*Danfoss*

Design Guide

# VLT® AutomationDrive FC 360

0.37–90 kW, Enclosure Sizes J1–J7

VLT®
AutomationDrive

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# 1 Introduction

## 1.1 Purpose of the Design Guide

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

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

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

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

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## 1.2 Additional Resources

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

- The operating guide provides detailed information for the installation and start-up of the drive.
- The programming guide provides greater detail on working with parameters and many application examples.
- Instructions for operation with optional equipment.

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

## 1.3 Document 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 Version**

| Edition | Remarks |
|---|---|
| AJ275647605270, version 1501 | Add information of 90 kW (125 hp) normal overload drives. |

## 1.4 Approvals and Certifications

### 1.4.1 CE Mark

The CE mark (Conformité Européenne) indicates that the product manufacturer conforms to all applicable EU directives.

The EU directives applicable to the design and manufacture of drives are:

- The Low Voltage Directive.
- The EMC Directive.
- The Machinery Directive (for units with an integrated safety function).

The CE mark is intended to eliminate technical barriers to free trade between the EC and EFTA states inside the ECU. The CE mark does not regulate the quality of the product. Technical specifications cannot be deduced from the CE mark.

## 1.4.2 **Low Voltage Directive**

Drives are classified as electronic components and must be CE-labeled in accordance with the Low Voltage Directive. The directive applies to all electrical equipment in the 50–1000 V AC and the 75–1500 V DC voltage ranges.

The directive mandates that the equipment design must ensure the safety and health of people and livestock, and the preservation of material by ensuring the equipment is properly installed, maintained, and used as intended. Danfoss CE labels comply with the Low Voltage Directive, and Danfoss provides a declaration of conformity upon request.

## 1.4.3 **EMC Directive**

Electromagnetic compatibility (EMC) means that electromagnetic interference between pieces of equipment does not hinder their performance. The basic protection requirement of the EMC Directive 2014/30/EU 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.

A drive can be used as a standalone device or as part of a more complex installation. Devices in either of these cases must bear the CE mark. Systems do not have to be CE-marked but must comply with the basic protection requirements of the EMC directive.

# 2 Safety

## 2.1 Safety Symbols

The following symbols are used in Danfoss documentation.

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

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

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

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

The guide also includes ISO warning symbols related to hot surfaces and burn hazard, high voltage and electrical shock, and referring to the instructions.

| | |
| --- | --- |
| ⚠ | ISO warning symbol for hot surfaces and burn hazard |
| ⚠ | ISO warning symbol for high voltage and electrical shock |
| 📖 | ISO action symbol for referring to the instructions |

## 2.2 Qualified Personnel

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

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

## 2.3 Safety Precautions

⚠ **WARNING**

**HIGH VOLTAGE**

Drives contain high voltage when connected to AC mains input, DC supply, load sharing, or permanent motors. Failure to use qualified personnel to install, start up, and maintain the drive can result in death or serious injury.

- Only qualified personnel must install, start up, and maintain the drive.

- Before performing any service or repair work, use an appropriate voltage measuring device to make sure that there is no remaining voltage on the drive.

⚠ **WARNING**

**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.

⚠ **WARNING**

**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 2: Discharge Time**

| Voltage [V] | Power range [kW (hp)] | Minimum waiting time (minutes) |
|---|---|---|
| 380–480 | 0.37–7.5 kW (0.5–10 hp) | 4 |
| 380–480 | 11–90 kW (15–125 hp) | 15 |

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### ⚠ WARNING

**ELECTRICAL SHOCK HAZARD - LEAKAGE CURRENT HAZARD >3.5 MA**

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

- Ensure reinforced protective earthing conductor according to IEC 60364-5-54 cl. 543.7 or according to local safety regulations for high touch current equipment. The reinforced protective earthing of the drive can be done with:

- a PE conductor with a cross-section of at least 10 mm$^2$ (8 AWG) Cu or 16 mm$^2$ (6 AWG) Al.

- an extra PE conductor of the same cross-sectional area as the original PE conductor as specified by IEC 60364-5-54 with a minimum cross-sectional area of 2.5 mm$^2$ (14 AWG) (mechanically protected) or 4 mm$^2$ (12 AWG) (not mechanically protected).

- a PE conductor completely enclosed with an enclosure or otherwise protected throughout its length against mechanical damage.

- a PE conductor part of a multi-conductor power cable with a minimum PE conductor cross-section of 2.5 mm$^2$ (14 AWG) (permanently connected or pluggable by an industrial connector. The multi-conductor power cable shall be installed with an appropriate strain relief).

- NOTE: In IEC/EN 60364-5-54 cl. 543.7 and some application standards (for example IEC/EN 60204-1), the limit for requiring reinforced protective earthing conductor is 10 mA leakage current.

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### ⚠ WARNING

**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 guide.

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### ⚠ CAUTION

**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.

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### NOTICE

**HIGH ALTITUDES**
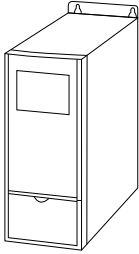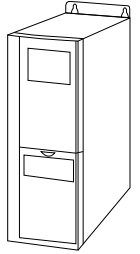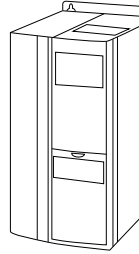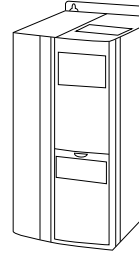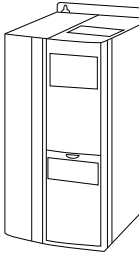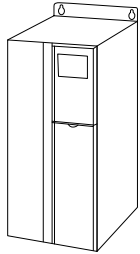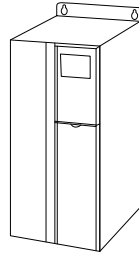
- For installation at altitudes above 2000 m (6562 ft), contact Danfoss regarding PELV.

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# 3 Product Overview

## 3.1 Enclosure Size Overview

Enclosure size depends on power range.

**Table 3: Enclosure Sizes**

| Enclosure size | **J1** | **J2** | **J3** | **J4** |
| --- | --- | --- | --- | --- |
| | e30ba870.11 | e30ba809.11 | e30ba810.11 | e30ba810.11 |
| Enclosure protection | IP20 | IP20 | IP20 | IP20 |
| | 0.37–2.2 kW/0.5–3 hp (380–480 V) | 3.0–5.5 kW/4.0–7.5 hp (380–480 V) | 7.5 kW/10 hp (380–480 V) | 11–15 kW/15–20 hp (380–480 V) |
| Enclosure size | **J5** | **J6** | **J7** | – |
| | e30ba810.11 | e30ba826.11 | e30ba826.11 | – |
| Enclosure protection | IP20 | IP20 | IP20 | – |
| | 18.5–22 kW/25–30 hp (380–480 V) | 30–45 kW/40–60 hp (380–480 V) | 55–90 kW/75–125 hp (380–480 V) | – |

- Enclosure size 0.37–90 kW (0.5–125 hp) normal overload type: 110% overload 1 minute.
- Enclosure size 0.37–7.5 kW (0.5–10 hp) high overload type: 160% overload 1 minute.
- Enclosure size 11–75 kW (15–100 hp) high overload type: 150% overload 1 minute.

## 3.2 **Electrical Installation**

### 3.2.1 **Wiring Diagram**
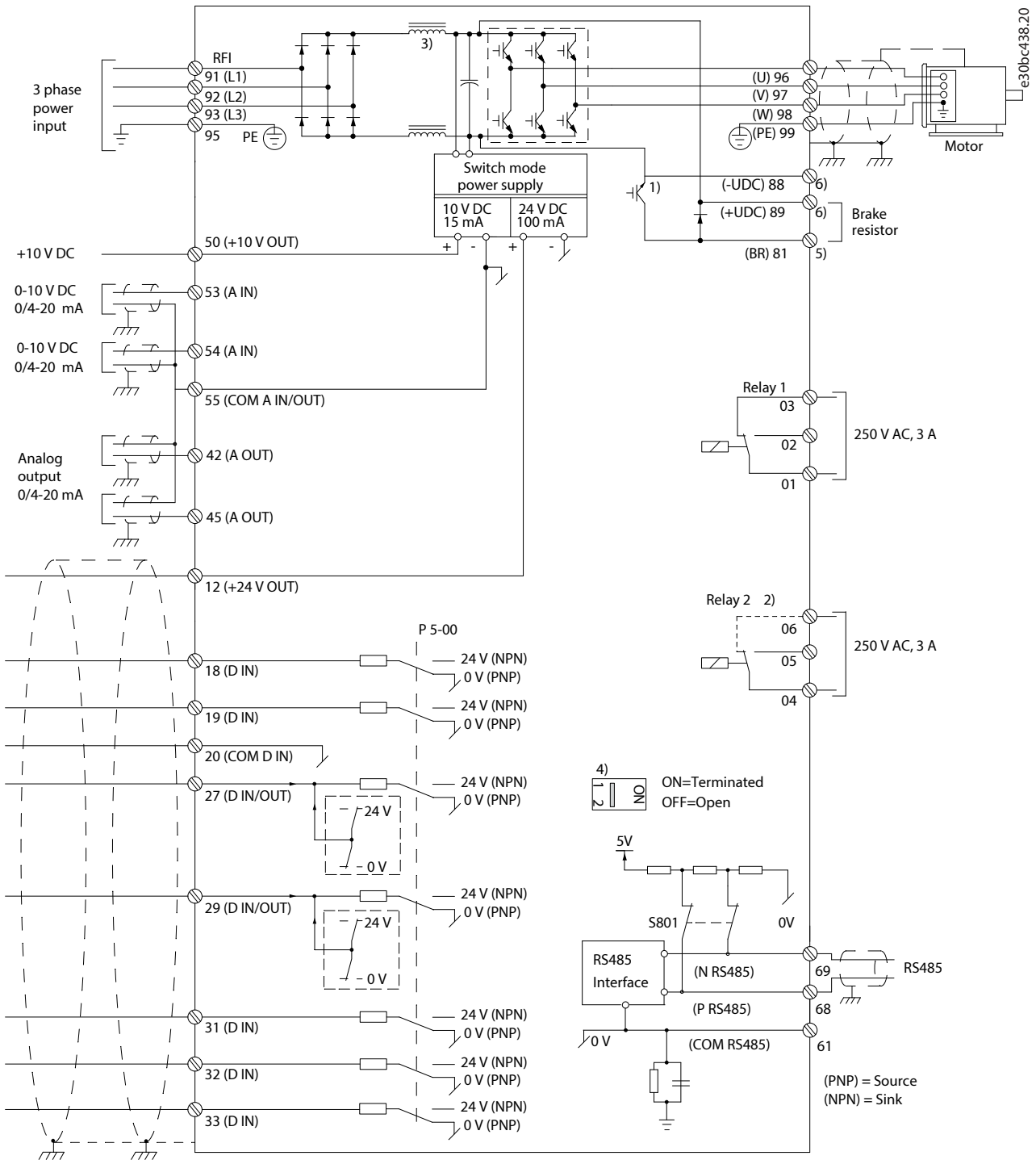


**Figure 1: Basic Wiring Diagram**

A        Analog

D        Digital

1)       Built-in brake chopper available from J1–J5.

2)      Relay 2 is 2-pole for J1–J3 and 3-pole for J4–J7. Relay 2 of J4–J7 with terminals 4, 5, and 6 has the same NO/NC logic as relay 1. Relays are pluggable in J1–J5 and fixed in J6–J7.

3)      Single DC choke in J1–J5; Dual DC choke in J6–J7.

4)      Switch S800 (bus terminal) can be used to enable termination on the RS485 port (terminals 68 and 69).

5)      No BR for J6–J7.

6)      Terminals 81, 88, and 89 for J1–J7.

## 3.2.2 Typical Electrical Connection
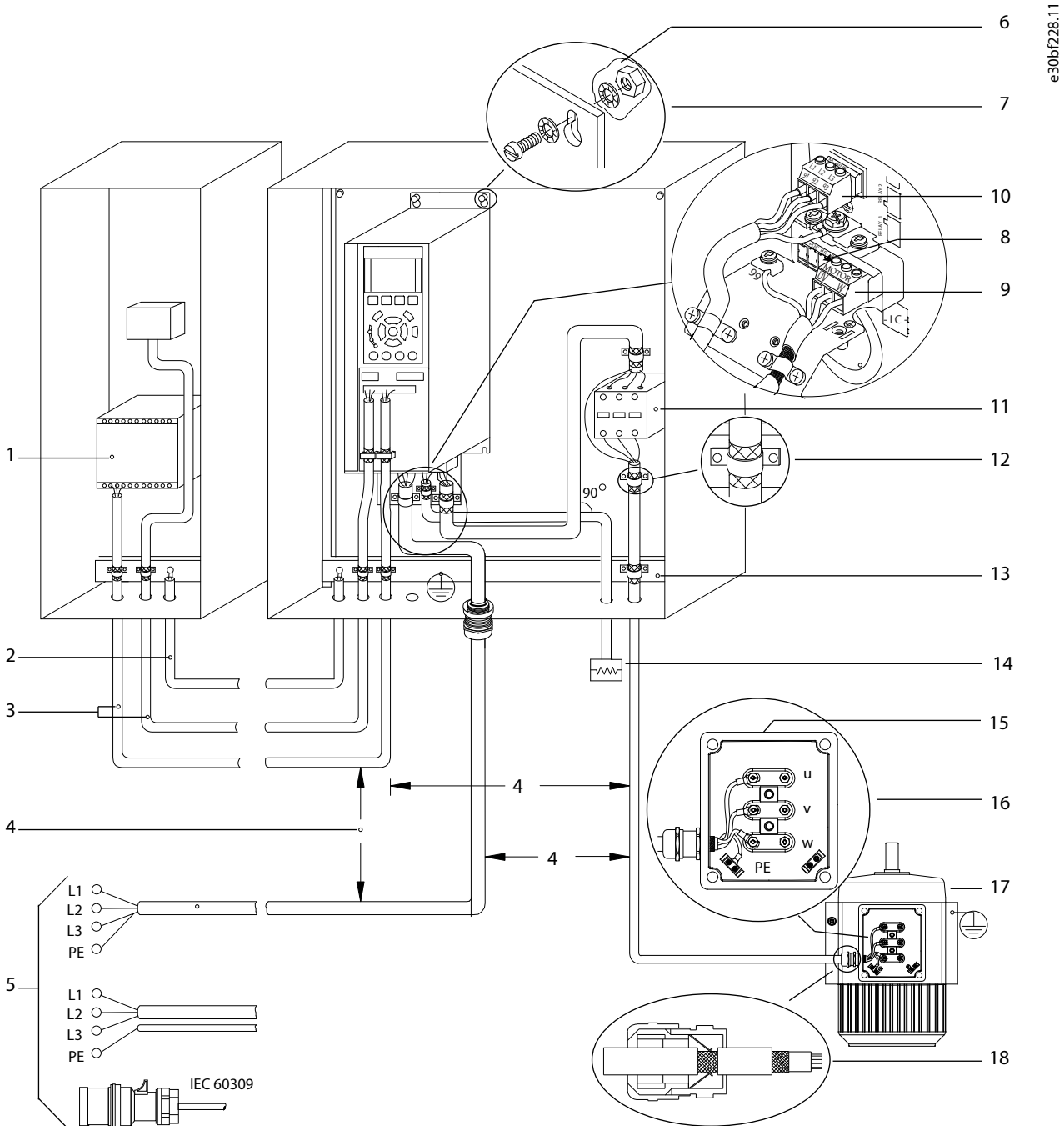


**Figure 2:  Typical Electrical Connection**

| | | | |
|---|---|---|---|
| 1 | PLC | 2 | Minimum 16 mm$^2$ (6 AWG) equalizing cable |
| 3 | Control cables | 4 | Minimum 200 mm (7.87 in) between control cables, motor cables, and mains cables. |
| 5 | Mains supply | 6 | Bare (unpainted) surface |
| 7 | Star washers | 8 | Brake cable (shielded) |
| 9 | Motor cable (shielded) | 10 | Mains cable (unshielded) |
| 11 | Output contactor, and more. | 12 | Cable insulation stripped |
| 13 | Common ground busbar. Follow local and national requirements for cabinet grounding. | 14 | Brake resistor |
| 15 | Metal box | 16 | Connection to motor |
| 17 | Motor | 18 | EMC cable gland |

### 3.2.3 General Requirements

⚠️ **WARNING**

**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 guide.

**NOTICE**

**WIRING ISOLATION**

Run input power, motor wiring, and control wiring in 3 separate metallic conduits, or use separated shielded cables for high-frequency noise isolation. Failure to isolate power, motor, and control wiring could result in less than optimum drive and associated equipment performance.

Run motor cables from multiple drives separately. Induced voltage from output motor cables 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.
- Use shielded cables.
- Lock out all drives simultaneously.

**Wire type and ratings**

- All wiring must comply with local and national regulations regarding cross-section and ambient temperature requirements.
- Danfoss recommends that all power connections are made with a minimum 75 °C (167 °F) rated copper wire.
- See *chapter Specifications* for recommended wire sizes.

## 3.2.4 Grounding Requirements

> **⚠ WARNING**
>
> **GROUNDING HAZARD**
>
> For operator safety, a certified electrical installer should ground the drive in accordance with national and local electrical codes as well as instructions contained within this manual. Ground currents are higher than 3.5 mA. Failure to ground the drive properly could result in death or serious injury.
>
> - Establish proper protective grounding for equipment with ground currents higher than 3.5 mA. See *chapter Ground Leakage Current* for details.
> - A dedicated ground wire is required for input power, motor power, and control wiring.
> - Use the clamps provided with the equipment for proper ground connections.
> - Do not ground 1 drive to another in a "daisy chain" fashion (see Figure 3).
> - Keep the ground wire connections as short as possible.
> - Use high-strand wire to reduce electrical noise.
> - Follow motor manufacturer wiring requirements.
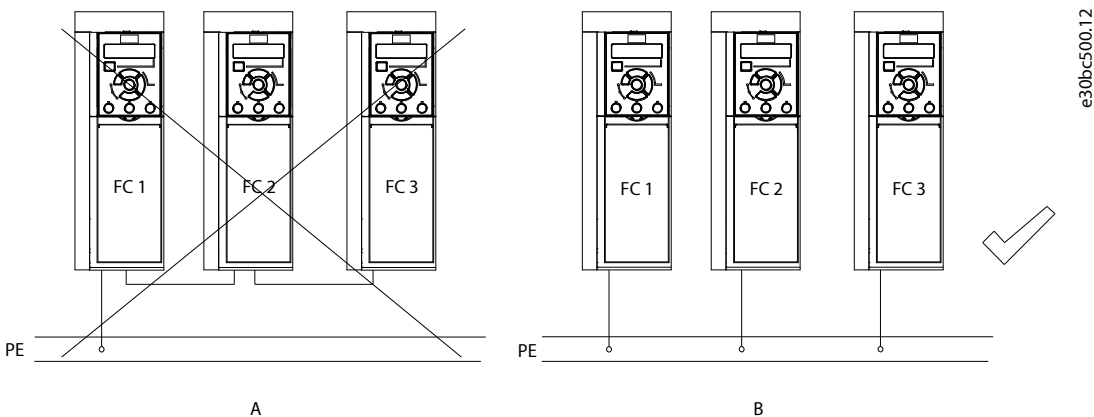


**Figure 3: Grounding Principle**

## 3.2.5 Mains, Motor, and Ground Connections

### 3.2.5.1 Considerations for Connection

> **⚠ 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.

- Do not install power factor correction capacitors between the drive and the motor.
- Do not wire a starting or pole-changing device between the drive and the motor.
- Follow motor manufacturer wiring requirements.
- All drives must be used with an isolated input source and with ground reference power lines. When supplied from an isolated mains source (IT mains or floating delta) or TT/TN-S mains with a grounded leg (grounded delta), set *parameter 14-50 RFI Filter* to

OFF (enclosure sizes J6–J7) or remove the RFI screw (enclosure sizes J1–J5). When off, the internal RFI filter capacitors between the chassis and the DC link are isolated to avoid damage to the DC link and reduce ground capacity currents in accordance with IEC 61800-3.

● Do not install a switch between the drive and the motor in IT mains.

### 3.2.5.2  Examples

Figure 4 and Figure 5 show mains input, motor, and grounding for enclosure sizes J1–J5 and enclosure sizes J6–J7. Actual configurations vary with unit types and optional equipment.

For enclosure sizes J1–J5, grounding clamps are provided for motor wiring.
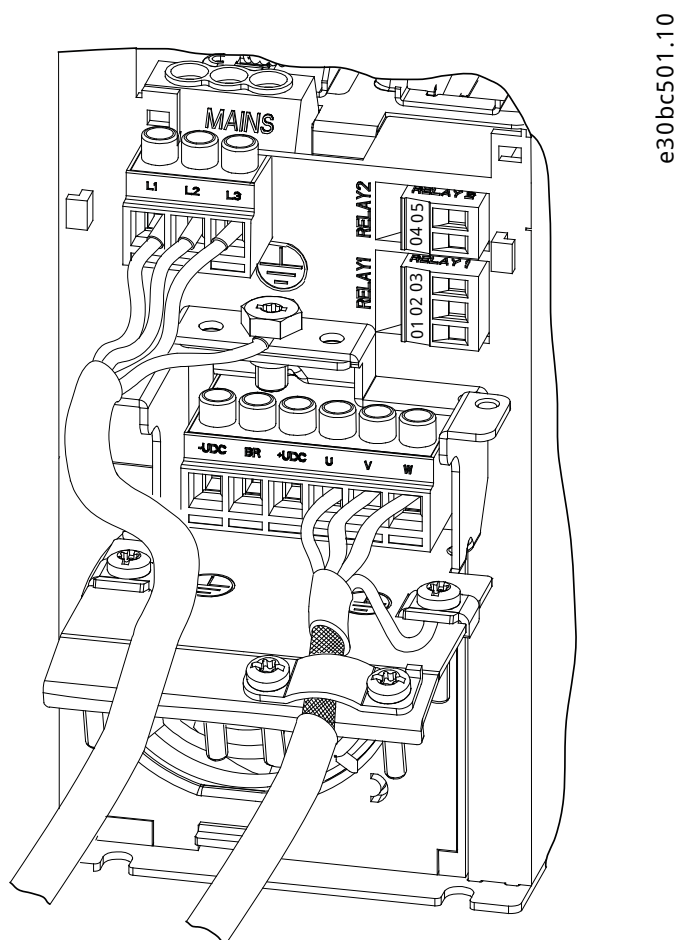


**Figure 4:  Mains, Motor, and Ground Connections for Enclosure Sizes J1–J5 (Taking J2 as an Example)**
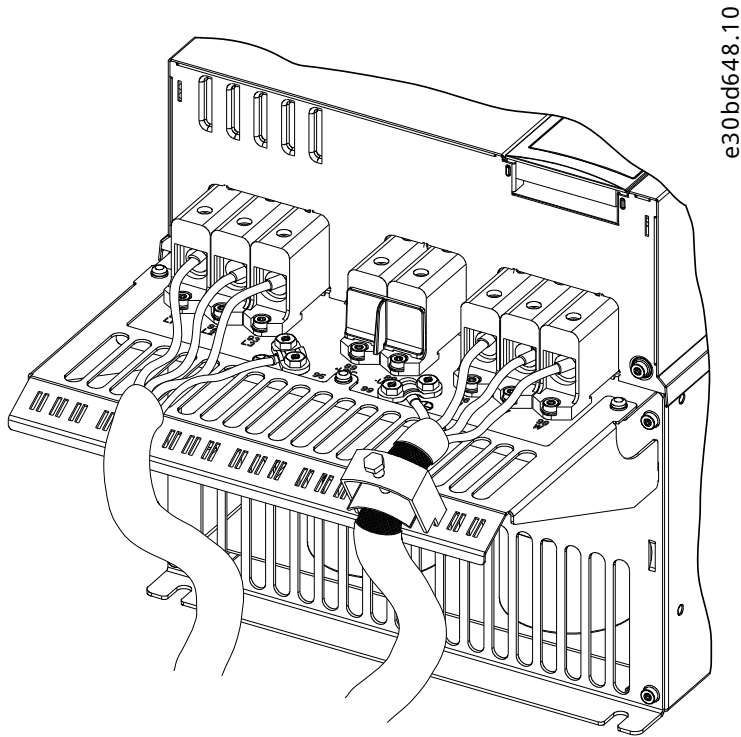
**Figure 5:  Mains, Motor, and Ground Connections for Enclosure Sizes J6–J7 (Taking J7 as an Example)**

## 3.2.6  Control Wiring

### 3.2.6.1  Control Wiring Access

- Remove the cover plate with a screwdriver. See the Figure 6.
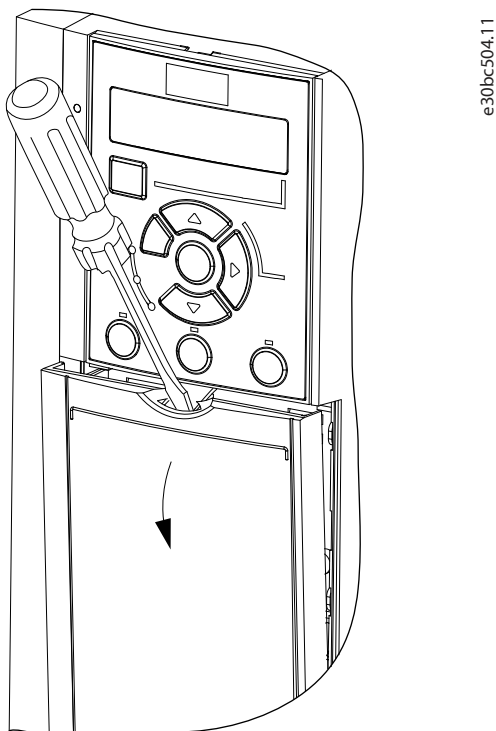


**Figure 6:  Control Wiring Access for Enclosure Sizes J1–J7**

### 3.2.6.2  **Control Terminal Types**
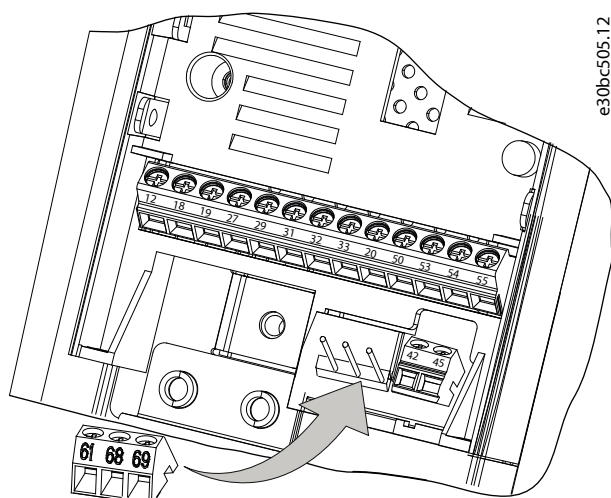


**Figure 7:  Control Terminal Locations**

**Table 4: Terminal Descriptions**

| Terminal | Parameter | Default setting | Description |
|---|---|---|---|
| **Digital I/O, pulse I/O, encoder** | | | |
| 12 | – | +24 V DC | 24 V DC supply voltage. Maximum output current is 100 mA for all 24 V loads. |
| 18 | *Parameter 5-10 Terminal 18 Digital Input* | *[8] Start* | Digital inputs. |
| 19 | *Parameter 5-11 Terminal 19 Digital Input* | *[10] Reversing* | |
| 31 | *Parameter 5-16 Terminal 31 Digital Input* | *[0] No operation* | Digital input. |
| 32 | *Parameter 5-14 Terminal 32 Digital Input* | *[0] No operation* | Digital input, 24 V encoder. Terminal 33 can be used for pulse input. |
| 33 | *Parameter 5-15 Terminal 33 Digital Input* | *[0] No operation* | |
| 27 | *Parameter 5-12 Terminal 27 Digital Input*<br>*Parameter 5-30 Terminal 27 Digital Output* | DI *[2] Coast inverse*<br>DO *[0] No operation* | Selectable for either digital input, digital output, or pulse output. Default setting is digital input. Terminal 29 can be used for pulse input. |
| 29 | *Parameter 5-13 Terminal 29 Digital Input*<br>*Parameter 5-31 Terminal 29 Digital Output* | DI *[14] Jog*<br>DO *[0] No operation* | |
| 20 | – | – | Common for digital inputs and 0 V potential for 24 V supply. |
| **Analog inputs/outputs** | | | |
| 42 | *Parameter 6-91 Terminal 42 Analog Output* | *[0] No operation* | Programmable analog output. The analog signal is 0–20 mA or 4–20 mA at a maximum of 500 Ω. Can also be configured as digital outputs. |
| 45 | *Parameter 6-71 Terminal 45 Analog Output* | *[0] No operation* | |
| 50 | – | +10 V DC | 10 V DC analog supply voltage. 15 mA maximum commonly used for potentiometer or thermistor. |

**Table 4: Terminal Descriptions** (continued)

| Terminal | Parameter | Default setting | Description |
|---|---|---|---|
| 53 | *Parameter group 6-1\* Analog Input 53* | – | Analog input. Selectable for voltage or current. |
| 54 | *Parameter group 6-2\* Analog Input 54* | – | |
| 55 | – | – | Common for analog input. |
| **Serial communication** | | | |
| 61 | – | – | Integrated RC filter for cable shield. ONLY for connecting the shield when experiencing EMC problems. |
| 68 (+) | *Parameter group 8-3\* FC Port Settings* | – | RS485 interface. A control card switch is provided for termination resistance. |
| 69 (-) | *Parameter group 8-3\* FC Port Settings* | – | |
| **Relays** | | | |
| 01, 02, 03 | *Parameter 5-40 Function Relay* [0] | *[0] No operation* | Form C relay output. These relays are in various locations depending on the drive configuration and size. Usable for AC or DC voltage and resistive or inductive loads. RO2 in J1–J3 enclosure is 2-pole, only terminals 04 and 05 are available. |
| 04, 05, 06 | *Parameter 5-40 Function Relay* [1] | *[0] No operation* | |

### 3.2.6.3 Control Terminal Functions

Drive functions are commanded by receiving control input signals.

- Program each terminal for the function it supports in the parameters associated with that terminal.
- Confirm that the control terminal is programmed for the correct function. See *chapter Programming* in the programming guide for details on accessing parameters and programming.
- The default terminal programming initiates drive functioning in a typical operational mode.

### 3.2.6.4 Shielded Control Cables

The preferred method is to secure control and serial communication cables with shielding clamps provided at both ends to ensure the best possible high frequency cable contact.

If the ground potential between the drive and the PLC is different, electric noise could disturb the entire system. Solve this problem by fitting an equalizing cable as close as possible to the control cable. Minimum cable cross-section: 16 mm$^2$ (6 AWG).
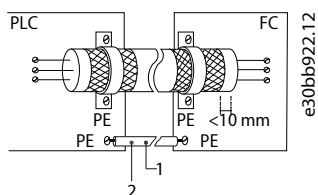


**Figure 8:  Shielding Clamps at Both Ends**

| | | | |
|---|---|---|---|
| **1** | Minimum 16 mm$^2$ (6 AWG) | **2** | Equalizing cable |

3.2.6.5 **50/60 Hz Ground Loops**

With long control cables, ground loops may occur. To eliminate ground loops, connect 1 end of the shield to the ground with a 100 nF capacitor (keeping leads short).
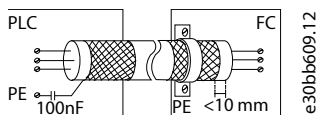


**Figure 9: Connection with a 100 nF Capacitor**

3.2.6.6 **Avoid EMC Noise on Serial Communication**

This terminal is connected to ground via an internal RC link. Use twisted-pair cables to reduce interference between conductors. The recommended method is shown in Figure 10.
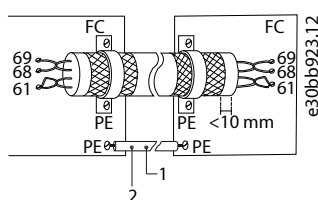


**Figure 10: Twisted-pair Cables**

| 1 | Minimum 16 mm$^2$ (6 AWG) | 2 | Equalizing cable |
|---|---|---|---|

Alternatively, the connection to terminal 61 can be omitted as shown in Figure 11.
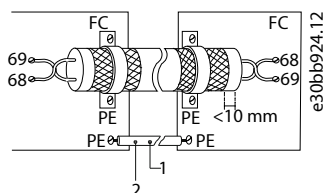


**Figure 11: Twisted-pair Cables without Terminal 61**

| 1 | Minimum 16 mm$^2$ (6 AWG) | 2 | Equalizing cable |
|---|---|---|---|

## 3.3 Control Structures

### 3.3.1 Control Principle

A drive rectifies AC voltage from mains into DC voltage. Then the DC voltage is converted into an AC current with a variable amplitude and frequency.

The motor is supplied with variable voltage/current and frequency, enabling variable speed control of 3-phased standard AC motors and permanent magnet synchronous motors.

### 3.3.2 Control Modes

The drive is capable of controlling either the speed or the torque on the motor shaft. Setting *parameter 1-00 Configuration Mode* determines the type of control.

**Speed control**

There are 2 types of speed control:

- Speed open-loop control, which does not require any feedback from the motor (sensorless).
- Speed closed-loop PID control, which requires a speed feedback to an input. A properly optimized speed closed-loop control has higher accuracy than a speed open-loop control.

Select which input to use as speed PID feedback in **parameter 7-00 Speed PID Feedback Source**.

**Torque control**

The torque control function is used in applications where the torque on the motor output shaft is controlling the application as tension control. The best performance is with flux basic closed loop, especially near 0 speed. Torque control can be selected in **parameter 1-00 Configuration Mode**. Torque setting is done by setting an analog, digital, or bus controlled reference. When running torque control, it is recommended to run a full AMA procedure, because correct motor data is important in achieving optimal performance.

- Closed loop. This function is used in applications with low to medium dynamic variation of shaft, and offers excellent performance in all 4 quadrants and at all motor speeds. The speed feedback signal is mandatory. Ensure that the encoder resolution is at least 1024 PPR, and the shield cable of the encoder is well grounded, because the accuracy of the speed feedback signal is important. Tune **parameter 7-06 Speed PID Lowpass Filter Time** to get the best speed feedback signal.
- Open loop. The function is used in mechanically robust applications, but the accuracy is limited. The open-loop torque function works for 2 directions. The torque is calculated based on the internal current measurement in the drive.

**Speed/torque reference**

The reference to these controls can be either a single reference or the sum of various references including relatively scaled references. Handling of reference is explained in detail in the *chapter Reference Handling*.

### 3.3.3  FC 360 Control Principle

VLT® AutomationDrive FC 360 is a general-purpose drive for variable speed applications. The control principle is based on Voltage Vector Control+ (VVC+) and Flux basic.

**0.37–22 kW (0.5–30 hp)**

FC 360 0.37–22 kW (0.5–30 hp) drives can handle induction motors and permanent magnet synchronous motors up to 22 kW (30 hp).

The current-sensing principle in FC 360 0.37–22 kW (0.5–30 hp) drives is based on the current measurement by a resistor in the DC link. The ground fault protection and short circuit behavior are handled by the same resistor.
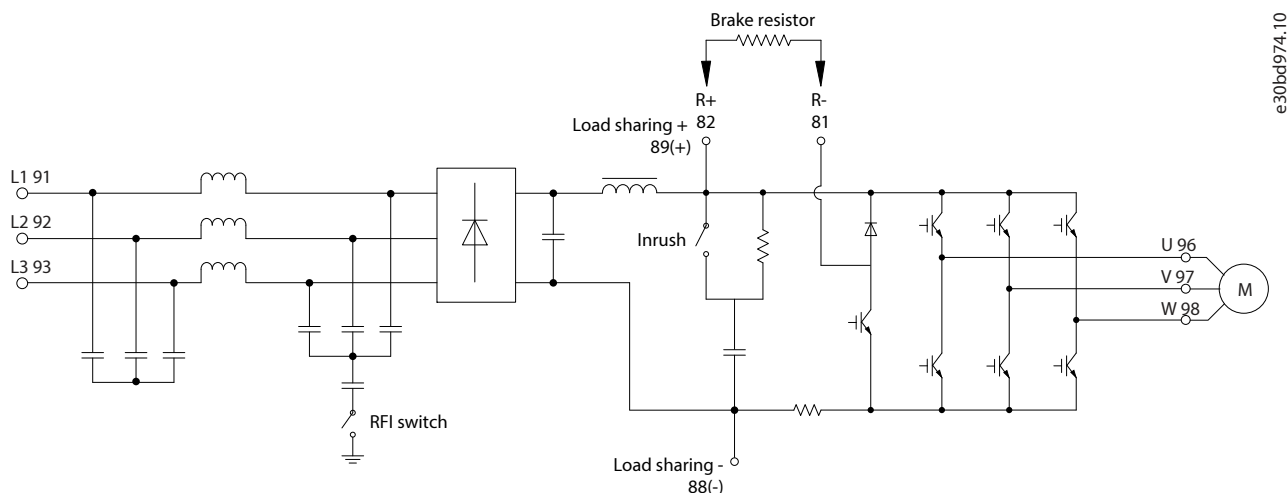


Figure 12:  Control Diagram for FC 360 0.37–22 kW (0.5–30 hp)

## 30–90 kW (40–125 hp)

The current-sensing principle in FC 360 30–90 kW (40–125 hp) drives is based on the current measurement in the motor phases.

The ground fault protection and short-circuit behavior on FC 360 30–90 kW (40–125 hp) drives are handled by the 3 current transducers in the motor phases.
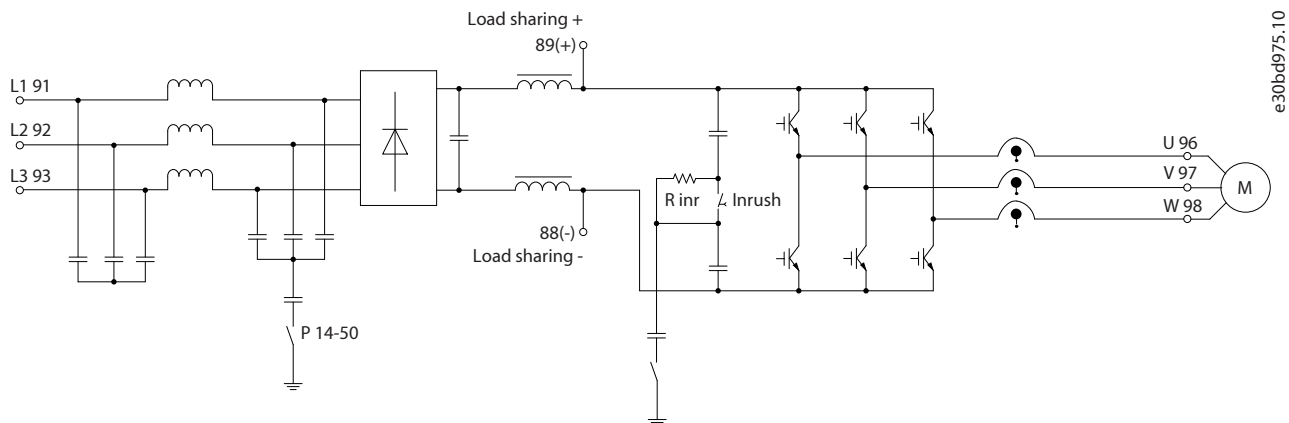


**Figure 13:  Control Diagram for FC 360 30–90 kW (40–125 hp)**

## 3.3.4  Control Structure in VVC+
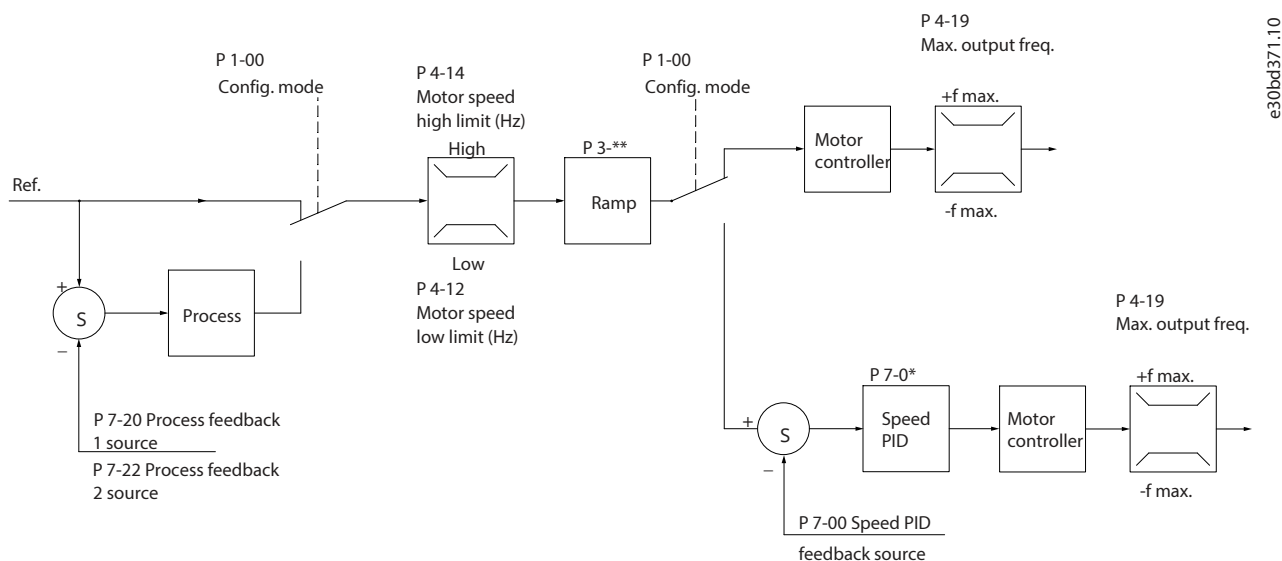


**Figure 14:  Control Structure in VVC+ Open-loop Configurations and Closed-loop Configurations**

In the configuration shown in Figure 14, *parameter 1-01 Motor Control Principle* is set to *[1] VVC+* and *parameter 1-00 Configuration Mode* is set to *[0] Speed open loop*. The resulting reference from the reference handling system is received and fed through the ramp limitation and speed limitation before being sent to the motor control. The output of the motor control is then limited by the maximum frequency limit.

If *parameter 1-00 Configuration Mode* is set to *[1] Speed closed loop*, the resulting reference is passed from the ramp limitation and speed limitation into a speed PID control. The speed PID control parameters are in *parameter group 7-0* Speed PID Ctrl*. The resulting reference from the speed PID control is sent to the motor control limited by the frequency limit.

Select *[3] Process* in *parameter 1-00 Configuration Mode* to use the process PID control for closed-loop control of speed or pressure in the controlled application. The process PID parameters are in *parameter groups 7-2* Process Ctrl. Feedb* and *parameter groups 7-3* Process PID Ctrl.*

### 3.3.5 Control Structure in Flux Basic with Motor Feedback
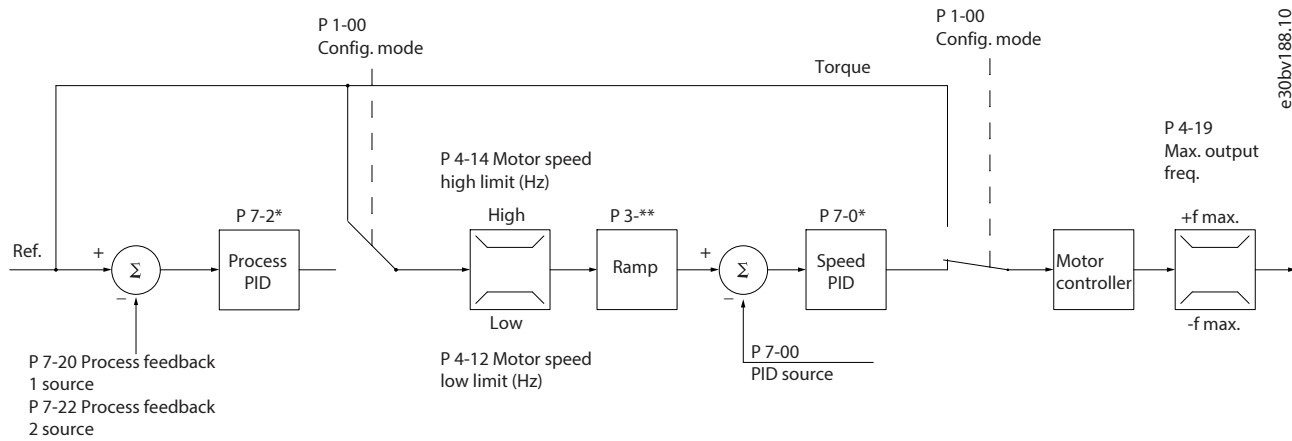


**Figure 15: Control Structure in Flux Basic with Motor Feedback**

In the configuration shown, *parameter 1-01 Motor Control Principle* is set to *[3] Flux Basic w/ motor feedb* and *parameter 1-00 Configuration Mode* is set to *[1] Speed closed loop*.

Select *[1] Speed closed loop* in *parameter 1-00 Configuration Mode* to use the resulting reference as an input for the speed PID control. The speed PID control parameters are in *parameter group 7-0* Speed PID Ctrl*.

Select *[2] Torque* in *parameter 1-00 Configuration Mode* to use the resulting reference directly as a torque reference. Torque control can only be selected in the flux basic with motor feedback (*parameter 1-01 Motor Control Principle*) configuration. When this mode has been selected, the reference uses the Nm unit. It requires no torque feedback, since the actual torque is calculated based on the current measurement of the drive.

Select *[3] Process* in *parameter 1-00 Configuration Mode* to use the process PID control for closed-loop control of a process variable (for example, speed) in the controlled application.

### 3.3.6 Local [Hand On] and Remote [Auto On] Control

Operate the drive manually via the local control panel (graphical LCP or numerical LCP) or remotely via analog/digital inputs or fieldbus.

Start and stop the drive by pressing the *[Hand On]* and *[Off/Reset]* keys on the LCP. Setup is required via the following parameters:

- *Parameter 0-40 [Hand on] Key on LCP*.
- *Parameter 0-44 [Off/Reset] Key on LCP*.
- *Parameter 0-42 [Auto on] Key on LCP*.

Reset alarms via the *[Off/Reset]* key or via a digital input, when the terminal is programmed to *Reset*.
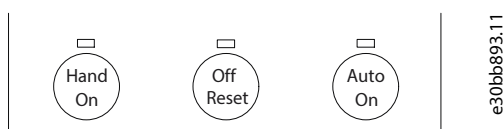


**Figure 16: LCP Control Keys**

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

Local reference is restored when the drive powers down.

## 3.4 Reference Handling

### 3.4.1 Local and Remote Reference

**Local reference**

The local reference is active when the drive is operated with *[Hand On]* active. Adjust the reference via the *Up* key, *Down* key, *Right* key and the *[Back]* key.

**Remote reference**

The reference handling system for calculating the remote reference is shown in the Figure 17.
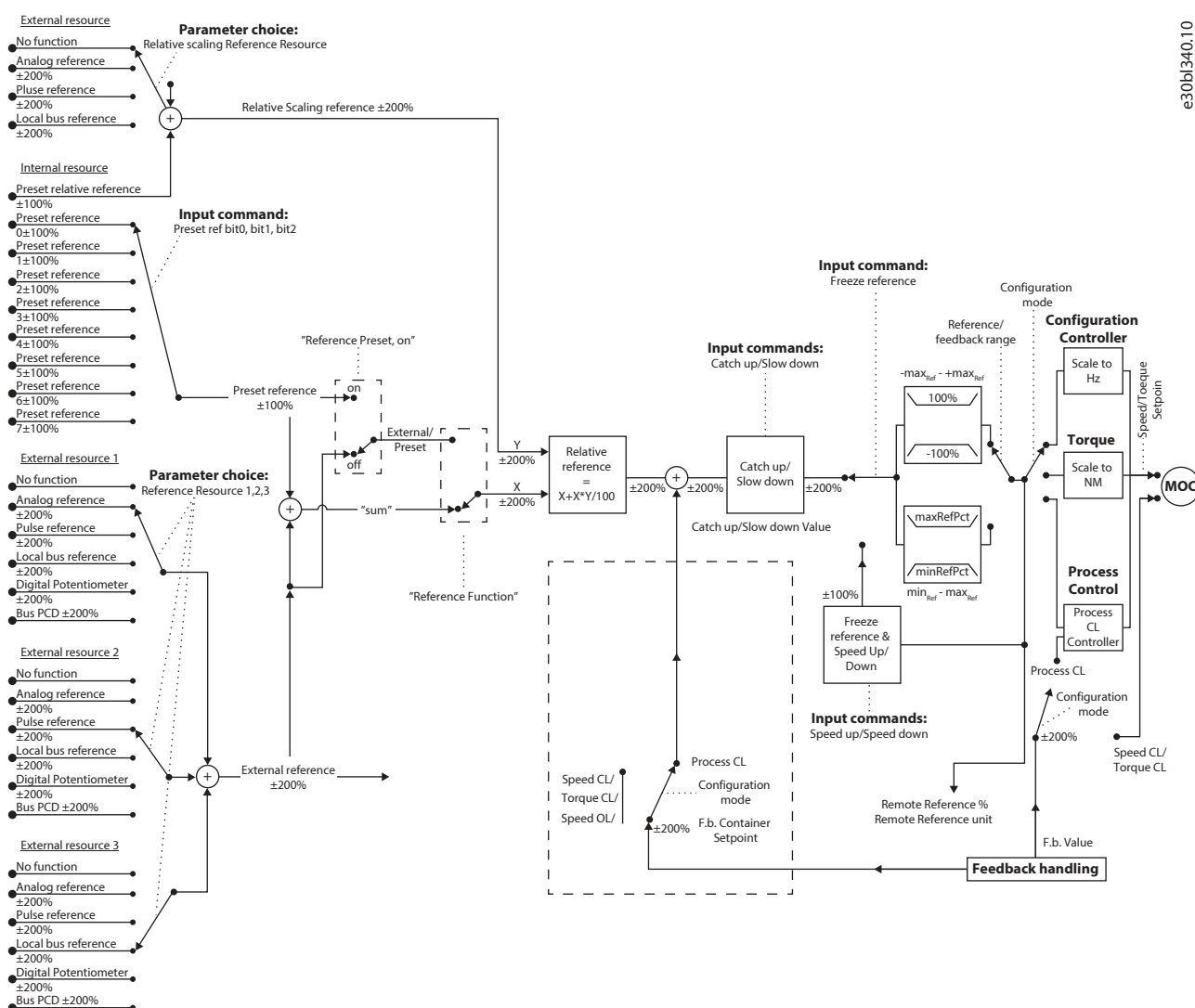


**Figure 17:  Remote Reference**

**The remote reference is calculated once in every scan interval and initially consists of 2 types of reference inputs:**

1. X (the external reference): A sum (see *parameter 3-04 Reference Function*) of up to 4 externally selected references, comprising any combination (determined by the setting in *parameter 3-15 Reference 1 Source*, *parameter 3-16 Reference 2 Source*, and *parameter 3-17 Reference 3 Source*) of a fixed preset reference (*parameter 3-10 Preset Reference*), variable analog references, variable digital pulse references, and various fieldbus references in any unit the drive is monitoring ([Hz], [RPM], [Nm], and so on).

2. Y (the relative reference): A sum of 1 fixed preset reference (*parameter 3-14 Preset Relative Reference*) and 1 variable analog reference (*parameter 3-18 Relative Scaling Reference Resource*) in [%].

The 2 types of reference inputs are combined in the following formula:

Remote reference=X+X*Y/100%.

If relative reference is not used, set *parameter 3-18 Relative Scaling Reference Resource* to *[0] No function* and *parameter 3-14 Preset Relative Reference* to 0%. The digital inputs on the drive can activate both the catch up/slow down function and the freeze reference function. The functions and parameters are described in the programming guide.

The scaling of analog references is described in *parameter group 6-1* Analog Input 53* and *parameter group 6-2* Analog Input 54*, and the scaling of digital pulse references is described in *parameter group 5-5* Pulse Input*.

Reference limits and ranges are set in *parameter group 3-0* Reference Limits*.

## 3.4.2  Reference Limits

*Parameter 3-00 Reference Range*, *parameter 3-02 Minimum Reference*, and *parameter 3-03 Maximum Reference* define the allowed range of the sum of all references. The sum of all references is clamped when necessary. The relation between the resulting reference (after clamping) and the sum of all references are shown in the following figures.
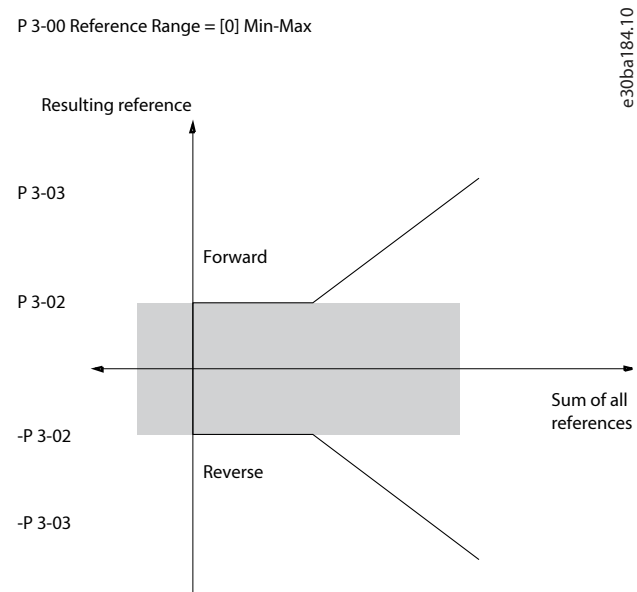


**Figure 18:  Sum of All References When Reference Range is Set to 0**
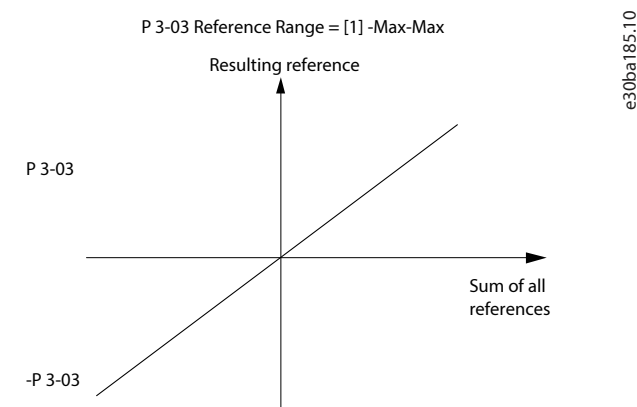


**Figure 19:  Sum of All References When Reference Range is Set to 1**

The value of *parameter 3-02 Minimum Reference* cannot be set to less than 0, unless *parameter 1-00 Configuration Mode* is set to *[3] Process Closed Loop*. In that case, the following relations between the resulting reference (after clamping) and the sum of all references are as shown in Figure 20.
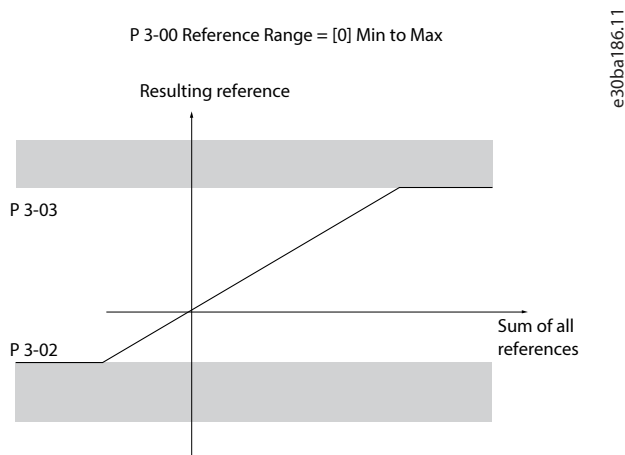


**Figure 20: Sum of All References When Minimum Range is Set to a Minus Value**

### 3.4.3 Scaling of Preset References and Bus References

**Preset references are scaled according to the following rules:**

- When *parameter 3-00 Reference Range* is set to *[0] Min–Max*, 0% reference equals 0 [unit] where unit can be any unit, for example RPM, m/s, and bar. 100% reference equals the maximum (absolute value of *parameter 3-03 Maximum Reference*, absolute value of *parameter 3-02 Minimum Reference*).
- When *parameter 3-00 Reference Range* is set to *[1] -Max–+Max*, 0% reference equals 0 [unit], and 100% reference equals maximum reference.

**Bus references are scaled according to the following rules:**

- When *parameter 3-00 Reference Range* is set to *[0] Min–Max*, 0% reference equals minimum reference, and 100% reference equals maximum reference.
- When *parameter 3-00 Reference Range* is set to *[1] -Max–+Max*, -100% reference equals -maximum reference, and 100% reference equals maximum reference.

### 3.4.4 Scaling of Analog and Pulse References and Feedback

References and feedback are scaled from analog and pulse inputs in the same way. The only difference is that a reference above or below the specified minimum and maximum endpoints (P1 and P2 in Figure 21) are clamped while a feedback above or below is not.
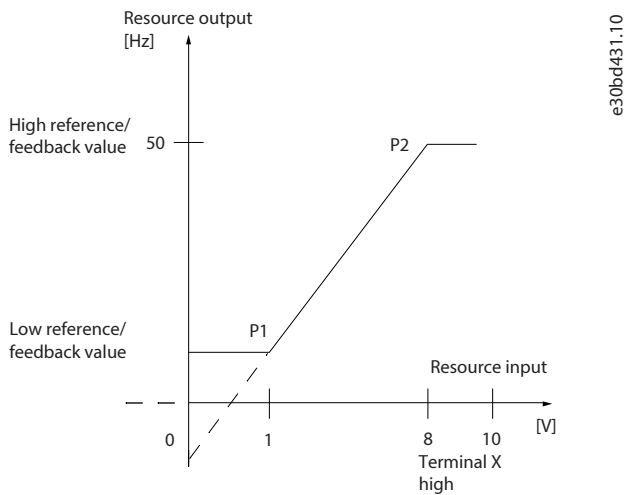
**Figure 21: Minimum and Maximum Endpoints**

The endpoints P1 and P2 are defined in the following table depending on choice of input.

**Table 5: P1 and P2 Endpoints**

| Input | Analog 53 voltage mode | Analog 53 current mode | Analog 54 voltage mode | Analog 54 current mode | Pulse input 29 | Pulse input 33 |
|---|---|---|---|---|---|---|
| P1=(Minimum input value, minimum reference value) | | | | | | |
| Minimum reference value | *Parameter 6-14 Terminal 53 Low Ref./Feedb. Value* | *Parameter 6-14 Terminal 53 Low Ref./Feedb. Value* | *Parameter 6-24 Terminal 54 Low Ref./Feedb. Value* | *Parameter 6-24 Terminal 54 Low Ref./Feedb. Value* | *Parameter 5-52 Term. 29 Low Ref./Feedb. Value* | *Parameter 5-57 Terminal 33 Low Ref./Feedb. Value* |
| Minimum input value | *Parameter 6-10 Terminal 53 Low Voltage [V]* | *Parameter 6-12 Terminal 53 Low Current [mA]* | *Parameter 6-20 Terminal 54 Low Voltage [V]* | *Parameter 6-22 Terminal 54 Low Current [mA]* | *Parameter 5-50 Terminal 29 Low Frequency [Hz]* | *Parameter 5-55 Terminal 33 Low Frequency [Hz]* |
| P2=(Maximum input value, maximum reference value) | | | | | | |
| Maximum reference value | *Parameter 6-15 Terminal 53 High Ref./Feedb. Value* | *Parameter 6-15 Terminal 53 High Ref./Feedb. Value* | *Parameter 6-25 Terminal 54 High Ref./Feedb. Value* | *Parameter 6-25 Terminal 54 High Ref./Feedb. Value* | *Parameter 5-53 Term. 29 High Ref./Feedb. Value* | *Parameter 5-58 Terminal 33 High Ref./Feedb. Value* |
| Maximum input value | *Parameter 6-11 Terminal 53 High Voltage [V]* | *Parameter 6-13 Terminal 53 High Current [mA]* | *Parameter 6-21 Terminal 54 High Voltage [V]* | *Parameter 6-23 Terminal 54 High Current [mA]* | *Parameter 5-51 Terminal 29 High Frequency [Hz]* | *Parameter 5-56 Terminal 33 High Frequency [Hz]* |

## 3.4.5 **Dead Band Around Zero**

Sometimes, the reference (in rare cases also the feedback) should have a dead band around 0 to ensure that the machine is stopped when the reference is near 0.

To make the dead band active and to set the amount of dead band, do the following:

● Set either the minimum reference value or maximum reference value at 0. In other words, either P1 or P2 must be on the X-axis in Figure 22.

- Ensure that both points defining the scaling graph are in the same quadrant.

P1 or P2 defines the size of the dead band as shown in Figure 22.
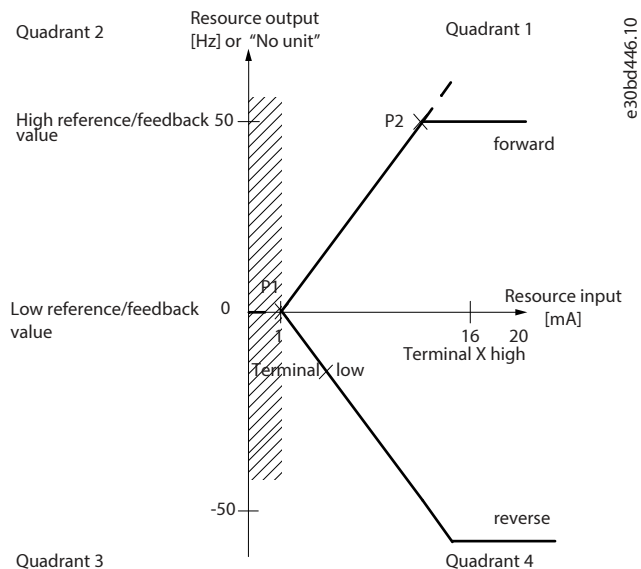


**Figure 22: Size of Dead Band**

## Case 1: Positive reference with dead band, digital input to trigger reverse, part I

Figure 23 shows how reference input with limits inside minimum to maximum limits clamps.
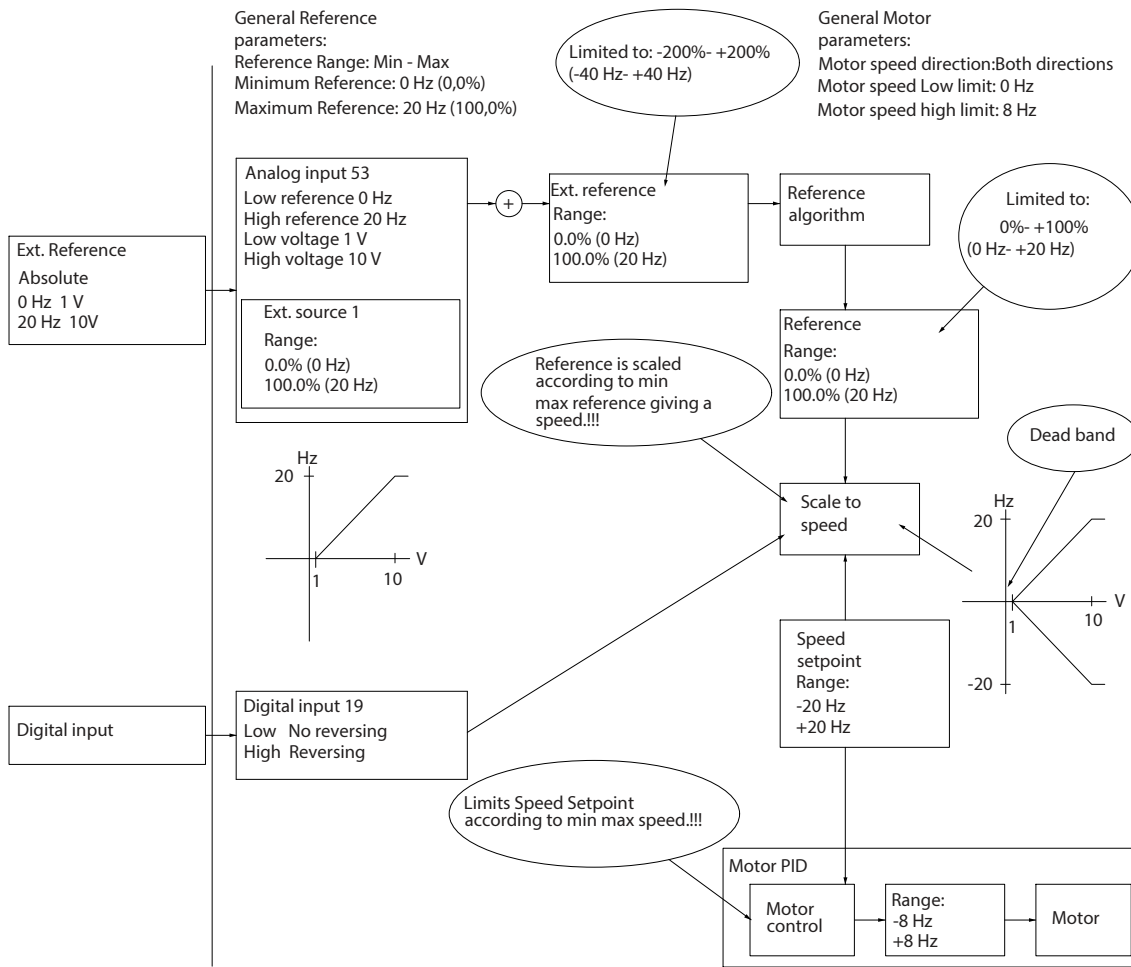
**Figure 23:** Clamping of Reference Input with Limits inside Minimum to Maximum

## Case 2: Positive reference with dead band, digital input to trigger reverse, part II

Figure 24 shows how reference input with limits outside -maximum to +maximum limits clamps to the input low and high limits before adding to external reference, and how the external reference is clamped to -maximum to +maximum by the reference algorithm.
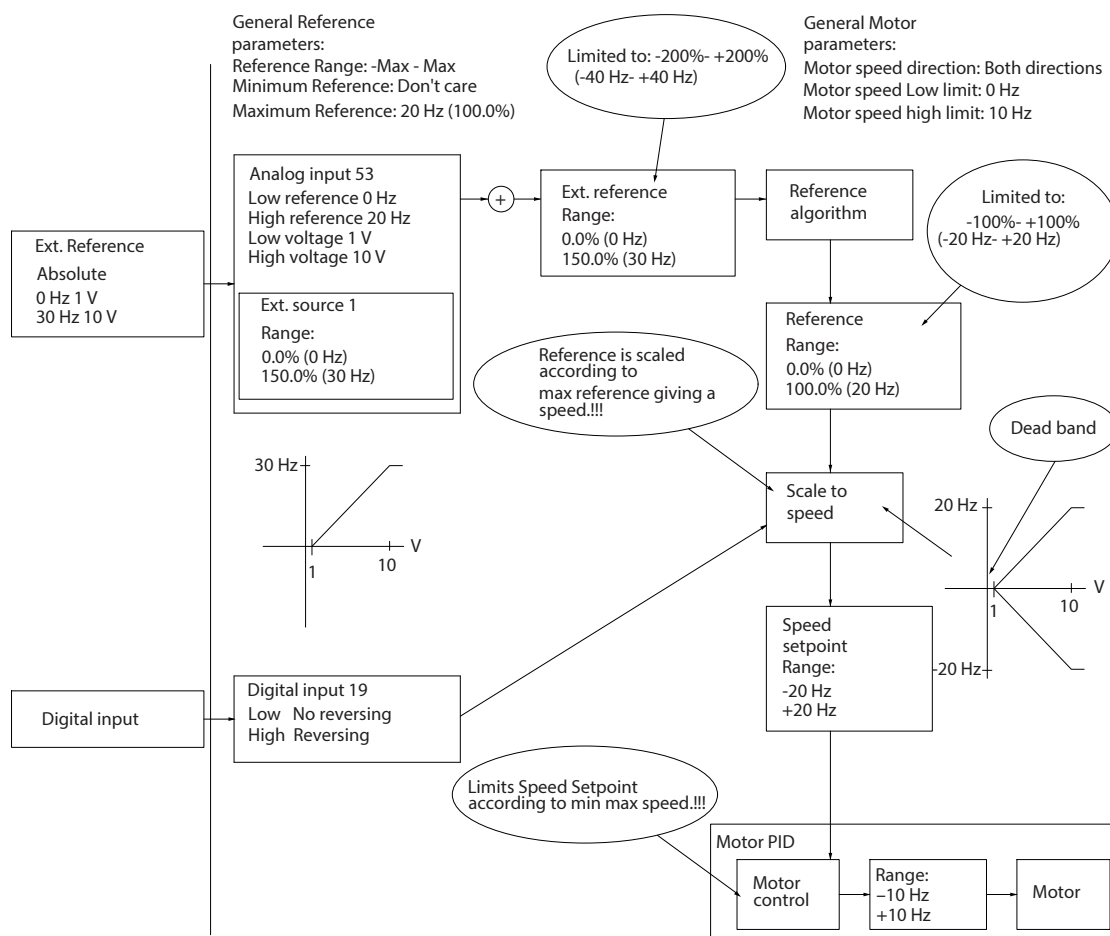
**Figure 24: Clamping of Reference Input with Limits outside -Maximum to +Maximum**

## 3.5 **Position Control**

In positioning and synchronization mode, the position PI controller is added as an outer loop providing the speed reference for the speed PID.

shows the control structure and parameters affecting the control behavior with flux basic motor control.
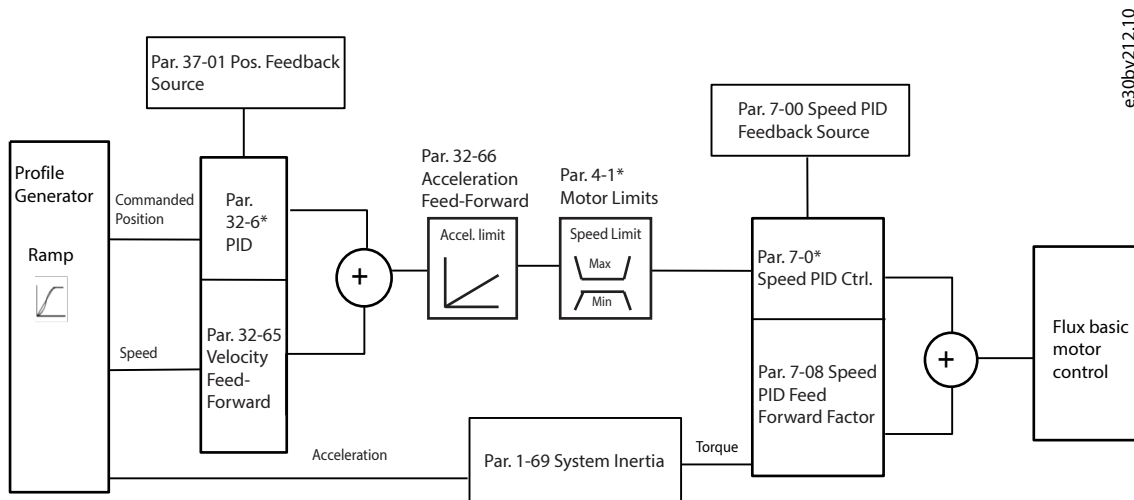
e30bv212.10

**Figure 25: Position Control**

## 3.6 PID Control

### 3.6.1 Speed PID Control

#### 3.6.1.1 Control Configurations

**Table 6: Control Configurations, Active Speed Control**

| Parameter 1-00 Configuration Mode | Parameter 1-01 Motor Control Principle | | |
|---|---|---|---|
| | U/f | VVC+ | Flux basic |
| [0] Open Loop | Only available for IM motor | Available | Available |
| [1] Speed Closed Loop | Not available | Only available for IM motor | Available |
| [2] Torque Closed Loop | Not available | Only available for IM motor | Available |
| [3] Process Closed Loop | Only available for IM motor | Available | Available |
| [4] Torque Open Loop | Not available | Available | Available |

#### 3.6.1.2 Speed Control Parameters

**Table 7: Speed Control Parameters**

| Parameter | Description of function |
|---|---|
| Parameter 7-00 Speed PID Feedback Source | Select from which input the speed PID gets its feedback. |
| Parameter 7-02 Speed PID Proportional Gain | The higher the value, the quicker the control. However, too high a value may lead to oscillations. |
| Parameter 7-03 Speed PID Integral Time | Eliminates steady state speed error. Lower values mean quicker reaction. However, too low a value may lead to oscillations. |

**Table 7: Speed Control Parameters** (continued)

| Parameter | Description of function |
|---|---|
| *Parameter 7-04 Speed PID Differentiation Time* | Provides a gain proportional to the rate of change of the feedback. A setting of 0 disables the differentiator. |
| *Parameter 7-05 Speed PID Diff. Gain Limit* | If there are quick changes in reference or feedback in a given application, which means that the error changes swiftly, the differentiator may soon become too dominant. This is because it reacts to changes in the error. The quicker the error changes, the stronger the differentiator gain is. The differentiator gain can thus be limited to allow setting of the reasonable differentiation time for slow changes and a suitably quick gain for quick changes. |
| *Parameter 7-06 Speed PID Lowpass Filter Time* | A low-pass filter that dampens oscillations on the feedback signal and improves steady state performance. However, too long a filter time deteriorates the dynamic performance of the speed PID control.<br><br>Practical settings of *parameter 7-06 Speed PID Lowpass Filter Time* taken from the number of pulses per revolution on from encoder (PPR): |

| Encoder PPR | *Parameter 7-06 Speed PID Lowpass Filter Time* |
|---|---|
| 512 | 10 ms |
| 1024 | 5 ms |
| 2048 | 2 ms |
| 4096 | 1 ms |

### 3.6.1.3 Example of Speed Control Programming

In this example, the speed PID control is used to maintain a constant motor speed regardless of the changing load on the motor. The required motor speed is set via a potentiometer connected to terminal 53. The speed range is 0–1500 RPM corresponding to 0–10 V over the potentiometer. A switch connected to terminal 18 controls starting and stopping. The speed PID monitors the actual RPM of the motor by using a 24 V (HTL) incremental encoder as feedback. The feedback sensor is an encoder (1024 pulses per revolution) connected to terminals 32 and 33. The pulse frequency range to terminals 32 and 33 is 4 Hz–32 kHz.
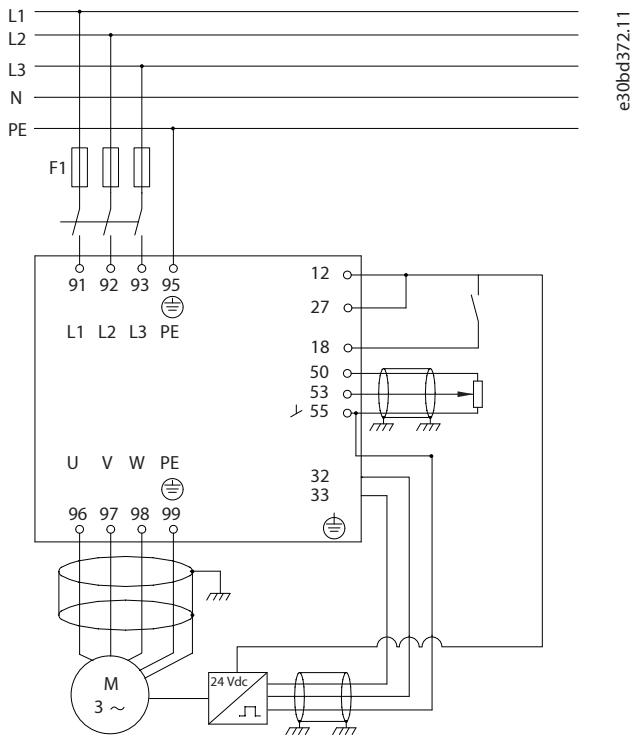
**Figure 26: Speed Control Programming**

## 3.6.1.4 Programming Order for Speed PID Control

Follow the steps in the following table to program the speed control (see explanation of settings in the programming guide).

In the following table, it is assumed that all other parameters and switches remain at their default setting.

**Table 8: Programming Order for Speed PID Control**

| Function | Parameter number | Setting |
|---|---|---|
| 1) Make sure that the motor runs properly. Do the following: | | |
| Set the motor parameters using the data on the nameplate. | *Parameter group 1-2* Motor Data* | As specified by motor nameplate. |
| Perform an AMA. | *Parameter 1-29 Automatic Motor Adaption (AMA)* | *[1] Enable complete AMA* |
| 2) Check that the motor is running and that the encoder is attached properly. Do the following: | | |
| Press *[Hand On]*. Check that the motor is running and note the rotation direction (referred to as the positive direction). | – | Set a positive reference. |
| 3) Make sure that the drive limits are set to safe values: | | |
| Set acceptable limits for the references. | *Parameter 3-02 Minimum Reference* | 0 |
| | *Parameter 3-03 Maximum Reference* | 50 |
| Check that the ramp settings are within the drive capabilities and allowed application operating specifications. | *Parameter 3-41 Ramp 1 Ramp Up Time* | Default setting |
| | *Parameter 3-42 Ramp 1 Ramp Down Time* | Default setting |

**Table 8: Programming Order for Speed PID Control** (continued)

| Function | Parameter number | Setting |
|---|---|---|
| Set acceptable limits for the motor speed and frequency. | *Parameter 4-12 Motor Speed Low Limit [Hz]* | 0 Hz |
| | *Parameter 4-14 Motor Speed High Limit [Hz]* | 50 Hz |
| | *Parameter 4-19 Max Output Frequency* | 60 Hz |
| 4) Configure the speed control and select the motor control principle: | | |
| Activation of speed control | *Parameter 1-00 Configuration Mode* | *[1] Speed closed loop* |
| Selection of motor control principle | *Parameter 1-01 Motor Control Principle* | *[1] VVC+* |
| 5) Configure and scale the reference to the speed control: | | |
| Set up analog input 53 as a reference source. | *Parameter 3-15 Reference 1 Source* | Not necessary (default) |
| Scale analog input 53 0 Hz (0 V) to 50 Hz (10 V) | *Parameter group 6-1* Analog Input 1* | Not necessary (default) |
| 6) Configure the 24 V HTL encoder signal as feedback for the motor control and the speed control: | | |
| Set up digital input 32 and 33 as encoder inputs. | *Parameter 5-14 Terminal 32 Digital Input* | *[82] Encoder input B* |
| | *Parameter 5-15 Terminal 33 Digital Input* | *[83] Encoder input A* |
| Select terminal 32/33 as speed PID feedback. | *Parameter 7-00 Speed PID Feedback Source* | *[1] 24 V Encoder* |
| 7) Tune the speed control PID parameters: | | |
| Use the tuning guidelines when relevant or tune manually. | *Parameter group 7-0* Speed PID Ctrl.* | – |
| 8) Finish: | | |
| Save the parameter setting to the LCP for safe-keeping. | *Parameter 0-50 LCP Copy* | *[1] All to LCP* |

### 3.6.2 Process PID Control

#### 3.6.2.1 Control Configuration

The process PID control can be used to control application parameters that can be measured by a sensor (for example pressure, temperature, flow) and affected by the connected motor through a pump, fan, or other connected devices.

The following table shows the control configurations in which the process control is possible. Refer to *chapter Control Structures* to see where the speed control is active.

**Table 9: Control Configuration**

| Control Configuration | *Parameter 1-01 Motor Control Principle* | |
|---|---|---|
| | U/f | VVC+ |
| [3] Process | Not available | Process |

| NOTICE |
|---|
| The process control PID works under the default parameter setting, but tuning the parameters is recommended to optimize the application control performance. |
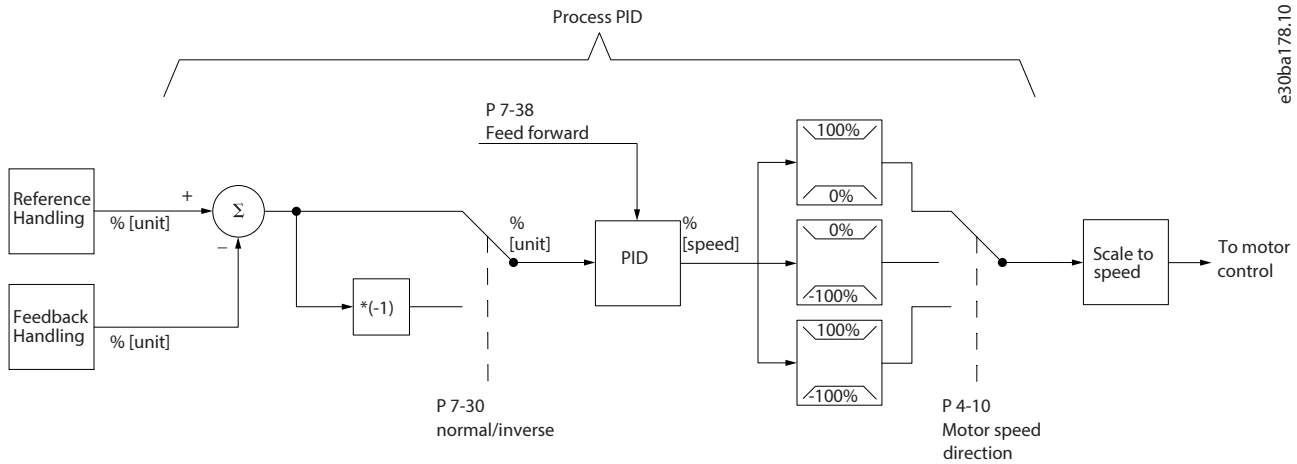


**Figure 27: Process PID Control Diagram**

### 3.6.2.2 Process Control Relevant Parameters

**Table 10: Process Control Parameters**

| Parameter | Description of function |
|---|---|
| *Parameter 7-20 Process CL Feedback 1 Resource* | Select from which source (analog or pulse input) the process PID gets its feedback. |
| *Parameter 7-22 Process CL Feedback 2 Resource* | Optional: Determine if (and from where) the process PID gets an additional feedback signal. If an additional feedback source is selected, the 2 feedback signals are added before being used in the process PID control. |
| *Parameter 7-30 Process PID Normal/ Inverse Control* | Under *[0] Normal operation*, the process control responds with an increase of the motor speed if the feedback is lower than the reference. Under *[1] Inverse operation*, the process control responds with a decreasing motor speed instead. |
| *Parameter 7-31 Process PID Anti Windup* | The anti-windup function ensures that when either a frequency limit or a torque limit is reached, the integrator is set to a gain that corresponds to the actual frequency. This avoids integrating on an error that cannot be compensated for by a speed change. Press *[0] Off* to disable this function. |
| *Parameter 7-32 Process PID Start Speed* | In some applications, reaching the required speed/setpoint can take a long time. In such applications, it may be an advantage to set a fixed motor speed from the drive before the process control is activated. Set a fixed motor speed by setting a process PID start value (speed) in *parameter 7-32 Process PID Start Speed*. |
| *Parameter 7-33 Process PID Proportional Gain* | The higher the value, the quicker the control. However, too large a value may lead to oscillations. |
| *Parameter 7-34 Process PID Integral Time* | Eliminates steady state speed error. A lower value means a quicker reaction. However, too small a value may lead to oscillations. |

**Table 10: Process Control Parameters** (continued)

| Parameter | Description of function |
|---|---|
| *Parameter 7-35 Process PID Differentiation Time* | Provides a gain proportional to the rate of feedback change. A setting of 0 disables the differentiator. |
| *Parameter 7-36 Process PID Diff. Gain Limit* | If there are quick changes in reference or feedback in a given application (which means that the error changes swiftly), the differentiator may soon become too dominant. This is because it reacts to changes in the error. The quicker the error changes, the stronger the differentiator gain is. The differentiator gain can thus be limited to allow setting of the reasonable differentiation time for slow changes. |
| *Parameter 7-38 Process PID Feed Forward Factor* | In applications where there is a good (and approximately linear) correlation between the process reference and the motor speed necessary for obtaining that reference, use the feed forward factor to achieve better dynamic performance of the process PID control. |
| • *Parameter 6-16 Terminal 53 Filter Time Constant (Analog term 53)*<br>• *Parameter 6-26 Terminal 54 Filter Time Constant (Analog term. 54)* | If there are oscillations of the current/voltage feedback signal, use a low-pass filter to dampen these oscillations.<br>Example: If the low-pass filter has been set to 0.1 s, the limit speed is 10 RAD/s (the reciprocal of 0.1 s), corresponding to (10/(2 x $\pi$))=1.6 Hz. This means that the filter dampens all currents/voltages that vary by more than 1.6 oscillations per second. The control is only carried out on a feedback signal that varies by a frequency (speed) of less than 1.6 Hz.<br>The low-pass filter improves steady state performance, but selecting a too long filter time deteriorates the dynamic performance of the process PID control. |

### 3.6.2.3  Example of Process PID Control

is an example of a process PID control used in a ventilation system:
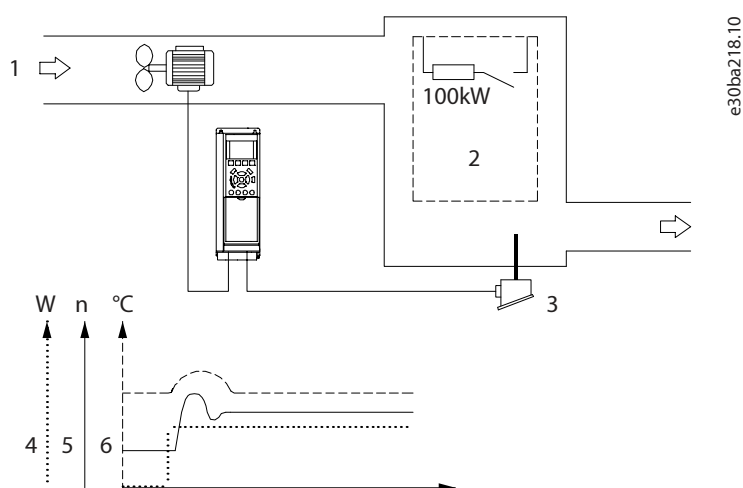


**Figure 28:  Process PID Control in a Ventilation System**

| | | | |
|---|---|---|---|
| **1** | Cold air | **2** | Heat generating process |
| **3** | Temperature transmitter | **4** | Heat |
| **5** | Fan speed | **6** | Temperature |

In a ventilation system, the temperature can be set from -5 °C to +35 °C (23–95 °F) with a potentiometer of 0–10 V. To keep the set temperature constant, use the process control.

The control is inverse, which means that when the temperature increases, the ventilation speed is increased as well to generate more air. When the temperature drops, the speed is reduced. The transmitter used is a temperature sensor with a working range of -10 °C to +40 °C (14–104 °F), 4–20 mA.
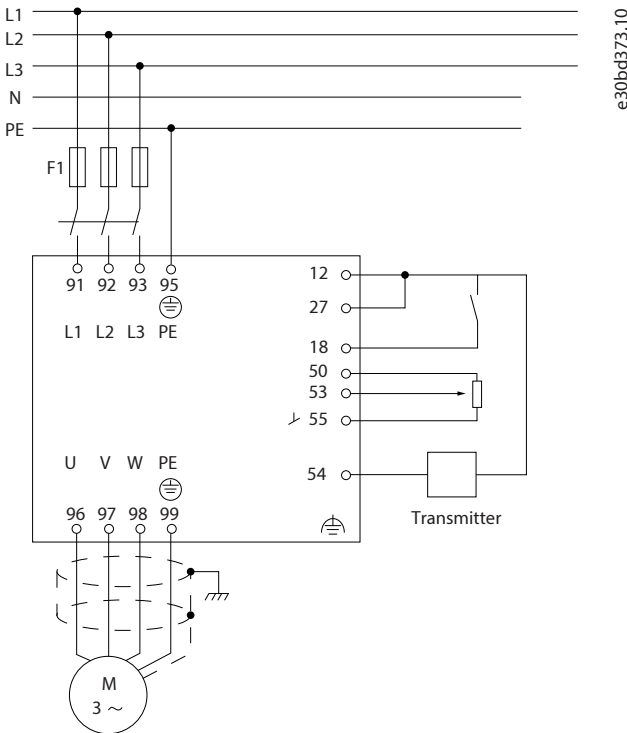


**Figure 29:  2-wire Transmitter**

1.  Start/stop via the switch connected to terminal 18.

2.  Temperature reference via potentiometer (-5 °C to +35 °C (23–95 °F), 0–10 V DC) connected to terminal 53.

3.  Temperature feedback via transmitter (-10 °C to +40 °C (14–104 °F), 4–20 mA) connected to terminal 54.

**Table 11: Example of Process PID Control Setup**

| Function | Parameter number | Setting |
|---|---|---|
| Initialize the drive. | *Parameter 14-22 Operation Mode* | *[2] Initialisation* - make a power cycling - press reset. |
| 1) Set motor parameters: | | |
| Set the motor parameters according to nameplate data. | *Parameter group 1-2* Motor Data* | As stated on motor nameplate. |
| Perform a full AMA. | *Parameter 1-29 Automatic Motor Adaption (AMA)* | *[1] Enable complete AMA*. |
| 2) Check that motor is running in the correct direction. When the motor is connected to the drive with straight forward phase order as U-U; V-V; W-W, the motor shaft usually turns clockwise seen into shaft end. | | |

**Table 11: Example of Process PID Control Setup** (continued)

| Function | Parameter number | Setting |
|---|---|---|
| Press *[Hand On]*. Check the shaft direction by applying a manual reference. | – | – |
| If the motor turns opposite of required direction:<br>1. Change motor direction in **parameter 4-10 Motor Speed Direction**.<br>2. Turn off mains, and wait for DC link to discharge.<br>3. Switch 2 of the motor phases. | **Parameter 4-10 Motor Speed Direction** | Select correct motor shaft direction. |
| Set configuration mode. | **Parameter 1-00 Configuration Mode** | *[3] Process* |
| 3) Set reference configuration that is the range for reference handling. Set scaling of analog input in **parameter group 6-** Analog In/Out**. | | |
| Set reference/feedback units.<br>Set minimum reference (10 °C (50 °F)).<br>Set maximum reference (80 °C (176 °F)).<br>If the set value is determined from a preset value (array parameter), set other reference sources to *[0] No Function*. | **Parameter 3-01 Reference/Feedback Unit**<br>**Parameter 3-02 Minimum Reference**<br>**Parameter 3-03 Maximum Reference**<br>**Parameter 3-10 Preset Reference** | [60] °C Unit shown on display.<br>-5 °C (23 °F).<br>35 °C (95 °F).<br>[0] 35%.<br>$\text{Ref} = \frac{\text{Par.3} - 10_{(0)}}{100} \times ((\text{Par.3} - 03) - (\text{Par.3} - 02)) = 24.5°C$<br>**Parameter 3-14 Preset Relative Reference** to **parameter 3-18 Relative Scaling Reference Resource** [0] = No Function. |
| 4) Adjust limits for the drive: | | |
| Set ramp times to an appropriate value as 20 s. | **Parameter 3-41 Ramp 1 Ramp Up Time**<br>**Parameter 3-42 Ramp 1 Ramp Down Time** | 20 s<br>20 s |
| Set minimum speed limits.<br>Set motor speed maximum limit.<br>Set maximum output frequency. | **Parameter 4-12 Motor Speed Low Limit [Hz]**<br>**Parameter 4-14 Motor Speed High Limit [Hz]**<br>**Parameter 4-19 Max Output Frequency** | 10 Hz<br>50 Hz<br>60 Hz |
| Set **parameter 6-19 Terminal 53 mode** and **parameter 6-29 Terminal 54 mode** to voltage or current mode. | | |
| 5) Scale analog inputs used for reference and feedback: | | |

**Table 11: Example of Process PID Control Setup** (continued)

| Function | Parameter number | Setting |
|---|---|---|
| Set terminal 53 low voltage.<br>Set terminal 53 high voltage.<br>Set terminal 54 low feedback value.<br>Set terminal 54 high feedback value.<br>Set feedback source. | *Parameter 6-10 Terminal 53 Low Voltage*<br>*Parameter 6-11 Terminal 53 High Voltage*<br>*Parameter 6-24 Terminal 54 Low Ref./Feedb. Value*<br>*Parameter 6-25 Terminal 54 High Ref./Feedb. Value*<br>*Parameter 7-20 Process CL Feedback 1 Resource* | 0 V<br>10 V<br>-5 °C (23 °F)<br>35 °C (95 °F)<br>*[2] Analog input 54* |
| 6) Basic PID settings: | | |
| Process PID normal/inverse. | *Parameter 7-30 Process PID Normal/ Inverse Control* | *[0] Normal* |
| Process PID anti wind up. | *Parameter 7-31 Process PID Anti Windup* | *[1] On* |
| Process PID start speed. | *Parameter 7-32 Process PID Start Speed* | 300 RPM |
| Save parameters to LCP. | *Parameter 0-50 LCP Copy* | *[1] All to LCP* |

## 3.6.2.4 Process Controller Optimization

After configuring the basic settings as described in 3.6.1.4 Programming Order for Speed PID Control, optimize the proportional gain, the integration time, and the differentiation time (*parameter 7-33 Process PID Proportional Gain*, *parameter 7-34 Process PID Integral Time*, and *parameter 7-35 Process PID Differentiation Time*).

| NOTICE |
|---|
| If necessary, start/stop can be activated several times to provoke a variation of the feedback signal. |

**In most processes, complete the following procedure:**

1. Start the motor.

2. Set *parameter 7-33 Process PID Proportional Gain* to 0.3 and increase it until the feedback signal again begins to vary continuously. Reduce the value until the feedback signal has stabilized. Lower the proportional gain by 40–60%.

3. Set *parameter 7-34 Process PID Integral Time* to 20 s and reduce the value until the feedback signal again begins to vary continuously. Increase the integration time until the feedback signal stabilizes, followed by an increase of 15–50%.

4. Only use *parameter 7-35 Process PID Differentiation Time* for fast-acting systems (differentiation time). The typical value is 4 times the set integration time. Use the differentiator when the setting of the proportional gain and the integration time has been fully optimized. Make sure that the lowpass filter dampens the oscillations on the feedback signal sufficiently.

## 3.6.3 Ziegler Nichols Tuning Method

To tune the PID controls of the drive, Danfoss recommends the Ziegler Nichols tuning method.

<table>
<tr><td>

**NOTICE**

Do not use the Ziegler Nichols Tuning method in applications that could be damaged by the oscillations created by marginally stable control settings.

</td></tr>
</table>

The criteria for adjusting the parameters are based on evaluating the system at the limit of stability rather than on taking a step response. Increase the proportional gain until observing continuous oscillations (as measured on the feedback), that is, until the system becomes marginally stable. The corresponding gain ($K_u$) is called the ultimate gain and is the gain, at which the oscillation is obtained. The period of the oscillation ($P_u$) (called the ultimate period) is determined as shown in Figure 30 and should be measured when the amplitude of oscillation is small.
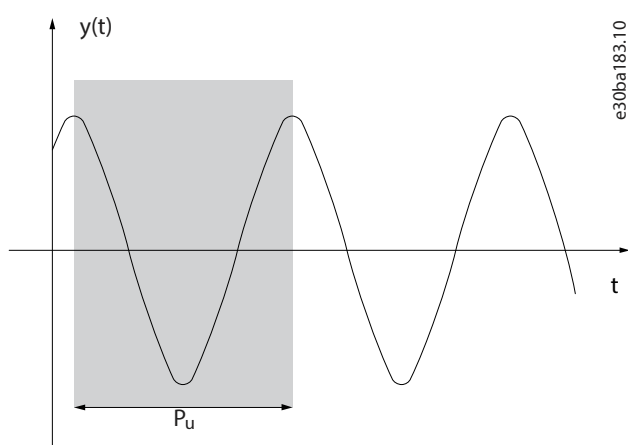


**Figure 30: Marginally Stable System**

The process operator can do the final tuning of the control iteratively to yield satisfactory control.

1. Select only proportional control, meaning that the integral time is set to the maximum value, while the differentiation time is set to 0.

2. Increase the value of the proportional gain until the point of instability is reached (sustained oscillations) and the critical value of gain, $K_u$, is reached.

3. Measure the period of oscillation to obtain the critical time constant, $P_u$.

4. Use the following table to calculate the necessary PID control parameters.

**Table 12: Ziegler Nichols Tuning for Regulator**

| Type of control | Proportional gain | Integral time | Differentiation time |
|---|---|---|---|
| PI-control | 0.45 x $K_u$ | 0.833 x $P_u$ | – |
| PID tight control | 0.6 x $K_u$ | 0.5 x $P_u$ | 0.125 x $P_u$ |
| PID some overshoot | 0.33 x $K_u$ | 0.5 x $P_u$ | 0.33 x $P_u$ |

## 3.7 EMC Emission and Immunity

### 3.7.1 General Aspects of EMC Emission

Electrical interference is conducted 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 drive, motor cable, and motor. Capacitive currents in the motor cable coupled with a high dU/dt from the motor voltage generate leakage currents. Using a shielded motor cable increases the leakage current (see Figure

[31](#)) 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.

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 the motor enclosure. This is best done by using integrated shield clamps to avoid twisted shield ends (pigtails). The shield clamps increase the shield impedance at higher frequencies, which reduces the shield effect and increases the leakage current ($I_4$).

Mount the shield on the enclosure at both ends if a shielded cable is used for the following purposes:

- Fieldbus
- Network
- Relay
- Control cable
- Signal interface
- Brake

In some situations, however, it is necessary to break the shield to avoid current loops.
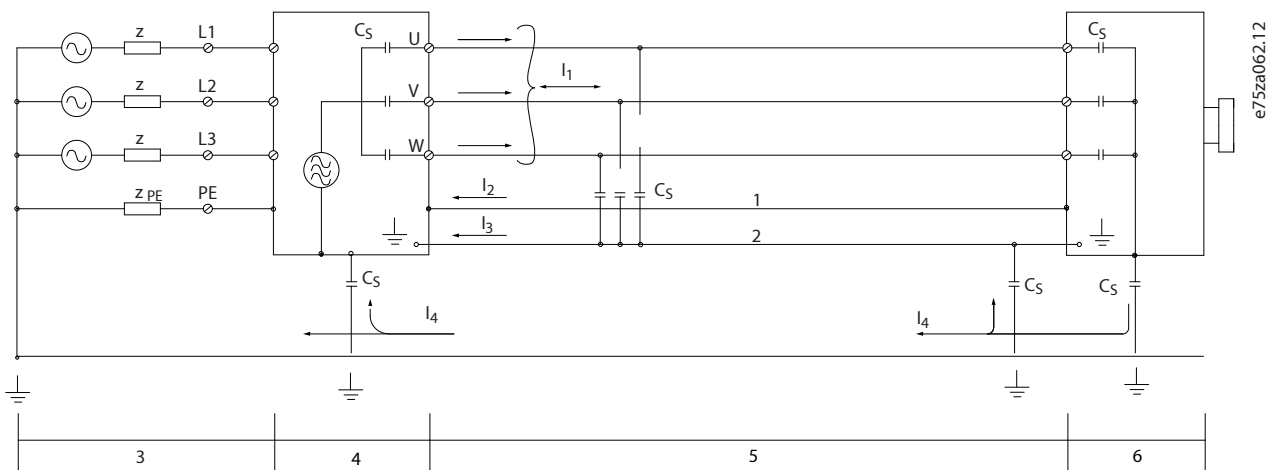


**Figure 31:  EMC Emission**

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

If placing the shield on a mounting plate for the drive, use a metal mounting plate to convey the shield currents back to the unit. 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 the immunity requirements are observed.

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

### 3.7.2  EMC Emission Requirements

The test results in [Table 13](#) have been obtained using a system with a drive (with the mounting plate), a motor and shielded motor cables.

**Table 13: EMC Emission (Filter Type: Internal)**

| Filter | Enclosure size and rated power | | Class A Group 2/EN 55011<br><br>Industrial environment | |
|---|---|---|---|---|
| | | | Category C3/EN/IEC 61800-3<br><br>Second environment | |
| | | | Conducted | Radiated |
| C3 filter | J1 | 0.37–2.2 kW (0.5–3.0 hp), 380–480 V | 5 m (16.4 ft) | Yes[1] |
| | J2 | 3.0–5.5 kW (4.0–7.5 hp), 380–480 V | 5 m (16.4 ft) | |
| | J3 | 7.5 kW (10 hp), 380–480 V | 5 m (16.4 ft) | |
| | J4 | 11–15 kW (15–20 hp), 380–480 V | 5 m (16.4 ft) | |
| | J5 | 18.5–22 kW (25–30 hp), 380–480 V | 5 m (16.4 ft) | |
| | J6 | 30–45 kW (40–60 hp), 380–480 V | 25 m (82 ft) | |
| | J7 | 55–90 kW (75–125 hp), 380–480 V | 25 m (82 ft) | |

1) *Frequency range from 150 kHz to 30 MHz is not harmonized between IEC/EN 61800-3 and EN 55011 and not mandatorily included.*

## 3.7.3 EMC 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. Therefore they also comply with the lower requirements for home and office environment with a large safety margin.

To document immunity against burst transient from electrical phenomena, the following immunity tests have been made on a system consisting of:

- A drive (with options if relevant).
- A shielded control cable.
- A control box with potentiometer, motor cable, and motor.

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

- **EN 61000-4-2 (IEC 61000-4-2) Electrostatic discharges (ESD):** Simulation of electrostatic discharges from human beings.
- **EN 61000-4-3 (IEC 61000-4-3) Radiated immunity:** Amplitude modulated simulation of the effects of radar and radio communication equipment and mobile communications equipment.
- **EN 61000-4-4 (IEC 61000-4-4) Burst transients:** Simulation of interference caused by switching a contactor, relay, or similar devices.
- **EN 61000-4-5 (IEC 61000-4-5) Surge transients:** Simulation of transients caused by, for example, lightning that strikes near installations.
- **EN 61000-4-6 (IEC 61000-4-6) Conducted immunity:** Simulation of the effect from radio-transmission equipment joined by connection cables.

The immunity requirements should follow product standard IEC 61800-3. See Table 14 for details.

**Table 14: EMC Immunity Requirements**

| Voltage range: 380–480 V | | | | | |
|---|---|---|---|---|---|
| **Product standard** | 61800-3 | | | | |
| **Test** | ESD | Radiated immunity | Burst | Surge | Conducted immunity |
| **Acceptance criterion** | B | B | B | A | A |
| Mains cable | – | – | 2 kV CN | 2 kV/2 Ω DM<br>2 kV/12 Ω CM | 10 V$_{RMS}$ |
| Motor cable | – | – | 4 kV CCC | – | 10 V$_{RMS}$ |
| Brake cable | – | – | 4 kV CCC | – | 10 V$_{RMS}$ |
| Load sharing cable | – | – | 4 kV CCC | – | 10 V$_{RMS}$ |
| Relay cable | – | – | 4 kV CCC | – | 10 V$_{RMS}$ |
| Control cable | – | – | Length>2 m (6.6 ft)<br>1 kV CCC | Unshielded: 1 kV/42 Ω CM | 10 V$_{RMS}$ |
| Standard/fieldbus cable | – | – | Length>2 m (6.6 ft)<br>1 kV CCC | Unshielded: 1 kV/42 Ω CM | 10 V$_{RMS}$ |
| LCP cable | – | – | Length>2 m (6.6 ft)<br>1 kV CCC | – | 10 V$_{RMS}$ |
| Enclosure | 4 kV CD<br>8 kV AD | 10 V/m | – | – | – |
| **Definitions** | | | | | |
| CD: Contact discharge<br>AD: Air discharge | | DM: Differential mode<br>CM: Common mode | | CN: Direct injection through coupling network<br>CCC: Injection through capacitive coupling clamp | |

## 3.8 Galvanic Isolation

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). This does not apply to grounded Delta leg above 400 V.

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

The components that make up the electrical isolation, as shown in Figure 32, 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 3 locations (see Figure 32):

To maintain PELV, all connections made to the control terminals must be PELV, for example, the thermistor must be reinforced/double insulated.
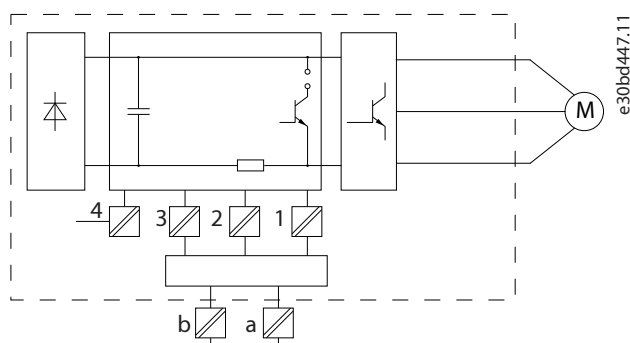
**Figure 32: Galvanic Isolation**

| | | | |
|---|---|---|---|
| **1** | Power supply (SMPS) for control cassette | **2** | Communication between power card and control cassette |
| **3** | Isolation between STO inputs and IGBT circuit | **4** | Customer relay |

Interface between Standard RS485 and I/O circuit (PELV) is functionally isolated.

> ⚠ **WARNING**
>
> Before touching any electrical parts, ensure that other voltage inputs have been disconnected, such as load sharing (linkage of DC link) and the motor connection for kinetic backup. Observe the discharge time stated in *chapter Safety*. Failure to follow recommendations could result in death or serious injury.

## 3.9 Ground Leakage Current

Follow national and local codes regarding protective grounding of equipment with a leakage current >3.5 mA. Drive technology implies high frequency switching at high power. This switching generates a leakage current in the ground connection. A fault current in the drive at the output power terminals might contain a DC component, which can charge the filter capacitors and cause a transient ground current.

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

- RFI filtering.
- Shielded motor cables.
- Motor cable length.
- Drive power.
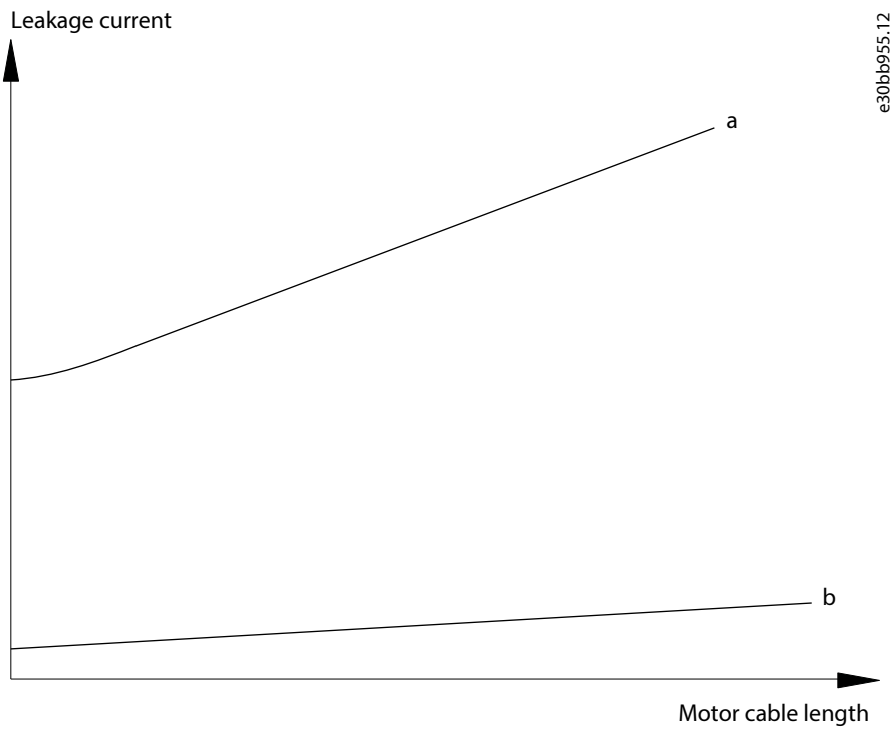
**Figure 33: Influence the Cable Length and Power Size on Leakage Current, $P_a > P_b$**

The leakage current also depends on the line distortion.
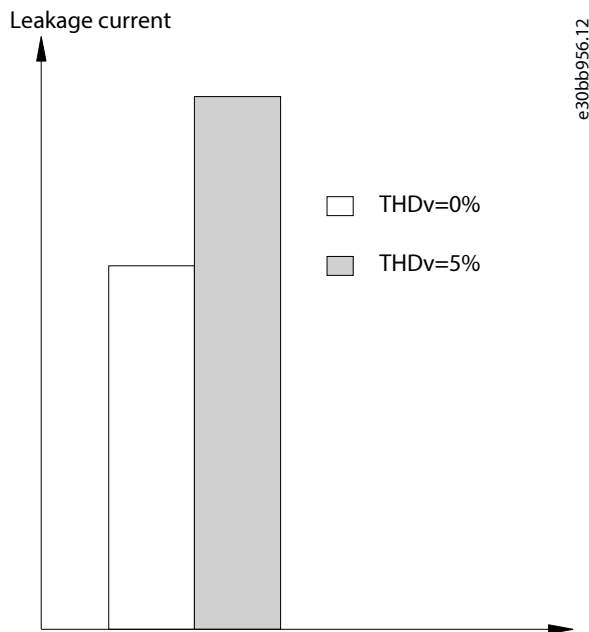


**Figure 34: Influence of Line Distortion on Leakage Current**

| NOTICE |
|---|
| High leakage current may cause the RCDs to switch off. To avoid this problem, remove the RFI screw (enclosure sizes J1–J5) or set *parameter 14-50 RFI Filter* to *[0] Off* (enclosure sizes J6–J7) when a filter is being charged. |

EN/IEC61800-5-1 (Power Drive System Product Standard) requires special care if the leakage current exceeds 3.5 mA. Reinforce grounding with 1 of the following protective ground connection requirements:

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

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

## 3.10 Using a Residual Current Device (RCD)

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

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

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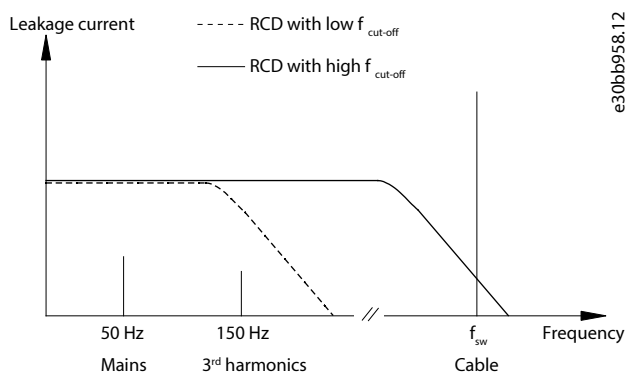


**Figure 35: Mains Contributions to Leakage Current**
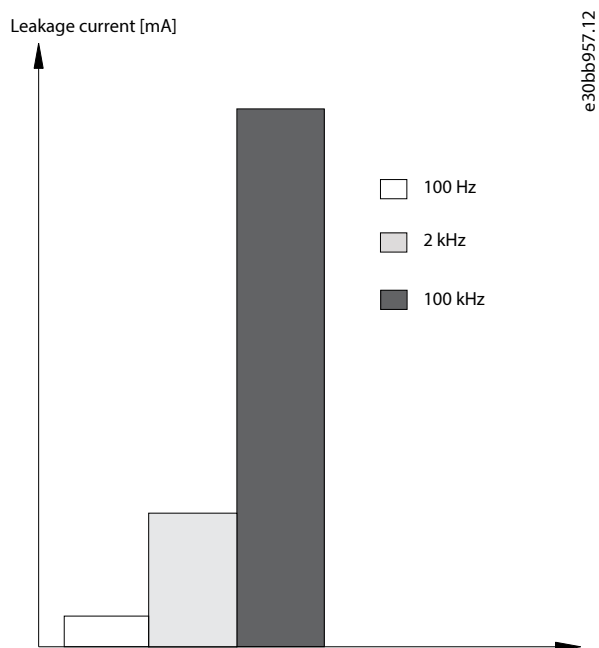


**Figure 36: Influence of Cut-off Frequency of the RCD on what is Responded to/Measured**

## 3.11 **Brake Functions**

### 3.11.1 **Mechanical Holding Brake**

A mechanical holding brake mounted directly on the motor shaft normally performs static braking.

| NOTICE |
|---|
| When the holding brake is included in a safety chain, a drive cannot provide a safe control of a mechanical brake. Include a redundancy circuitry for the brake control in the total installation. |

### 3.11.2 **Dynamic Braking**

Dynamic braking is established by:

- Resistor brake: A brake IGBT keeps the overvoltage under a certain threshold by directing the brake energy from the motor to the connected brake resistor (*parameter 2-10 Brake Function*= *[1] Resistor brake*). Adjust the threshold in *parameter 2-14 Brake voltage reduce*, with 70 V range for 3x380–480 V.
- AC brake: The brake energy is distributed in the motor by changing the loss conditions in the motor. The AC brake function cannot be used in applications with high cycling frequency as this overheats the motor (*parameter 2-10 Brake Function*= *[2] AC brake*).
- DC brake: An overmodulated DC current added to the AC current works as an eddy current brake (*parameter 2-02 DC Braking Time*≠0 s).

### 3.11.3 **Brake Resistor Selection**

#### 3.11.3.1 **Introduction**

To handle higher demands by generating braking, a brake resistor is necessary. Using a brake resistor ensures that the heat is absorbed in the brake resistor and not in the drive. For more information, see the *VLT® Brake Resistor MCE 101 Design Guide*.

If the amount of kinetic energy transferred to the resistor in each braking period is not known, calculate the average power based on the cycle time and braking time. The resistor intermittent duty cycle is an indication of the duty cycle at which the resistor is active. Figure 37 shows a typical braking cycle.
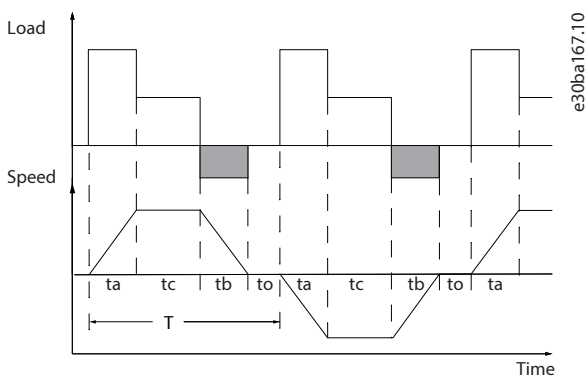


**Figure 37: Typical Braking Cycle**

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

Duty cycle = $t_b$/T

$t_b$ is the braking time in seconds.

T = cycle time in seconds.

**Table 15: Braking at High Overload Torque Level**

| | |
|---|---|
| Power range: | 0.37–90 kW (0.5–125 hp) |
| 3x380–480 V | |
| Cycle time (s) | 120 |
| Braking duty cycle at 100% torque | Continuous |
| Braking duty cycle at overtorque (150/160%) | 40% |

1) For 30–90 kW (40–125 hp) drives, an external brake resistor is needed to meet the specification in this table.

Danfoss offers brake resistors with duty cycles of 10% and 40%. If a 10% duty cycle is applied, the brake resistors are able to absorb brake power for 10% of the cycle time. The remaining 90% of the cycle time is used for dissipating excess heat.

| NOTICE |
|---|
| Make sure that the resistor is designed to handle the required braking time. |

### 3.11.3.2 Brake Resistance Calculation

The maximum allowed load on the brake resistor is stated as a peak power at a given intermittent duty cycle and can be calculated as:

$$R_{br}[\Omega] = \frac{U^2_{dc,\,br} \times 0.83}{P_{peak}}$$

Where

$$P_{peak} = P_{motor} \times M_{br(\%)} \times \eta_{motor} \times \eta_{VLT}[W]$$

As shown, the brake resistor depends on the DC-link voltage ($U_{dc}$).

**Table 16: Threshold of the Brake Resistance**

| Size | Brake active $U_{dc,\,br}$ | Warning before cutout | Cutout (trip) |
|---|---|---|---|
| FC 360 3x380–480 V | 770 V | 800 V | 800 V |

The threshold can be adjusted in *parameter 2-14 Brake voltage reduce*, with 70 V range.

| NOTICE |
|---|
| Make sure that the brake resistor can cope with a voltage of 410 V or 820 V. |

### 3.11.3.3 Danfoss Recommended Brake Resistance Calculation

Danfoss recommends calculating the brake resistance $R_{rec}$ according to the following formula. The recommended brake resistance guarantees that the drive is able to brake at the highest braking torque ($M_{br(\%)}$) of 160%.

$$R_{rec}[\Omega] = \frac{U^2_{dc} \times 100 \times 0.83}{P_{motor} \times M_{br(\%)} \times \eta_{VLT} \times \eta_{motor}}$$

$\eta_{motor}$ is typically at 0.80 (≤7.5 kW (10 hp)); 0.85 (11–22 kW (15–30 hp)).

$\eta_{VLT}$ is typically at 0.97.

For FC 360, $R_{rec}$ at 160% braking torque is written as:

480 V: $R_{rec} = \frac{396349}{P_{motor}}[\Omega]$, for drives ≤7.5 kW (10 hp) shaft output.

480 V: $R_{rec} = \frac{397903}{P_{motor}} [\Omega]$, for drives as 11–75 kW (15–100 hp) shaft output.

| NOTICE |
|---|
| The resistance of the brake resistor should not be higher than the value recommended by Danfoss. For brake resistors with a higher ohmic value, the 160% braking torque may not be achieved because the drive might cut out for safety reasons. The resistance should be bigger than $R_{min}$. |

| NOTICE |
|---|
| If a short circuit in the brake transistor occurs, prevent power dissipation in the brake resistor by using a mains switch or contactor to disconnect the mains for the drive. The drive can control the contactor. |

| NOTICE |
|---|
| Do not touch the brake resistor because it can get hot during braking. To avoid fire risk, place the brake resistor in a secure environment. |

### 3.11.4 Control with Brake Function

The brake is protected against short-circuiting of the brake resistor, and the brake transistor is monitored to ensure that short-circuiting of the transistor is detected. A relay/digital output can be used for protecting the brake resistor from overloading caused by a fault in the drive.

In addition, the brake enables readout of the momentary power and the mean power for the latest 120 s. The brake can also monitor the power energizing and make sure that it does not exceed a limit selected in *parameter 2-12 Brake Power Limit (kW)*.

| NOTICE |
|---|
| Monitoring the brake power is not a safety function. A thermal switch is required to prevent the brake power from exceeding the limit. The brake resistor circuit is not ground leakage protected. |

Overvoltage control (OVC) (exclusive brake resistor) can be selected as an alternative brake function in *parameter 2-17 Over-voltage Control*. This function is active for all units. The function ensures that a trip can be avoided if the DC-link voltage increases. This is done by increasing the output frequency to limit the voltage from the DC link. It is a useful function, for example if the ramp-down time is too short to avoid tripping of the drive. In this situation, the ramp-down time is extended.

| NOTICE |
|---|
| OVC can be activated when running a PM motor (when *parameter 1-10 Motor Construction* is set to *[1] PM nonsalient SPM*). |

### 3.12 Smart Logic Control (SLC)

Smart logic control (SLC) is a sequence of user-defined actions (see *parameter 13-52 SL Controller Action* [x]) executed by the SLC when the associated user-defined event (see *parameter 13-51 SL Controller Event* [x]) is evaluated as TRUE by the SLC.

The condition for an event can be a particular status, or that the output from a logic rule or a comparator operand becomes TRUE. The condition leads to an associated action as shown in .
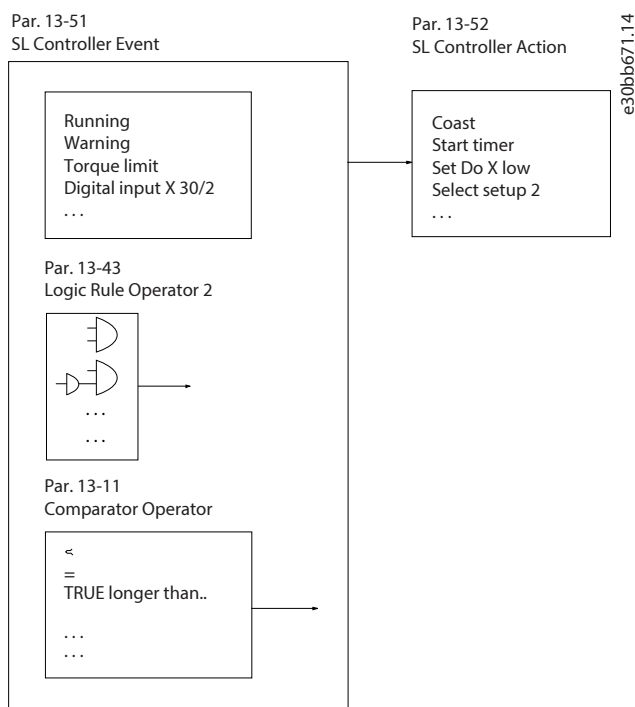
**Figure 38: SLC Event and Action**

Events and actions are each numbered and linked in pairs (states), which means that when event [0] is fulfilled (attains the value TRUE), action [0] is executed. After the 1st action is executed, the conditions of the next event are evaluated. If this event is evaluated as true, then the corresponding action is executed. Only 1 event is evaluated at any time. If an event is evaluated as FALSE, nothing happens in the SLC during the current scan interval, and no other events are evaluated. When the SLC starts, it only evaluates event [0] during each scan interval. Only when event [0] is evaluated as true, the SLC executes action [0] and starts evaluating the next event. It is possible to program 1–20 events and actions. When the last event/action has been executed, the sequence starts over again from event [0]/action [0]. Figure 39 shows an example with 4 event/actions:
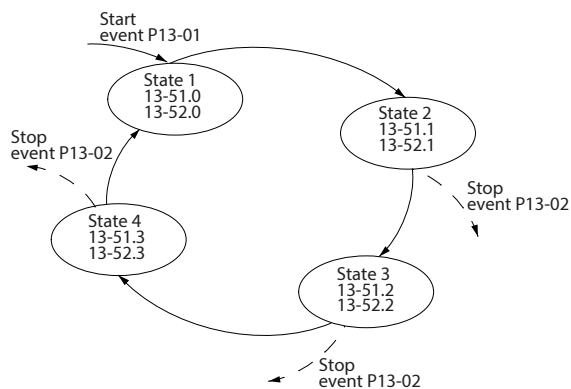


**Figure 39: Order of Execution when 4 Events/Actions are Programmed**

## Comparators

Comparators are used for comparing continuous variables (output frequency, output current, analog input, and so on) to fixed preset values.
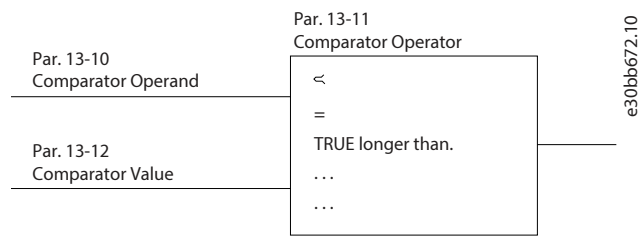
**Figure 40: Comparators**

## Logic rules

Combine up to 3 boolean inputs (TRUE/FALSE inputs) from timers, comparators, digital inputs, status bits, and events using the logical operators AND, OR, and NOT.
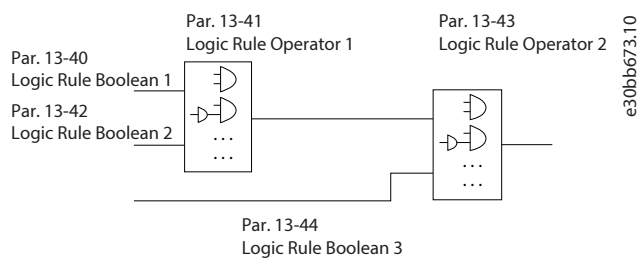


**Figure 41: Logic Rules**

## 3.13 Extreme Running Conditions

### Short circuit (motor phase-to-phase)

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

### Switching on the output

Switching on the output between the motor and the drive is fully allowed, and does not damage the drive. 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 the following cases:

- The load drives the motor (at constant output frequency from the drive).
- If the inertia moment is high during deceleration (ramp-down), 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 may cause higher DC-link voltage.

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

To select the method used for controlling the DC-link voltage level, see *parameter 2-10 Brake Function* and *parameter 2-17 Over-voltage Control*.

**Mains dropout**

During a mains dropout, the drive keeps running until the DC-link voltage drops below the minimum stop level, which is 320 V. The mains voltage before the drop-out and the motor load determines how long it takes for the inverter to coast.

**Static overload in VVC+ mode**

When the drive is overloaded, the torque limit in *parameter 4-16 Torque Limit Motor Mode*/*parameter 4-17 Torque Limit Generator Mode* is reached, the control unit reduces the output frequency to reduce the load.

If the overload is excessive, a current which makes the drive cut out after approximately 5–10 s may occur.

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

## 3.14  Motor Thermal Protection

To protect the application from serious damage, the drive offers several dedicated features.

**Torque limit**

The torque limit protects the motor from being overloaded independent of the speed. Torque limit is controlled in *parameter 4-16 Torque Limit Motor Mode* and *parameter 4-17 Torque Limit Generator Mode*. *Parameter 14-25 Trip Delay at Torque Limit* controls the time before the torque limit warning trips.

**Current limit**

*Parameter 4-18 Current Limit* controls the current limit, and *parameter 14-24 Trip Delay at Current Limit* controls the time before the current limit warning trips.

**Minimum speed limit**

*Parameter 4-12 Motor Speed Low Limit [Hz]* sets the minimum output speed that the drive can provide.

**Maximum speed limit**

*Parameter 4-14 Motor Speed High Limit [Hz]* or *parameter 4-19 Max Output Frequency* sets the maximum output speed that the drive can provide.

**ETR (electronic thermal relay)**

The drive ETR function measures the actual current, speed, and time to calculate motor temperature. The function also protects the motor from being overheated (warning or trip). An external thermistor input is also available. ETR is an electronic feature that simulates a bimetal relay based on internal measurements. The characteristic is shown in .
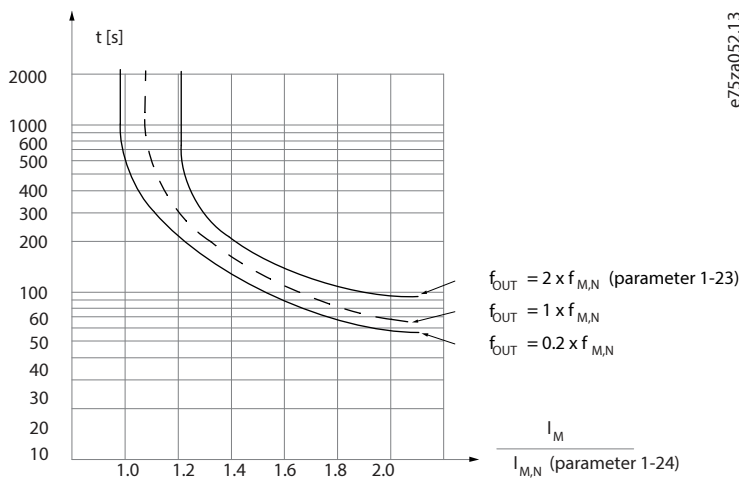
**Figure 42:  ETR**

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 0.2 x the nominal speed.

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. The calculated temperature is visible as a readout parameter in *parameter 16-18 Motor Thermal*.

The motor ETR function is based on NEMA thermal relay function Class 10.

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**NOTICE**

The drive contains a software ETR function, which means that the drive has no information about what happens with the motor at different ambient temperatures and/or what happens at 1000 m (3300 ft) above sea level. The software ETR function cannot fully replace a thermistor relay, because the thermistor relay includes a PTC sensor mounted on the motor, which is controlling the relay. However, the software ETR function is flexible and takes different parameters into account to get the required results. Besides the software ETR function, the drive has other protection features, for example, current limit and inverter thermal. In many situations, these features protect the drive and motor against overloads.

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# 4 Type Code and Selection

## 4.1 Ordering

Confirm that the equipment matches the requirements and ordering information by checking power size, voltage data, and overload data on the nameplate of the drive.
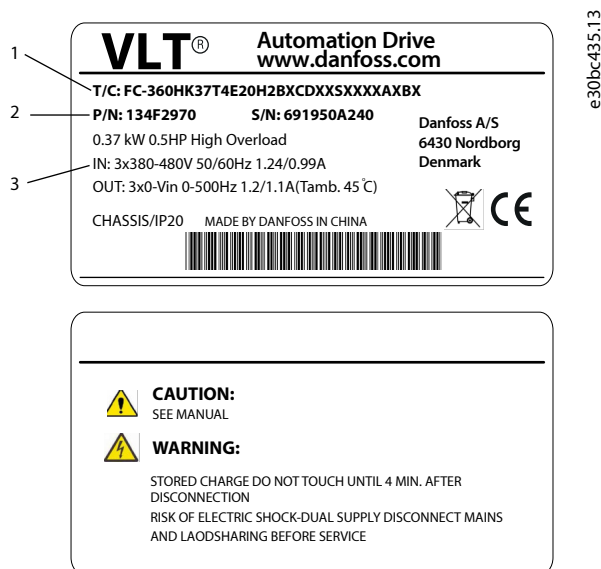


**Figure 43: Nameplates 1 and 2**

| **1** | Type code | **2** | Code number |
|---|---|---|---|
| **3** | Specifications | | |



**Figure 44: Type Code String**

**Table 17: Type Code: Selection of Different Features and Options**

| 1–6: Product Name | |
|---|---|
| 7: Overload | H: Heavy duty <br> Q: Normal duty[1] |
| 8–10: Power size | 0.37–90 kW (0.5–125 hp). <br> For example: <br> • K37: 0.37 kW (0.5 hp)[2] <br> • 1K1: 1.1 kW (1.5 hp) <br> • 11 K: 11 kW (15 hp) |
| 11–12: Voltage class | T4: 380–480 V 3-phases |

**Table 17: Type Code: Selection of Different Features and Options** (continued)

| 13–15: Protection rating | E20: IP20 |
|---|---|
| 16–17: RFI | H2: C3 Class |
| 18: Brake chopper | X: No<br>B: Built-in[3] |
| 19: LCP | X: No |
| 20: PCB coating | C: 3C3 |
| 21: Mains terminals | D: Load sharing |
| 29–30: Embedded fieldbus | AX: No<br>A0: PROFIBUS<br>AL: PROFINET |
| 31–32: Option B | BX: No option |

1) 0.37–90 kW (0.5–125 hp) for normal duty variants. PROFIBUS is unavailable for normal duty. PROFINET is available for normal duty.

2) For all power sizes, see chapter Mains Supply 3x380–480 V AC.

3) 0.37–22 kW (0.5–30 hp) with built-in brake chopper. 30–90 kW (40–125 hp) with external brake chopper only.

## 4.2 Code Numbers: Options, Accessories, and Spare Parts

**Table 18: Code Numbers for Options and Accessories**

| Description | Code numbers |
|---|---|
| VLT® Control Panel LCP 21 | 132B0254[1] |
| LCP remote mounting kit with 3 m cable | 132B0102[2] |
| Blind cover, FC 360 | 132B0262[1] |
| Graphical LCP adapter | 132B0281 |
| VLT® graphical control panel LCP 23 | 132B0801 |
| VLT® Encoder Input MCB 102, FC 360 | 132B0282 |
| VLT® Resolver Input MCB 103, FC 360 | 132B0283 |
| VLT® 24 V DC supply MCB 106 | 132B0368 |
| VLT® Sensor Input MCB 114 | 130B1272 |
| Terminal cover for MCB, J1, FC 360 | 132B0263 |
| Terminal cover for MCB, J2, FC 360 | 132B0265 |
| Terminal cover for MCB, J3, FC 360 | 132B0266 |
| Terminal cover for MCB, J4, FC 360 | 132B0267 |
| Terminal cover for MCB, J5, FC 360 | 132B0268 |
| Decoupling plate mounting kit, J1 | 132B0258 |
| Decoupling plate mounting kit, J2, J3 | 132B0259 |
| Decoupling plate mounting kit, J4, J5 | 132B0260 |

**Table 18: Code Numbers for Options and Accessories** (continued)

| Description | Code numbers |
|---|---|
| Decoupling plate mounting kit, J6 | 132B0284 |
| Decoupling plate mounting kit, J7 | 132B0285 |
| LCP remote mounting cable, 3 m (10 ft) | 132B0132 |
| VLT® Control Panel LCP 21 - RJ45 Converter Kit | 132B0254 |

1)  2 kinds of packages, 6 pieces or 72 pieces.

2)  2 pieces in 1 package.

**Table 19: Code Numbers for Spare Parts**

| Description | Code numbers |
|---|---|
| Standard control cassette | 132B0255 |
| Control cassette (with PROFIBUS) | 132B0256 |
| Control cassette (with PROFINET) | 132B0257 |
| Control cassette (with PROFINET) (supports VLT® 24 V DC Supply MCB 106) | 132B2183 |
| Fan 50x15 IP21 for J1 0.37–1.5 kW (0.5–2 hp) | 132B0275 |
| Fan 50x20 IP21 for J1 2.2 kW (3 hp) | 132B0276 |
| Fan 60x20 IP21 for J2 | 132B0277 |
| Fan 70x20 IP21 for J3 | 132B0278 |
| Fan 92x38 IP21 for J4 | 132B0279 |
| Fan 120x38 IP21 for J5 | 132B0280 |
| Fan 92x38 IP21 for J6 | 132B0295 |
| Fan 120x38 IP21 for J7 | 132B0313 |
| Relay & RS485 header for J1–J5 | 132B0264 |
| Power control card, 30 kW (40 hp) | 132B0287 |
| Power control card, 37 kW (50 hp) | 132B0290 |
| Power control card, 45 kW (60 hp) | 132B0291 |
| RFI auxiliary card, J6 | 132B0292 |
| Rectifier module, 30–37 kW (40–50 hp) | 132B0293 |
| Rectifier module, 45 kW (60 hp) | 132B0294 |
| Front cover for enclosure size J6 (Metal version) | 132B0296 |
| Front cover for enclosure size J6 (Plastic version) | 132B2184 |
| Mains terminal, J6 | 132B0297 |
| Motor terminal, J6 | 132B0298 |
| DC bus terminal, J6 | 132B0299 |

**Table 19: Code Numbers for Spare Parts** (continued)

| Description | Code numbers |
|---|---|
| Power control card supply cable, J6 | 132B0300 |
| Fan extension cable, J6 | 132B0301 |
| Isolation RFI foil, J6 | 132B0302 |
| Cradle for power card & bus bar, J6 | 132B0303 |
| Power control card, 55 kW (75 hp) | 132B0305 |
| Power control card, 75 kW (100 hp) | 132B0306 |
| Power control card, 90 kW (125 hp) | 132B1460 |
| Power card, J7 | 132B0307 |
| RFI auxiliary card, J7 | 132B0308 |
| Rectifier module, J7 | 132B0309 |
| IGBT module with gate drive cable, J7 | 132B0310 |
| DC capacitor, 55 kW (75 hp) | 132B0311 |
| DC capacitor, 75 kW (100 hp) | 132B0312 |
| Front cover, J7 | 132B0314 |
| Mains, motor terminal, 55 kW (75 hp) | 132B0315 |
| DC bus terminal, 55 kW (75 hp) | 132B0316 |
| Mains, motor, DC bus terminal, 75 kW (100 hp) | 132B0317 |
| Temperature sensing cable, J7 | 132B0318 |
| Power control card supply cable, J7 | 132B0319 |
| Fan extension cable, J7 | 132B0320 |
| Isolation RFI foil, J7 | 132B0321 |
| Isolation inrush foil, J7 | 132B0322 |

## 4.3 Code Numbers: Brake Resistors

### 4.3.1 Introduction

Danfoss offers a wide variety of different resistors that are specially designed for our drives. See *chapter Control with Brake Function* for the dimensioning of brake resistors. This section lists the code numbers for the brake resistors.

### 4.3.2 Code Numbers: Brake Resistors 10%

**Table 20: FC 360 - Mains: 380–480 V (T4), 10% Duty Cycle**

| FC 360 | $P_{m\,(HO)}$ | $R_{min}$ | $R_{br.\,nom}$ | $R_{rec}$ | $P_{br\,avg}$ | Code number | Period | Cable cross-section[1] | Thermal relay | Maximum brake torque with $R_{rec}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| T4 | [kW] | [Ω] | [Ω] | [Ω] | [kW] | 175Uxxxx | [s] | [mm$^2$] | [A] | [%] |
| HK37 | 0.37 | 890 | 1041.98 | 989 | 0.030 | 3000 | 120 | 1.5 | 0.3 | 139 |
| HK55 | 0.55 | 593 | 693.79 | 659 | 0.045 | 3001 | 120 | 1.5 | 0.4 | 131 |
| HK75 | 0.75 | 434 | 508.78 | 483 | 0.061 | 3002 | 120 | 1.5 | 0.4 | 129 |
| H1K1 | 1.1 | 288 | 338.05 | 321 | 0.092 | 3004 | 120 | 1.5 | 0.5 | 132 |
| H1K5 | 1.5 | 208 | 244.41 | 232 | 0.128 | 3007 | 120 | 1.5 | 0.8 | 145 |
| H2K2 | 2.2 | 139 | 163.95 | 155 | 0.190 | 3008 | 120 | 1.5 | 0.9 | 131 |
| H3K0 | 3 | 100 | 118.86 | 112 | 0.262 | 3300 | 120 | 1.5 | 1.3 | 131 |
| H4K0 | 4 | 74 | 87.93 | 83 | 0.354 | 3335 | 120 | 1.5 | 1.9 | 128 |
| H5K5 | 5.5 | 54 | 63.33 | 60 | 0.492 | 3336 | 120 | 1.5 | 2.5 | 127 |
| H7K5 | 7.5 | 38 | 46.05 | 43 | 0.677 | 3337 | 120 | 1.5 | 3.3 | 132 |
| H11K | 11 | 27 | 32.99 | 31 | 0.945 | 3338 | 120 | 1.5 | 5.2 | 130 |
| H15K | 15 | 19 | 24.02 | 22 | 1.297 | 3339 | 120 | 1.5 | 6.7 | 129 |
| H18K | 18.5 | 16 | 19.36 | 18 | 1.610 | 3340 | 120 | 1.5 | 8.3 | 132 |
| H22K | 22 | 16 | 18.00 | 17 | 1.923 | 3357 | 120 | 1.5 | 10.1 | 128 |
| H30K | 30 | 11 | 14.6 | 13 | 2.6 | 3341 | 120 | 2.5 | 13.3 | 150 |
| H37K | 37 | 9 | 11.7 | 11 | 3.2 | 3359 | 120 | 2.5 | 15.3 | 150 |
| H45K | 45 | 8 | 9.6 | 9 | 3.9 | 3065 | 120 | 10 | 20 | 150 |
| H55K | 55 | 6 | 7.8 | 7 | 4.8 | 3070 | 120 | 10 | 26 | 150 |
| H75K | 75 | 4 | 5.7 | 5 | 6.6 | 3231 | 120 | 10 | 36 | 150 |

1) All cabling must comply with national and local regulations on cable cross-sections and ambient temperature.

### 4.3.3 Code Numbers: Brake Resistors 40%

**Table 21: FC 360 - Mains: 380–480 V (T4), 40% Duty Cycle**

| FC 360 | $P_{m\,(HO)}$ | $R_{min}$ | $R_{br.\,nom}$ | $R_{rec}$ | $P_{br\,avg}$ | Code number | Period | Cable cross-section[1] | Thermal relay | Maximum brake torque with $R_{rec}$ |
|--------|------|------|------|------|------|------|------|------|------|------|
| T4 | [kW] | [Ω] | [Ω] | [Ω] | [kW] | 175Uxxxx | [s] | [mm$^2$] | [A] | [%] |
| HK37 | 0.37 | 890 | 1041.98 | 989 | 0.127 | 3101 | 120 | 1.5 | 0.4 | 139 |
| HK55 | 0.55 | 593 | 693.79 | 659 | 0.191 | 3308 | 120 | 1.5 | 0.5 | 131 |
| HK75 | 0.75 | 434 | 508.78 | 483 | 0.260 | 3309 | 120 | 1.5 | 0.7 | 129 |
| H1K1 | 1.1 | 288 | 338.05 | 321 | 0.391 | 3310 | 120 | 1.5 | 1 | 132 |
| H1K5 | 1.5 | 208 | 244.41 | 232 | 0.541 | 3311 | 120 | 1.5 | 1.4 | 145 |
| H2K2 | 2.2 | 139 | 163.95 | 155 | 0.807 | 3312 | 120 | 1.5 | 2.1 | 131 |
| H3K0 | 3 | 100 | 118.86 | 112 | 1.113 | 3313 | 120 | 1.5 | 2.7 | 131 |
| H4K0 | 4 | 74 | 87.93 | 83 | 1.504 | 3314 | 120 | 1.5 | 3.7 | 128 |
| H5K5 | 5.5 | 54 | 63.33 | 60 | 2.088 | 3315 | 120 | 1.5 | 5 | 127 |
| H7K5 | 7.5 | 38 | 46.05 | 43 | 2.872 | 3316 | 120 | 1.5 | 7.1 | 132 |
| H11K | 11 | 27 | 32.99 | 31 | 4.226 | 3236 | 120 | 2.5 | 11.5 | 130 |
| H15K | 15 | 19 | 24.02 | 22 | 5.804 | 3237 | 120 | 2.5 | 14.7 | 129 |
| H18K | 18.5 | 16 | 19.36 | 18 | 7.201 | 3238 | 120 | 4 | 19 | 132 |
| H22K | 22 | 16 | 18.00 | 17 | 8.604 | 3203 | 120 | 4 | 23 | 128 |
| H30K | 30 | 11 | 14.6 | 13 | 11.5 | 3206 | 120 | 10 | 32 | 150 |
| H37K | 37 | 9 | 11.7 | 11 | 14.3 | 3210 | 120 | 10 | 38 | 150 |
| H45K | 45 | 8 | 9.6 | 9 | 17.5 | 3213 | 120 | 16 | 47 | 150 |
| H55K | 55 | 6 | 7.8 | 7 | 21.5 | 3216 | 120 | 25 | 61 | 150 |
| H75K | 75 | 4 | 5.7 | 5 | 29.6 | 3219 | 120 | 35 | 81 | 150 |

1) *All cabling must comply with national and local regulations on cable cross-sections and ambient temperature.*

# 5 Specifications

## 5.1 Electrical Data

Table 22: Electrical Data for High Overload, Mains Supply 3x380–480 V AC, Enclosure Size J1–J3

| Drive | HK37 | HK55 | HK75 | H1K1 | H1K5 | H2K2 | H3K0 | H4K0 | H5K5 | H7K5 |
|---|---|---|---|---|---|---|---|---|---|---|
| Enclosure size | J1 | J1 | J1 | J1 | J1 | J1 | J2 | J2 | J2 | J3 |
| **High overload=160% current during 60 s** | | | | | | | | | | |
| Typical shaft output [kW] | 0.37 | 0.55 | 0.75 | 1.1 | 1.5 | 2.2 | 3 | 4 | 5.5 | 7.5 |
| Typical shaft output [hp] | 0.5 | 0.75 | 1 | 1.5 | 2 | 3 | 4 | 5.5 | 7.5 | 10 |
| **Output current (3-phase)** | | | | | | | | | | |
| Continuous (3x380–440 V) [A] | 1.2 | 1.7 | 2.2 | 3 | 3.7 | 5.3 | 7.2 | 9 | 12 | 15.5 |
| Continuous (3x441–480 V) [A] | 1.1 | 1.6 | 2.1 | 2.8 | 3.4 | 4.8 | 6.3 | 8.2 | 11 | 14 |
| Intermittent (60 s overload) [A] | 1.9 | 2.7 | 3.5 | 4.8 | 5.9 | 8.5 | 11.5 | 14.4 | 19.2 | 24.8 |
| Continuous kVA (400 V AC) [kVA] | 0.84 | 1.18 | 1.53 | 2.08 | 2.57 | 3.68 | 4.99 | 6.24 | 8.32 | 10.74 |
| Continuous kVA (480 V AC) [kVA] | 0.9 | 1.3 | 1.7 | 2.5 | 2.8 | 4.0 | 5.2 | 6.8 | 9.1 | 11.6 |
| Maximum input current | | | | | | | | | | |
| Continuous (3x380–440 V) [A] | 1.2 | 1.6 | 2.1 | 2.6 | 3.5 | 4.7 | 6.3 | 8.3 | 11.2 | 15.1 |
| Continuous (3x441–480 V) [A] | 1.0 | 1.2 | 1.8 | 2.0 | 2.9 | 3.9 | 4.3 | 6.8 | 9.4 | 12.6 |
| Intermittent (60 s overload) [A] | 1.9 | 2.6 | 3.4 | 4.2 | 5.6 | 7.5 | 10.1 | 13.3 | 17.9 | 24.2 |
| Maximum cable cross-section (mains,motor, brake, and load sharing) [mm$^2$ (AWG)] | 4 (12) | | | | | | | | | |
| Estimated power loss at rated maximum load [W] | 20.88 | 25.16 | 30.01 | 40.01 | 52.91 | 73.97 | 94.81 | 115.5 | 157.54 | 192.83 |
| Weight [kg (lb)], enclosure protection rating IP20 | 2.3 (5.1) | 2.3 (5.1) | 2.3 (5.1) | 2.3 (5.1) | 2.3 (5.1) | 2.5 (5.5) | 3.6 (7.9) | 3.6 (7.9) | 3.6 (7.9) | 4.1 (9.0) |
| Efficiency [%] | 96.2 | 97.0 | 97.2 | 97.4 | 97.4 | 97.6 | 97.5 | 97.6 | 97.7 | 98.0 |

Table 23: Electrical Data for Normal Overload, Mains Supply 3x380–480 V AC, Enclosure Size J1–J3

| Drive | QK37 | QK55 | QK75 | Q1K1 | Q1K5 | Q2K2 | Q3K0 | Q4K0 | Q5K5 | Q7K5 |
|---|---|---|---|---|---|---|---|---|---|---|
| Enclosure size | J1 | J1 | J1 | J1 | J1 | J1 | J2 | J2 | J2 | J3 |
| **Normal overload=110% current during 60 s** | | | | | | | | | | |
| Typical shaft output [kW] | 0.37 | 0.55 | 0.75 | 1.1 | 1.5 | 2.2 | 3 | 4 | 5.5 | 7.5 |
| Typical shaft output [hp] | 0.5 | 0.75 | 1 | 1.5 | 2 | 3 | 4 | 5.5 | 7.5 | 10 |
| **Output current (3-phase)** | | | | | | | | | | |
| Continuous (3x380–440 V) [A] | 1.2 | 1.7 | 2.2 | 3 | 3.7 | 5.3 | 7.2 | 9 | 12 | 15.5 |

**Table 23: Electrical Data for Normal Overload, Mains Supply 3x380–480 V AC, Enclosure Size J1–J3** (continued)

| Drive | QK37 | QK55 | QK75 | Q1K1 | Q1K5 | Q2K2 | Q3K0 | Q4K0 | Q5K5 | Q7K5 |
|---|---|---|---|---|---|---|---|---|---|---|
| Continuous (3x441–480 V) [A] | 1.1 | 1.6 | 2.1 | 2.8 | 3.4 | 4.8 | 6.3 | 8.2 | 11 | 14 |
| Intermittent (60 s overload) [A] | 1.3 | 1.9 | 2.4 | 3.3 | 4.1 | 5.8 | 7.9 | 9.9 | 13.2 | 17.1 |
| Continuous kVA (400 V AC) [kVA] | 0.84 | 1.18 | 1.53 | 2.08 | 2.57 | 3.68 | 4.99 | 6.24 | 8.32 | 10.74 |
| Continuous kVA (480 V AC) [kVA] | 0.9 | 1.3 | 1.7 | 2.5 | 2.8 | 4.0 | 5.2 | 6.8 | 9.1 | 11.6 |
| Maximum input current | | | | | | | | | | |
| Continuous (3x380–440 V) [A] | 1.2 | 1.6 | 2.1 | 2.6 | 3.5 | 4.7 | 6.3 | 8.3 | 11.2 | 15.1 |
| Continuous (3x441–480 V) [A] | 1.0 | 1.2 | 1.8 | 2.0 | 2.9 | 3.9 | 4.3 | 6.8 | 9.4 | 12.6 |
| Intermittent (60 s overload) [A] | 1.3 | 1.8 | 2.3 | 2.9 | 3.9 | 5.2 | 6.9 | 9.1 | 12.3 | 16.6 |
| Maximum cable cross-section (mains,motor, brake, and load sharing) [mm$^2$ (AWG)] | 4 (12) | | | | | | | | | |
| Estimated power loss at rated maximum load [W] | 20.88 | 25.16 | 30.01 | 40.01 | 52.91 | 73.97 | 94.81 | 115.5 | 157.54 | 192.83 |
| Weight [kg (lb)], enclosure protection rating IP20 | 2.3 (5.1) | 2.3 (5.1) | 2.3 (5.1) | 2.3 (5.1) | 2.3 (5.1) | 2.5 (5.5) | 3.6 (7.9) | 3.6 (7.9) | 3.6 (7.9) | 4.1 (9.0) |
| Efficiency [%] | 96.2 | 97.0 | 97.2 | 97.4 | 97.4 | 97.6 | 97.5 | 97.6 | 97.7 | 98.0 |

**Table 24: Electrical Data for High Overload, Mains Supply 3x380–480 V AC, Enclosure Size J4–J7**

| Drive | H11K | H15K | H18K | H22K | H30K | H37K | H45K | H55K | H75K |
|---|---|---|---|---|---|---|---|---|---|
| Enclosure size | J4 | J4 | J5 | J5 | J6 | J6 | J6 | J7 | J7 |
| **High overload=150% current during 60 s** | | | | | | | | | |
| Typical shaft output [kW] | 11 | 15 | 18.2 | 22 | 30 | 37 | 45 | 55 | 75 |
| Typical shaft output [hp] | 15 | 20 | 25 | 30 | 40 | 50 | 60 | 75 | 100 |
| **Output current (3-phase)** | | | | | | | | | |
| Continuous (3x380–440 V) [A] | 23 | 31 | 37 | 42.5 | 61 | 73 | 90 | 106 | 147 |
| Continuous (3x441–480 V) [A] | 21 | 27 | 34 | 40 | 52 | 65 | 77 | 96 | 124 |
| Intermittent (60 s overload) [A] | 34.5 | 46.5 | 55.5 | 63.8 | 91.5 | 109.5 | 135 | 159 | 220.5 |
| Continuous kVA (400 V AC) [kVA] | 15.94 | 21.48 | 25.64 | 29.45 | 42.3 | 50.6 | 62.4 | 73.4 | 101.8 |
| Continuous kVA (480 V AC) [kVA] | 17.5 | 22.4 | 28.3 | 33.3 | 43.2 | 54.0 | 64.0 | 79.8 | 103.1 |
| **Maximum input current** | | | | | | | | | |
| Continuous (3x380–440 V) [A] | 22.1 | 29.9 | 35.2 | 41.5 | 57 | 70.3 | 84.2 | 102.9 | 140.3 |
| Continuous (3x441–480 V) [A] | 18.4 | 24.7 | 29.3 | 34.6 | 49.3 | 60.8 | 72.7 | 88.8 | 121.1 |
| Intermittent (60 s overload) [A] | 33.2 | 44.9 | 52.8 | 62.3 | 85.5 | 105.5 | 126.3 | 154.4 | 210.5 |

**Table 24: Electrical Data for High Overload, Mains Supply 3x380–480 V AC, Enclosure Size J4–J7** (continued)

| Drive | H11K | H15K | H18K | H22K | H30K | H37K | H45K | H55K | H75K |
|---|---|---|---|---|---|---|---|---|---|
| Maximum cable size (mains, motor, brake) [mm$^2$ (AWG)] | 16 (6) | | | | 50 (1/0) | | | | 95 (3/0) |
| Estimated power loss at rated maximum load [W] | 289.53 | 393.36 | 402.83 | 467.52 | 630 | 848 | 1175 | 1250 | 1507 |
| Weight [kg (lb)], enclosure protection rating IP20 | 9.4 (20.7) | 9.5 (20.9) | 12.3 (27.1) | 12.5 (27.6) | 22.4 (49.4) | 22.5 (49.6) | 22.6 (49.8) | 37.3 (82.2) | 38.7 (85.3) |
| Efficiency [%] | 97.8 | 97.8 | 98.1 | 97.9 | 98.1 | 98.0 | 97.7 | 98.0 | 98.2 |

**Table 25: Electrical Data for Normal Overload, Mains Supply 3x380–480 V AC, Enclosure Size J4–J7**

| Drive | Q11K | Q15K | Q18K | Q22K | Q30K | Q37K | Q45K | Q55K | Q75K | Q90K |
|---|---|---|---|---|---|---|---|---|---|---|
| Enclosure size | J4 | J4 | J5 | J5 | J6 | J6 | J6 | J7 | J7 | J7 |
| **Normal overload=110% current during 60 s** | | | | | | | | | | |
| Typical shaft output [kW] | 11 | 15 | 18.5 | 22 | 30 | 37 | 45 | 55 | 75 | 90 |
| Typical shaft output [hp] | 15 | 20 | 25 | 30 | 40 | 50 | 60 | 75 | 100 | 125 |
| **Output current (3-phase)** | | | | | | | | | | |
| Continuous (3x380–440 V) [A] | 23 | 31 | 37 | 42.5 | 61 | 73 | 90 | 106 | 147 | 177 |
| Continuous (3x441–480 V) [A] | 21 | 27 | 34 | 40 | 52 | 65 | 77 | 96 | 124 | 160 |
| Intermittent (60 s overload) [A] | 25.3 | 34.1 | 40.7 | 46.8 | 67.1 | 80.3 | 99 | 116.6 | 161.7 | 194.7 |
| Continuous kVA (400 V AC) [kVA] | 15.94 | 21.48 | 25.64 | 29.45 | 42.3 | 50.6 | 62.4 | 73.4 | 101.8 | 122.6 |
| Continuous kVA (480 V AC) [kVA] | 17.5 | 22.4 | 28.3 | 33.3 | 43.2 | 54.0 | 64.0 | 79.8 | 103.1 | 133 |
| **Maximum input current** | | | | | | | | | | |
| Continuous (3x380–440 V) [A] | 22.1 | 29.9 | 35.2 | 41.5 | 57 | 70.3 | 84.2 | 102.9 | 140.3 | 165.6 |
| Continuous (3x441–480 V) [A] | 18.4 | 24.7 | 29.3 | 34.6 | 49.3 | 60.8 | 72.7 | 88.8 | 121.1 | 142.7 |
| Intermittent (60 s overload) [A] | 24.3 | 32.9 | 38.7 | 45.7 | 62.7 | 77.3 | 92.6 | 113.2 | 154.3 | 182.2 |
| Maximum cable size (mains, motor, brake) [mm$^2$ (AWG)] | 16 (6) | | | | 50 (1/0) | | | | 95 (3/0) | 120 (4/0) |
| Estimated power loss at rated maximum load [W] | 289.53 | 393.36 | 402.83 | 467.52 | 630 | 848 | 1175 | 1250 | 1507 | 1781 |
| Weight [kg (lb)], enclosure protection rating IP20 | 9.4 (20.7) | 9.5 (20.9) | 12.3 (27.1) | 12.5 (27.6) | 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 [%] | 97.8 | 97.8 | 98.1 | 97.9 | 98.1 | 98.0 | 97.7 | 98.0 | 98.2 | 98.3 |

## 5.2 General Specifications

### 5.2.1 Mains Supply (L1, L2, L3)

| | |
|---|---|
| Supply terminals | L1, L2, L3 |
| Supply voltage | 380–480 V: -15% (-25%)[1] to +10% |
| Supply frequency | 50/60 Hz ±5% |
| Maximum imbalance temporary between mains phases | 3.0% of rated supply voltage |
| True power factor (λ) | ≥0.9 nominal at rated load |
| Displacement power factor (cos φ) | Near unity (>0.98) |
| Switching on input supply L1, L2, L3 (power-ups) ≤7.5 kW (10 hp) | Maximum 2 times/minute |
| Switching on input supply L1, L2, L3 (power-ups) 11–90 kW (125 hp) | Maximum 1 time/minute |

1) The drive can run at -25% input voltage with reduced performance. The maximum output power of the drive is 75% if input voltage is -25%, and 85% if input voltage is -15%. Full torque cannot be expected at mains voltage lower than 10% below the lowest rated supply voltage of the drive.

The unit is suitable for use on a circuit capable of delivering less than 5000 RMS symmetrical Amperes, 480 V maximum.

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

| | |
|---|---|
| Output voltage | 0–100% of supply voltage |
| Output frequency in U/f mode (for IM motor) | 0–500 Hz |
| Output frequency in VVC+/Flux basic mode (for IM motor) | 0–200 Hz |
| Output frequency in VVC+/Flux basic mode (for PM motor) | 0–400Hz/0–300Hz |
| Switching on output | Unlimited |
| Ramp times | 0.01–3600 s |

### 5.2.3 Torque Characteristics

| | |
|---|---|
| Starting torque (high overload) | Maximum 160% for 60 s[1][2] |
| Overload torque (high overload) | Maximum 160% for 60 s[1][2] |
| Starting torque (normal overload) | Maximum 100% for 60 s[1][2] |
| Overload torque (normal overload) | Maximum 100% for 60 s[1][2] |
| Starting current | Maximum 200% for 1 s |
| Torque rise time in VVC+ (independent of $f_{sw}$) | Maximum 50 ms |

1) Percentage relates to the nominal torque. It is 150% for 11–90 kW (15–125 hp) drives.

2) Once every 10 minutes.

### 5.2.4 Ambient Conditions

| | |
|---|---|
| Enclosure sizes J1–J7 | IP20 |
| Vibration test, enclosure sizes J1–J7 | 1.0 g |
| Relative humidity | 5–95% (IEC 721-3-3); Class 3K3 (non-condensing) during operation |
| Aggressive environment (IEC 60068-2-43) $H_2S$ test | Class Kd |
| Test method according to IEC 60068-2-43 $H_2S$ (10 days) | |
| Ambient temperature (at 60 AVM switching mode) | |
| - with derating | Maximum 55 °C (131 °F)[1], [2] |
| - at full continuous output current with some power size | Maximum 50 °C (122 °F) |
| - at full continuous output current | Maximum 45 °C (113 °F)[3] |
| Minimum ambient temperature during full-scale operation | 0 °C (32 °F) |
| Minimum ambient temperature at reduced performance | -10 °C (14 °F) |
| Temperature during storage/transport | -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) |
| EMC standards, emission | EN 61800-3, EN 61000-3-2, EN 61000-3-3, EN 61000-3-11, EN 61000-3-12, EN 61000-6-3/4, EN 55011, IEC 61800-3 |
| EMC standards, immunity | EN 61800-3, EN 61000-6-1/2, EN 61000-4-2, EN 61000-4-3, EN 61000-4-4, EN 61000-4-5, EN 61000-4-6 |
| Energy efficiency class[4] | IE2 |

1) *Refer to* chapter Special Conditions *for:*

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

2) *To prevent control card overtemperature on PROFIBUS and PROFINET variants of VLT® AutomationDrive FC 360, avoid full digital/analog I/O load at ambient temperature higher than 45 °C (113 °F).*

3) *Drive of 90 kW (125 hp) normal overload operates at 40 °C (104 °F).*

4) *Determined according to EN 50598-2 at:*

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

### 5.2.5 Cable Lengths and Cross-sections

| | |
|---|---|
| Maximum motor cable length, shielded | 50 m (164 ft) |
| Maximum motor cable length, unshielded | 0.37–22 kW (0.5–30 hp): 75 m (246 ft); 30–90 kW (40–125 hp): 100 m (328 ft) |
| Maximum cross-section to motor and mains | See *chapter Electrical Data*. |
| Maximum cross-section to control terminals, flexible/rigid wire | 2.5 mm$^2$/14 AWG |

| | |
|---|---|
| Minimum cross-section to control terminals | 0.55 mm$^2$/30 AWG |

## 5.2.6 Digital Inputs

| | |
|---|---|
| Programmable digital inputs | 7 |
| Terminal number | 18, 19, 27, 29, 31, 32, 33[1] |
| 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 |
| Pulse frequency range | 4 Hz–32 kHz |
| (Duty cycle) minimum pulse width | 4.5 ms |
| Input resistance, Ri | Approximately 4 kΩ |

*1) Terminals 27 and 29 can also be programmed as output.*

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

## 5.2.7 Analog Inputs

| | |
|---|---|
| Number of analog inputs | 2 |
| Terminal number | 53, 54 |
| Modes | Voltage or current |
| Mode select | Software |
| Voltage level | 0–10 V |
| Input resistance, Ri | Approximately 10 kΩ |
| Maximum voltage | -15 V to +20 V |
| Current level | 0/4 to 20 mA (scaleable) |
| Input resistance, Ri | Approximately 200 Ω |
| Maximum current | 30 mA |
| Resolution for analog inputs | 11 bit |
| Accuracy of analog inputs | Maximum error 0.5% of full-scale |
| Bandwidth | 100 Hz |

The analog inputs are galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.
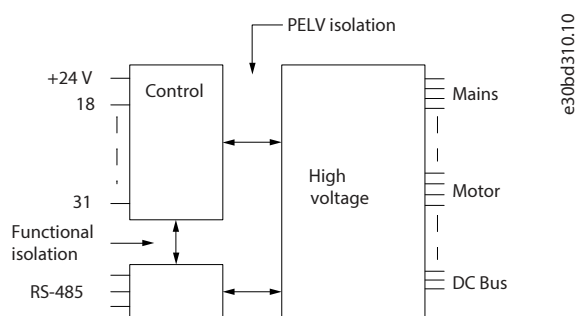
**Figure 45: Analog Inputs**

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**NOTICE**

**HIGH ALTITUDES**

● For installation at altitudes above 2000 m (6562 ft), contact Danfoss regarding PELV.

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## 5.2.8 Pulse Inputs

| | |
|---|---|
| Programmable pulse inputs | 2 |
| Terminal number pulse | 29, 33 |
| Maximum frequency at terminal 29, 33 (push-pull driven) | 32 kHz |
| Maximum frequency at terminal 29, 33 (open collector) | 5 kHz |
| Minimum frequency at terminal 29, 33 | 4 Hz |
| Voltage level | See the section on digital input |
| Maximum voltage on input | 28 V DC |
| Input resistance, Ri | Approximately 4 kΩ |
| Pulse input accuracy | Maximum error: 0.1% of full-scale |

## 5.2.9 Digital Outputs

| | |
|---|---|
| Programmable digital/pulse outputs | 2 |
| Terminal number | 27, 29 |
| Voltage level at digital/frequency outputs | 0–24 V |
| Maximum output current (sink or source) | 40 mA |
| Maximum load at frequency outputs | 1 kΩ |
| Maximum capacitive load at frequency outputs | 10 nF |
| Minimum output frequency at frequency outputs | 4 Hz |
| Maximum output frequency at frequency outputs | 32 kHz |
| Accuracy of frequency outputs | Maximum error: 0.1% of full-scale |
| Resolution of frequency outputs | 10 bit |

*1) Terminals 27 and 29 can also be programmed as inputs.*

---

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

## 5.2.10 Analog Outputs

| | |
|---|---|
| Number of programmable analog outputs | 2 |
| Terminal number | 45, 42 |
| Current range at analog outputs | 0/4–20 mA |
| Maximum resistor load to common at analog outputs | 500 Ω |
| Accuracy on analog outputs | Maximum error: 0.8% of full-scale |
| Resolution on analog outputs | 10 bit |

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

## 5.2.11 Relay Outputs

| | |
|---|---|
| Programmable relay outputs | 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 |

*1) IEC 60947 t 4 and 5.*

The relay contacts are galvanically isolated from the rest of the circuit by reinforced isolation.

The relays can be used on different loads (resistive load or inductive load) with different life cycles. The lifecycle depends on the configuration of the specific load.

## 5.2.12 Control Card, 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 circuit is galvanically isolated from the supply voltage (PELV).

## 5.2.13 Control Card, 24 V DC Output

| | |
|---|---|
| Terminal number | 12 |
| Maximum load | 100 mA |

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

## 5.2.14 Control Card, +10 V DC Output

| | |
|---|---|
| Terminal number | 50 |
| Output voltage | 10.5 V ±0.5 V |
| Maximum load | 15 mA |

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

## 5.2.15 Control Characteristics

| | |
|---|---|
| Resolution of output frequency at 0–500 Hz | ±0.003 Hz |
| System response time (terminals 18, 19, 27, 29, 31, 32, and 33) | ≤2 ms |
| Speed control range (open loop) | 1:100 of synchronous speed |
| Speed accuracy (open loop) | ±0.5% of nominal speed |
| Speed accuracy (close loop) | ±0.1% of nominal speed |

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

## 5.2.16 Control Card Performance

| | |
|---|---|
| Scan interval | 1 ms |

## 5.2.17 Protection and Features

- Electronic motor thermal protection against overload.
- Temperature monitoring of the heat sink ensures that the drive trips when the temperature reaches a predefined level. An overload temperature cannot be reset until the temperature of the heat sink is below the temperature limit.
- The drive is protected against short circuits on motor terminals U, V, W.
- If a mains phase is missing, the drive trips or issues a warning (depending on the load and parameter setting).
- Monitoring of the DC-link voltage ensures that the drive trips when the DC-link voltage is too low or too high.
- The drive is protected against ground faults on motor terminals U, V, W.

## 5.3 **Fuses**

### 5.3.1 **Introduction**

Use fuses and/or circuit breakers on the supply side to protect service personnel and equipment from injuries and damage if there is component breakdown inside the drive (first fault).

**Branch circuit protection**

Protect all branch circuits in an installation, switchgear, and machines against short circuit and overcurrent according to national/ international regulations.

| NOTICE |
| --- |
| The recommendations do not cover branch circuit protection for UL. |

| ⚠ WARNING |
| --- |
| **PERSONAL INJURY AND EQUIPMENT DAMAGE RISK** |
| Malfunction or failing to follow the recommendations may result in personal risk and damage to the drive and other equipment. |
| • Select fuses according to recommendations. Possible damages can be limited to be inside the drive. |

### 5.3.2 **Recommendation of Fuses**

| NOTICE |
| --- |
| Using fuses or circuit breakers is mandatory to ensure compliance with IEC 60364 for CE. |

Danfoss recommends using the fuses in Table 26 on a circuit capable of delivering 100000 $A_{rms}$ (symmetrical), 380–480 V depending on the drive voltage rating. With the proper fusing, the drive short-circuit current rating (SCCR) is 100000 $A_{rms}$.

Table 26 lists the recommended fuses that have been tested.

**Table 26: CE Fuse, 380–480 V, Enclosure Sizes J1–J7**

| Enclosure size | Power [kW (hp)] | CE compliance fuse |
| --- | --- | --- |
| J1 | 0.37–1.1 (0.5–1.5) | gG-10 |
| | 1.5 (2) | |
| | 2.2 (3) | |
| J2 | 3.0 (4) | gG-25 |
| | 4.0 (5.5) | |
| | 5.5 (7.5) | |
| J3 | 7.5 (10) | gG-32 |
| J4 | 11–15 (15–20) | gG-50 |
| J5 | 18.5 (25) | gG-80 |
| | 22 (30) | |

**Table 26: CE Fuse, 380–480 V, Enclosure Sizes J1–J7** (continued)

| Enclosure size | Power [kW (hp)] | CE compliance fuse |
|---|---|---|
| J6 | 30 (40) | gG-125 |
| | 37 (50) | |
| | 45 (60) | |
| J7 | 55 (75) | aR-250 |
| | 75 (100) | |
| | 90 (125) | |

## 5.4 Efficiency

### 5.4.1 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 Figure 46. Multiply the factor in Figure 46 by the specific efficiency factor listed in the specification tables.
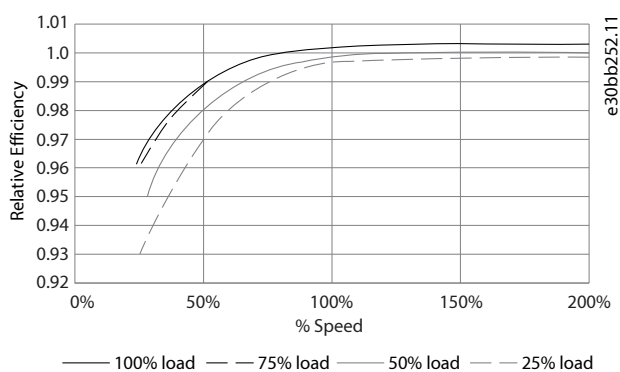


**Figure 46: Typical Efficiency Curves**

### 5.4.2 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.

### 5.4.3 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 ($\eta_{MOTOR}$):

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

## 5.5 Acoustic Noise

The acoustic noise from the drive comes from 3 sources:

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

The typical values measured at a distance of 1 m (3.3 ft) from the unit are:

**Table 27: Typical Measured Values**

| Enclosure size [kW (hp)] | 50% fan speed [dBA] | Full fan speed [dBA] |
|---|---|---|
| J1 0.37–2.2 (0.5–3.0) | N.A.[1] | 51 |
| J2 3.0–5.5 (4.0–7.5) | | 55 |
| J3 7.5 (10) | | 54 |
| J4 11–15 (15–20) | 52 | 66 |
| J5 18.5–22 (25–30) | 57.5 | 63 |
| J6 30–45 (40–60) | 56 | 71 |
| J7 55–90 (75–125) | 63 | 72 |

1) For J1–J3, the fan speed is fixed.

## 5.6 dU/dt Conditions

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

- The motor cable type.
- The cross-section of the motor cable.
- The length of the motor cable.
- Whether the motor cable is shielded or not.
- 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 DC link. The rise time and the peak voltage $U_{PEAK}$ affect the service life of the motor.

If the peak voltage is too high, motors without phase coil insulation are affected. The longer the motor cable, the higher the rise time and peak voltage.

Switching of the IGBTs causes peak voltage on the motor terminals. The drive complies with IEC 60034-25 regarding motors designed to be controlled by drives. The drive also complies with IEC 60034-17 regarding Norm motors controlled by drives.

The following dU/dt data are measured at the motor terminal side:

**Table 28: dU/dt Data for FC 360, 2.2 kW (3.0 hp)**

| Cable length [m (ft)] | Mains voltage [V] | Rise time [$\mu_{sec}$] | $U_{PEAK}$ [kV] | dU/dt [kV/$\mu_{sec}$] |
|---|---|---|---|---|
| 5 (16.4) | 400 | 0.164 | 0.98 | 5.4 |
| 50 (164) | 400 | 0.292 | 1.04 | 2.81 |
| 5 (16.4) | 480 | 0.168 | 1.09 | 5.27 |
| 50 (164) | 480 | 0.32 | 1.23 | 3.08 |

**Table 29: dU/dt Data for FC 360, 5.5 kW (7.5 hp)**

| Cable length [m (ft)] | Mains voltage [V] | Rise time [$\mu_{sec}$] | $U_{PEAK}$ [kV] | dU/dt [kV/$\mu_{sec}$] |
|---|---|---|---|---|
| 5 (16.4) | 400 | 0.18 | 0.86 | 3.84 |
| 50 (164) | 400 | 0.376 | 0.96 | 2.08 |
| 5 (16.4) | 480 | 0.196 | 0.97 | 3.98 |
| 50 (164) | 480 | 0.38 | 1.19 | 2.5 |

**Table 30: dU/dt Data for FC 360, 7.5 kW (10 hp)**

| Cable length [m (ft)] | Mains voltage [V] | Rise time [$\mu_{sec}$] | $U_{PEAK}$ [kV] | dU/dt [kV/$\mu_{sec}$] |
|---|---|---|---|---|
| 5 (16.4) | 400 | 0.166 | 0.992 | 4.85 |
| 50 (164) | 400 | 0.372 | 1.08 | 2.33 |
| 5 (16.4) | 480 | 0.168 | 1.1 | 5.2 |
| 50 (164) | 480 | 0.352 | 1.25 | 2.85 |

**Table 31: dU/dt Data for FC 360, 15 kW (20 hp)**

| Cable length [m (ft)] | Mains voltage [V] | Rise time [$\mu_{sec}$] | $U_{PEAK}$ [kV] | dU/dt [kV/$\mu_{sec}$] |
|---|---|---|---|---|
| 5 (16.4) | 400 | 0.224 | 0.99 | 3.54 |
| 50 (164) | 400 | 0.392 | 1.07 | 2.19 |
| 5 (16.4) | 480 | 0.236 | 1.14 | 3.87 |
| 50 (164) | 480 | 0.408 | 1.33 | 2.61 |

**Table 32: dU/dt Data for FC 360, 22 kW (30 hp)**

| Cable length [m (ft)] | Mains voltage [V] | Rise time [$\mu_{sec}$] | $U_{PEAK}$ [kV] | dU/dt [kV/$\mu_{sec}$] |
|---|---|---|---|---|
| 5 (16.4) | 400 | 0.272 | 0.947 | 2.79 |
| 50 (164) | 400 | 0.344 | 1.03 | 2.4 |
| 5 (16.4) | 480 | 0.316 | 1.01 | 2.56 |
| 50 (164) | 480 | 0.368 | 1.2 | 2.61 |

**Table 33: dU/dt Data for FC 360, 37 kW (50 hp)**

| Cable length [m (ft)] | Mains voltage [V] | Rise time [$\mu_{sec}$] | U$_{PEAK}$ [kV] | dU/dt [kV/$\mu_{sec}$] |
|---|---|---|---|---|
| 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 |

**Table 34: dU/dt Data for FC 360, 45 kW (60 hp)**

| Cable length [m (ft)] | Mains voltage [V] | Rise time [$\mu_{sec}$] | U$_{PEAK}$ [kV] | dU/dt [kV/$\mu_{sec}$] |
|---|---|---|---|---|
| 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 |

**Table 35: dU/dt Data for FC 360, 55 kW (75 hp)**

| Cable length [m (ft)] | Mains voltage [V] | Rise time [$\mu_{sec}$] | U$_{PEAK}$ [kV] | dU/dt [kV/$\mu_{sec}$] |
|---|---|---|---|---|
| 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 |

**Table 36: dU/dt Data for FC 360, 75 kW (100 hp)**

| Cable length [m (ft)] | Mains voltage [V] | Rise time [$\mu_{sec}$] | U$_{PEAK}$ [kV] | dU/dt [kV/$\mu_{sec}$] |
|---|---|---|---|---|
| 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 |

**Table 37: dU/dt Data for FC 360, 90 kW (125 hp)**

| Cable length [m (ft)] | Mains voltage [V] | Rise time [$\mu_{sec}$] | U$_{PEAK}$ [kV] | dU/dt [kV/$\mu_{sec}$] |
|---|---|---|---|---|
| 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 |

## 5.7 Special Conditions

### 5.7.1 Introduction

Under some special conditions, where the operation of the drive is challenged, consider derating. In some conditions, derating must be done manually. In other conditions, the drive automatically performs a degree of derating when necessary. Derating is done to ensure the performance at critical stages where the alternative could be a trip.

### 5.7.2 Manual Derating

Manual derating must be considered for:

- Air pressure – for installation at altitudes above 1000 m (3281 ft).
- Motor speed – at continuous operation at low RPM in constant torque applications.
- Ambient temperature – above 45 °C (113 °F), for some types above 50 °C (122 °F), for details, see the following figures and tables.
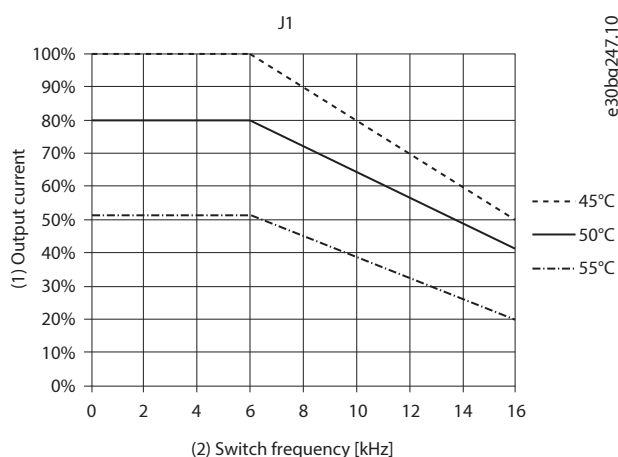


**Figure 47: J1 Derating Curve**
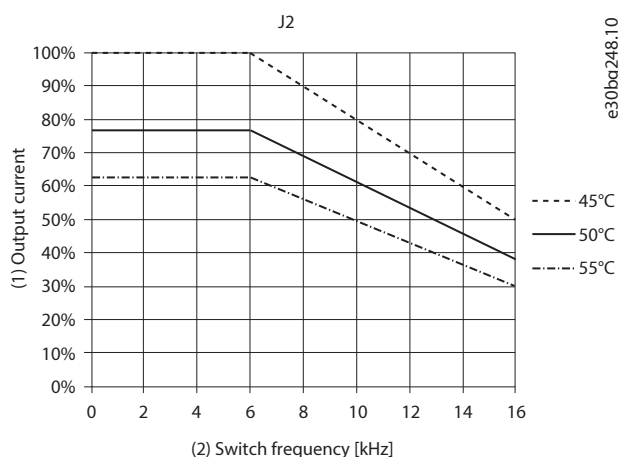


**Figure 48: J2 Derating Curve**
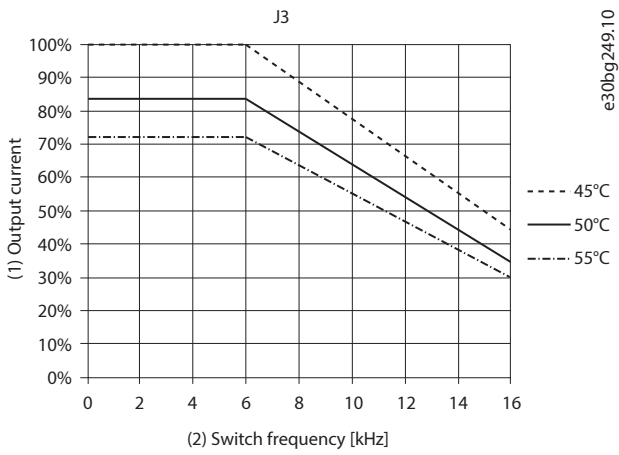
**Figure 49: J3 Derating Curve**
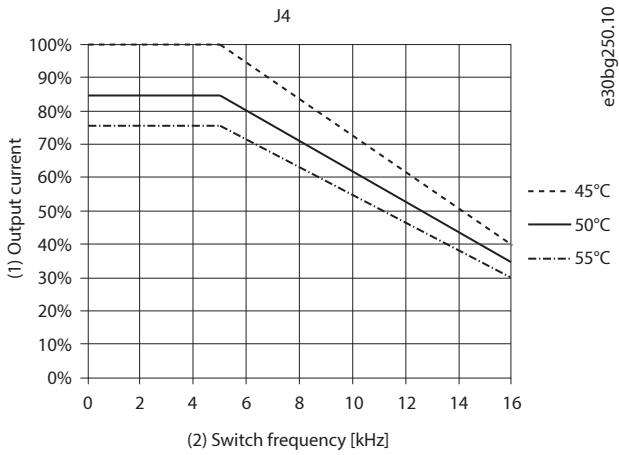


**Figure 50: J4 Derating Curve**
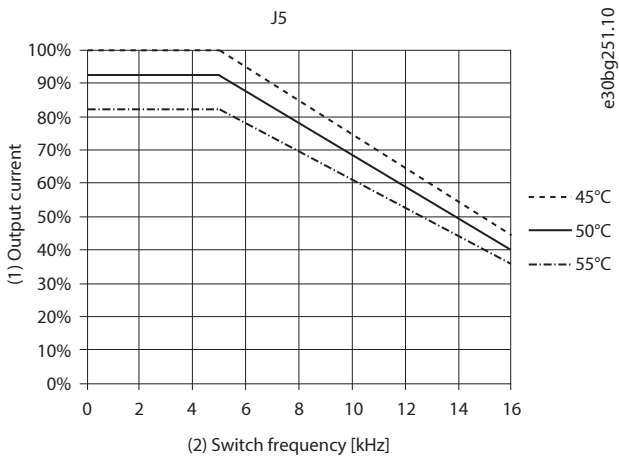


**Figure 51: J5 Derating Curve**
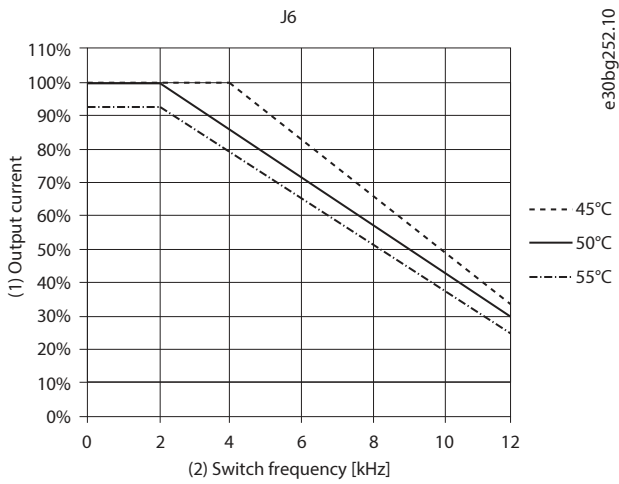
**Figure 52: J6 Derating Curve**
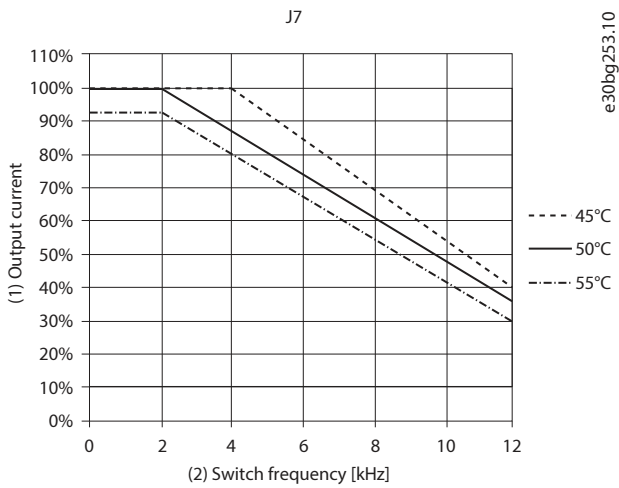


**Figure 53: J7 (55–75 kW/75–100 hp) Derating Curve**
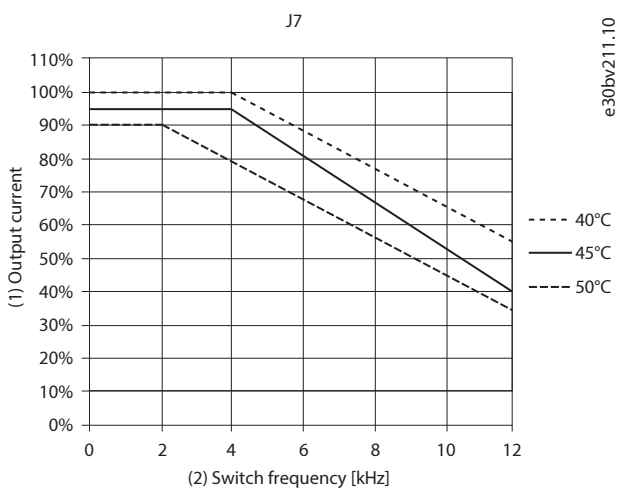


**Figure 54: J7 (90 kW/125 hp) Derating Curve**

**Table 38: Derating at 380 V**

| Enclosure size | Power size [kW (hp)] | Maximum output current at 45 °C (113 °F) | Maximum output current at 50 °C (122 °F) |
|---|---|---|---|
| J1 | 0.37 (0.5) | 1.2 | 1.2 |
| | 0.55 (0.75) | 1.7 | 1.7 |
| | 0.75 (1.0) | 2.2 | 2.2 |
| | 1.1 (1.5) | 3.0 | 3.0 |
| | 1.5 (2.0) | 3.7 | 3.0 |
| | 2.2 (3.0) | 5.3 | 4.1 |
| J2 | 3 (4) | 7.2 | 7.2 |
| | 4 (5.5) | 9.0 | 9.0 |
| | 5.5 (7.5) | 12.0 | 10.2 |
| J3 | 7.5 (10) | 15.5 | 13.1 |
| J4 | 11 (15) | 23.0 | 23.0 |
| | 15 (20) | 31.0 | 26.0 |
| J5 | 18.5 (25) | 37.0 | 37.0 |
| | 22 (30) | 42.5 | 40.0 |
| J6 | 30 (40) | 61 | 61 |
| | 37 (50) | 73 | 73 |
| | 45 (60) | 90 | 77 |
| J7 | 55 (75) | 106 | 106 |
| | 75 (100) | 147 | 125 |
| | 90 (125) | 177 (measured at 40 °C (104 °F)) | 168 |

**Table 39: Derating at 480 V**

| Enclosure size | Power size [kW (hp)] | Maximum output current at 45 °C (113 °F) | Maximum output current at 50 °C (122 °F) |
|---|---|---|---|
| J1 | 0.37 (0.5) | 1.1 | 1.1 |
| | 0.55 (0.75) | 1.6 | 1.6 |
| | 0.75 (1.0) | 2.1 | 2.1 |
| | 1.1 (1.5) | 3.0 | 2.8 |
| | 1.5 (2.0) | 3.4 | 2.8 |
| | 2.2 (3.0) | 4.8 | 3.8 |

**Table 39: Derating at 480 V** (continued)

| Enclosure size | Power size [kW (hp)] | Maximum output current at 45 °C (113 °F) | Maximum output current at 50 °C (122 °F) |
|---|---|---|---|
| J2 | 3 (4) | 6.3 | 6.3 |
|  | 4 (5.5) | 8.2 | 8.2 |
|  | 5.5 (7.5) | 11.0 | 9.4 |
| J3 | 7.5 (10) | 14.0 | 11.9 |
| J4 | 11 (15) | 21.0 | 21.0 |
|  | 15 (20) | 27.0 | 22.6 |
| J5 | 18.5 (25) | 34.0 | 34.0 |
|  | 22 (30) | 40.0 | 37.7 |
| J6 | 30 (40) | 52 | 52 |
|  | 37 (50) | 65 | 65 |
|  | 45 (60) | 77 | 76 |
| J7 | 55 (75) | 96 | 96 |
|  | 75 (100) | 124 | 117 |

### 5.7.3 Automatic Derating

The drive constantly checks for critical levels:

- Critical high temperature on the control card or heat sink.
- High motor load.
- Low motor speed.
- Protection signals (overvoltage/undervoltage, overcurrent, ground fault, and short circuit) are triggered.

As a response to a critical level, the drive adjusts the switching frequency.

## 5.8 Enclosure Sizes, Power Ratings, and Dimensions

**Table 40: Enclosure Sizes, Power Ratings, and Dimensions**

| Enclosure size | | J1 | J2 | J3 | J4 | J5 | J6 | J7 |
|---|---|---|---|---|---|---|---|---|
| Power size [kW (hp)] | 3-phase 380–480 V | 0.37–2.2 (0.5–3.0) | 3.0–5.5 (4.0–7.5) | 7.5 (10) | 11–15 (15–20) | 18.5–22 (25–30) | 30–45 (40–60) | 55–90 (75–125) |
| Dimensions [mm (in)] | Height A | 210 (8.3) | 272.5 (10.7) | 272.5 (10.7) | 317.5 (12.5) | 410 (16.1) | 515 (20.28) | 550 (21.7) |
|  | Width B | 75 (3.0) | 90 (3.5) | 115 (4.5) | 133 (5.2) | 150 (5.9) | 231 (9.1) | 308 (12.1) |
|  | Depth C | 168 (6.6) | 168 (6.6) | 168 (6.6) | 245 (9.6) | 245 (9.6) | 241 (9.49) | 323 (12.72) |
|  | Depth C with option B | 181 (7.1) | 181 (7.1) | 181 (7.1) | 258 (10.2) | 258 (10.2) | 241 (9.49) | 323 (12.72) |

**Table 40: Enclosure Sizes, Power Ratings, and Dimensions** (continued)

| Enclosure size | | J1 | J2 | J3 | J4 | J5 | J6 | J7 |
|---|---|---|---|---|---|---|---|---|
| **Weight [kg (lb)]** | IP20 | 0.37–1.5 kW/ 0.5–2.0 hp: 2.3 (5.1) | 3.6 (7.9) | 4.1 (9.0) | 11 kW/15 hp: 9.4 (20.7) | 18.5 kW/25 hp: 12.3 (27.1) | 30 kW/40 hp: 22.4 (49.4) | 55 kW/75 hp: 37.3 (82.2) |
| | | | | | | | 37 kW/50 hp: 22.5 (49.6) | |
| | | 2.2 kW/3.0 hp: 2.5 (5.5) | | | 15 kW/20 hp: 9.5 (20.9) | 22 kW/30 hp: 12.5 (27.6) | 45 kW/60 hp: 22.6 (49.8) | 75 kW/100 hp: 38.7 (85.3) |
| **Mounting holes [mm (in)]** | a | 198 (7.8) | 260 (10.2) | 260 (10.2) | 297.5 (11.7) | 390 (15.4) | 495 (19.49) | 521 (20.5) |
| | b | 60 (2.4) | 70 (2.8) | 90 (3.5) | 105 (4.1) | 120 (4.7) | 200 (7.87) | 270 (10.63) |
| | c | 5 (0.2) | 6.4 (0.25) | 6.5 (0.26) | 8 (0.32) | 7.8 (0.31) | 140 (5.5) | 204 (8.0) |
| | d | 9 (0.35) | 11 (0.43) | 11 (0.43) | 12.4 (0.49) | 12.6 (0.5) | 8.5 (0.33) | 8.5 (0.33) |
| | e | 4.5 (0.18) | 5.5 (0.22) | 5.5 (0.22) | 6.8 (0.27) | 7 (0.28) | 8.5 (0.33) | 8.5 (0.33) |
| | f | 7.3 (0.29) | 8.1 (0.32) | 9.2 (0.36) | 11 (0.43) | 11.2 (0.44) | 8.5 (0.33) | 8.5 (0.33) |
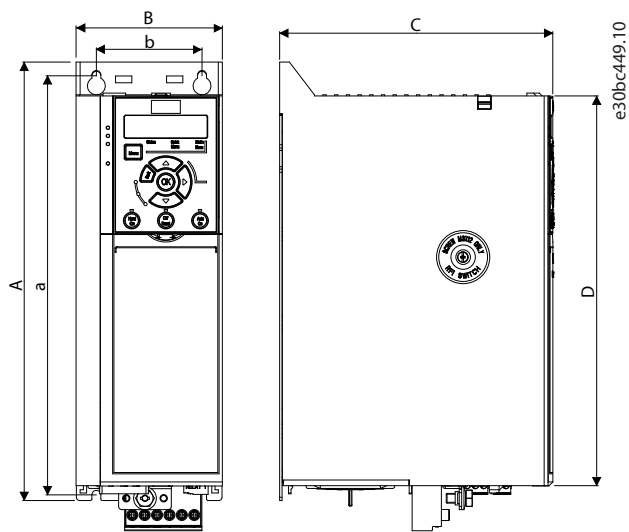


**Figure 55: Dimensions**
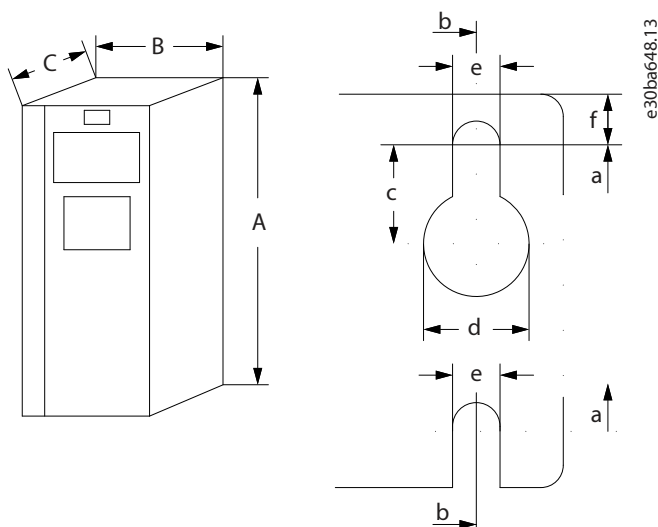
**Figure 56: Top and Bottom Mounting Holes J1–J5**
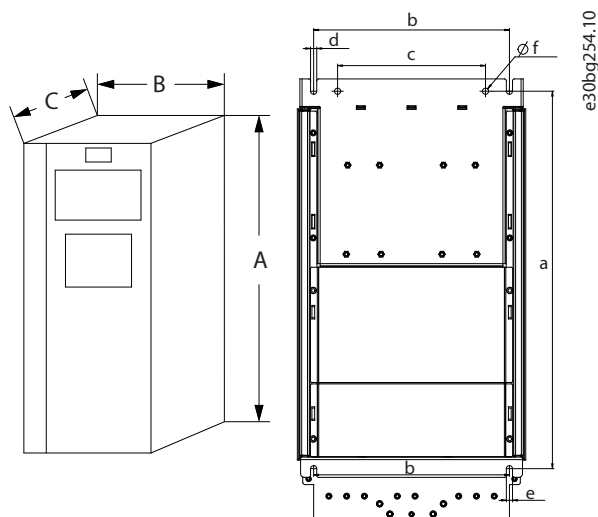


**Figure 57: Top and Bottom Mounting Holes J6–J7**

## 5.9 Cooling and Airflow Requirements

- 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 Special Conditions* for detailed information.

- The drive's maximum heating value could be estimated via the following formula. Refer to 5.1 Electrical Data for the drive's efficiency at rated load.

$$Maximum\,heating\,value \approx Power \times (1 - Efficiency)$$

- 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 a dust screen, contact the dust screen supplier.

**Table 41: 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) | 6 | 11 |
| 0.55 (0.75) | 8 | 13 |
| 0.75 (1.0) | 9 | 15 |
| 1.1 (1.5) | 16 | 27 |
| 1.5 (2.0) | 16 | 27 |
| 2.2 (3.0) | 20 | 34 |
| 3 (4.0) | 25 | 43 |
| 4 (5.0) | 28 | 48 |
| 5.5 (7.5) | 34 | 58 |
| 7.5 (10) | 43 | 73 |
| 11 (15) | 89 | 151 |
| 15 (20) | 121 | 206 |
| 18.5 (25) | 140 | 237 |
| 22 (30) | 162 | 275 |
| 30 (40) | 178 | 303 |
| 37 (50) | 220 | 374 |
| 45 (60) | 240 | 408 |
| 55 (70) | 257 | 436 |
| 75 (100) | 350 | 595 |
| 90 (125) | 370 | 629 |

## 5.10 Preventive Maintenance Recommendations

Generally, all technical equipment, including Danfoss AC drives, need a minimum level of preventive maintenance. To ensure trouble-free operation and long life of the drive, regular maintenance is recommended. It is also recommended as a good service practice to record a maintenance log with counter values, date, and time describing the maintenance and service actions.

Danfoss recommends the following inspections and service intervals for air-cooled drives/systems.

| NOTICE |
| --- |
| The service schedule for part replacements can vary depending on operating conditions. Under specific conditions, the combination of stressful operation and environmental conditions work together to reduce the lifetime of the components significantly. These conditions can include, for example, extreme temperature, dust, high humidity, hours of use, corrosive environment, and loading. |

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

**Table 42: Maintenance Schedule for Air-cooled Drives**

| Component | Inspection interval[1] | Service schedule[2] | Preventive maintenance actions |
|---|---|---|---|
| **Installation** | | | |
| Visual inspection | 1 year | – | Check for the unusual, for example, for signs of overheating, aging, corrosion, and for dusty and damaged components. |
| Auxiliary equipment | 1 year | According to manufacturer recommendations | Inspect equipment, switchgear, relays, disconnects, or fuses/circuit breakers. Examine the operation and condition for possible causes of operational faults or defects. The continuity check on fuses must be performed by trained service personnel. |
| EMC consideration | 1 year | – | Inspect the wiring regarding the electromagnetic capability and the separation distance between control wiring and power cables. |
| Cable routing | 1 year | – | Check for parallel routing of motor cables, mains wiring, and signal wiring. Avoid parallel routing. Avoid routing cables through free air without support. Check for aging and wearing of the cable insulation. |
| Control wiring | 1 year | – | Check for tightness, damaged or crimped wires, or ribbon wires. Terminate the connections correctly with solid crimped ends. The use of shielded cables and grounded EMC plate, or a twisted pair is recommended. |
| Clearances | 1 year | – | Check that the external clearances for proper airflow for cooling follow the requirements for the frame and product type. For clearances, refer to the local design regulations. |
| Sealing | 1 year | – | Check that the sealing of the enclosure, the covers, and the cabinet doors are in good condition. |
| Corrosive environments | 1 year | – | Conductive dust and aggressive gases, such as sulphide, chloride, and salt mist, can damage the electrical and mechanical components. Air filters do not remove airborne corrosive chemicals. Act based on the findings. |
| **Drive** | | | |
| Programming | 1 year | – | Check that the AC drive parameter settings are correct according to the motor, drive application, and I/O configuration. Only trained service personnel are allowed to perform this action. |
| Control panel | 1 year | – | Check that the display pixels are intact. Check the event log for warnings and faults. Repetitive events are a sign of potential issues. If necessary, contact a local service center. |
| Drive cooling capacity | 1 year | – | Check for blockages or constrictions in the air passages of the cooling channel. The heat sinks must be free of dust and condensation. |

**Table 42: Maintenance Schedule for Air-cooled Drives** (continued)

| Component | Inspection interval[1] | Service schedule[2] | Preventive maintenance actions |
|---|---|---|---|
| Capacitors, DC link | 1 year | 8–15+ years | The expected lifetime of the capacitors depends on the loading profile of the application and the ambient temperature. For applications with heavy loads in demanding environments or high ripple currents, replace electrolytic capacitors every 8 years and plastic foil capacitors every 12 years. If within the specifications of the drive type, replace every 10–15+ years. Only trained service personnel are allowed to perform this action. |
| Cleaning and filters | 1 year | – | Clean the interior of the enclosure annually, and more frequently if necessary. The amount of dust in the filter or inside the enclosure is an indicator for when the next cleaning or filter replacement is required. |
| Fans | 1 year | 3–10 years | Inspect the condition and operational status of all cooling fans. With the power off, the fan axis should feel tight, and spinning the fan with a finger, the rotation should be almost silent and not have abnormal rotation resistance. When in RUN mode, fan vibration, excessive or strange noise is a sign of the bearings wearing, and the fan must be replaced. |
| Grounding | 1 year | – | The drive system requires a dedicated ground wire connecting the drive, the output filter, and the motor to the building ground. Check that the ground connections are tight and free of paint or oxidation. Daisy-chain connections are not allowed. If applicable, braided straps are recommended. |
| PCB | 1 year | 10–12 years | Visually inspect the printed circuit boards for signs of damage or degrading due to aging, corrosive environments, dust, or environments with high temperatures. Only trained service personnel are allowed to perform the inspection and service action. |
| Power cables and wiring | 1 year | – | Check for loose connections, aging, insulation condition, and proper torque to the drive connections. Check for proper rating of fuses and continuity check. Observe if there are any signs of operation in a demanding environment. For example, discoloration of the fuse housing can be a sign of condensation or high temperatures. |
| Vibration | 1 year | – | Check for abnormal vibration or noise coming from the drive to ensure that the environment is stable for electronic components. |
| Insulator gaskets | 1 year | 10–15 years | Inspect the insulators for signs of degradation due to high temperature and aging. Replacement is based on findings or done at the same time as DC capacitor replacement. Only trained service personnel are allowed to perform this action. |
| Batteries | 1 year | 7–10 years | Replace the batteries according to the manufacturer recommendation. Replace the real-time clock battery in the control unit every 7–10 years. |
| **Spare parts** | | | |

**Table 42: Maintenance Schedule for Air-cooled Drives** (continued)

| Component | Inspection interval[1] | Service schedule[2] | Preventive maintenance actions |
|---|---|---|---|
| Spare parts | 1 year | 2 years | Stock spares in their original boxes in a dry and clean environment. Avoid hot storage areas. Electrolytic capacitors require reforming as stated in the service schedule. The reforming must be performed by trained service personnel. |
| Exchange units and units stored for long periods before commissioning | 1 year | 2 years | Visually inspect for signs of damage, water, high humidity, corrosion, and dust within the visual field of view without disassembly. The exchange units with mounted electrolytic capacitors require reforming as stated in the service schedule. The reforming must be performed by trained service personnel. |

1) *Defined as the time after the commissioning/startup or the time from the previous inspection.*

2) *Defined as the time after the commissioning/startup or the time from the previous service schedule actions.*

# 6 RS485 Installation and Setup

## 6.1 Introduction

### 6.1.1 Overview

RS485 is a 2-wire bus interface compatible with multi-drop network topology. The nodes can be connected as a bus or via drop cables from a common trunk line. A total of 32 nodes can be connected to 1 network segment.

Repeaters divide network segments, see Figure 58.
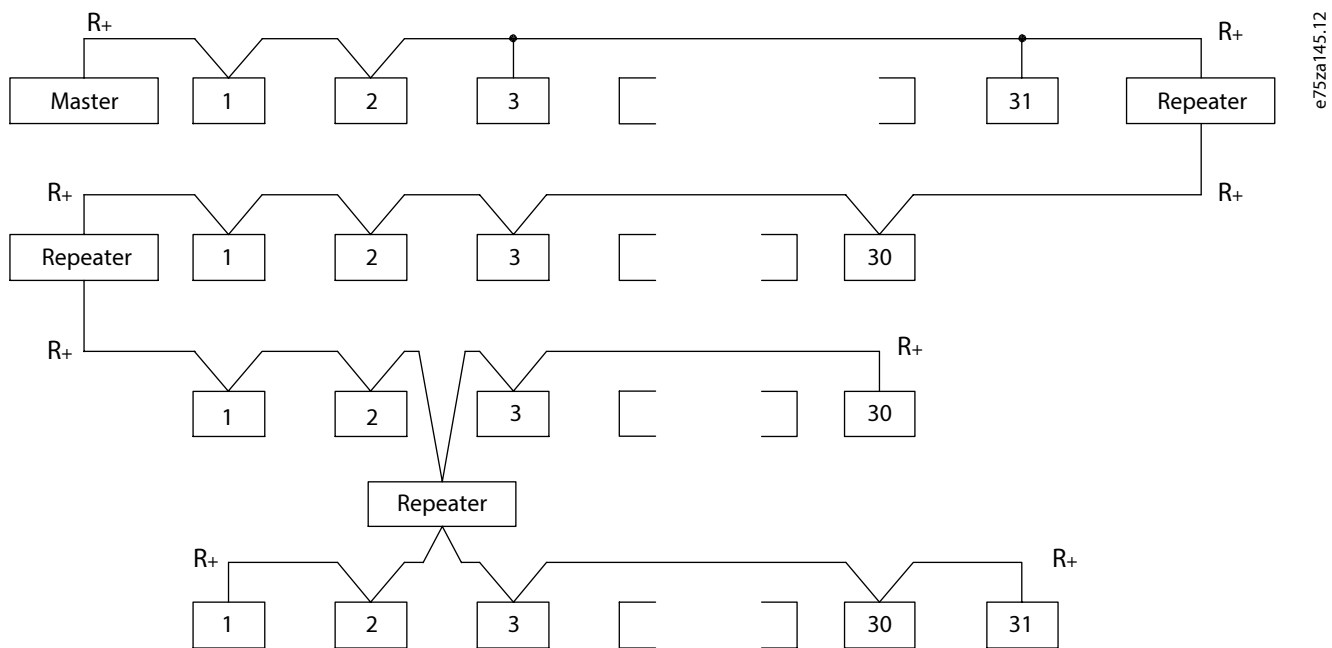


**Figure 58: RS485 Bus Interface**

| 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 43: Cable Specifications**

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

## 6.1.2 Network Connection

Connect the drive to the RS485 network as follows (see also Figure 59):

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

2.  Connect the cable shield to the cable clamps.

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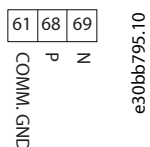


**Figure 59: Network Connection**

## 6.1.3 Hardware Setup

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

The factory setting for the switch is OFF.

## 6.1.4 Parameter Settings for Modbus Communication

**Table 44: 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><br> **NOTICE** <br> The address range depends on the protocol selected in *parameter 8-30 Protocol*. |
| *Parameter 8-32 Baud Rate* | Set the baud rate. <br><br> **NOTICE** <br> The default baud rate depends on the protocol selected in *parameter 8-30 Protocol*. |

**Table 44: Modbus Communication Parameter Settings** (continued)

| Parameter | Function |
|---|---|
| *Parameter 8-33 Parity/Stop Bits* | Set the parity and number of stop bits.<br><br>**NOTICE**<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><br>**NOTICE**<br>The default selection depends on the protocol selected in *parameter 8-30 Protocol*. |

### 6.1.5 EMC Precautions

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

**NOTICE**

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

## 6.2 FC Protocol

### 6.2.1 Overview

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

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

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

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

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

## 6.2.2 FC with Modbus RTU

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

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

- Start.
- Stop of the drive in various ways:
  - Coast stop.
  - Quick stop.
  - DC brake stop.
  - Normal (ramp) stop.
- Reset after a fault trip.
- Run at various preset speeds.
- Run in reverse.
- Change of the active setup.
- Control of the 2 relays built into the drive.

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

## 6.3 FC Protocol Network Configuration

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

**Table 45: Parameters to Enable the Protocol**

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

## 6.4 FC Protocol Message Framing Structure

### 6.4.1 Content of a Character (byte)

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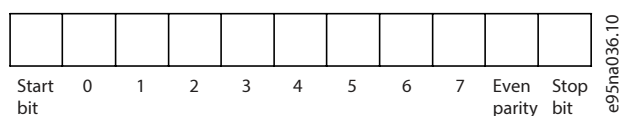


**Figure 60: Content of a Character**

### 6.4.2 **Telegram Structure**

Each telegram has the following structure:

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

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

A data control byte (BCC) completes the telegram.



**Figure 61: Telegram Structure**

### 6.4.3 **Telegram Length (LGE)**

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

**Table 46: 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+n bytes |

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

### 6.4.4 **Drive Address (ADR)**

Address format 1–126

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

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

### 6.4.5 **Data Control Byte (BCC)**

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

### 6.4.6 **The Data Field**

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

The 3 types of telegram are:

**Process block (PCD)**

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

- Control word and reference value (from master to follower).
- Status word and present output frequency (from follower to master).
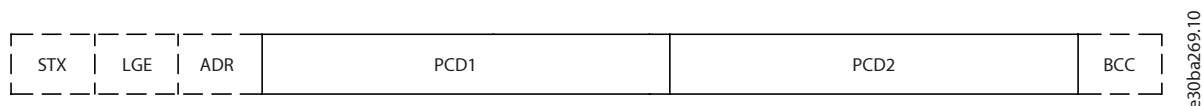
**Figure 62: Process Block**

## Parameter block

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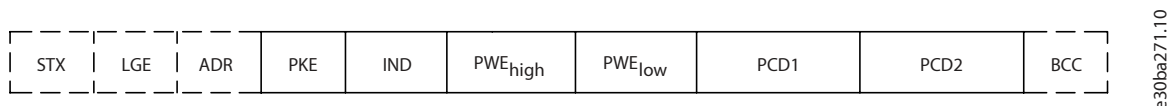


**Figure 63: Parameter Block**

## Text block

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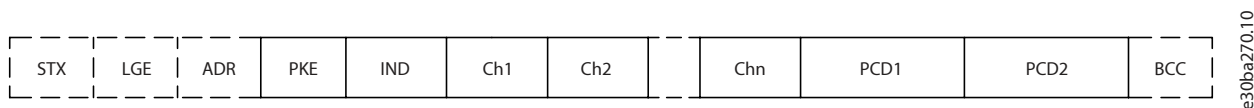


**Figure 64: Text Block**

### 6.4.7 The PKE Field

The PKE field contains 2 subfields:

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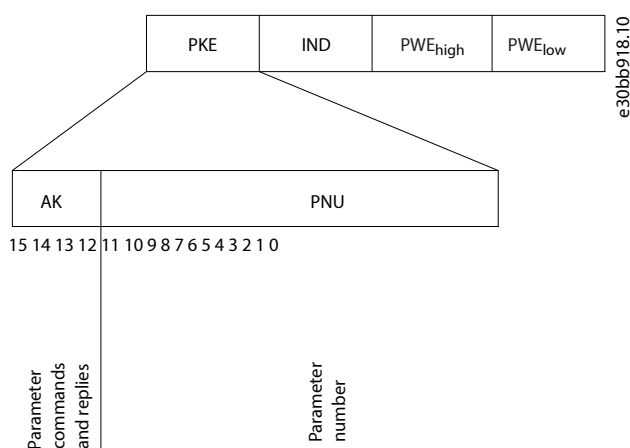


**Figure 65: PKE Field**

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

**Table 47: Parameter Commands**

| Parameter commands master to 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 48: Response**

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

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

**Table 49: Follower Report**

| Fault code | FC specification |
|---|---|
| 0 | Illegal parameter number. |
| 1 | Parameter cannot be changed. |
| 2 | Upper or lower limit is exceeded. |
| 3 | Sub-index is corrupted. |
| 4 | No array. |
| 5 | Wrong data type. |
| 6 | Not used. |
| 7 | Not used. |
| 9 | Description element is not available. |

**Table 49: Follower Report** (continued)

| Fault code | FC specification |
| --- | --- |
| 11 | No parameter write access. |
| 15 | No text available. |
| 17 | Not applicable while running. |
| 18 | Other errors. |
| 100 | – |
| >100 | – |
| 130 | No bus access for this parameter. |
| 131 | Write to factory setup is not possible. |
| 132 | No LCP access. |
| 252 | Unknown viewer. |
| 253 | Request is not supported. |
| 254 | Unknown attribute. |
| 255 | No error. |

### 6.4.8  Parameter Number (PNU)

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

### 6.4.9  Index (IND)

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

Only the low byte is used as an index.

### 6.4.10  Parameter Value (PWE)

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

When a follower responds to a parameter request (read command), the present parameter value in the PWE block is transferred and returned to the master. If a parameter contains several data options, for example, *parameter 0-01 Language*, select the data value by entering the value in the PWE block. Serial communication is only capable of reading parameters containing data type 9 (text string).

*Parameter 15-40 FC Type* to *parameter 15-53 Power Card Serial Number* contain data type 9. For example, read the unit size and mains voltage range in *parameter 15-40 FC Type*. When a text string is transferred (read), the length of the telegram is variable, and the texts are of different lengths. The telegram length is defined in the 2nd byte of the telegram (LGE). When using text transfer, the index character indicates whether it is a read, or a write command.

To read a text via the PWE block, set the parameter command (AK) to F hex. The index character high-byte must be 4.

## 6.4.11 Data Types Supported by the Drive

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

**Table 50: Data Types**

| Data types | Description |
|---|---|
| 3 | Integer 16 |
| 4 | Integer 32 |
| 5 | Unsigned 8 |
| 6 | Unsigned 16 |
| 7 | Unsigned 32 |
| 9 | Text string |

## 6.4.12 Conversion

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

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

**Table 51: Conversion**

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

## 6.4.13 Process Words (PCD)

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

**Table 52: Process Words (PCD)**

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

## 6.5  Examples

### 6.5.1  Writing a Parameter Value

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

Write the data in EEPROM.

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

- IND = 0000 hex.
- PWEHIGH = 0000 hex.
- PWELOW = 03E8 hex.

Data value 1000, corresponding to 100 Hz, see the chapter 6.4.12 Conversion.

The telegram looks like Figure 66.

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

e30ba092.10
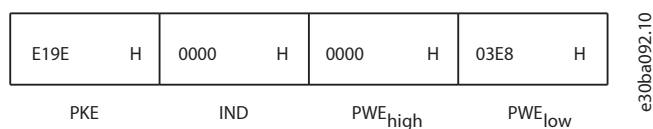
**Figure 66:  Telegram**

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

The response from the follower to the master is shown in Figure 67.

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

e30ba093.10
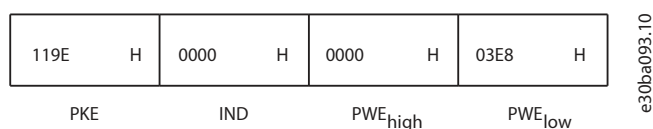
**Figure 67:  Response from Master**

### 6.5.2  Reading a Parameter Value

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

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

- IND = 0000 hex.
- PWE$_{HIGH}$ = 0000 hex.
- PWE$_{LOW}$ = 0000 hex.

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

e30ba094.10
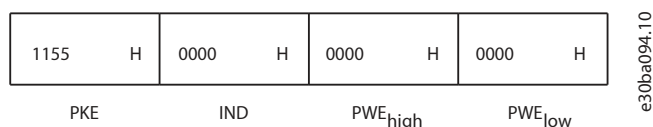
**Figure 68:  Telegram**

If the value in *parameter 3-41 Ramp 1 Ramp Up Time* is 10 s, the response from the follower to the master is shown in Figure 69.

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

e30ba267.10

**Figure 69: Response**

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

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

## 6.6 Modbus RTU

### 6.6.1 Prerequisite Knowledge

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

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

### 6.6.2 Overview

Regardless of the type of physical communication networks, this section describes the process that a controller uses to request access to another device. This process includes how the Modbus RTU responds to requests from another device, and how errors are detected and reported. It also establishes a common format for the layout and contents of telegram fields.

During communications over a Modbus RTU network, the protocol:

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

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

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

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

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

The response telegram of the follower device is also constructed using Modbus protocol. It contains fields confirming the action taken, any data to be returned, and an error-checking field. If an error occurs in receipt of the telegram, or if the follower is unable to perform the requested action, the follower constructs and sends an error message. Alternatively, a timeout occurs.

### 6.6.3 Drive with Modbus RTU

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

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

- Start.
- Various stops:
  - Coast stop.
  - Quick stop.
  - DC brake stop.
  - Normal (ramp) stop.
- Reset after a fault trip.
- Run at various preset speeds.
- Run in reverse.
- Change the active setup.
- Control built-in relay of the drive.

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

## 6.7 Modbus RTU Network Configuration

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

**Table 53: Parameters to Enable the Modbus RTU**

| 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) |

## 6.8 Modbus RTU Message Framing Structure

### 6.8.1 Introduction

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

**Table 54: Format for Each Byte**

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

**Table 55: Byte Details**

| | |
|---|---|
| Coding system | 8-bit binary, hexadecimal 0–9, A–F.<br>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). |

## 6.8.2 Modbus RTU Telegram Structure

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

**Table 56: Typical Modbus RTU Telegram Structure**

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

## 6.8.3 Start/Stop Field

Telegrams start with a silent period of at least 3.5 character intervals. The silent period is implemented as a multiple of character intervals at the selected network baud rate (shown as Start T1-T2-T3-T4). The 1st field to be transmitted is the device address. Following the last transmitted character, a similar period of at least 3.5 character intervals marks the end of the telegram. A new telegram can begin after this period.

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

## 6.8.4 Address Field

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

## 6.8.5 Function Field

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

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

## 6.8.6 Data Field

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

The information can include items such as:

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

## 6.8.7 CRC Check Field

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

## 6.8.8 Coil Register Addressing

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).

**Table 57: 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 |

**Table 57: Coil Register** (continued)

| Coil number | Description | Signal direction |
|---|---|---|
| 49–64 | Open-loop mode: Drive output frequency.<br>Closed-loop mode: Drive feedback signal. | Follower to master |
| 65 | Parameter write control (master to slave). | 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. | – |

**Table 58: Drive Control Word (FC Profile)**

| Coil | 0 | 1 |
|---|---|---|
| 01 | Preset reference lsb | |
| 02 | Preset reference msb | |
| 03 | DC brake | No DC brake |
| 04 | Coast stop | No coast stop |
| 05 | Quick stop | No quick stop |
| 06 | Freeze frequency | No freeze frequency |
| 07 | Ramp stop | Start |
| 08 | No reset | Reset |
| 09 | No jog | Jog |
| 10 | Ramp 1 | Ramp 2 |
| 11 | Data not valid | Data valid |
| 12 | Relay 1 off | Relay 1 on |
| 13 | Relay 2 off | Relay 2 on |
| 14 | Set up lsb | |
| 15 | – | |
| 16 | No reversing | Reversing |

**Table 59: 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 |

**Table 59: Drive Status Word (FC Profile)** (continued)

| Coil | 0 | 1 |
|------|---|---|
| 38 | Not used | Not used |
| 39 | Not used | Not used |
| 40 | No warning | Warning |
| 41 | Not at reference | At reference |
| 42 | Hand-on mode | Auto mode |
| 43 | Out of frequency range | In frequency range |
| 44 | Stopped | Running |
| 45 | Not used | Not used |
| 46 | No voltage warning | Voltage warning |
| 47 | Not in current limit | Current limit |
| 48 | No thermal warning | Thermal warning |

**Table 60: Address/Registers**

| Bus address | Bus register[1] | PLC register | Content | Access | Description |
|-------------|-----------------|--------------|---------|--------|-------------|
| 0 | 1 | 40001 | Reserved | – | Reserved for legacy frequency converters VLT® 5000 and VLT® 2800. |
| 1 | 2 | 40002 | Reserved | – | Reserved for legacy frequency converters VLT® 5000 and VLT® 2800. |
| 2 | 3 | 40003 | Reserved | – | Reserved for legacy frequency converters VLT® 5000 and VLT® 2800. |
| 3 | 4 | 40004 | Free | – | – |
| 4 | 5 | 40005 | Free | – | – |
| 5 | 6 | 40006 | Modbus configuration | Read/Write | TCP only. Reserved for Modbus TCP (*parameter 12-28 Store Data Values* and *parameter 12-29 Store* Always - stored in, for example, EEPROM). |
| 6 | 7 | 40007 | Last fault code | Read only | Fault code received from parameter database, refer to WHAT 38295 for details. |
| 7 | 8 | 40008 | Last error register | Read only | Address of register with which last error occurred, refer to WHAT 38296 for details. |
| 8 | 9 | 40009 | Index pointer | Read/Write | Sub-index of parameter to be accessed. Refer to WHAT 38297 for details. |

**Table 60: Address/Registers** (continued)

| Bus address | Bus register[1] | PLC register | Content | Access | Description |
|---|---|---|---|---|---|
| 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 | *Parameter 0-02 Motor Speed Unit* | Dependent on parameter access | *Parameter 0-02 Motor Speed Unit* 20 bytes space reserved for parameter in Modbus map. |
| 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.*

### 6.8.9  How to Control the Drive

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

### 6.8.10  Function Codes Supported by Modbus RTU

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

**Table 61: Function Codes**

| Function | Function code (hex) |
|---|---|
| Read coils | 1 |
| Read holding registers | 3 |
| Write single coil | 5 |
| Write single register | 6 |
| Diagnostics | 8 |
| Get comm. event counter | B |
| Write multiple coils | F |
| Write multiple registers | 10 |
| Report follower ID | 11 |
| Read/Write multiple registers | 17 |
| Encapsulated Interface Transport | 2b |

**Table 62: Subfunction Code of Function Code 8**

| Function | Function code | Subfunction code | Subfunction |
|---|---|---|---|
| Diagnostics | 8 | 1 | Restart communication. |
| | | 2 | Return diagnostic register. |
| | | 10 | Clear counters and diagnostic register. |
| | | 11 | Return bus message count. |
| | | 12 | Return bus communication error count. |
| | | 13 | Return follower error count. |
| | | 14 | Return follower message count. |

## 6.8.11 Modbus Exception Codes

For a full explanation of the structure of an exception code response, refer to <u>6.8.5 Function Field</u>.

**Table 63: Modbus Exception Codes**

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

## 6.9 How to Access Parameters

### 6.9.1 Parameter Handling

The PNU (parameter number) is translated from the register address contained in the Modbus read or write message. The parameter number is translated to Modbus as (10 x parameter number) decimal. Example: Reading *parameter 3-12 Catch up/slow Down Value* (16 bit): The holding register 3120 holds the values of the parameters. A value of 1352 (decimal) means that the parameter is set to 12.52%.

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

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

## 6.9.2 Storage of Data

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

## 6.9.3 IND (Index)

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

## 6.9.4 Text Blocks

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

## 6.9.5 Conversion Factor

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

## 6.9.6 Parameter Values

**Standard data types**

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

**Non-standard data types**

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

## 6.10 Examples

### 6.10.1 Overview of the Examples

The examples in the following chapters show various Modbus RTU commands.

### 6.10.2 Read Coil Status (01 hex)

**Description**

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

**Query**

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

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

**Table 64: Query**

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

**Response**

The coil status in the response telegram is packed as 1 coil per bit of the data field. Status is indicated as: 1 = ON; 0 = OFF. The lsb of the 1st data byte contains the coil addressed in the query. The other coils follow toward the high-order end of this byte, and from low order to high order in subsequent bytes.

If the returned coil quantity is not a multiple of 8, the remaining bits in the final data byte are padded with values 0 (toward the high-order end of the byte). The byte count field specifies the number of complete bytes of data.

**Table 65: 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.

---

### 6.10.3 Force/Write Single Coil (05 hex)

**Description**

This function forces the coil to either ON or OFF. When broadcast, the function forces the same coil references in all attached followers.

**Query**

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

**Table 66: 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 67: Response**

| Field name | Example (hex) |
|---|---|
| Follower address | 01 |
| Function | 05 |
| Force data HI | FF |
| Force data LO | 00 |
| Quantity of coils HI | 00 |
| Quantity of coils LO | 01 |
| Error check (CRC) | – |

## 6.10.4 Force/Write Multiple Coils (0F hex)

### Description

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

### Query

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

---

**NOTICE**

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

---

**Table 68: 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<br>(Coils 8–1) | 20 |
| Force data LO<br>(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 69: Response**

| Field name | Example (hex) |
| --- | --- |
| Follower address | 01 (drive address) |
| Function | 0F (write multiple coils) |
| Coil address HI | 00 |
| Coil address LO | 10 (coil address 17) |
| Quantity of coils HI | 00 |
| Quantity of coils LO | 10 (16 coils) |
| Error check (CRC) | – |

## 6.10.5 Read Holding Registers (03 hex)

### Description

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

### Query

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

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

**Table 70: 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 71: Response**

| Field name | Example (hex) |
|---|---|
| Follower address | 01 |
| Function | 03 |
| Byte count | 04 |
| Data HI (register 3030) | 00 |
| Data LO (register 3030) | 16 |
| Data HI (register 3031) | E3 |
| Data LO (register 3031) | 60 |
| Error check (CRC) | – |

### 6.10.6 Preset Single Register (06 hex)

**Description**

This function presets a value into a single holding register.

**Query**

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

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

**Table 72: Query**

| Field name | Example (hex) |
|---|---|
| Follower address | 01 |
| Function | 06 |
| Register address HI | 03 (register address 999) |
| Register address LO | E7 (register address 999) |
| Preset data HI | 00 |
| Preset data LO | 01 |
| Error check (CRC) | – |

**Response**

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

**Table 73: Response**

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

## 6.10.7 Preset Multiple Registers (10 hex)

**Description**

This function presets values into a sequence of holding registers.

**Query**

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

Example of a request to preset 2 registers (set *parameter 1-24 Motor Current* to 738 (7.38 A)):

**Table 74: Query**

| Field name | Example (hex) |
|---|---|
| Follower address | 01 |
| Function | 10 |
| Starting address HI | 04 |
| Starting address LO | 07 |

**Table 74: Query** (continued)

| Field name | Example (hex) |
|---|---|
| Number of registers HI | 00 |
| Number of registers LO | 02 |
| Byte count | 04 |
| Write data HI (Register 4: 1049) | 00 |
| Write data LO (Register 4: 1049) | 00 |
| Write data HI (Register 4: 1050) | 02 |
| Write data LO (Register 4: 1050) | E2 |
| Error check (CRC) | – |

**Response**

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

**Table 75: Response**

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

## 6.11  Danfoss FC Control Profile

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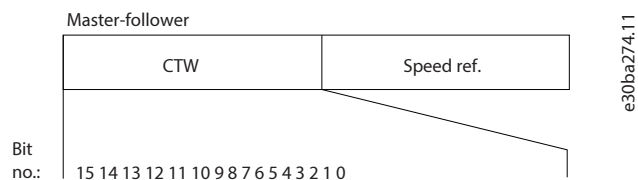


**Figure 70:  Control Word According to FC Profile**

**Table 76: Control Word According to FC Profile**

| Bit | Bit value=0 | Bit value=1 |
|---|---|---|
| 00 | Reference value | External selection lsb |
| 01 | Reference value | External selection msb |

**Table 76: Control Word According to FC Profile** (continued)

| 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 setup | Selection lsb |
| 15 | No function | Reverse |

## Explanation of the control bits

### Bits 00/01

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

**Table 77: Control Bits**

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

---

**NOTICE**

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

---

### Bit 02, DC brake

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

Bit 02 = 1: Leads to ramping.

### Bit 03, Coasting

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

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

In *parameter 8-50 Coasting Select*, define how bit 03 gates with the corresponding function on a digital input.

**Bit 04, Quick stop**

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

**Bit 05, Hold output frequency**

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

---

**NOTICE**

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

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

---

**Bit 06, Ramp stop/start**

Bit 06 = 0: Causes a stop and makes the motor speed ramp down to stop via the selected ramp-down parameter.

Bit 06 = 1: If the other starting conditions are met, bit 06 allows the drive to start the motor.

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

**Bit 07, Reset**

Bit 07 = 0: No reset.

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

**Bit 08, Jog**

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

**Bit 09, Selection of ramp 1/2**

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

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

**Bit 10, Data not valid/Data valid**

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

Bit 10 = 0: The control word is ignored.

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

**Bit 11, Relay 01**

Bit 11 = 0: Relay not activated.

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

**Bit 12, Relay 02**

Bit 12 = 0: Relay 02 is not activated.

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

**Bit 13, Set-up selection**

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

**Table 78: Menu Setups**

| Setup | Bit 13 |
|-------|--------|
| 1 | 0 |
| 2 | 1 |

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

To define how bit 13 gates with the corresponding function on the digital inputs, use *parameter 8-55 Set-up Select*.
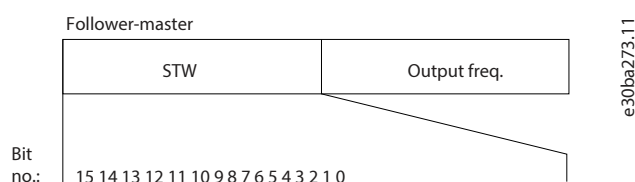
**Bit 15 Reverse**

Bit 15 = 0: No reversing.

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

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

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



**Figure 71: Status Word**

**Table 79: Status Word According to FC Profile**

| Bit | Bit value=0 | Bit value=1 |
|-----|-------------|-------------|
| 00 | Control not ready | Control ready |
| 01 | Drive not ready | Drive ready |
| 02 | Coasting | Enable |
| 03 | No error | Trip |
| 04 | No error | Error (no trip) |
| 05 | Reserved | – |
| 06 | No error | Trip lock |
| 07 | No warning | Warning |
| 08 | Speed≠reference | Speed=reference |
| 09 | Local operation | Bus control |
| 10 | Out of frequency limit | Frequency limit OK |

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

| Bit | Bit value=0 | Bit value=1 |
| --- | --- | --- |
| 11 | No operation | In operation |
| 12 | Drive OK | Stopped, auto start |
| 13 | Voltage OK | Voltage exceeded |
| 14 | Torque OK | Torque exceeded |
| 15 | Timer OK | Timer exceeded |

## Explanation of the status bits

### Bit 00, Control not ready/ready

Bit 00=0: The drive trips.

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

### Bit 01, Drive ready

Bit 01=0: The drive is not ready.

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

### Bit 02, Coast stop

Bit 02=0: The drive releases the motor.

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

### Bit 03, No error/trip

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

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

### Bit 04, No error/error (no trip)

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

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

### Bit 05, Not used

Bit 05 is not used in the status word.

### Bit 06, No error/triplock

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

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

### Bit 07, No warning/warning

Bit 07=0: There are no warnings.

Bit 07=1: A warning has occurred.

### Bit 08, Speed reference/speed=reference

Bit 08=0: The motor runs, but the present speed is different from the preset speed reference. It might happen when the speed ramps up/down during start/stop.

Bit 08=1: The motor speed matches the preset speed reference.

**Bit 09, Local operation/bus control**

Bit 09=0: *[Off/Reset]* is activated on the control unit or *[2] Local* in **parameter 3-13 Reference Site** is selected. It is not possible to control the drive via serial communication.

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

**Bit 10, Out of frequency limit**

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

Bit 10=1: The output frequency is within the defined limits.

**Bit 11, No operation/in operation**

Bit 11=0: The motor is not running.

Bit 11=1: The drive has a start signal without coast.

**Bit 12, Drive OK/stopped, auto start**

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

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

**Bit 13, Voltage OK/limit exceeded**

Bit 13=0: There are no voltage warnings.

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

**Bit 14, Torque OK/limit exceeded**

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

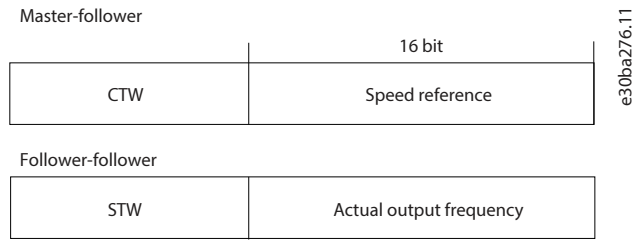Bit 14=1: The current limit in **parameter 4-18 Current Limit** is exceeded.

**Bit 15, Timer OK/limit exceeded**

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

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

## 6.11.3 **Bus Speed Reference Value**

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

Master-follower

| CTW | Speed reference |
|-----|-----------------|

16 bit

Follower-follower

| STW | Actual output frequency |
|-----|-------------------------|

**Figure 72: Actual Output Frequency (MAV)**

The reference and MAV are scaled as follows:
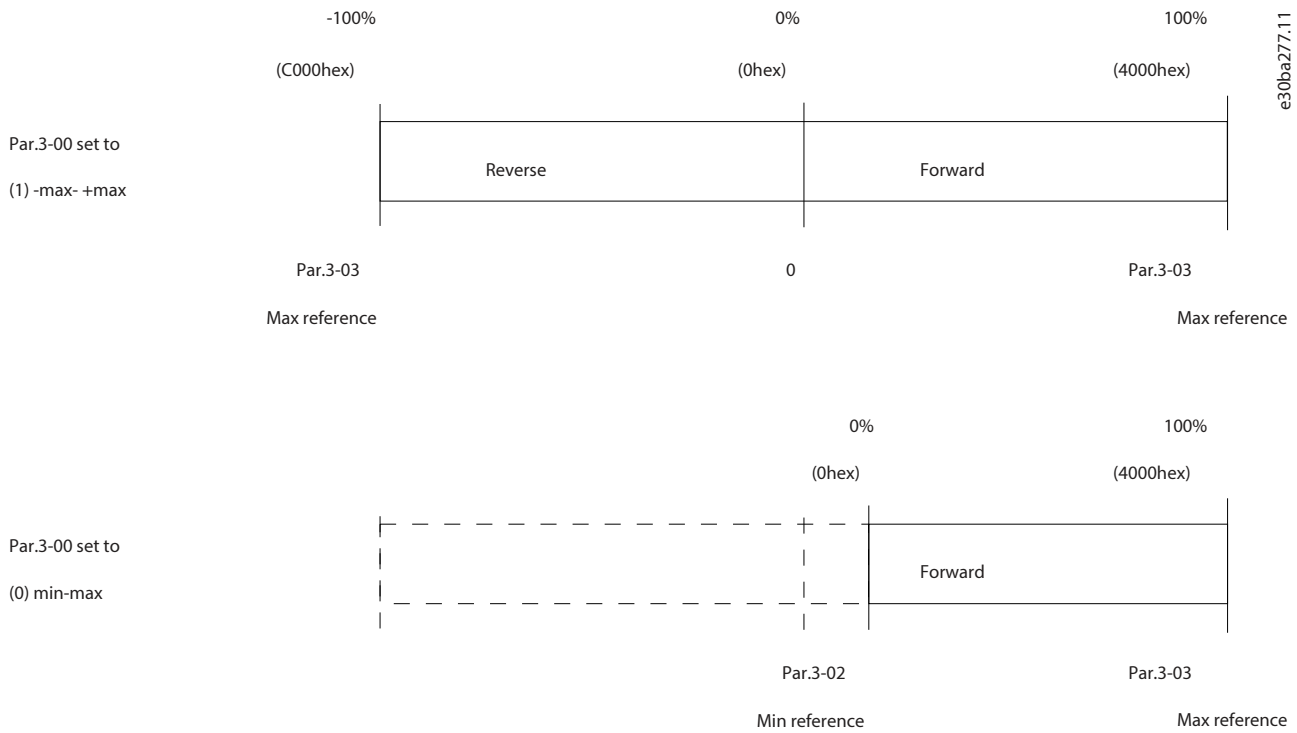


**Figure 73: Reference and MAV**

# 7 Application Examples

## 7.1 Introduction

The examples in this section are intended as a quick reference for common applications.

- Parameter settings are the regional default values unless otherwise indicated (selected in *parameter 0-03 Regional Settings*).
- Parameters associated with the terminals and their settings are shown next to the drawings.
- Required switch settings for analog terminals 53 or 54 are also shown.

## 7.2 AMA

**Table 80: AMA with T27 Connected**

| | Parameter function | Parameter setting |
|---|---|---|
|  | *Parameter 1-29 Automatic Motor Adaptation (AMA)* | *[1] Enable complete AMA* |
| | *Parameter 5-12 Terminal 27 Digital Input* | *[2] Coast inverse* |
| | *=Default value | |
| | **Notes/comments:** Set *parameter group 1-2* Motor Data* according to motor specifications. | |

**NOTICE**

If terminals 12 and 27 are not connected, set *parameter 5-12 Terminal 27 Digital Input* to *[0] No operation*.

## 7.3 **Speed**

**Table 81: Analog Speed Reference (Voltage)**

| | Parameter function | Parameter setting |
|---|---|---|
|  | *Parameter 6-10 Terminal 53 Low Voltage* | *0.07 V |
| | *Parameter 6-11 Terminal 53 High Voltage* | *10 V |
| | *Parameter 6-14 Terminal 53 Low Ref./ Feedb. Value* | *0 |
| | *Parameter 6-15 Terminal 53 High Ref./ Feedb. Value* | 50 Hz |
| | *Parameter 6-19 Terminal 53 mode* | *[1] Voltage |
| | *=Default value | |
| | **Notes/comments:** | |

**Table 82: Analog Speed Reference (Current)**

| | Parameter function | Parameter setting |
|---|---|---|
|  | *Parameter 6-22 Terminal 54 Low Current* | *4 mA |
| | *Parameter 6-23 Terminal 54 High Current* | *20 mA |
| | *Parameter 6-24 Terminal 54 Low Ref./ Feedb. Value* | *0 |
| | *Parameter 6-25 Terminal 54 High Ref./ Feedb. Value* | 50 Hz |
| | *Parameter 6-29 Terminal 54 mode* | [0] Current |
| | *=Default value | |
| | **Notes/comments:** | |

**Table 83: Speed Reference (Using a Manual Potentiometer)**

| | Parameter function | Parameter setting |
|---|---|---|
| FC<br><br>+24 V  12<br>D IN  18<br>D IN  19<br>D IN  27<br>D IN  29<br>D IN  31<br>D IN  32<br>D IN  33<br><br>+10 V  50<br>A IN  53<br>A IN  54<br>COM  55<br>A OUT  42<br>≈5kΩ<br>e30bf820.10 | *Parameter 6-10 Terminal 53 Low Voltage* | *0.07 V |
| | *Parameter 6-11 Terminal 53 High Voltage* | *10 V |
| | *Parameter 6-14 Terminal 53 Low Ref./ Feedb. Value* | *0 |
| | *Parameter 6-15 Terminal 53 High Ref./ Feedb. Value* | 50 Hz |
| | *Parameter 6-19 Terminal 53 mode* | *[1] Voltage |
| | *=Default value | |
| | **Notes/comments:** | |

**Table 84: Speed Up/Speed Down**

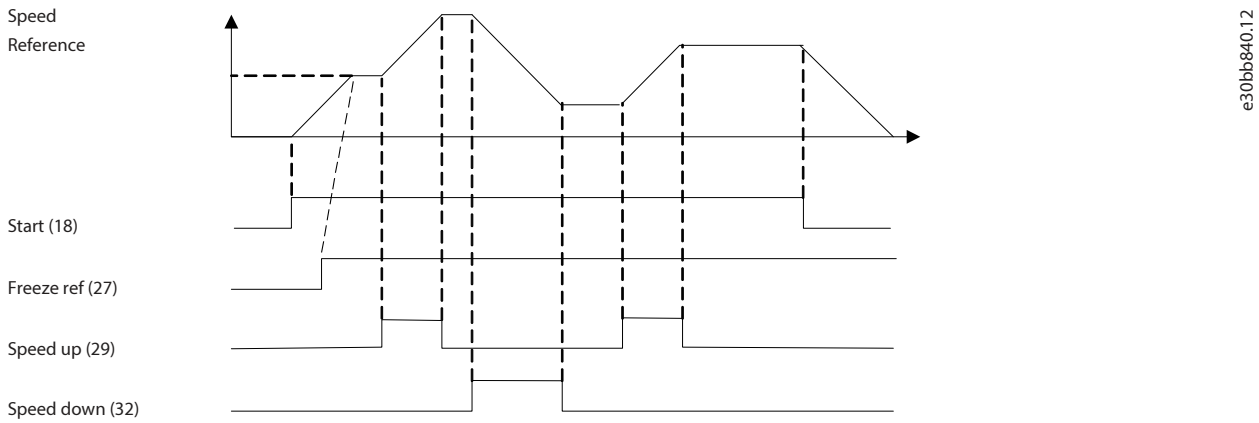| | Parameter function | Parameter setting |
|---|---|---|
| FC<br><br>+24 V  12<br>D IN  18<br>D IN  19<br>D IN  27<br>D IN  29<br>D IN  31<br>D IN  32<br>D IN  33<br><br>+10 V  50<br>A IN  53<br>A IN  54<br>COM  55<br>A OUT  42<br>e30bf821.10 | *Parameter 5-10 Terminal 18 Digital Input* | *[8] Start |
| | *Parameter 5-12 Terminal 27 Digital Input* | [19] Freeze Reference |
| | *Parameter 5-13 Terminal 29 Digital Input* | [21] Speed Up |
| | *Parameter 5-14 Terminal 32 Digital Input* | [21] Speed Down |
| | *=Default value | |
| | **Notes/comments:** | |

**Figure 74: Speed Up/Speed Down**

## 7.4 Start/Stop

**Table 85: Start/Stop with Reversing and 4 Preset Speeds**



| | Parameter function | Parameter setting |
|---|---|---|
| | *Parameter 5-10 Terminal 18 Digital Input* | *[8] Start* |
| | *Parameter 5-11 Terminal 19 Digital Input* | *[10] Reversing* |
| | *Parameter 5-12 Terminal 27 Digital Input* | [0] No operation |
| | *Parameter 5-14 Terminal 32 Digital Input* | [16] Preset ref bit 0 |
| | *Parameter 5-15 Terminal 33 Digital Input* | [17] Preset ref bit 1 |
| | *Parameter 3-10 Preset Reference*<br>Preset ref. 0<br>Preset ref. 1<br>Preset ref. 2<br>Preset ref. 3 | <br>25%<br>50%<br>75%<br>100% |
| | *=Default value | |
| | **Notes/comments:** | |

## 7.5 External Alarm Reset

**Table 86: External Alarm Reset**

| | Parameter function | Parameter setting |
|---|---|---|
|  | *Parameter 5-11 Terminal 19 Digital Input* | *[1] Reset* |
| | *=Default value | |
| | **Notes/comments:** | |

## 7.6 Motor Thermistor

| NOTICE |
|---|
| To meet PELV insulation requirements, use reinforced or double insulation on the thermistors. |

**Table 87: Motor Thermistor**

| | Parameter function | Parameter setting |
|---|---|---|
|  | *Parameter 1-90 Motor Thermal Protection* | *[2] Thermistor trip* |
| | *Parameter 1-93 Motor Thermal Source* | *[1] Analog input 53* |
| | *Parameter 6-19 Terminal 53 mode* | *[1] Voltage* |
| | *=Default value | |
| | **Notes/comments:** If only a warning is needed, set *parameter 1-90 Motor Thermal Protection* to *[1] Thermistor warning*. | |

**Table 88: Using SLC to Set a Relay**

| | | Parameter function | Parameter setting |
|---|---|---|---|
|  | e30bd150.12 | Parameter 4-30 Motor Feedback Loss Function | [1] Warning |
| | | Parameter 4-31 Motor Feedback Speed Error | 100 |
| | | Parameter 4-32 Motor Feedback Loss Timeout | 5 s |
| | | Parameter 7-00 Speed PID Feedback Source | [2] MCB 102 |
| | | Parameter 17-11 Resolution (PPR) | *1024 |
| | | Parameter 13-00 SL Controller Mode | [1] On |
| | | Parameter 13-01 Start Event | [19] Warning |
| | | Parameter 13-02 Stop Event | [44] Reset key |
| | | Parameter 13-10 Comparator Operand | [21] Warning no. |
| | | Parameter 13-11 Comparator Operator | *[1]≈ |
| | | Parameter 13-13 Comparator Value | 90 |
| | | Parameter 13-51 SL Controller Event | [22] Comparator 0 |
| | | Parameter 13-52 SL Controller Action | [32] Set digital out A low |
| | | Parameter 5-40 Function Relay | [80] SL digital output A |
| | | *=Default value | |
| | | **Notes/comments:** If the limit in the feedback monitor is exceeded, **warning 90, feedback monitor** is issued. The SLC monitors **warning 90, feedback monitor**. If **warning 90, feedback monitor** becomes true, relay 1 is triggered. External equipment could indicate that service is required. If the feedback error goes below the limit again within 5 s, the drive continues and the warning disappears. But relay 1 persists until [Off/Reset] is pressed. | |

## 7.7 Encoder Connection

The purpose of this guideline is to ease the setup of encoder connection to the drive. Before setting up the encoder, the basic settings for a closed-loop speed-control system are shown.

- For more information about encoder input, refer to the VLT® encoder input MCB 102 Installation Guide.
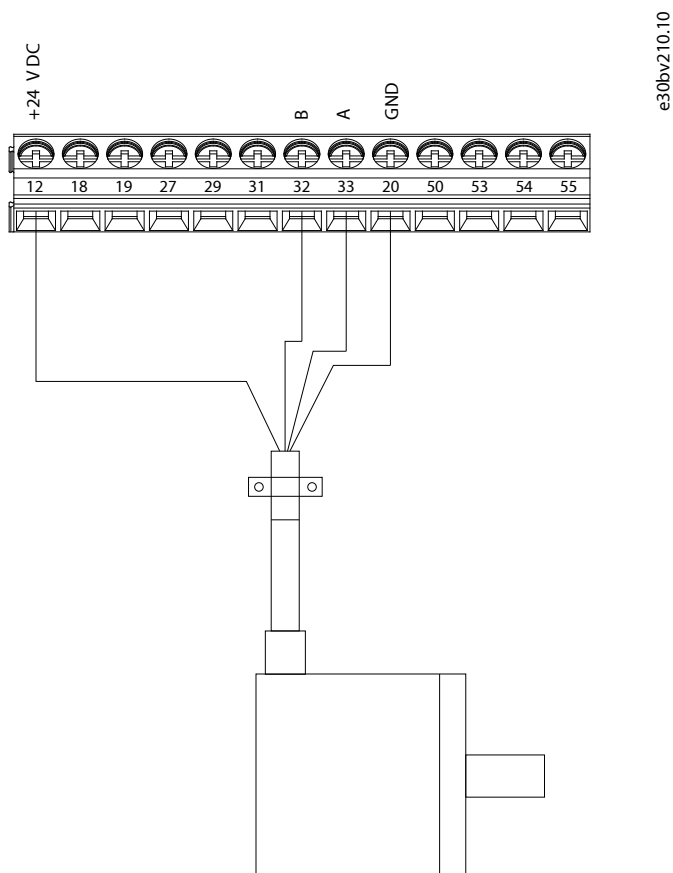- For more information about resolver input, refer to the VLT® resolver input MCB 103 Installation Guide.
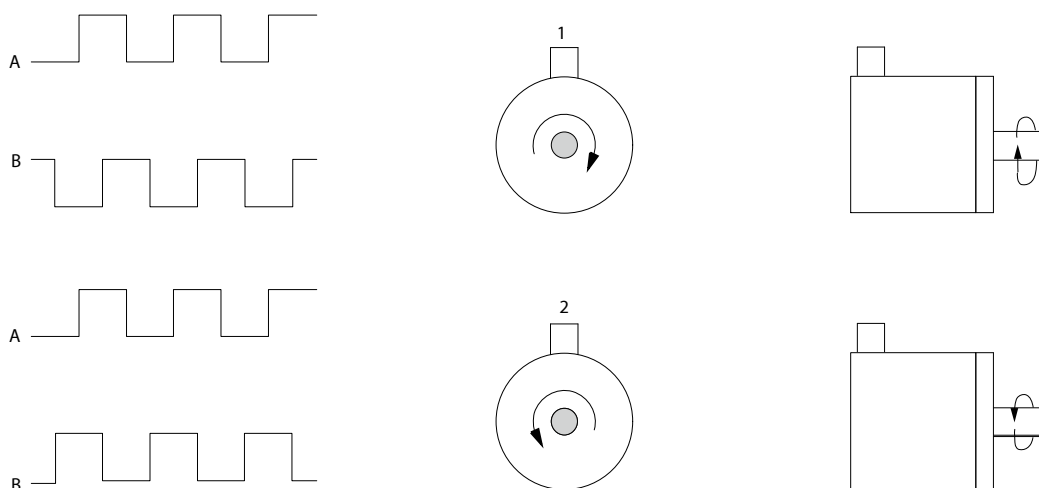
**Figure 75: 24 V or 10–30 V Encoder**



**Figure 76: 24 V Incremental Encoder, Maximum Cable Length 5 m (16.4 ft)**

## 7.8 Encoder Direction

The order in which the pulses enter the drive determines the direction of the encoder.

- Clockwise direction means that channel A is 90 electrical degrees before channel B.
- Counterclockwise direction means that channel B is 90 electrical degrees before A.

The direction is determined by looking into the shaft end.

## 7.9 Closed-loop Drive System

A drive system usually consists of more elements such as:

- Motor.
- Brake (gearbox, mechanical brake).
- Drive.
- Encoder as feedback system.
- Brake resistor for dynamic brake.
- Transmission.
- Load.

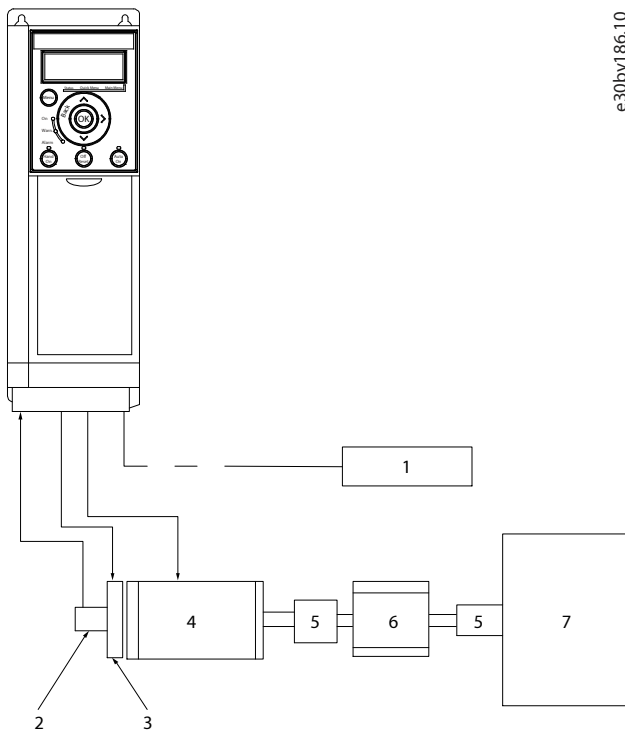Applications demanding mechanical brake control usually need a brake resistor.



**Figure 77: Basic Setup for Closed-loop Speed Control**

| **1** | Brake resistor | **2** | Encoder |
|-------|----------------|-------|---------|
| **3** | Mechanical brake | **4** | Motor |
| **5** | Transmission | **6** | Gearbox |
| **7** | Load | | |

# 8  Appendix

## 8.1  Abbreviations and Symbols

**Table 89: Abbreviations and Symbols**

| | |
|---|---|
| 60° AVM | 60° asynchronous vector modulation |
| A | Ampere/AMP |
| AC | Alternating current |
| ACP | Application control processor |
| AD | Air discharge |
| AEO | Automatic energy optimization |
| AI | Analog input |
| AIC | Ampere interrupting current |
| AMA | Automatic motor adaptation |
| AWG | American wire gauge |
| °C | Degrees Celsius |
| CB | Circuit breaker |
| CD | Constant discharge |
| CDM | Complete Drive Module: The drive, feeding section, and auxiliaries. |
| CE | European conformity (European safety standards) |
| CM | Common-mode |
| CT | Constant torque |
| DC | Direct current |
| DI | Digital input |
| DM | Differential mode |
| D-TYPE | Drive dependent |
| EEPROM | Electrically erasable programmable read-only memory |
| EMC | Electromagnetic compatibility |
| EMF | Electromotive force |
| EMI | Electromagnetic interference |
| ESD | Electrostatic discharge |
| ETR | Electronic thermal relay |
| °F | Degrees Fahrenheit |
| $f_{JOG}$ | Motor frequency when jog function is activated. |
| $f_M$ | Motor frequency |

**Table 89: Abbreviations and Symbols** (continued)

| | |
|---|---|
| $f_{MAX}$ | Maximum output frequency that the drive applies on its output. |
| $f_{MIN}$ | Minimum motor frequency from the drive. |
| $f_{M, N}$ | Nominal motor frequency |
| FC | Frequency converter (drive) |
| FSP | Fixed-speed pump |
| g | Gram |
| HO | High overload |
| Hp | Horse power |
| Hz | Hertz |
| $I_{INV}$ | Rated inverter output current |
| $I_{LIM}$ | Current limit |
| $I_{M, N}$ | Nominal motor current |
| $I_{VLT, MAX}$ | Maximum output current |
| $I_{VLT, N}$ | Rated output current supplied by the drive |
| IGBT | Insulated-gate bipolar transistor |
| IP | Ingress protection |
| kHz | Kilohertz |
| LCP | Local control panel |
| LED | Light-emitting diode |
| $L_d$ | Motor d-axis inductance |
| $L_q$ | Motor q-axis inductance |
| Lsb | Least significant bit |
| m | Meter |
| mA | Milliampere |
| MCM | Mille circular mil |
| MCP | Motor control processor |
| MCT | Motion control tool |
| mH | Inductance in milli Henry |
| min | Minute |
| mm | Millimeter |
| ms | Millisecond |
| Msb | Most significant bit |
| $\eta_{VLT}$ | Efficiency of the drive defined as ratio between power output and power input. |

**Table 89: Abbreviations and Symbols** (continued)

| | |
|---|---|
| NEMA | National Electrical Manufacturers Association |
| nF | Capacitance in nano Farad |
| NLCP | Numerical local control panel |
| Nm | Newton meter |
| NO | Normal overload |
| $n_s$ | Synchronous motor speed |
| On/Offline parameters | Changes to online parameters are activated immediately after the data value is changed |
| $P_{br, cont.}$ | Rated power of the brake resistor (average power during continuous braking) |
| PCB | Printed circuit board |
| PCD | Process data |
| PDS | Power drive system: CDM and a motor |
| PE | Protective earth |
| PELV | Protective extra low voltage |
| $P_m$ | Drive nominal output power as high overload |
| $P_{M, N}$ | Nominal motor power |
| PM motor | Permanent magnet motor |
| Process PID | Proportional integrated differential regulator that maintains the speed, pressure, temperature, and so on. |
| PWM | Pulse width modulation |
| $R_{br, nom}$ | Nominal resistor value that ensures a brake power on the motor shaft of 150/160% for 1 minute. |
| RCD | Residual current device |
| Regen | Regenerative terminals |
| RFI | Radio frequency interference |
| $R_{min}$ | Minimum allowed brake resistor value by the drive |
| RMS | Root average square |
| RPM | Revolutions per minute |
| $R_{rec}$ | Recommended brake resistor resistance of Danfoss brake resistors |
| $R_s$ | Stator resistance |
| s | Second |
| SCR | Silicon controlled rectifier |
| SCCR | Short-circuit current rating |
| SFAVM | Stator flux-oriented asynchronous vector modulation |
| STW | Status word |
| SMPS | Switch mode power supply |

**Table 89: Abbreviations and Symbols** (continued)

| THD | Total harmonic distortion |
|---|---|
| $T_{LIM}$ | Torque limit |
| TTL | TTL encoder (5 V) pulses - transistor logic |
| $U_{M, N}$ | Nominal motor voltage |
| UL | Underwriters Laboratories (US organization for the safety certification) |
| V | Volts |
| VSP | Variable-speed pump |
| VT | Variable torque |
| VVC+ | Voltage vector control plus |
| $X_h$ | Motor main reactance |

## 8.2 Definitions

### 8.2.1 AC Drive

**Coast**

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

$I_{VLT, MAX}$

Maximum output current.

$I_{VLT, N}$

Rated output current supplied by the drive.

$U_{VLT, MAX}$

Maximum output voltage.

### 8.2.2 Input

**Control commands**

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

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

**Table 90: Function Groups**

| Group 1 | Coast stop, reset and coast stop, quick stop, DC braking, stop, and [OFF]. |
|---|---|
| Group 2 | Start, latched start, start reversing, jog, freeze output, and [Hand On]. |

### 8.2.3 Motor

**Motor running**

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

$f_{JOG}$

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

**f**$_M$

Motor frequency.

**f**$_{MAX}$

Maximum motor frequency.

**f**$_{MIN}$

Minimum motor frequency.

**f**$_{M, N}$

Rated motor frequency (nameplate data).

**I**$_M$

Motor current (actual).

**I**$_{M, N}$

Nominal motor current (nameplate data).

**n**$_{M, N}$

Nominal motor speed (nameplate data).

**n**$_S$

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

**n**$_{slip}$

Motor slip.

**P**$_{M, N}$

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

**T**$_{M, N}$

Rated torque (motor).

**U**$_M$

Instantaneous motor voltage.

**U**$_{M, N}$

Rated motor voltage (nameplate data).

**Break-away torque**
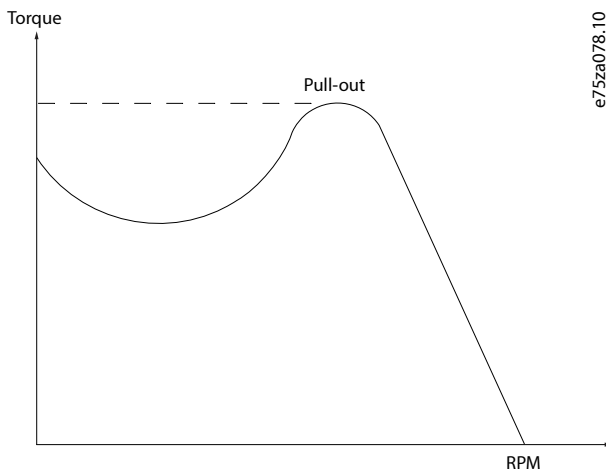
**Figure 78: Break-away Torque**

**η**<sub>VLT</sub>

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

**Start-disable command**

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

**Stop command**

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

## 8.2.4 References

**Analog reference**

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

**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.

**Pulse reference**

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

**Ref**<sub>MAX</sub>

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**<sub>MIN</sub>

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

## 8.2.5 Miscellaneous

**Analog inputs**

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

There are 2 types of analog inputs:

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

**Analog outputs**

The analog outputs can supply a signal of 0–20 mA or 4–20 mA.

**Automatic motor adaptation, AMA**

The AMA algorithm determines the electrical parameters for the connected motor at standstill.

**Brake resistor**

The brake resistor is a module capable of absorbing the brake power generated in regenerative braking. This regenerative brake power increases the DC-link voltage and a brake chopper ensures that the power is transmitted to the brake resistor.

**CT characteristics**

Constant torque characteristics used for all applications such as conveyor belts, displacement pumps, and cranes.

**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.

**ETR**

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

**FC standard bus**

Includes RS485 bus with FC protocol or MC protocol. See *parameter 8-30 Protocol*.

**Initializing**

If initializing is carried out (*parameter 14-22 Operation Mode*), the drive returns to the default setting.

**Intermittent duty cycle**

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

**LCP**

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

**GLCP**

The 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.

**NLCP**

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

**lsb**

Least significant bit.

**msb**

Most significant bit.

**MCM**

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

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

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

**Process PID**

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

**PCD**

Process control data.

**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 $I_{RMS}$.

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

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

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

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

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

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

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

**Pulse input/incremental encoder**

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

**RCD**

Residual current device.

**Setup**

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

**SFAVM**

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

**Slip compensation**

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

**Smart logic control (SLC)**

The SLC is a sequence of user-defined actions executed when the associated user-defined events are evaluated as true by the SLC. (*Parameter group 13-** Smart Logic*).

**STW**

Status word.

**THD**

Total harmonic distortion states the total contribution of harmonic distortion.

**Thermistor**

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

**Trip**

A state entered in fault situations, for example, if the drive is subject to overvoltage or when it is protecting the motor, process, or mechanism. Restart is prevented until the cause of the fault has disappeared, and the trip state is canceled by activating reset or, sometimes, by being programmed to reset automatically. Do not use trip for personal safety.

**Trip lock**

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

**VT characteristics**

Variable torque characteristics for pumps and fans.

**VVC+**

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

**60° AVM**

Refers to the switching pattern 60° asynchronous vector modulation.

## 8.3 Conventions

- Numbered lists indicate procedures and description of figures.
- Bullet lists indicate other information.
- Italicized text indicates:

    o Cross-reference.

    o Link.

    o Parameter name.

    o Parameter group name.

    o Parameter option.

    o Footnote.

- All dimensions in drawings are in [mm] (in).
- An asterisk (*) indicates a default setting of a parameter.

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