



**Illustration 72: Response**

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.

# 7.6 Modbus RTU

## 7.6.1 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.

## 7.6.2 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.

### 7.6.3 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.

## 7.7 Network Configuration

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

**Table 52: Network Configuration**

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

## 7.8 Modbus RTU Message Framing Structure

### 7.8.1 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 53: Format for Each Byte**

| Start bit | Data byte | | | | | | | | Stop/ parity | Stop |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |

**Table 54: Byte Details**

| | |
|---|---|
| Coding system | 8-bit binary, hexadecimal 0–9, A–F. |

| | |
|---|---|
| | 2 hexadecimal characters contained in each 8-bit field of the telegram. |
| Bits per byte | • 1 start bit.<br>• 8 data bits, least significant bit sent first.<br>• 1 bit for even/odd parity; no bit for no parity.<br>• 1 stop bit if parity is used; 2 bits if no parity. |
| Error check field | Cyclic redundancy check (CRC). |

## 7.8.2 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 1$^{st}$ 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 55: 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 |

## 7.8.3 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 1$^{st}$ 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.

## 7.8.4 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.

## 7.8.5 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 7.8.10.2 Function Codes Supported by Modbus RTU and 7.8.10.3 Modbus Exception Codes.

## 7.8.6 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.

## 7.8.7 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.

## 7.8.8 Coil Register Addressing

### 7.8.8.1 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).

### 7.8.8.2 Coil Register

**Table 56: 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.<br>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. | – |

### 7.8.8.3 Drive Control Word (FC Profile)

**Table 57: 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 |

## 7.8.8.4 Drive Status Word (FC Profile)

**Table 58: 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 |

### 7.8.8.5 Address/Registers

**Table 59: 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 (*parameter 12-28 Store Data Values* and *parameter 12-29 Store Always* - stored in, for example, EEPROM). |
| 6 | 7 | 40007 | Last fault code | Read only | Fault code received from parameter database, refer to WHAT 38295 for details. |
| 7 | 8 | 40008 | Last error register | Read only | Address of register with which last error occurred, refer to WHAT 38296 for details. |
| 8 | 9 | 40009 | Index pointer | Read/Write | Subindex of parameter to be accessed. Refer to WHAT 38297 for details. |
| 9 | 10 | 40010 | *Parameter 0-01 Language* | Dependent on parameter access | *Parameter 0-01 Language* (Modbus register = 10 parameter number) 20 bytes space reserved for parameter in Modbus map. |
| 19 | 20 | 40020 | Free | – | – |
| 29 | 30 | 40030 | *Parameter 0-03 Regional Settings* | Dependent on parameter access | *Parameter 0-03 Regional Settings* 20 bytes space reserved for parameter in Modbus map. |

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

## 7.8.9 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.

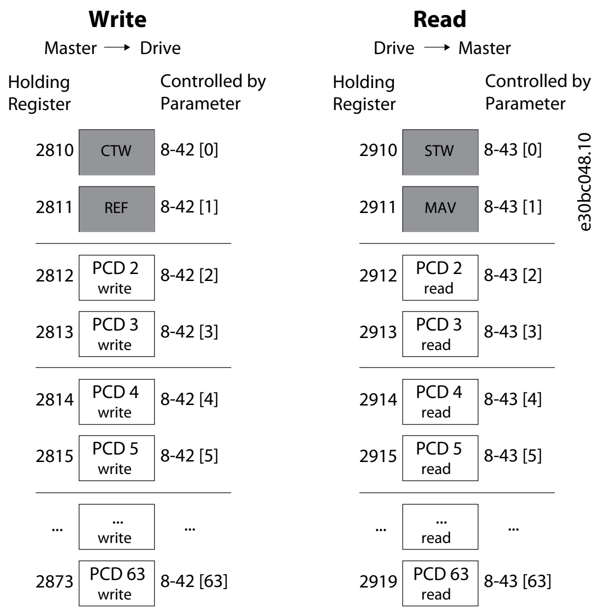



**Illustration 73: Accessing via PCD write/read**

**N O T I C E**

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

**N O T I C E**

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*.

## 7.8.10 How to Control the Drive

### 7.8.10.1 Introduction

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

### 7.8.10.2 Function Codes Supported by Modbus RTU

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

**Table 60: 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 61: 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. |

## 7.8.10.3 Modbus Exception Codes

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

**Table 62: 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. |

## 7.9 How to Access Parameters

## 7.9.1 Parameter Handling

The PNU (parameter number) is translated from the register address contained in the Modbus read or write 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 parameters 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 parameters values. A value of 11300 (decimal), means that the parameter is set to 1113.00.

For information on the parameters, size, and conversion index, see the drive's Programming Guide.

## 7.9.2 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).

## 7.9.3 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.

## 7.9.4 Text Blocks

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

## 7.9.5 Conversion Factor

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

## 7.9.6 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).

# 7.10 Examples

## 7.10.1 Introduction

The following examples show various Modbus RTU commands.

## 7.10.2 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 63: 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 1$^{st}$ 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 64: Response**

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

**NOTICE**

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

## 7.10.3 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 65: 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 66: 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) | – |

## 7.10.4 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 67: 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 68: 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) | – |

## 7.10.5 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 69: Query**

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

**Response**

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

Example: hex 000088B8 = 35.000 = 35 Hz.

**Table 70: 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) | – |

## 7.10.6 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 71: 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 72: 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) | – |

## 7.10.7 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 73: 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 74: 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) | – |

## 7.10.8 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 75: 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 (*Parameter 3-03 Maximum Reference* 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 76: 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) | – |

## 7.11 Danfoss FC Control Profile

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

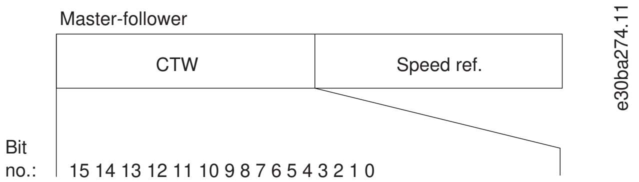



**Illustration 74: Control Word According to FC Profile**

**Table 77: 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 |

## 7.11.2 Explanation of Each Control Bit

### 7.11.2.1 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 78: Control Bits**

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

**NOTICE**

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

### 7.11.2.2 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.

### 7.11.2.3 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.

### 7.11.2.4 Bit 04, Quick Stop

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

### 7.11.2.5 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*).

**NOTICE**

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

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

### 7.11.2.6 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.

### 7.11.2.7 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.

### 7.11.2.8 Bit 08, Jog

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

### 7.11.2.9 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.

### 7.11.2.10 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.

### 7.11.2.11 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*.

### 7.11.2.12 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*.

### 7.11.2.13 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 79: 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*.

### 7.11.2.14 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.

## 7.11.3 Status Word According to FC Profile (STW)

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

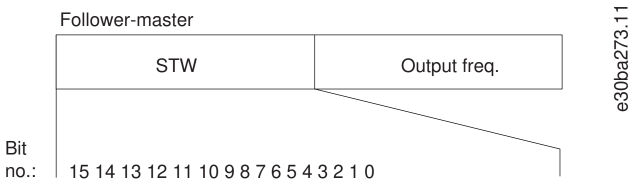



**Illustration 75: Status Word**

**Table 80: 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 |

## 7.11.4 Explanation of Each Status Bit

### 7.11.4.1 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).

### 7.11.4.2 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.

### 7.11.4.3 Bit 02, Coast Stop

Bit 02=0: The drive releases the motor.

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

### 7.11.4.4 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].

### 7.11.4.5 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.

### 7.11.4.6 Bit 05, Not Used

Bit 05 is not used in the status word.

### 7.11.4.7 Bit 06, No Error/Triplock

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

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

### 7.11.4.8 Bit 07, No Warning/Warning

Bit 07=0: There are no warnings.

Bit 07=1: A warning has occurred.

### 7.11.4.9 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.

### 7.11.4.10 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.

### 7.11.4.11 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.

### 7.11.4.12 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.

### 7.11.4.13 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.

### 7.11.4.14 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.

### 7.11.4.15 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.

### 7.11.4.16 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%.

## 7.11.5 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.

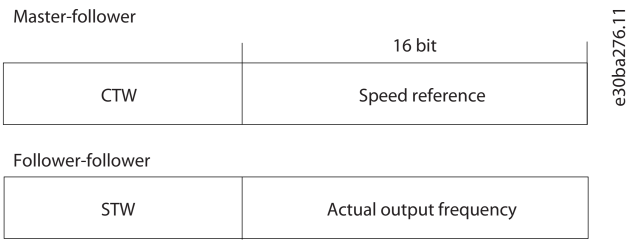



**Illustration 76: Actual Output Frequency (MAV)**

The reference and MAV are scaled as follows:

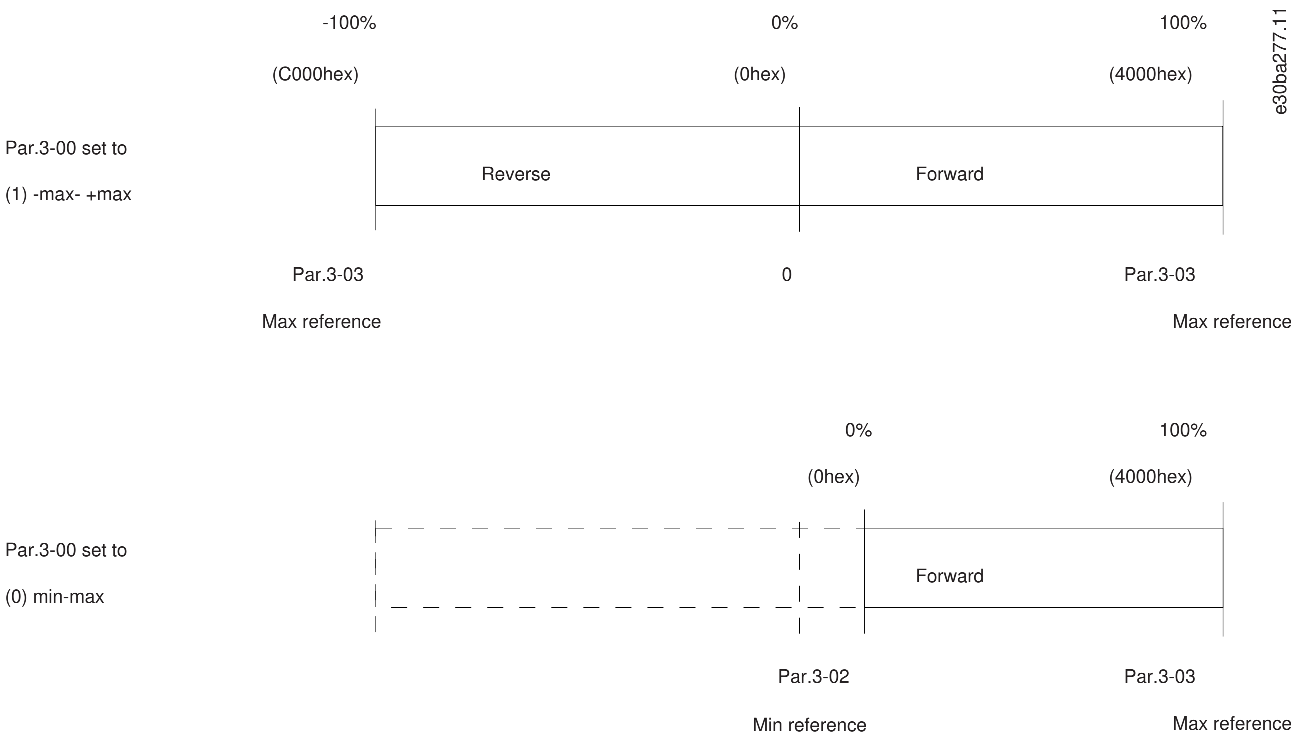



**Illustration 77: Reference and MAV**

# 8 General Specifications

## 8.1 Mains Supply

### 8.1.1 3x380–480 V AC

**Table 81: 3x380–480 V AC, 0.37–15 kW (0.5–20 hp), Enclosure Sizes H1–H4**

| Drive | PK37 | PK75 | P1K5 | P2K2 | P3K0 | P4K0 | P5K5 | P7K5 | P11K | P15K |
|---|---|---|---|---|---|---|---|---|---|---|
| Typical shaft output [kW] | 0.37 | 0.75 | 1.5 | 2.2 | 3.0 | 4.0 | 5.5 | 7.5 | 11.0 | 15.0 |
| Typical shaft output [hp] | 0.5 | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | 7.5 | 10.0 | 15.0 | 20.0 |
| Protection rating IP20 | H1 | H1 | H1 | H2 | H2 | H2 | H3 | H3 | H4 | H4 |
| Maximum cable size in terminals (mains, motor) [$mm^2$ (AWG)] | 4 (10) | 4 (10) | 4 (10) | 4 (10) | 4 (10) | 4 (10) | 4 (10) | 4 (10) | 16 (6) | 16 (6) |
| **Output current at 40 °C (104 °F) ambient temperature**[1] | | | | | | | | | | |
| Continuous [A] | 1.2 | 2.2 | 3.7 | 5.3 | 7.2 | 9.0 | 12.0 | 15.5 | 23.0 | 31.0 |
| Intermittent (110% overload 60 s) [A] | 1.3 | 2.4 | 4.1 | 5.8 | 7.9 | 9.9 | 13.2 | 17.1 | 25.3 | 34.0 |
| **Maximum input current** | | | | | | | | | | |
| Continuous [A] | 1.2 | 2.1 | 3.5 | 4.7 | 6.3 | 8.3 | 11.2 | 15.1 | 22.1 | 29.9 |
| Intermittent [A] | 1.3 | 2.3 | 3.9 | 5.2 | 6.9 | 9.1 | 12.3 | 16.6 | 24.3 | 32.9 |
| Maximum external mains fuses [A] | See 6.9.5 Recommendation of Fuses. | | | | | | | | | |
| Estimated power loss [W][2] | 15 | 21 | 57 | 58 | 83 | 118 | 131 | 198 | 274 | 379 |
| Weight enclosure protection rating IP20 [kg (lb)] | 2.0 (4.4) | 2.0 (4.4) | 2.1 (4.6) | 3.3 (7.3) | 3.3 (7.3) | 3.4 (7.5) | 4.3 (9.5) | 4.5 (9.9) | 7.9 (17.4) | 7.9 (17.4) |
| Efficiency [%][3] | 97.3 | 97.6 | 97.2 | 97.9 | 97.8 | 97.6 | 98.0 | 97.8 | 97.9 | 97.8 |

[1] Refer to the *chapter Derating* in the design guide for the derating curves at 50 °C (122 °F) ambient temperature.

[2] 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.

[3] Efficiency measured at nominal current. For energy efficiency class, see 8.2.13 Ambient Conditions. For part load losses, see Danfoss MyDrive® ecoSmart website.

**Table 82: 3x380–480 V AC, 18.5–90 kW (25–125 hp), Enclosure Sizes H5, H11–H12**

| Drive | P18K | P22K | P30K | P37K | P45K | P55K | P75K | P90K |
|---|---|---|---|---|---|---|---|---|
| Typical shaft output [kW] | 18.5 | 22.0 | 30.0 | 37.0 | 45.0 | 55.0 | 75.0 | 90.0 |
| Typical shaft output [hp] | 25.0 | 30.0 | 40.0 | 50.0 | 60.0 | 70.0 | 100.0 | 125.0 |
| Protection rating IP20 | H5 | H5 | H11 | H11 | H11 | H12 | H12 | H12 |
| Maximum cable size in terminals (mains, motor) [$mm^2$ (AWG)] | 16 (6) | 16 (6) | 50 (1) | 50 (1) | 50 (1) | 50 (1) | 95 (0) | 120 (250 MCM) |
| **Output current at 40 °C/45 °C (104 °F/113 °F) ambient temperature**[1] | | | | | | | | |

| Drive | P18K | P22K | P30K | P37K | P45K | P55K | P75K | P90K |
|---|---|---|---|---|---|---|---|---|
| Continuous [A] | 37.0 | 42.5 | 61.0 | 73.0 | 90.0 | 106.0 | 147.0 | 177.0 |
| Intermittent (110% overload 60 s) [A][(2)] | 40.7 | 46.8 | 67.1 | 80.3 | 99.0 | 116.6 | 161.7 | 194.7 |
| **Maximum input current** | | | | | | | | |
| Continuous [A] | 35.2 | 41.5 | 57.0 | 70.3 | 84.2 | 102.9 | 140.3 | 165.6 |
| Intermittent [A] | 38.7 | 45.7 | 62.7 | 77.3 | 92.6 | 113.2 | 154.3 | 182.2 |
| Maximum external mains fuses [A] | See 6.9.5 Recommendation of Fuses. | | | | | | | |
| Estimated power loss [W][(3)] | 403 | 468 | 630 | 848 | 1175 | 1250 | 1507 | 1781 |
| Weight enclosure protection rating IP20 [kg (lb)] | 9.5 (20.9) | 9.5 (20.9) | 22.4 (49.4) | 22.5 (49.6) | 22.6 (49.8) | 37.3 (82.2) | 38.7 (85.3) | 40.7 (89.7) |
| Efficiency [%][(4)] | 98.1 | 97.9 | 98.1 | 98 | 97.7 | 98 | 98.2 | 98.3 |

[1] P18K, P22K, and P90K operates at 40 °C (104 °F). P30K, P37K, P45K, P55K, and P75K operates at 45 °C (113 °F). Refer to the *chapter Derating* in the design guide for the derating curves at 50 °C (122 °F) ambient temperature.

[2] The 30–90 kW (40–125 hp) drives also support 150% overload for 60 s when selecting 1 level higher power size.

[3] 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.

[4] Efficiency measured at nominal current. For energy efficiency class, see 8.2.13 Ambient Conditions. For part load losses, see Danfoss MyDrive® ecoSmart website.

**Table 83: 3x380–480 V AC, 110–315 kW (150–450 hp), Enclosure Sizes H13–H14**

| Drive | P110 | P132 | P160 | P200 | P250 | P315 |
|---|---|---|---|---|---|---|
| Typical shaft output [kW] | 110 | 132 | 160 | 200 | 250 | 315 |
| Typical shaft output [hp] | 150 | 175 | 250 | 300 | 350 | 450 |
| Protection rating IP20 | H13 | H13 | H13 | H14 | H14 | H14 |
| Maximum cable size in terminals (mains, motor) [mm$^2$ (AWG)] | 2x95 (2x3/0) | | | 2x185 (2x350 mcm) | | |
| **Output current at 40 °C/45 °C (104 °F/113 °F) ambient temperature[(1)]** | | | | | | |
| Continuous [A] | 212 | 260 | 315 | 395 | 480 | 588 |
| Intermittent (110% overload 60 s) [A][(2)] | 233 | 286 | 347 | 435 | 528 | 647 |
| **Maximum input current** | | | | | | |
| Continuous [A] | 204 | 251 | 304 | 381 | 463 | 567 |
| Intermittent [A] | 224 | 276 | 334 | 419 | 509 | 623 |
| Maximum external mains fuses [A] | See 6.9.5 Recommendation of Fuses. | | | | | |
| Estimated power loss [W][(3)(4)] | 2559 | 2954 | 3770 | 4116 | 5137 | 6674 |
| Efficiency[(4)] | 0.98 | | | | | |

| Drive | P110 | P132 | P160 | P200 | P250 | P315 |
|---|---|---|---|---|---|---|
| Output frequency [Hz] | 0–500 | | | | | |
| Heat sink overtemperature trip [°C (°F)] | 110 (230) | | | | | |
| Weight, enclosure protection rating IP20 kg (lbs) | 98 (216) | | | 164 (362) | | |
| Control card overtemperature trip [°C (°F)] | 75 (167) | | | 80 (176) | | |

[1] Refer to the *chapter Derating* in the design guide for the derating curves at 50 °C (122 °F) ambient temperature.

[2] The 110–315 kW (150–450 hp) drives also support 150% overload for 60 s when selecting 1 level higher power size.

[3] Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions). These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the drive. Applies for dimensioning of drive cooling. If the switching frequency is higher than the default setting, the power losses can 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. Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.

[4] Measured using 5 m (16.4 ft) shielded motor cables at rated load and rated frequency. Efficiency measured at nominal current. For energy efficiency class, see 8.2.13 Ambient Conditions. For part load losses, see Danfoss MyDrive® ecoSmart website.

## 8.2 General Technical Data

### 8.2.1 Protection and Features

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

### 8.2.2 Mains Supply

| | |
|---|---|
| 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 (cosφ) near unity | (>0.98) |
| Switching on the input supply L1, L2, L3 (power-ups) enclosure sizes H1–H5 | Maximum 1 time/30 s |
| Switching on the input supply L1, L2, L3 (power-ups) enclosure sizes H11–H12 | Maximum 1 time/minute |
| Switching on the input supply R, S, T (power-ups) enclosure sizes H13–H14 | Maximum 1 time/2 minutes |
| Environment according to EN 60664-1 | Overvoltage category III/pollution degree 2 |

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

### 8.2.3 Motor Output (U, V, W)

| | |
|---|---|
| Output voltage | 0–100% of supply voltage |
| Output frequency in U/f mode (for AM motor) | 0–500 Hz |

| | |
|---|---|
| Output frequency in VVC+ mode (for AM motor) | 0–200 Hz |
| Output frequency in VVC+ mode (for PM motor) | 0–400 Hz |
| Switching on output | Unlimited |
| Ramp time | 0.01–3600 s |

## 8.2.4 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/unarmored, H1–H5 | 50 m (164 ft) |
| Maximum motor cable length, shielded, H11–H12 | 50 m (164 ft) |
| Maximum motor cable length, unshielded/unarmored, H11–H12 | 100 m (328 ft) |
| Maximum motor cable length, shielded, H13–H14 | 150 m (492 ft) |
| Maximum motor cable length, unshielded, H13–H14 | 300 m (984 ft) |
| Maximum cross-section to motor, mains | See 8.1.1 3x380–480 V AC for more information |
| Cross-section DC terminals for filter feedback on enclosure sizes H1–H3 | 4 mm$^2$/12 AWG |
| Cross-section DC terminals for filter feedback on enclosure sizes H4–H5 | 16 mm$^2$/6 AWG |
| Maximum cross-section to control terminals, rigid wire, H1–H5 & H11–H12 | 2.5 mm$^2$/14 AWG |
| Maximum cross-section to control terminals, rigid wire, H13–H14 | 1.5 mm$^2$/16 AWG (2x0.75 mm$^2$) |
| Maximum cross-section to control terminals, flexible cable, H1–H5 & H11–H12 | 2.5 mm$^2$/14 AWG |
| Maximum cross-section to control terminals, flexible cable, H13–H14 | 1 mm$^2$/18 AWG |
| Maximum cross-section to control terminals, cable with enclosed core, H13–H14 | 0.05 mm$^2$/20 AWG |
| Minimum cross-section to control terminals, H1–H5 & H11–H12 | 0.05 mm$^2$/30 AWG |
| Minimum cross-section to control terminals, H13–H14 | 0.25 mm$^2$/23 AWG |

## 8.2.5 Digital Inputs

| | |
|---|---|
| Programmable digital inputs | 4 |
| Terminal number | 18, 19, 27, 29 |
| Logic | PNP or NPN |
| Voltage level | 0–24 V DC |
| Voltage level, logic 0 PNP | <5 V DC |
| Voltage level, logic 1 PNP | >10 V DC |
| Voltage level, logic 0 NPN | >19 V DC |
| Voltage level, logic 1 NPN | <14 V DC |
| Maximum voltage on input | 28 V DC |
| Input resistance, $R_i$ | Approximately 4 kΩ |
| Digital input 29 as thermistor input | Fault: >2.9 kΩ and no fault: <800 Ω |
| Digital input 29 as pulse input | Maximum frequency 32 kHz push-pull-driven & 5 kHz (O.C.) |

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

## 8.2.6 Analog Inputs

| | |
|---|---|
| Number of analog inputs | 2 |
| Terminal number | 53, 54 |

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

## 8.2.7 Analog Outputs

| | |
|---|---|
| Number of programmable analog outputs | 2 |
| Terminal number | 42, 45[1] |
| Current range at analog output | 0/4–20 mA |
| The load resistor to common at analog out | ≤ 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.

## 8.2.8 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 |
| The load resistor 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.

## 8.2.9 RS485 Serial Communication

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

The RS485 serial communication outputs are galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

## 8.2.10 24 V DC Output

| | |
|---|---|
| Terminal number | 12 |
| Maximum load | 80 mA |

The 24 V DC output is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

### 8.2.11 Relay Output

| | |
|---|---|
| Programmable relay output | 2 |
| Relay 01 and 02 | 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.

### 8.2.12 10 V DC Output

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

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

### 8.2.13 Ambient Conditions

| | |
|---|---|
| Enclosure protection rating (H1–H5 & H11–H14) | IP20/Chassis |
| Vibration test (H1–H5 & H11–H14) | 1.0 g |
| Maximum relative humidity (H1–H5 & H11–H14) | 5–95% (non-condensing) during operation |
| Aggressive environment (IEC 60721-3-3), coated enclosure sizes (H1–H5 & H11–H14) | Class 3C3 |
| Aggressive gases (IEC 60721-3-3), enclosure sizes (H13–H14) | Class 3C3 |
| Aggressive environment (IEC 60068-2-43) $H_2S$ test enclosure sizes H13–H14 | Class Kd |
| Test method according to IEC 60068-2-43 | $H_2S$ (10 days) |
| Ambient temperature-full output current (H1–H5 & H11–H14)[1] | See maximum output current at 45 °C (113 °F) in 8.1.1 3x380–480 V AC[2]. |
| Ambient temperature with derating (H1–H5 & H11–H14) | Maximum 55 °C (131 °F)[1] |
| Minimum ambient temperature during full-scale operation (H1–H5 & H11–H14) | -15 °C (5 °F)[3] |
| Minimum ambient temperature at reduced performance (H1–H5 & H11–H14) | -20 °C (-4 °F)[4] |
| Temperature during storage/transport (H1–H5 & H11–H12) | -30 to +65/70 °C (-22 to +149/158 °F) |
| Temperature during storage/transport (H13–H14) | -25 to +65/70 °C (-13 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)[1] |

| | |
|---|---|
| Derating for high altitude | See 5.9.3 Derating for Low Air Pressure and High Altitudes. |
| Safety standards (H1–H5 & H11–H12) | EN/IEC 61800-5-1 |
| EMC standards, Emission (H1–H5 & H11–H14) | EN/IEC 61800-3, IEC 61000-6-2/3/12, EN55011 |
| EMC standards, Immunity (H1–H5 & H11–H14) | EN/IEC 61800-3, IEC 61000-6-2, IEC 61000-4-2/3/4/5/6, IEC 61000-4-11/13/27/28/34 |
| Energy efficiency class | IE2[5] |

[1] For more information on derating, see *chapter Derating* in the design guide.

[2] Apply for enclosure sizes H1, H2, H4, H11, H12, H13, and H14. For enclosure sizes H3, H5, and 90 kW (125 hp) drives, the maximum ambient temperature is 40 °C (104 °F).

[3] Apply for enclosure sizes H13–H14. For enclosure sizes H1–H5 and H11–H12 drives, the minimum ambient temperature during full-scale operation is -10 °C (14 °F).

[4] Apply for enclosure sizes H13–H14. For enclosure sizes H1–H5 and H11–H12 drives, the minimum ambient temperature at reduced performance is -15 °C (5 °F).

[5] Determined according to EN 50598-2 at:

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

# 9 Appendix

## 9.1 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 |

## 9.2 Definitions

### 9.2.1 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.

### 9.2.2 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 84: 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. |

### 9.2.3 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.

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

**$n_{slip}$**

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**

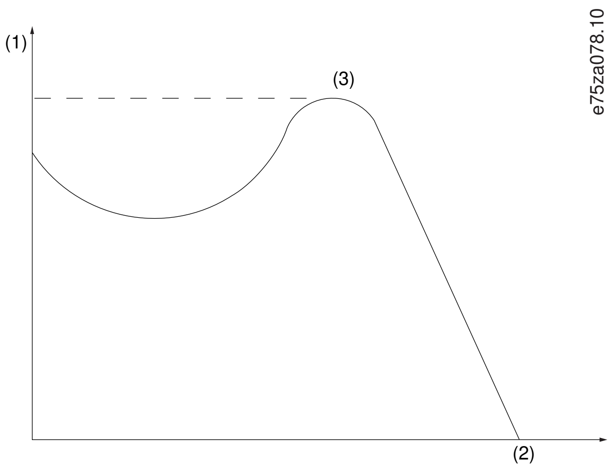



**Illustration 78: Break-away Torque**

| | | | |
|---|---|---|---|
| 1 | Torque | 3 | Pull-out |
| 2 | RPM | | |

**$\eta_{VLT}$**

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.

## 9.2.4 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*.

## 9.2.5 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 $mm^2$.

**On-line/off-line parameters**

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

**PI controller**

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

**Process PID**

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

**PCD**

Process control data.

**PFC**

Power factor correction.

**Power cycle**

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

**Power factor**

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

$$\text{Power factor} = \frac{\sqrt{3} \times U \times I_1 \cos\phi 1}{\sqrt{3} \times U \times I_{RMS}}$$

For VLT® Flow DriveFC 111 drives, cosϕ1 = 1, therefore:

$$\text{Power factor} = \frac{I1 \times \cos\phi 1}{I_{RMS}} = \frac{I_1}{I_{RMS}}$$

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.

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

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.

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