



# Design Guide

## VLT<sup>®</sup> AutomationDrive FC 360





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# 1 Introduction

## 1.1 How to Read This Design Guide

This design guide provides information on how to select, commission, and order a frequency converter. It provides information about mechanical and electrical installation.

The design guide is intended for use by qualified personnel.

Read and follow the design guide to use the frequency converter safely and professionally, and pay particular attention to the safety instructions and general warnings.

VLT® is a registered trademark.

- *VLT® AutomationDrive FC 360 Quick Guide* provides the necessary information for getting the frequency converter up and running.
- *VLT® AutomationDrive FC 360 Programming Guide* provides information on how to programme and includes complete parameter descriptions.

FC 360 technical literature is also available online at [www.danfoss.com/fc360](http://www.danfoss.com/fc360).

### 1.1.1 Symbols

The following symbols are used in this document:

#### **⚠ WARNING**

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

#### **⚠ CAUTION**

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

#### **NOTICE**

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

### 1.1.2 Abbreviations

Alternating current	AC
American wire gauge	AWG
Ampere/AMP	A
Automatic motor adaptation	AMA
Current limit	I <sub>LIM</sub>
Degrees Celsius	°C
Direct current	DC
Drive dependent	D-TYPE
Electromagnetic compatibility	EMC
Electronic thermal relay	ETR
Gram	g
Hertz	Hz
Horsepower	hp
Kilohertz	kHz
Local control panel	LCP
Meter	m
Millihenry inductance	mH
Milliamper	mA
Millisecond	ms
Minute	min
Motion control tool	MCT
Nanofarad	nF
Newton meter	Nm
Nominal motor current	I <sub>M,N</sub>
Nominal motor frequency	f <sub>M,N</sub>
Nominal motor power	P <sub>M,N</sub>
Nominal motor voltage	U <sub>M,N</sub>
Permanent magnet motor	PM motor
Protective extra low voltage	PELV
Printed circuit board	PCB
Rated inverter output current	I <sub>INV</sub>
Revolutions per minute	RPM
Regenerative terminals	Regen
Second	s
Synchronous motor speed	n <sub>s</sub>
Torque limit	T <sub>LIM</sub>
Volts	V
Maximum output current	I <sub>VLT,MAX</sub>
Rated output current supplied by the frequency converter	I <sub>VLT,N</sub>

## 1.2 Definitions

### 1.2.1 Frequency Converter

#### 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 frequency converter.

#### $U_{VLT, MAX}$

Maximum output voltage.

### 1.2.2 Input

#### Control commands

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

Functions are divided into 2 groups.

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

Group 1	Reset, coasting stop, reset and coasting stop, quick-stop, DC braking, stop, and [OFF].
Group 2	Start, pulse start, reversing, start reversing, jog, and freeze output.

Table 1.1 Function Groups

### 1.2.3 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).

#### $f_M$

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).

#### $I_{M, N}$

Rated motor current (nameplate data).

#### $n_{M, N}$

Rated motor speed (nameplate data).

#### $n_s$

Synchronous motor speed

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

#### $n_{slip}$

Motor slip.

#### $P_{M, N}$

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

#### $T_{M, N}$

Rated torque (motor).

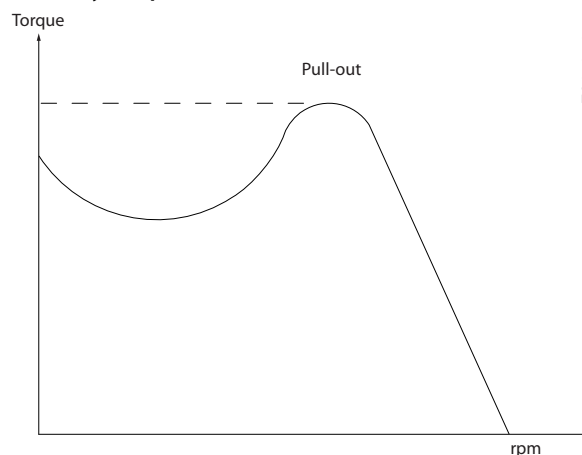
#### $U_M$

Instantaneous motor voltage.

#### $U_{M, N}$

Rated motor voltage (nameplate data).

#### Breakaway torque



175ZA078.10

Illustration 1.1 Breakaway Torque

#### $\eta_{VLT}$

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

#### Start-disable command

A stop command belonging to the group 1 control commands. See *chapter 1.2.2 Input* for more details.

#### Stop command

A stop command belonging to the group 1 control commands. See *chapter 1.2.2 Input* for more details.

### 1.2.4 References

#### Analog reference

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

#### Binary reference

A signal transmitted to 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.

**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 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 3-02 *Minimum Reference*.

## 1.2.5 Miscellaneous

**Analog inputs**

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

There are 2 types of analog inputs:

- Current input, 0–20 mA and 4–20 mA
- Voltage input, 0 to +10 V DC

**Analog outputs**

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

**Automatic Motor Adaptation, AMA**

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

**Brake resistor**

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

**CT characteristics**

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

**Digital inputs**

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

**Digital outputs**

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

**DSP**

Digital signal processor.

**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 8-30 *Protocol*.

**Initialising**

If initialising is carried out (14-22 *Operation Mode*), the frequency converter 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 frequency converter. The control panel is detachable and can be installed up to 3 m from the frequency converter, i.e. in a front panel with the installation kit option.

**NLCP**

The numerical local control panel interface for control and programming of the frequency converter. The display is numerical and the panel is used to display 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<sup>2</sup>.

**On-line/Off-line parameters**

Changes to on-line parameters are activated immediately after the data value is changed. Press [OK] to activate changes to off-line parameters.

**Process PID**

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

**PCD**

Process control data

**Power cycle**

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

**Power factor**

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

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

For FC 360 frequency converters,  $\cos\phi_1=1$ , therefore:

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

The power factor indicates to which extent the frequency converter imposes a load on the mains supply. The lower the power factor, the higher the  $I_{RMS}$  for the same kW performance.

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

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

The built-in DC coils produce a high power factor minimising 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.

#### Set-up

Save parameter settings in 2 set-ups. Change between the 2 parameter set-ups and edit 1 set-up while another set-up is active.

#### SFAVM

Acronym describing the switching pattern *Stator Flux oriented Asynchronous Vector Modulation*.

#### Slip compensation

The frequency converter 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 smart logic controller (parameter group 13-\*\* *Smart Logic Control*).

#### 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 (frequency converter or motor).

#### Trip

A state entered in fault situations, e.g. if the frequency converter is subject to an overtemperature or when it is protecting the motor, process, or mechanism. Restart is prevented until the cause of the fault has disappeared, and the trip state is cancelled by activating reset or, in some cases, by being programmed to reset automatically. Do not use trip for personal safety.

#### Trip locked

A state entered in fault situations when the frequency converter is protecting itself and requiring physical intervention, e.g. if the frequency converter is subject to a short circuit on the output. A locked trip can only be cancelled by cutting off mains, removing the cause of the fault, and reconnecting the frequency converter. Restart is prevented until the trip state is cancelled by activating reset or, in some cases, by being programmed to reset automatically. Do not use trip locked for personal safety.

#### VT characteristics

Variable torque characteristics used for pumps and fans.

#### VVC+

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

#### 60° AVM

Refers to the switching pattern *60° Asynchronous Vector Modulation*.

## 1.3 Safety Precautions

### **WARNING**

**The voltage of the frequency converter is dangerous whenever connected to mains. Incorrect installation of the motor, frequency converter or fieldbus may cause death, serious personal injury or damage to the equipment. Consequently, the instructions in this manual, as well as national and local rules and safety regulations, must be complied with.**

#### Safety Regulations

1. Always disconnect mains supply to the frequency converter before carrying out repair work. Check that the mains supply has been disconnected and observe the discharge time stated in *Table 1.2* before removing motor and mains supply.
2. [Off/Reset] on the LCP does not disconnect the mains supply and must not be used as a safety switch.
3. Ground the equipment properly, protect the user against supply voltage, and protect the motor against overload in accordance with applicable national and local regulations.
4. Protection against motor overload is not included in the factory setting. If this function is desired, set *1-90 Motor Thermal Protection* to [4] *ETR trip 1* or [3] *ETR warning 1*.
5. The frequency converter has more voltage sources than L1, L2 and L3, when load sharing (linking of DC intermediate circuit). Check that all voltage sources have been disconnected and that

the necessary time has elapsed before commencing repair work.

**Warning against unintended start**

1. The motor can be stopped with digital commands, bus commands, references or a local stop, while the frequency converter is connected to mains. If personal safety considerations (e.g. risk of personal injury caused by contact with moving parts following an unintentional start) make it necessary to ensure that no unintended start occurs, these stop functions are not sufficient. In such cases, disconnect the mains supply.
2. The motor may start while setting the parameters. If this means that personal safety may be compromised, motor starting must be prevented, for instance by secure disconnection of the motor connection.
3. A motor that has been stopped with the mains supply connected, may start if faults occur in the electronics of the frequency converter, through temporary overload or if a fault in the power supply grid or motor connection is remedied. If unintended start must be prevented for personal safety reasons, the normal stop functions of the frequency converter are not sufficient. In such cases, disconnect the mains supply.
4. In rare cases, control signals from, or internally within, the frequency converter may be activated in error, be delayed, or fail to occur entirely. When used in situations where safety is critical, e.g. when controlling the electromagnetic brake function of a hoist application, do not rely on these control signals exclusively.

**⚠ WARNING**

**High Voltage**

Touching the electrical parts may be fatal—even after the equipment has been disconnected from mains.

Make sure that all voltage inputs have been disconnected, including load sharing (linkage of DC intermediate circuit), as well as motor connection for kinetic back up.

Systems where frequency converters are installed must, if necessary, be equipped with additional monitoring and protective devices according to valid safety regulations, such as laws on mechanical tools, regulations for the prevention of accidents, etc. Modifications to the frequency converters via the operating software are allowed.

**NOTICE**

Hazardous situations shall be identified by the machine builder/integrator responsible for considering necessary preventive means. Additional monitoring and protective devices may be included, always according to valid national safety regulations, such as laws on mechanical tools and regulations for the prevention of accidents.

**⚠ WARNING**

**DISCHARGE TIME**

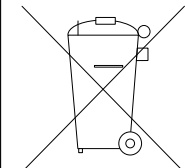
The frequency converter contains DC-link capacitors, which can remain charged even when the frequency converter is not powered. Failure to wait the specified time after power has been removed before performing service or repair work, could result in death or serious injury.

1. Stop the motor.
2. Disconnect AC mains, permanent magnet type motors, and remote DC-link power supplies, including battery back-ups, UPS, and DC-link connections to other frequency converters.
3. Wait for the capacitors to discharge fully, before performing any service or repair work. The duration of waiting time is specified in *Table 1.2*.

Voltage [V]	Minimum waiting time (minutes)	
	4	15
380–480	0.37–7.5 kW	11–75 kW
High voltage may be present even when the warning LEDs are off.		

Table 1.2 Discharge Time

1.4 Disposal Instruction



Equipment containing electrical components may not be disposed of together with domestic waste. It must be collected separately with electrical and electronic waste according to local and currently valid legislation.

1.5 Document and Software Version

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

Edition	Remarks	Software version
MG06B4xx	Replaces MG06B3xx	1.4x

## 1.6 Approvals and Certifications

Frequency converters are designed in compliance with the directives described in this section.

For more information on approvals and certificates, go to the download area at [www.danfoss.com/fc360](http://www.danfoss.com/fc360).

### 1.6.1 CE Mark

The CE mark (Communauté européenne) indicates that the product manufacturer conforms to all applicable EU directives. The EU directives applicable to the design and manufacture of frequency converters are the directive low-voltage, the EMC directive, and (for units with an integrated safety function) the machinery directive.

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.

### 1.6.2 Low Voltage Directive

Frequency converters are classified as electronic components and must be CE labelled in accordance with the low-voltage directive. The directive applies to all electrical equipment in the 50–1000 V AC and the 75–1600 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 will provide a declaration of conformity upon request.

### 1.6.3 EMC Directive

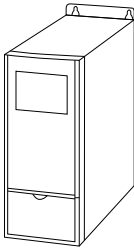
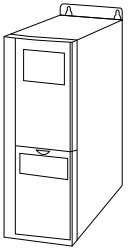
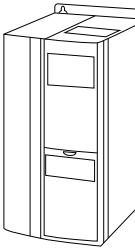
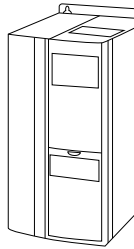
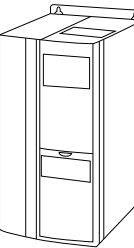
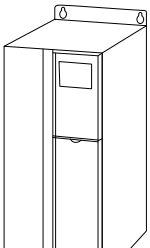
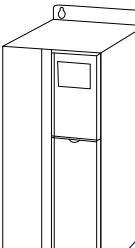
Electromagnetic compatibility (EMC) means that electromagnetic interference between pieces of equipment does not hinder their performance. The basic protection requirement of the EMC Directive 2004/108/EC states that devices that generate electromagnetic interference (EMI) or whose operation could be 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 frequency converter can be used as stand-alone device or as part of a more complex installation. Devices in either of these cases must bear the CE mark. Systems must not be CE marked but must comply with the basic protection requirements of the EMC directive.

## 2 Product Overview

### 2.1 Enclosure Size Overview

Enclosure size depends on power range.

Enclosure size	<b>J1</b>	<b>J2</b>	<b>J3</b>	<b>J4</b>
	 130BA870.10	 130BA809.10	 130BA810.10	 130BA810.10
Enclosure protection	IP20	IP20	IP20	IP20
High overload rated power - maximum 160% overload <sup>1)</sup>	0.37–2.2 kW (380–480 V)	3.0–5.5 kW (380–480 V)	7.5 kW (380–480 V)	11–15 kW (380–480 V)
Enclosure size	<b>J5</b>	<b>J6</b>	<b>J7</b>	
	 130BA810.10	 130BA826.10	 130BA826.10	
Enclosure protection	IP20	IP20	IP20	
High overload rated power - maximum 160% overload <sup>1)</sup>	18.5–22 kW (380–480 V)	30–45 kW (380–480 V)	55–75 kW (380–480 V)	

**Table 2.1 Enclosure Sizes**

1) Sizes 11–75 kW normal overload type: 110% overload 1 minute

Sizes 0.37–7.5 kW high overload type: 160% overload 1 minute

Sizes 11–22 kW high overload type: 150% overload 1 minute

Sizes 30–75 kW high overload type: 150% overload 1 minute

## 2.2 Electrical Installation

This section describes how to wire the frequency converter.

2

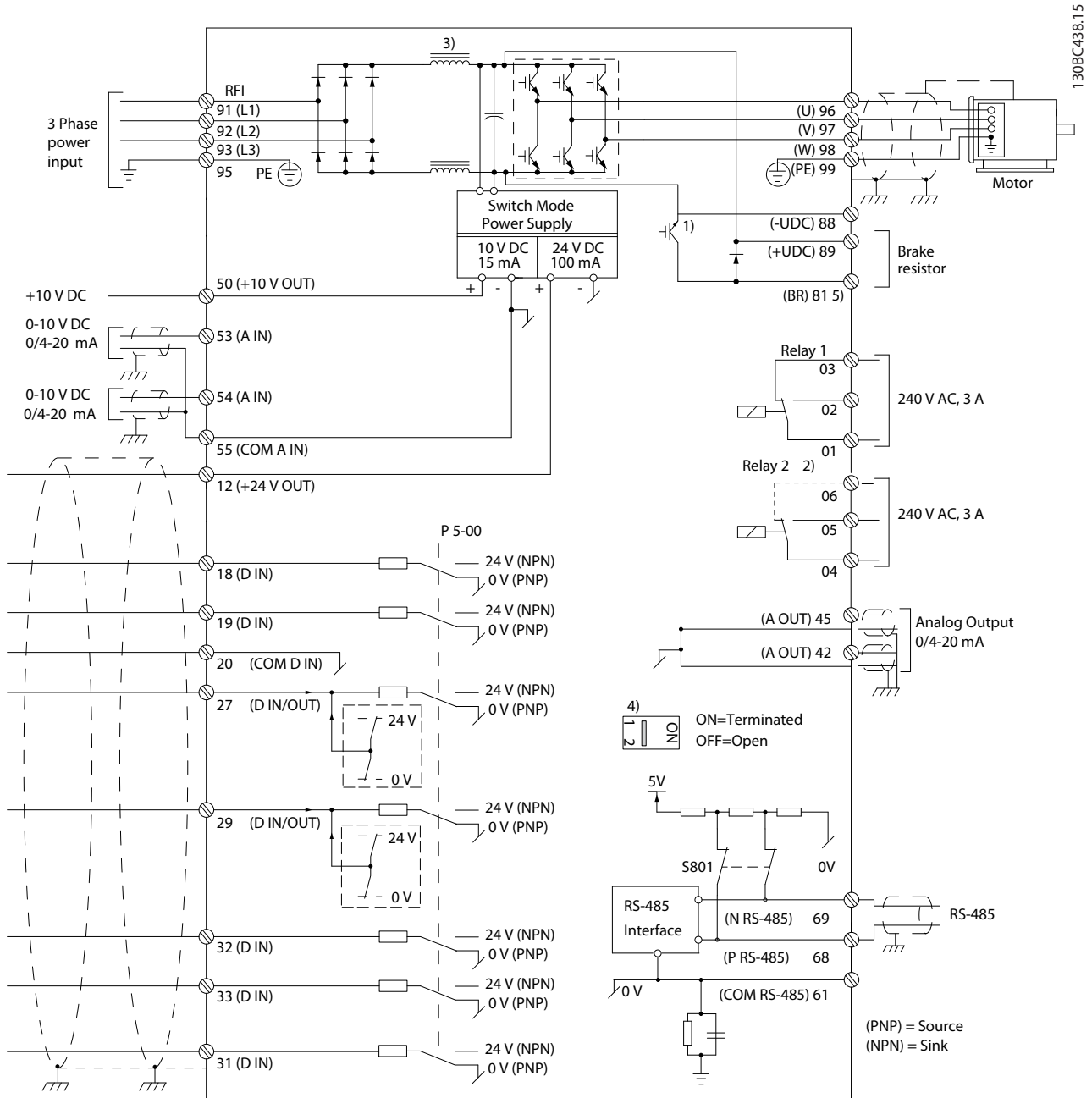


Illustration 2.1 Basic Wiring Schematic Drawing

A=Analog, D=Digital

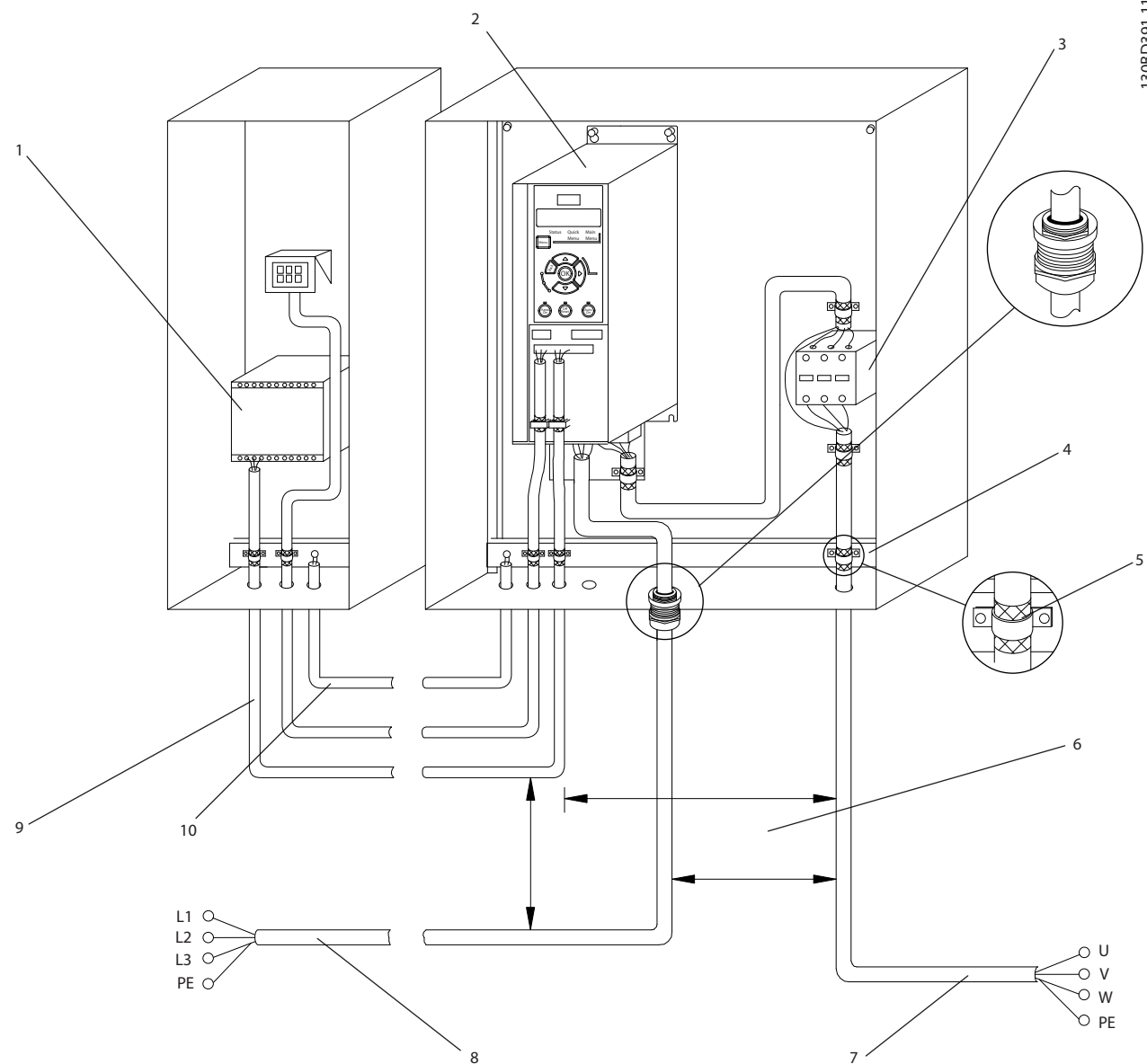
1) Built-in brake chopper available from 0.37–22 kW

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 0.37–22 kW (J1–J5); Dual DC choke in 30–75 kW (J6–J7).

4) Switch S801 (bus terminal) can be used to enable termination on the RS485 port (terminals 68 and 69).

5) No BR for 30–75 kW (J6–J7).



1	PLC	6	Minimum 200 mm (7.9 inch) between control cables, motor and mains
2	Frequency converter	7	Motor, 3-phase and PE
3	Output contactor (generally not recommended)	8	Mains, 3-phase and reinforced PE
4	Grounding rail (PE)	9	Control wiring
5	Cable shielding (stripped)	10	Equalising minimum 16 mm <sup>2</sup> (6 AWG)

Illustration 2.2 Typical Electrical Connection

### 2.2.1 General Requirements

#### **⚠ WARNING**

##### **EQUIPMENT HAZARD!**

Rotating shafts and electrical equipment can be hazardous. It is important to protect against electrical hazards when applying power to the unit. All electrical work must conform to national and local electrical codes and installation, start up, and maintenance should only be performed by trained and qualified personnel. Failure to follow these guidelines could result in death or serious injury.

#### **⚠ CAUTION**

##### **WIRING ISOLATION!**

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

Run motor cables from multiple frequency converters separately. Induced voltage from output motor cables run together can charge equipment capacitors even with the equipment turned off and locked out.

- An electronically activated function within the frequency converter provides overload protection for the motor. The overload provides Class 20 motor protection.

##### **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 be made with a minimum 75 °C rated copper wire.
- See *chapter 4 Specifications* for recommended wire sizes.

- Establish proper protective grounding for equipment with ground currents higher than 3.5 mA must be established. See *chapter 2.8 Earth 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 frequency converter to another in a “daisy chain” fashion (see *Illustration 2.3*).
- Keep the ground wire connections as short as possible.
- Use high-strand wire to reduce electrical noise.
- Follow motor manufacturer wiring requirements.

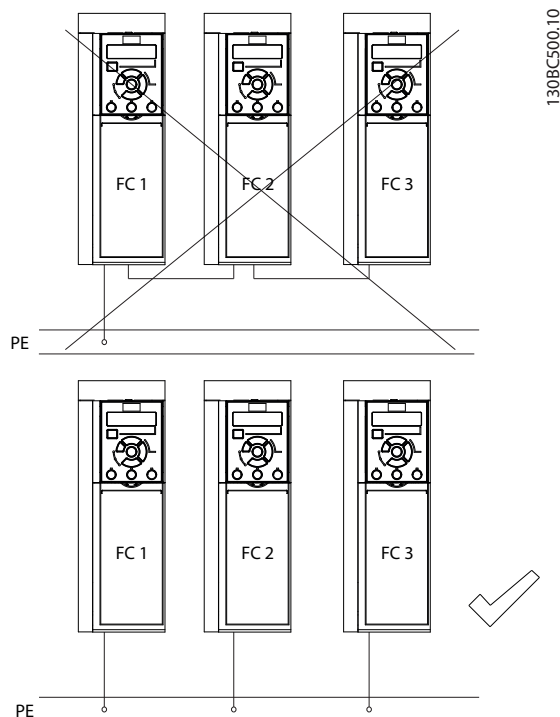


Illustration 2.3 Grounding Principle

### 2.2.2 Grounding Requirements

#### **⚠ WARNING**

##### **GROUNDING HAZARD!**

For operator safety, a certified electrical installer should ground the frequency converter in accordance with national and local electrical codes as well as instructions contained within this document. Ground currents are higher than 3.5 mA. Failure to ground the frequency converter properly could result in death or serious injury.



### 2.2.3 Mains, Motor, and Ground Connections

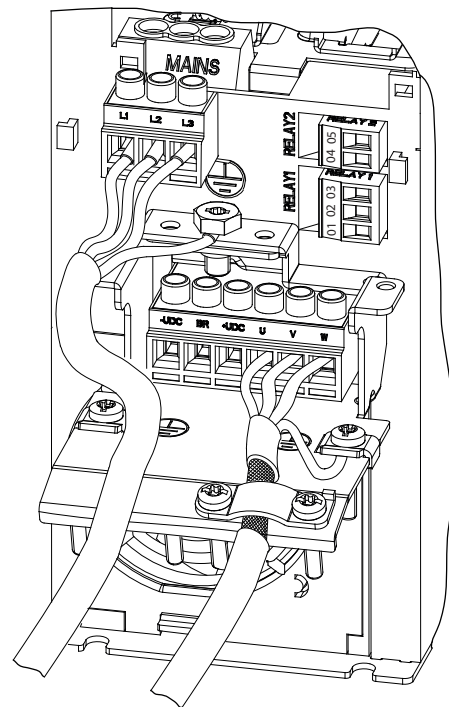
#### **⚠ WARNING**

##### **INDUCED VOLTAGE!**

Run output motor cables from multiple frequency converters separately. Induced voltage from output motor cables run together can charge equipment capacitors even when the equipment is turned off and locked out. Failure to run output motor cables separately could result in death or serious injury.

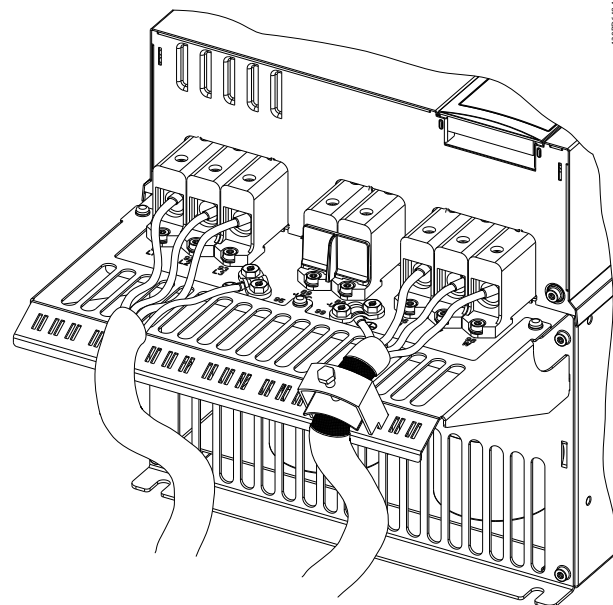
Grounding clamps are provided for motor wiring (see *Illustration 2.4*).

- Do not install power factor correction capacitors between the frequency converter and the motor
- Do not wire a starting or pole-changing device between the frequency converter and the motor
- Follow motor manufacturer wiring requirements
- All frequency converters may be used with an isolated input source as well as 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 *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 intermediate circuit are isolated to avoid damage to the intermediate circuit and reduce earth capacity currents in accordance with IEC 61800-3.
- Do not install a switch between the frequency converter and the motor in IT mains.



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**Illustration 2.4 Mains, Motor and Ground Connections for Enclosure Sizes J1–J5**



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**Illustration 2.5 Mains, Motor, and Ground Connections for Enclosure Size J7**

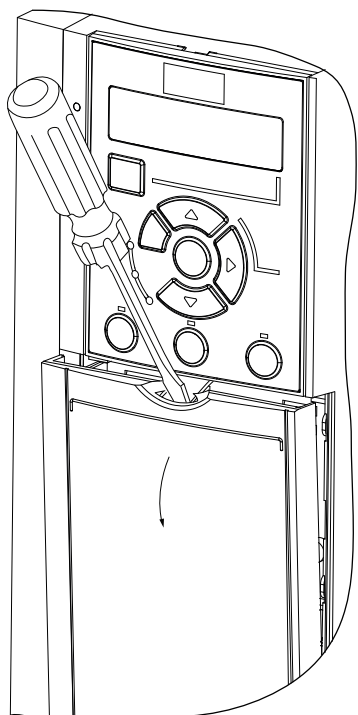
*Illustration 2.4* displays mains input, motor, and grounding for enclosure sizes J1–J5. *Illustration 2.5* displays mains input, motor, and grounding for enclosure size J7. Actual configurations vary with unit types and optional equipment.

2

### 2.2.4 Control Wiring

#### Access

- Remove the cover plate with a screwdriver. See *Illustration 2.6*.

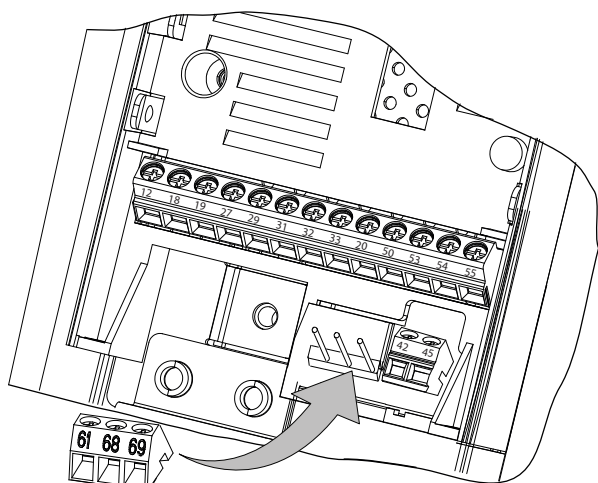


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Illustration 2.6 Control Wiring Access for Enclosure Sizes J1-J7

#### Control Terminal Types

*Illustration 2.7* shows the frequency converter control terminals. Terminal functions and default settings are summarised in *Table 2.2*.



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Illustration 2.7 Control Terminal Locations

Terminal	Parameter	Default setting	Description
<b>Digital I/O, Pulse I/O, Encoder</b>			
12	-	+24 V DC	24 V DC supply voltage. Maximum output current is 100 mA for all 24 V loads.
18	5-10 Terminal 18 Digital Input	[8] Start	Digital inputs.
19	5-11 Terminal 19 Digital Input	[10] Reversing	
31	5-16 Terminal 31 Digital Input	[0] No operation	Digital input
32	5-14 Terminal 32 Digital Input	[0] No operation	Digital input, 24 V encoder. Terminal 33 can be used for pulse input.
33	5-15 Terminal 33 Digital Input	[0] No operation	
27	5-12 Terminal 27 Digital Input 5-30 Terminal 27 Digital Output	DI [2] Coast inverse 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	5-13 Terminal 29 Digital Input 5-31 Terminal 29 Digital Output	DI [14] Jog DO [0] No operation	
20	-	-	Common for digital inputs and 0 V potential for 24 V supply.
<b>Analog inputs/outputs</b>			
42	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	6-71 Terminal 45 Analog Output	[0] No operation	

See *chapter 4.2 General Specifications* for terminal ratings details.

Terminal	Parameter	Default setting	Description
50	-	+10 V DC	10 V DC analog supply voltage. 15 mA maximum commonly used for potentiometer or thermistor.
53	6-1* parameter group	Reference	Analog input. Selectable for voltage or current.
54	6-2* parameter group	Feedback	
55	-		Common for analog input
<b>Serial communication</b>			
61	-		Integrated RC-Filter for cable screen. ONLY for connecting the screen when experiencing EMC problems.
68 (+)	8-3* parameter group		RS485 interface. A control card switch is provided for termination resistance.
69 (-)	8-3* parameter group		
<b>Relays</b>			
01, 02, 03	5-40 [0]	[0] No operation	Form C relay output. These relays are in various locations depending upon the frequency converter 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	5-40 [1]	[0] No operation	

Table 2.2 Terminal Descriptions

**Control terminal functions**

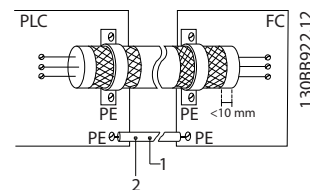
Frequency converter functions are commanded by receiving control input signals.

- Programme 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 Local Control Panel and Programming* in the quick guide for details on accessing parameters and programming.
- The default terminal programming initiates frequency converter functioning in a typical operational mode.

**Using screened control cables**

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

If the ground potential between the frequency converter and the PLC is different, electric noise may occur that disturbs the entire system. Solve this problem by fitting an equalising cable as close as possible to the control cable. Minimum cable cross section: 16 mm<sup>2</sup> (6 AWG).



1	Minimum 16 mm <sup>2</sup> (6 AWG)
2	Equalising cable

Illustration 2.8 Screening Clamps at Both Ends

**50/60 Hz ground loops**

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

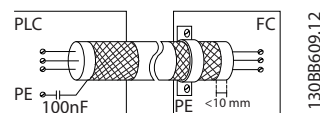
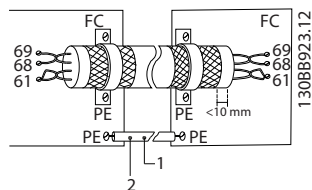


Illustration 2.9 Connection with a 100 nF Capacitor

**Avoid EMC noise on serial communication**

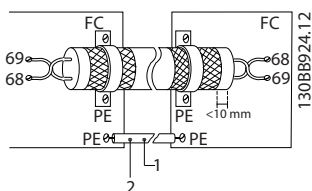
This terminal is connected to ground via an internal RC link. Use twisted-pair cables to reduce interference between conductors. The recommended method is shown in *Illustration 2.10*.



1	Minimum 16 mm <sup>2</sup> (6 AWG)
2	Equalising cable

**Illustration 2.10 Twisted-pair Cables**

Alternatively, the connection to terminal 61 can be omitted.



1	Minimum 16 mm <sup>2</sup> (6 AWG)
2	Equalising cable

**Illustration 2.11 Twisted-pair Cables without Terminal 61**

**2.3 Control Structures**

**2.3.1 Control Principle**

A frequency converter rectifies AC voltage from mains into DC voltage, after which this 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 infinitely variable speed control of 3-phased, standard AC motors and permanent magnet synchronous motors.

**2.3.2 Control Modes**

The frequency converter is capable of controlling either the speed or the torque on the motor shaft. Setting *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 optimised speed closed loop control has higher accuracy than a speed open loop control.

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

**Torque control**

The torque control function is used in applications where the torque on motor output shaft is controlling the application as tension control. Torque control can be selected in *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 in VVC<sup>+</sup> mode. 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. It is recommended to use MCB102 option card. Ensure 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 *7-06 Speed PID Lowpass Filter Time* to get the best speed feedback signal.
- Open loop in VVC<sup>+</sup> mode. The function is used in mechanically robust applications, but the accuracy is limited. Open loop torque function works for 2 directions. The torque is calculated on the basis of the internal current measurement in the frequency converter.

**Speed/torque reference**

The reference to these controls can be either a single reference or the sum of various references including relatively scaled references. Reference handling is explained in detail in *chapter 2.4 Reference Handling*.

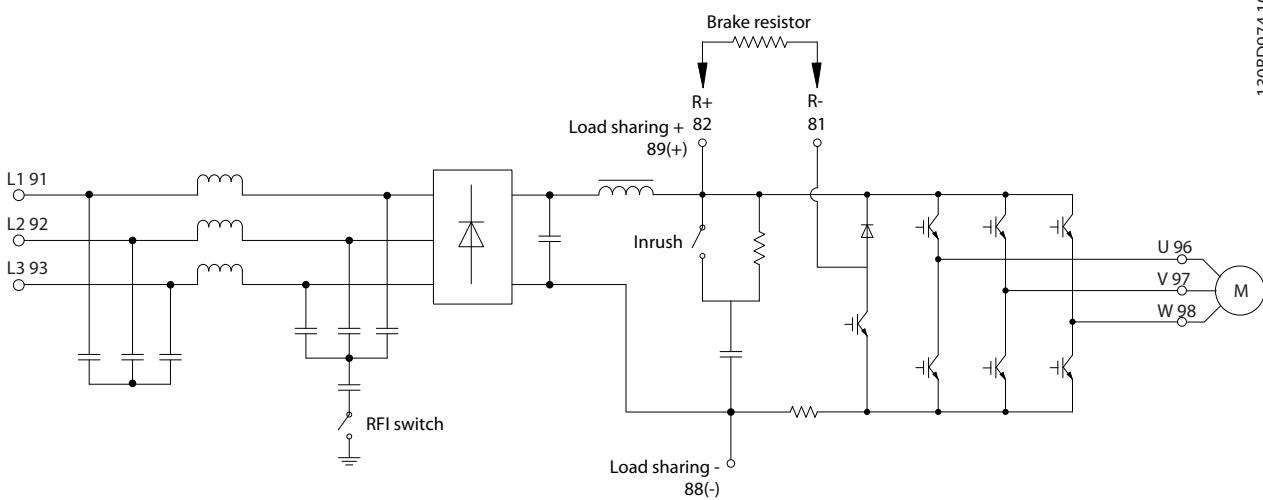
### 2.3.3 FC 360 Control Principle

FC 360 is a general-purpose frequency converter for variable speed applications. The control principle is based on voltage vector control<sup>†</sup>.

#### 0.37–22 kW

FC 360 0.37–22 kW frequency converters can handle asynchronous motors and permanent magnet synchronous motors up to 22 kW.

The current-sensing principle in FC 360 0.37–22 kW frequency converters 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.



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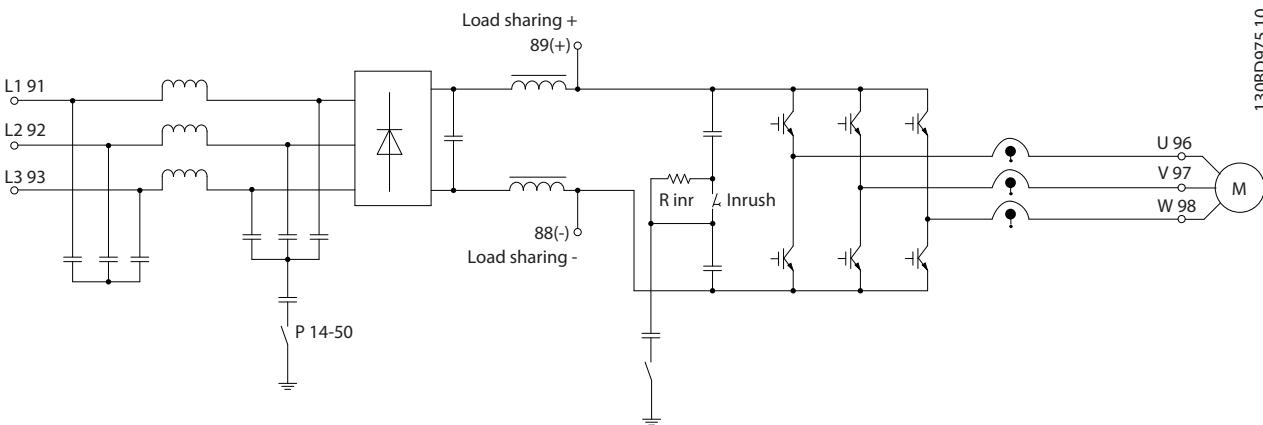
Illustration 2.12 Control Diagram for FC 360 0.37–22 kW

#### 30–75 kW

FC 360 30–75 kW frequency converters can handle asynchronous motors only.

The current-sensing principle in FC 360 30–75 kW frequency converters is based on the current measurement in the motor phases.

The ground fault protection and short circuit behavior on FC 360 30–75 kW frequency converters are handled by the 3 current transducers in the motor phases.

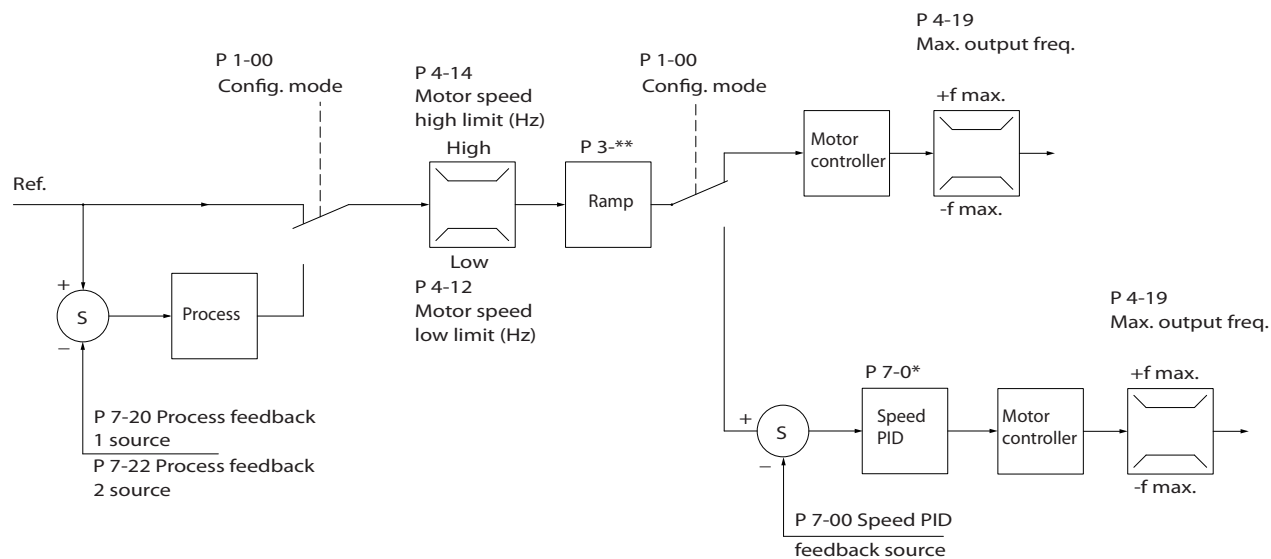


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Illustration 2.13 Control Diagram for FC 360 30–75 kW

2.3.4 Control Structure in VVC+

2



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Illustration 2.14 Control Structure in VVC+ Open-Loop and Closed-Loop Configurations

In the configuration shown in *Illustration 2.14*, *1-01 Motor Control Principle* is set to [1] *VVC+* and *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 *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 located 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 *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 located in parameter group *7-2\* Process Ctrl. Feedb* and *7-3\* Process PID Ctrl*.

### 2.3.5 Internal Current Control in VVC<sup>+</sup> Mode

The frequency converter features an integral current limit control, which is activated when the motor current, and thus the torque, is higher than the torque limits set in *4-16 Torque Limit Motor Mode*, *4-17 Torque Limit Generator Mode*, and *4-18 Current Limit*.

When the frequency converter is at the current limit during motor operation or regenerative operation, the frequency converter tries to get below the preset torque limits as quickly as possible without losing control of the motor.

### 2.3.6 Local (Hand On) and Remote (Auto On) Control

Operate the frequency converter manually via the local control panel (LCP) or remotely via analog/digital inputs or serial bus.

Start and stop the frequency converter pressing the [Hand On] and [Off/Reset] keys on the LCP. Setup required:

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



Illustration 2.15 LCP Control Keys

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

Local Reference is restored at power-down.

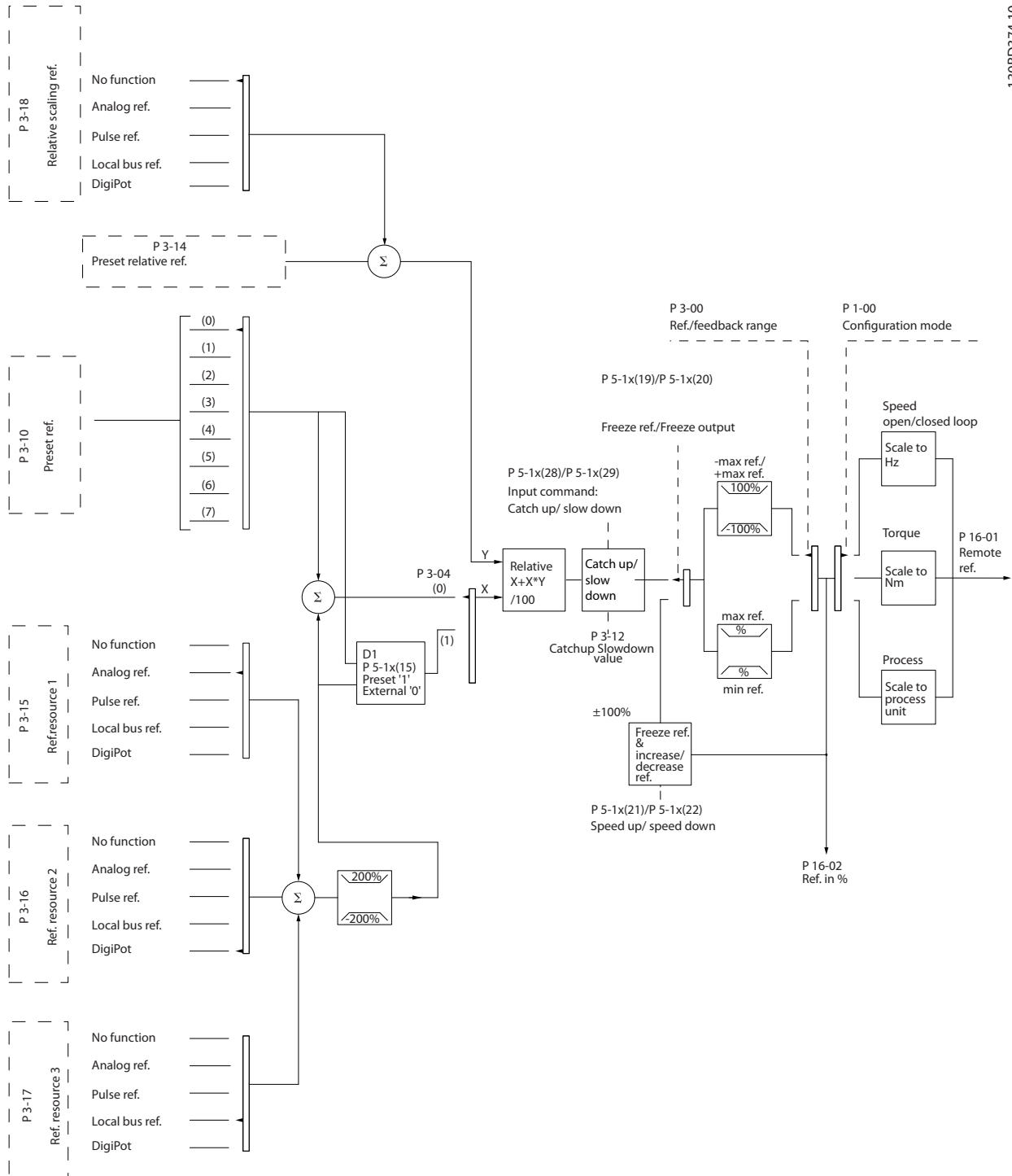
## 2.4 Reference Handling

### Local reference

The local reference is active when the frequency converter is operated with [Hand On] active. Adjust the reference by [▲]/[▼] and [←]/[→].

### Remote reference

The reference handling system for calculating the remote reference is shown in *Illustration 2.16*.



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Illustration 2.16 Remote Reference



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

1. X (the external reference): A sum (see 3-04 Reference Function) of up to 4 externally selected references, comprising any combination (determined by the setting of 3-15 Reference 1 Source, 3-16 Reference 2 Source and 3-17 Reference 3 Source) of a fixed preset reference (3-10 Preset Reference), variable analog references, variable digital pulse references, and various serial bus references in any unit the frequency converter is monitoring ([Hz], [RPM], [Nm] etc.).
2. Y (the relative reference): A sum of one fixed preset reference (3-14 Preset Relative Reference) and one variable analog reference (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 3-18 Relative Scaling Reference Resource to [0] No function and 3-14 Preset Relative Reference to 0%. The catch up/slow down function and the freeze reference function can both be activated by digital inputs on the frequency converter. The functions and parameters are described in the VLT® AutomationDrive FC 360 Programming Guide.

The scaling of analog references is described in parameter groups 6-1\* Analog Input 53 and 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.

### 2.4.1 Reference Limits

3-00 Reference Range, 3-02 Minimum Reference and 3-03 Maximum Reference together 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 is shown in Illustration 2.17 and Illustration 2.18.

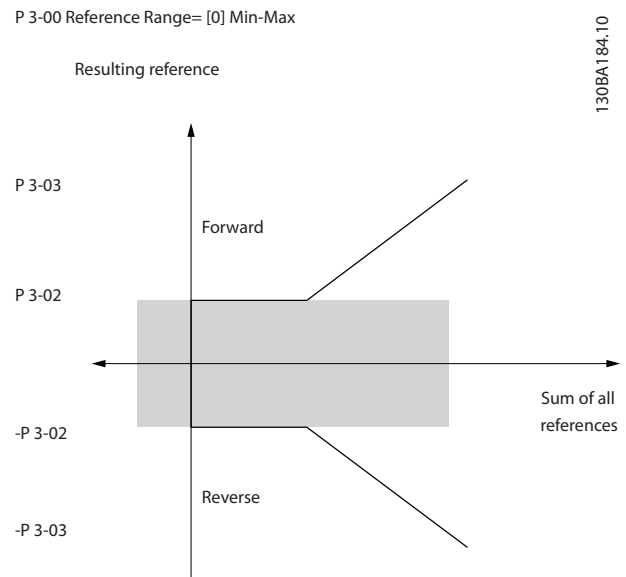


Illustration 2.17 Sum of All References When Reference Range is Set to 0

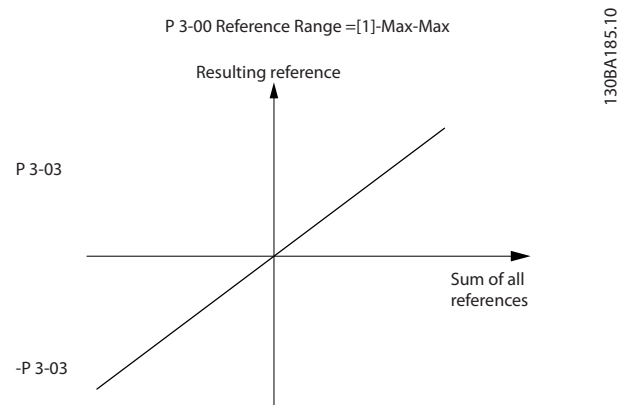
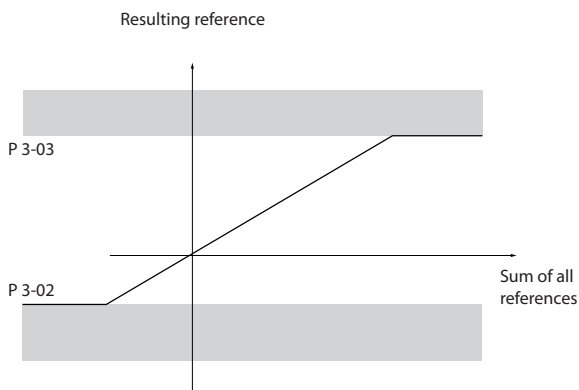


Illustration 2.18 Sum of All References When Reference Range is Set to 1

The value of 3-02 Minimum Reference cannot be set to less than 0, unless 1-00 Configuration Mode is set to [3] Process. In that case, the following relations between the resulting reference (after clamping) and the sum of all references is as shown in Illustration 2.19.

P 3-00 Reference Range= [0] Min to Max



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Illustration 2.19 Sum of All References When Minimum Reference is Set to a Minus Value

### 2.4.2 Scaling of Preset References and Bus References

Preset references are scaled according to the following rules:

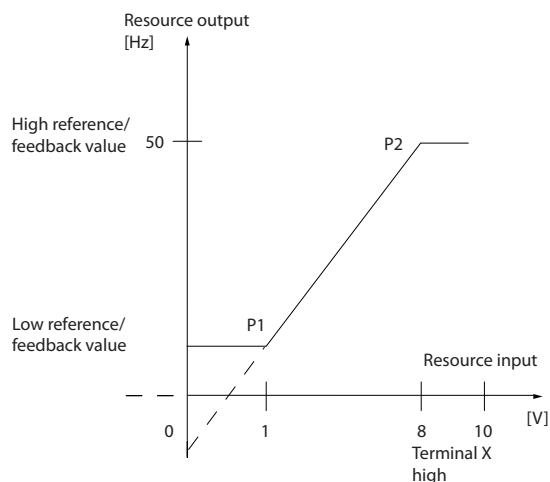
- When 3-00 Reference Range is set to [0] Min–Max, 0% reference equals 0 [unit], where unit can be any unit e.g. RPM, m/s, bar, etc. 100% reference equals the maximum (abs (3-03 Maximum Reference), abs (3-02 Minimum Reference)).
- When 3-00 Reference Range is set to [1] -Max–+Max, 0% reference equals 0 [unit], and 100% reference equals maximum reference.

Bus references are scaled according to the following rules:

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

### 2.4.3 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 Illustration 2.20) are clamped whereas a feedback above or below is not.



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Illustration 2.20 Minimum and Maximum Endpoints

The endpoints P1 and P2 are defined in *Table 2.3* depending on choice of input.

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

**Table 2.3 P1 and P2 Endpoints**

2

2.4.4 Dead Band Around Zero

In some cases, the reference (in rare cases also the feedback) should have a dead band around 0 (i.e. to make sure 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 (see Table 2.3 for relevant parameter) or maximum reference value at 0. In other words, either P1 or P2 must be on the X-axis in Illustration 2.21.
- Ensure that both points defining the scaling graph are in the same quadrant.

The size of the dead band is defined by either P1 or P2 as shown in Illustration 2.21.

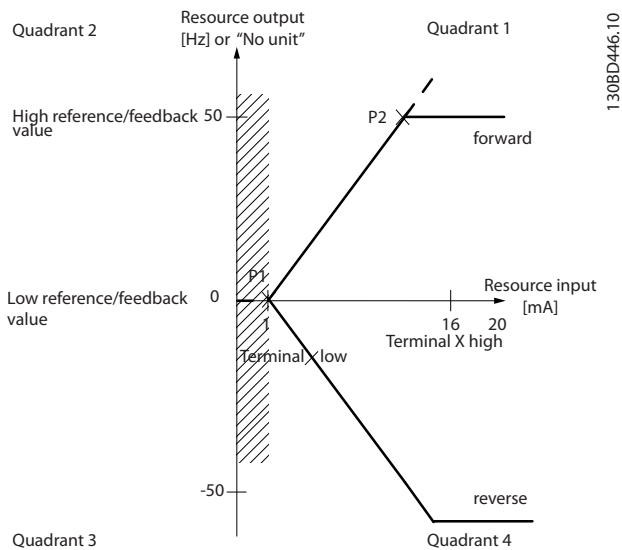
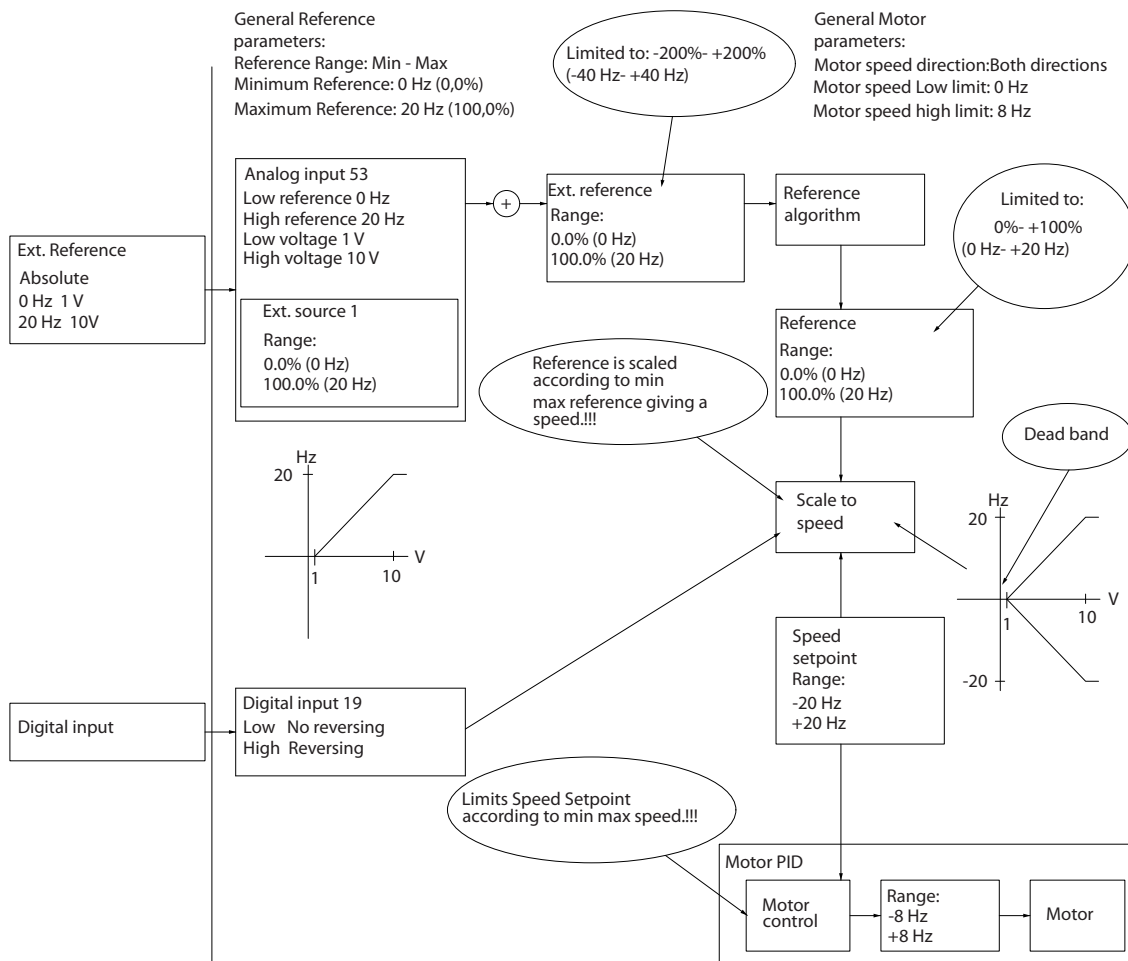


Illustration 2.21 Size of Dead Band

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

Illustration 2.22 shows how reference input with limits inside minimum to maximum limits clamps.

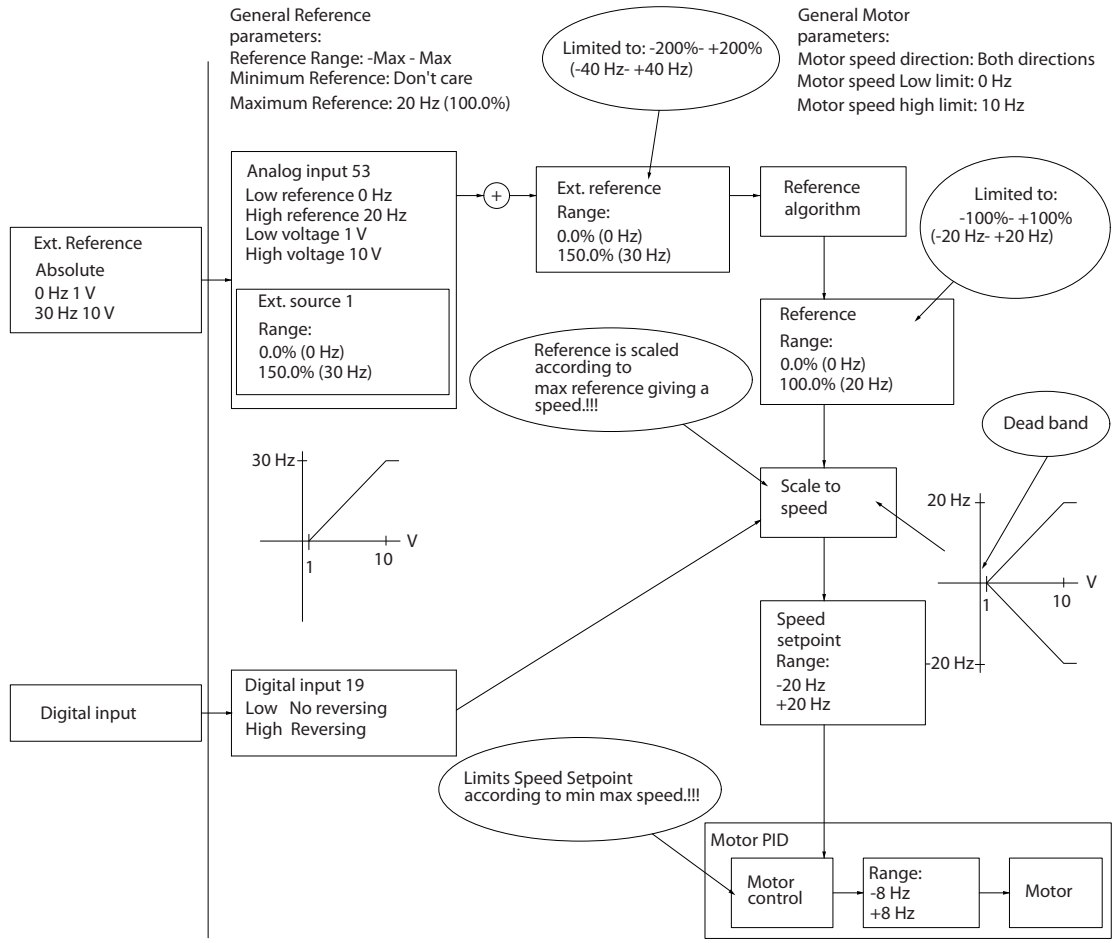


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Illustration 2.22 Clamping of Reference Input with Limits inside Minimum to Maximum

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

Illustration 2.23 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.



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Illustration 2.23 Clamping of Reference Input with Limits outside -Maximum to +Maximum

## 2.5 PID Control

### 2.5.1 Speed PID Control

1-00 Configuration Mode	1-01 Motor Control Principle	
	U/f	VVC+
[0] Speed open loop	Not Active <sup>1)</sup>	Not Active
[1] Speed closed loop	Not Available <sup>2)</sup>	ACTIVE
[2] Torque	Not Available	Not Active
[3] Process	Not Active	Not Active

**Table 2.4 Control Configurations, Active Speed Control**

1) Not Active indicates that the specific mode is available but the speed control is not active in that mode.

2) Not Available indicates that the specific mode is not available at all.

The following parameters are relevant for the speed control:

Parameter	Description of function	
7-00 Speed PID Feedback Source	Select from which input the Speed PID should get its feedback.	
7-02 Speed PID Proportional Gain	The higher the value, the quicker the control. However, too high a value may lead to oscillations.	
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.	
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.	
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.	
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 will deteriorate the dynamic performance of the speed PID control. Practical settings of 7-06 Speed PID Lowpass Filter Time taken from the number of pulses per revolution on from encoder (PPR):	
	<b>Encoder PPR</b>	<b>7-06 Speed PID Lowpass Filter Time</b>
	512	10 ms
	1024	5 ms
	2048	2 ms
4096	1 ms	

**Table 2.5 Speed Control Parameters**

2

**Example about how to programme the speed control**

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. Starting and stopping is controlled by a switch connected to terminal 18. 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 (1,024 pulses per revolution) connected to terminals 32 and 33. The pulse frequency range to terminals 32 and 33 is 4 Hz–32 kHz

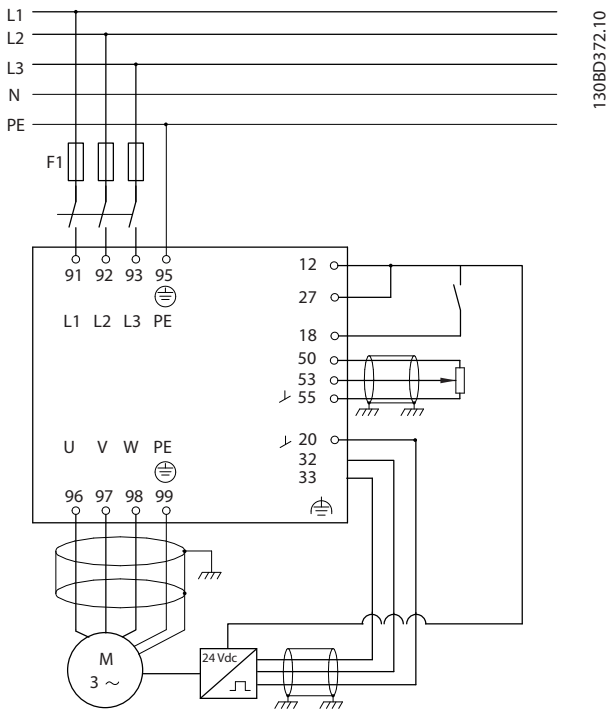


Illustration 2.24 Speed Control Programming



Follow the steps in *Table 2.6* to programme the speed control (see explanation of settings in the *Programming Guide*) In *Table 2.6* it is assumed that all other parameters and switches remain at their default setting.

Function	Parameter number	Setting
1) Make sure the motor runs properly. Do the following:		
Set the motor parameters using the data on the name plate.	1-2* Motor Data	As specified by motor name plate.
Perform an Automatic Motor Adaptation.	1-29 Automatic Motor Adaption (AMA)	[1] Enable complete AMA
2) Check the motor is running and the encoder is attached properly. Do the following:		
Press [Hand On]. Check that the motor is running and note in which direction it is turning (henceforth referred to as the "positive direction").		Set a positive reference.
3) Make sure the frequency converter limits are set to safe values:		
Set acceptable limits for the references.	3-02 Minimum Reference	0
	3-03 Maximum Reference	50
Check that the ramp settings are within frequency converter capabilities and allowed application operating specifications.	3-41 Ramp 1 Ramp Up Time	default setting
	3-42 Ramp 1 Ramp Down Time	default setting
Set acceptable limits for the motor speed and frequency.	4-12 Motor Speed Low Limit [Hz]	0 Hz
	4-14 Motor Speed High Limit [Hz]	50 Hz
	4-19 Max Output Frequency	60 Hz
4) Configure the speed control and select the motor control principle:		
Activation of speed control	1-00 Configuration Mode	[1] Speed closed loop
Selection of motor control principle	1-01 Motor Control Principle	[1] VVC <sup>+</sup>
5) Configure and scale the reference to the speed control:		
Set up analog input 53 as a reference source.	3-15 Reference 1 Source	Not necessary (default)
Scale analog input 53 0 RPM (0 V) to 50 RPM (10 V)	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.	5-14 Terminal 32 Digital Input	[82] Encoder input B
	5-15 Terminal 33 Digital Input	[83] Encoder input A
Choose terminal 32/33 as speed PID feedback.	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.	7-0* Speed PID Ctrl.	
8) Finish:		
Save the parameter setting to the LCP for safe keeping	0-50 LCP Copy	[1] All to LCP

**Table 2.6 Programming Order for Speed PID Control**

## 2.5.2 Process PID Control

2

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

Table 2.7 shows the control configurations in which the process control is possible. Refer to *chapter 2.3 Control Structures* to see where the speed control is active.

1-00 Configuration Mode	1-01 Motor Control Principle	
	U/f	VVC+
[3] Process	Not Available	Process

Table 2.7 Control Configuration

### NOTICE

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

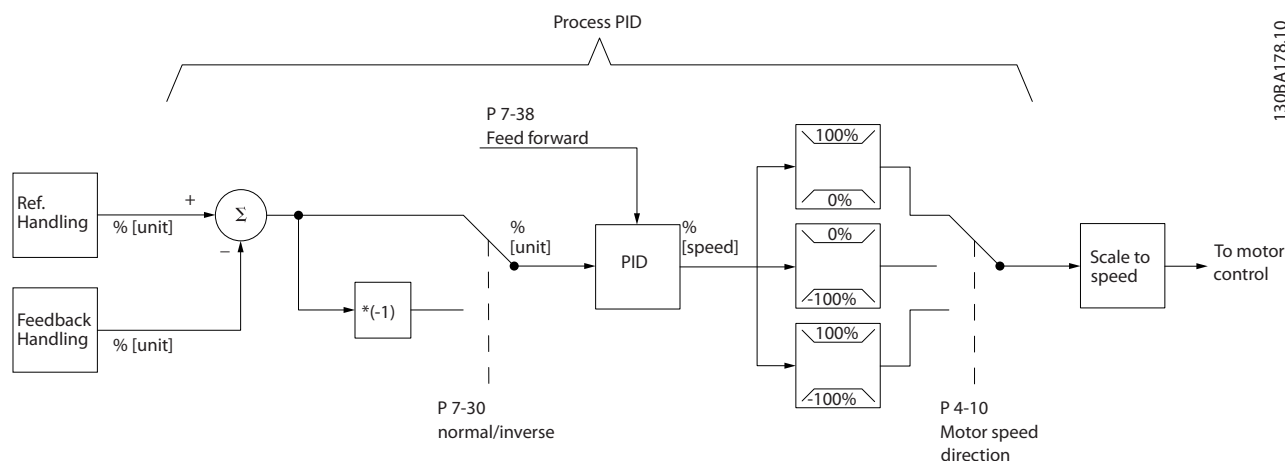


Illustration 2.25 Process PID Control Diagram

### 2.5.3 Process Control Relevant Parameters

Parameter	Description of function
7-20 Process CL Feedback 1 Resource	Select from which source (i.e. analog or pulse input) the process PID should get its feedback
7-22 Process CL Feedback 2 Resource	Optional: Determine if (and from where) the process PID should get an additional feedback signal. If an additional feedback source is selected, the 2 feedback signals are added together before being used in the process PID control.
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.
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. This function can be disabled by selecting [0] Off.
7-32 Process PID Start Speed	In some applications, reaching the required speed/set point can take a long time. In such applications, it may be an advantage to set a fixed motor speed from the frequency converter before the process control is activated. This is done by setting a process PID start value (speed) in 7-32 Process PID Start Speed.
7-33 Process PID Proportional Gain	The higher the value, the quicker the control. However, too large a value may lead to oscillations.
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.
7-35 Process PID Differentiation Time	Provides a gain proportional to the rate of change of the feedback. A setting of 0 disables the differentiator.
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.
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, the feed forward factor can be used to achieve better dynamic performance of the process PID control.
<ul style="list-style-type: none"> <li>• 5-54 Pulse Filter Time Constant #29 (Pulse term. 29)</li> <li>• 5-59 Pulse Filter Time Constant #33 (Pulse term. 33)</li> <li>• 6-16 Terminal 53 Filter Time Constant (Analog term 53)</li> <li>• 6-26 Terminal 54 Filter Time Constant (Analog term. 54)</li> </ul>	<p>If there are oscillations of the current/voltage feedback signal, these can be dampened by a low-pass filter. The pulse filter time constant represents the speed limit of the ripples occurring on the feedback signal.</p> <p>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 <math>(10/(2 \times \pi))=1.6</math> Hz. This means that all currents/ voltages that vary by more than 1.6 oscillations per second are damped by the filter. The control is only carried out on a feedback signal that varies by a frequency (speed) of less than 1.6 Hz.</p> <p>The low-pass filter improves steady state performance, but selecting a too long filter time deteriorates the dynamic performance of the process PID control.</p>

Table 2.8 Process Control Parameters

2

2.5.4 Example of Process PID Control

Illustration 2.26 is an example of a process PID control used in a ventilation system:

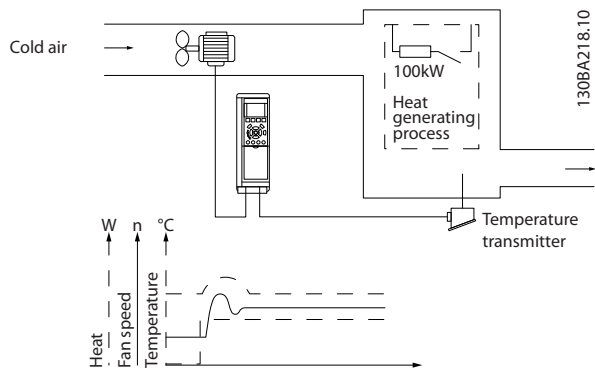


Illustration 2.26 Process PID Control in a Ventilation System

In a ventilation system, the temperature can be set from -5 to 35 °C with a potentiometer of 0–10 V. Use the process control to keep the set temperature constant.

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 to 40 °C, 4–20 mA. minimum/maximum speed 300/1500 RPM.

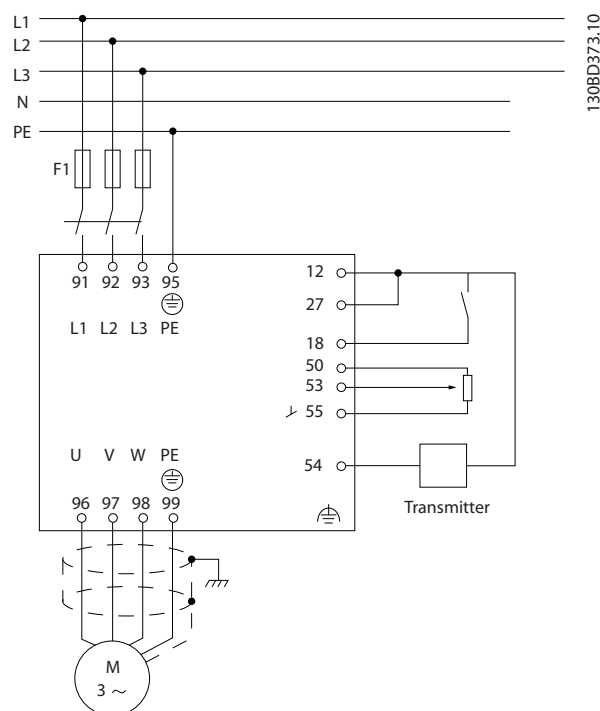


Illustration 2.27 2-wire Transmitter

1. Start/Stop via the switch connected to terminal 18.
2. Temperature reference via potentiometer (-5 to 35 °C, 0–10 V DC) connected to terminal 53.
3. Temperature feedback via transmitter (-10 to 40 °C, 4–20 mA) connected to terminal 54.

Function	Parameter number	Setting
Initialise the frequency converter	14-22	[2] Initialisation - make a power cycling - press reset
1) Set motor parameters:		
Set the motor parameters according to name plate data	1-2*	As stated on motor name plate
Perform a full Automation Motor Adaptation	1-29	[1] Enable complete AMA
2) Check that motor is running in the correct direction. When the motor is connected to the frequency converter with straight forward phase order as U-U; V-V; W-W, the motor shaft usually turns clockwise seen into shaft end.		
Press [Hand On]. Check the shaft direction by applying a manual reference.		
If the motor turns opposite of required direction: 1. Change motor direction in <i>4-10 Motor Speed Direction</i> . 2. Turn off mains, and wait for DC link to discharge. 3. Switch 2 of the motor phases.	4-10	Select correct motor shaft direction
Set configuration mode	1-00	[3] Process
3) Set reference configuration, ie. the range for reference handling. Set scaling of analog input in parameter 6-**		
Set reference/feedback units	3-01	[60] °C Unit shown on display
Set minimum reference (10 °C)	3-02	-5 °C
Set maximum reference (80 °C)	3-03	35 °C
If the set value is determined from a preset value (array parameter), set other reference sources to No Function	3-10	[0] 35% $Ref = \frac{Par. 3-10(0)}{100} \times ((Par. 3-03) - (par. 3-02)) = 24,5^{\circ}C$ <i>3-14 Preset Relative Reference to 3-18 Relative Scaling Reference</i> Resource [0] = No Function
4) Adjust limits for the frequency converter:		
Set ramp times to an appropriate value as 20 s	3-41	20 s
	3-42	20 s
Set minimum speed limits	4-12	10 Hz
Set motor speed maximum limit	4-14	50 Hz
Set maximum output frequency	4-19	60 Hz
Set <i>6-19 Terminal 53 mode</i> and <i>6-29 Terminal 54 mode</i> to voltage or current mode.		
5) Scale analog inputs used for reference and feedback		
Set terminal 53 low voltage	6-10	0 V
Set terminal 53 high voltage	6-11	10 V
Set terminal 54 low feedback value	6-24	-5 °C
Set terminal 54 high feedback value	6-25	35 °C
Set feedback source	7-20	[2] Analog input 54
6) Basic PID settings		
Process PID normal/inverse	7-30	[0] Normal
Process PID anti wind-up	7-31	[1] On
Process PID start speed	7-32	300 RPM
Save parameters to LCP	0-50	[1] All to LCP

Table 2.9 Example of Process PID Control Set-up

### 2.5.5 Optimisation of the Process Regulator

After configuring the basic settings as described in *chapter 2.5.5 Programming Order*, optimise the proportional gain, the integration time and the differentiation time (7-33 *Process PID Proportional Gain*, 7-34 *Process PID Integral Time*, 7-35 *Process PID Differentiation Time*). In most processes, complete the following procedure:

1. Start the motor.
2. Set 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 stabilised. Lower the proportional gain by 40-60%.
3. Set 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 stabilises, followed by an increase of 15-50%.
4. Only use 7-35 *Process PID Differentiation Time* for fast-acting systems only (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 optimised. Make sure that oscillations on the feedback signal are sufficiently damped by the lowpass filter on the feedback signal.

**NOTICE**

If necessary, start/stop can be activated a number of times in order to provoke a variation of the feedback signal.

### 2.5.6 Ziegler Nichols Tuning Method

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

**NOTICE**

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

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 *Illustration 2.28* and

should be measured when the amplitude of oscillation is quite small.

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 *Table 2.10* to calculate the necessary PID control parameters.

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

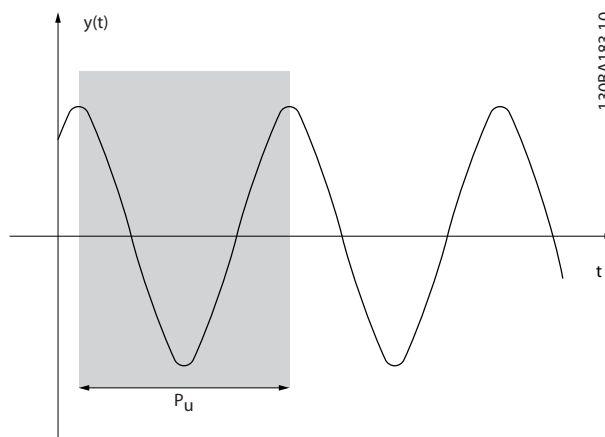


Illustration 2.28 Marginally Stable System

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

Table 2.10 Ziegler Nichols Tuning for Regulator

## 2.6 EMC Emission and Immunity

### 2.6.1 General Aspects of EMC Emission

Electrical interference is usually conducted at frequencies in the range 150 kHz to 30 MHz. Airborne interference from the frequency converter system in the range 30 MHz to 1G Hz is generated from the frequency converter, motor cable, and motor.

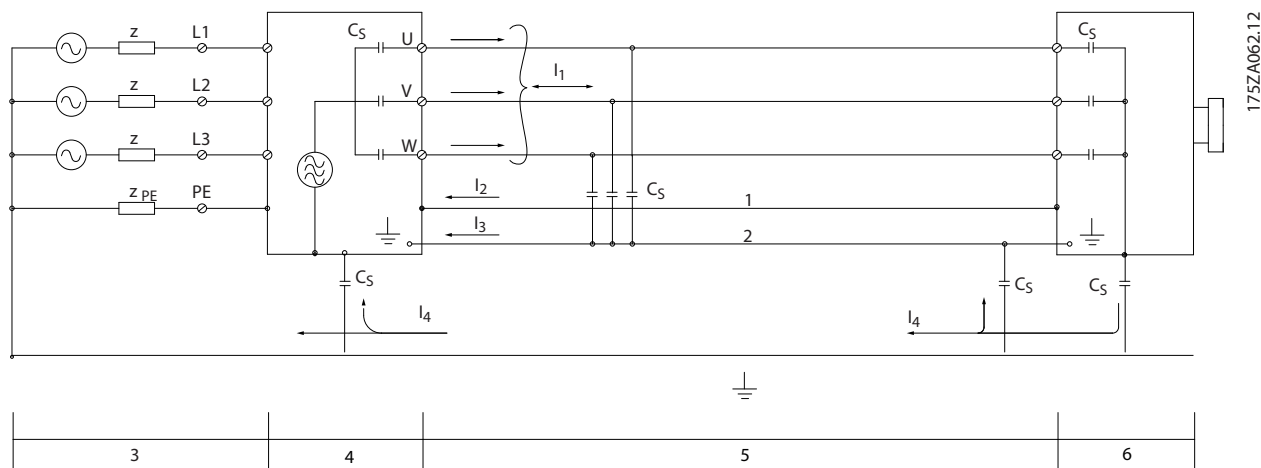
Capacitive currents in the motor cable coupled with a high  $dU/dt$  from the motor voltage generate leakage currents. Using a screened motor cable increases the leakage current (see *Illustration 2.29*) because screened cables have higher capacitance to ground than unscreened cables. If the leakage 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 screen ( $I_3$ ), there is only a small electro-magnetic field ( $I_4$ ) from the screened motor cable.

The screen reduces the radiated interference but increases the low-frequency interference on the mains. Connect the motor cable screen to the frequency converter enclosure as well as the motor enclosure. This is best done by using integrated screen clamps to avoid twisted screen ends (pigtailed). These increase the screen impedance at higher frequencies, which reduces the screen effect and increases the leakage current ( $I_4$ ).

Mount the screen on the enclosure at both ends if a screened 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 screen to avoid current loops.



1	Ground cable
2	Screen
3	AC mains supply
4	Frequency converter
5	Screened motor cable
6	Motor

Illustration 2.29 EMC Emission

If the screen is to be placed on a mounting plate for the frequency converter, the mounting plate must be made of metal, because the screen currents have to be conveyed back to the unit. Ensure good electrical contact from the mounting plate through the mounting screws to the frequency converter chassis.

When using unscreened 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.

## 2.6.2 EMC Emission Requirements

The test results in *Table 2.11* have been obtained using a system with a frequency converter (with the mounting plate), a motor and screened motor cables.

Standards and requirements	EN 55011		Conducted emission	Radiated emission
	EN/IEC 61800-3		Class A Group 2 Industrial environment	Class A Group 1 Industrial environment
			Category C3 Second environment	Category C2 First environment Restricted
J1	0.37–2.2 kW, 380–480 V		25 m	Yes
J2	3.0–5.5 kW, 380–480 V		25 m	Yes
J3	7.5 kW, 380–480 V		25 m	Yes
J4	11–15 kW, 380–480 V		25 m	Yes
J5	18.5–22 kW, 380–480 V		25 m	Yes
J6	30–45 kW, 380–480 V		25 m	Yes
J7	55–75 kW, 380–480 V		25 m	Yes

Table 2.11 EMC Emission Requirements

## 2.6.3 EMC Immunity Requirements

The immunity requirements for frequency converters 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 frequency converters comply with the requirements for the industrial environment and consequently comply also with the lower requirements for home and office environment with a large safety margin.

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

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

- **EN 61000-4-2 (IEC 61000-4-2) Electrostatic discharges (ESD):** Simulation of electrostatic discharges from human beings.
- **EN 61000-4-3 (IEC 61000-4-3) Radiated immunity:** Amplitude modulated simulation of the effects of radar and radio communication equipment as well as mobile communications equipment.
- **EN 61000-4-4 (IEC 61000-4-4) 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 e.g. by 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 2.12* for details.

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 2kV/12 Ω CM	10 V <sub>RMS</sub>
Motor cable	—	—	4 kV CCC	—	10 V <sub>RMS</sub>
Brake cable	—	—	4 kV CCC	—	10 V <sub>RMS</sub>
Load sharing cable	—	—	4 kV CCC	—	10 V <sub>RMS</sub>
Relay cable	—	—	4 kV CCC	—	10 V <sub>RMS</sub>
Control cable	—	—	length>2m 1 kV CCC	Unshielded: 1 kV/42 Ω CM	10 V <sub>RMS</sub>
Standard/fieldbus cable	—	—	length>2m 1 kV CCC	Unshielded: 1 kV/42 Ω CM	10 V <sub>RMS</sub>
LCP cable	—	—	length>2m 1 kV CCC	—	10 V <sub>RMS</sub>
Enclosure	4 kV CD 8 kV AD	10 V/m	—	—	—

**Table 2.12 EMC Immunity Requirements**

*Definition:*

*CD: Contact discharge*

*AD: Air discharge*

*DM: Differential mode*

*CM: Common mode*

*CN: Direct injection through coupling network*

*CCC: Injection through capacitive coupling clamp*

2

## 2.7 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.

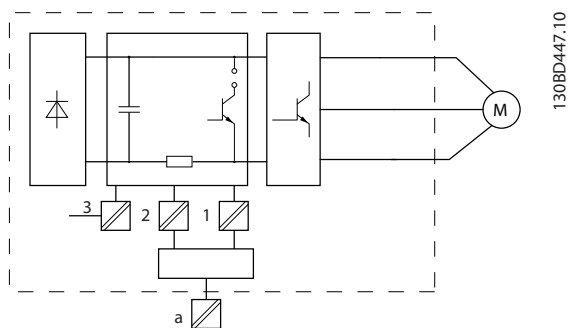
All control terminals and relay terminals 01-03/04-06 comply with PELV (Protective Extra Low Voltage). This does not apply to grounded Delta leg above 400 V.

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

The components that make up the electrical isolation, as shown in *Illustration 2.30*, 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 *Illustration 2.30*):

To maintain PELV, all connections made to the control terminals must be PELV, e.g. thermistor must be reinforced/double insulated.



1	Power supply (SMPS) for control cassette
2	Communication between power card and control cassette
3	Customer relays

Illustration 2.30 Galvanic Isolation

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 intermediate circuit) and the motor connection for kinetic back-up. Wait at least the amount of time indicated in *Table 1.2*. Failure to follow recommendations could result in death or serious injury.

## 2.8 Earth Leakage Current

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

The earth leakage current is made up of several contributions and depends on various system configurations including RFI filtering, screened motor cables, and frequency converter power.

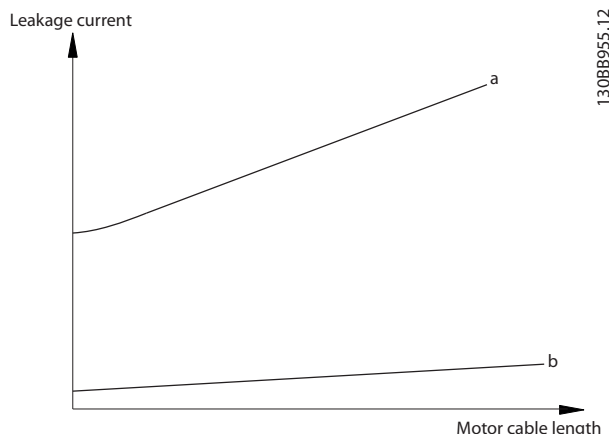
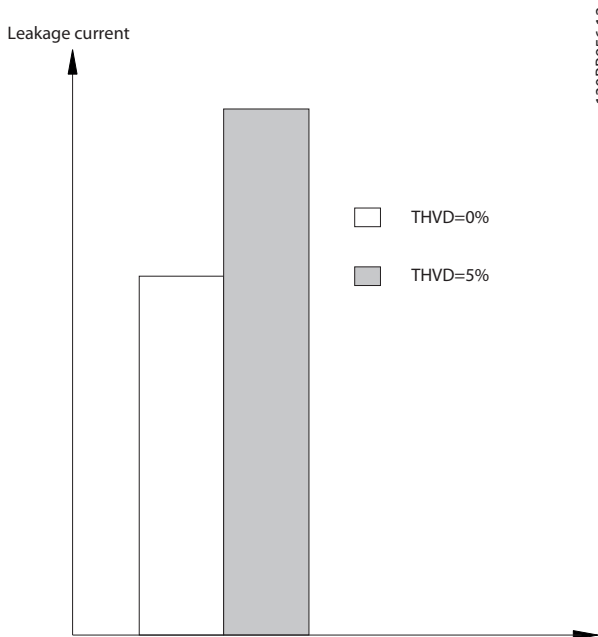


Illustration 2.31 Influence the Cable Length and Power Size on Leakage Current,  $P_a > P_b$

The leakage current also depends on the line distortion.



130BB956.12

Illustration 2.32 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 to J5) or set 14-50 RFI Filter to [0] Off (enclosure sizes J6 and J7) when a filter is being charged.

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

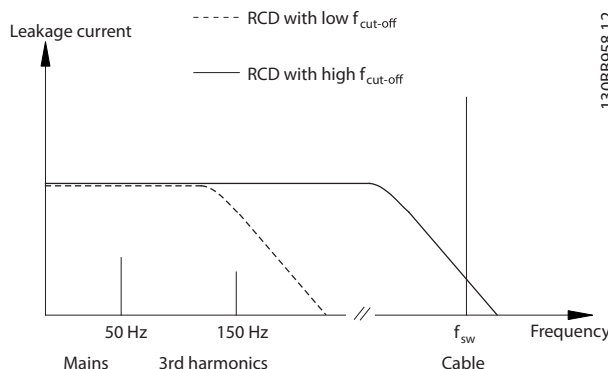
- Ground wire (terminal 95) of at least 10 mm<sup>2</sup>.
- 2 separate ground wires that comply with the dimensioning rules.

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

**Using RCDs**

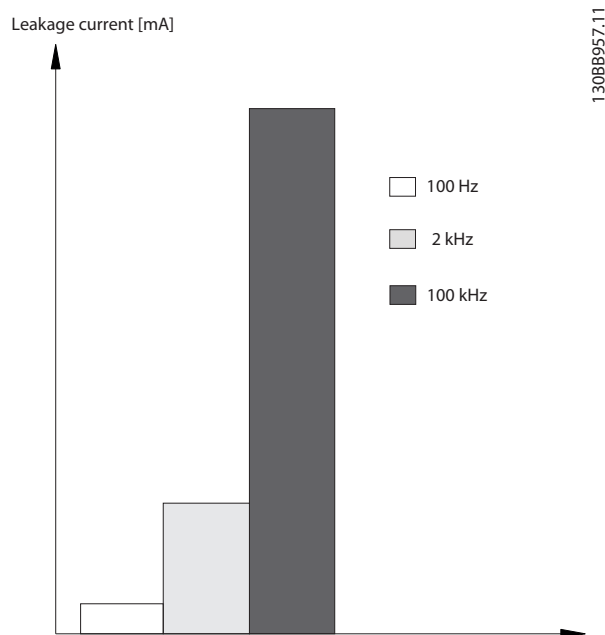
Where residual current devices (RCDs), also known as earth leakage circuit breakers (ELCBs), are used, comply with the following:

- 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 earth currents.
- Dimension RCDs according to the system configuration and environmental considerations.



130BB958.12

Illustration 2.33 Main Contributions to Leakage Current



130BB957.11

Illustration 2.34 Influence of Cut-off Frequency of the RCD on What is Responded to/Measured

For more details, refer to the RCD Application Note.

2.9 Brake Functions

2.9.1 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 frequency converter cannot provide a safe control of a mechanical brake. Redundancy circuitry for the brake control must be included in the total installation.

2

### 2.9.2 Dynamic Braking

Dynamic Brake 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 (2-10 Brake Function = [1] Resistor brake).  
The threshold can be adjusted by 2-14 Brake voltage reduce, with 70 V range
- 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 will overheat the motor (2-10 Brake Function = [2] AC brake).
- DC brake: An over-modulated DC current added to the AC current works as an eddy current brake (2-02 DC Braking Time≠0 s).

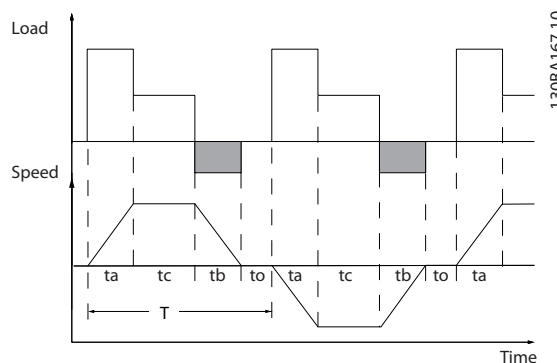


Illustration 2.35 Typical Braking Cycle

### 2.9.3 Brake Resistor Selection

To handle higher demands by generative braking, a brake resistor is necessary. Using a brake resistor ensures that the heat is absorbed in the brake resistor and not in the frequency converter. For more information, see the *Brake Resistor Design Guide*.

If the amount of kinetic energy transferred to the resistor in each braking period is not known, the average power can be calculated on the basis of the cycle time and braking time. The resistor intermittent duty cycle is an indication of the duty cycle at which the resistor is active. *Illustration 2.35* shows a typical braking cycle.

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

$$\text{Duty cycle} = t_b/T$$

$t_b$  is the braking time in seconds

T = cycle time in seconds

Power range	0.37–75 kW <sup>1)</sup>
<b>380–480 V</b>	
Cycle time (s)	120
Braking duty cycle at 100% torque	Continuous
Braking duty cycle at overtorque (150/160%)	40%

Table 2.13 Braking at High Overload Torque Level

1) For 30-75 kW frequency converters, an external brake resistor is needed to meet the specification in Table 2.13.

Danfoss offers brake resistors with duty cycle 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 the resistor is designed to handle the required braking time.**

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

#### Brake Resistance Calculation

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

where

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

As can be seen, the brake resistance depends on the intermediate circuit voltage ( $U_{dc}$ ).

Size	Brake active $U_{dc,br}$	Warning before cut out	Cut out (trip)
FC 360 3x380–480 V	770 V	800 V	800 V

The threshold can be adjusted in 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.**

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

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

$\eta_{motor}$  is typically at 0.80 ( $\leq 75$  kW); 0.85 (11–22 kW)

$\eta_{VLT}$  is typically at 0.97

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

$$480 V: R_{rec} = \frac{396349}{P_{motor}} [\Omega] \text{ 1)}$$

$$480 V: R_{rec} = \frac{397903}{P_{motor}} [\Omega] \text{ 2)}$$

1) For frequency converters  $\leq 7.5$  kW shaft output

2) For frequency converters 11–75 kW shaft output

### NOTICE

The resistance of the brake resistor should not be higher than the value recommended by Danfoss. If a brake resistor with a higher ohmic value is selected, the 160% braking torque may not be achieved because the frequency converter might cut out for safety reasons. The resistance should be bigger than  $R_{min}$ .

### NOTICE

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

### NOTICE

Do not touch the brake resistor because it can get very hot during braking. Place the brake resistor in a secure environment to avoid fire risk.

## 2.9.4 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 frequency converter.

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 energising and make sure it does not exceed a limit selected in 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 earth leakage protected.**

*Overvoltage control (OVC)* (exclusive brake resistor) can be selected as an alternative brake function in 2-17 *Overvoltage 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, e.g. if the ramp-down time is too short to avoid tripping of the frequency converter. In this situation, the ramp-down time is extended.

### NOTICE

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

## 2.10 Smart Logic Controller

Smart logic control (SLC) is a sequence of user-defined actions (see 13-52 *SL Controller Action [x]*) executed by the SLC when the associated user defined event (see 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. That leads to an associated action as shown in *Illustration 2.36*.

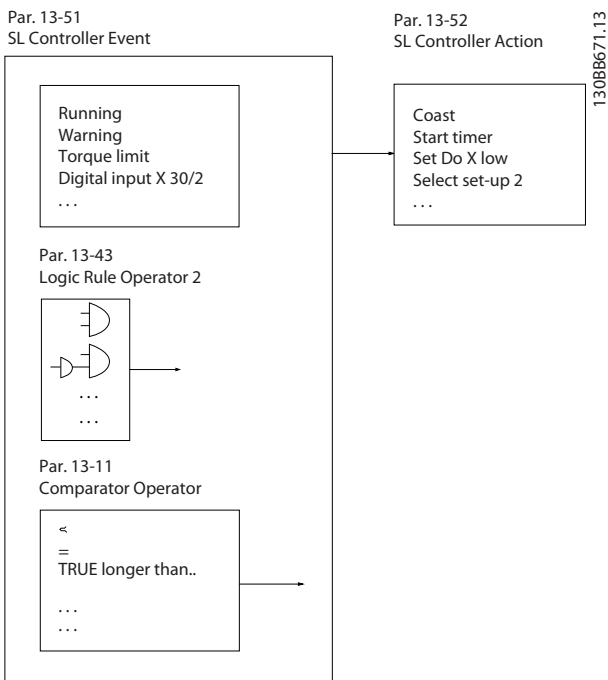


Illustration 2.36 Associated Action

Events and actions are each numbered and linked in pairs (states). This means that when *event [0]* is fulfilled (attains the value TRUE), *action [0]* is executed. After this, the conditions of *event [1]* are evaluated and if evaluated *true*, *action [1]* is executed and so on. Only one *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 evaluates *event [0]* (and only *event [0]*) each scan interval. Only when *event [0]* is evaluated *true*, the SLC executes *action [0]* and starts evaluating *event [1]*. It is possible to programme from 1 to 20 *events* and *actions*. When the last *event/action* has been executed, the sequence starts over again from *event [0]/action [0]*. *Illustration 2.37* shows an example with 3 *event/actions*:

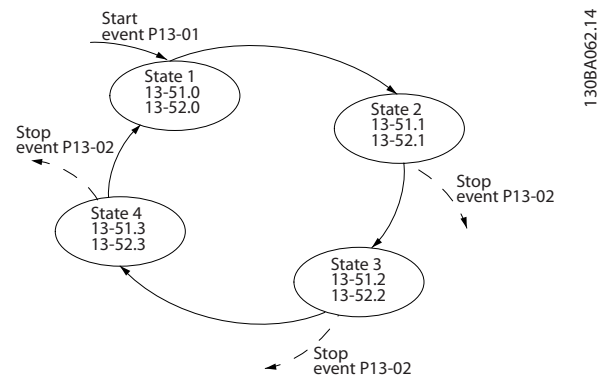


Illustration 2.37 Sequence with 3 Event/Actions

### Comparators

Comparators are used for comparing continuous variables (i.e. output frequency, output current, analog input etc.) to fixed preset values.

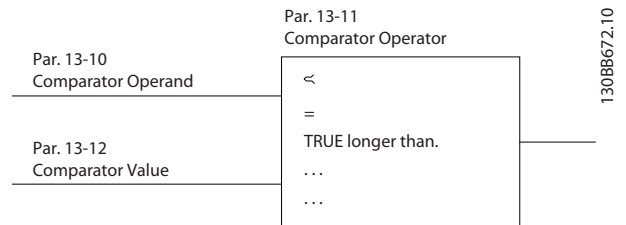


Illustration 2.38 Comparators

### 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*.

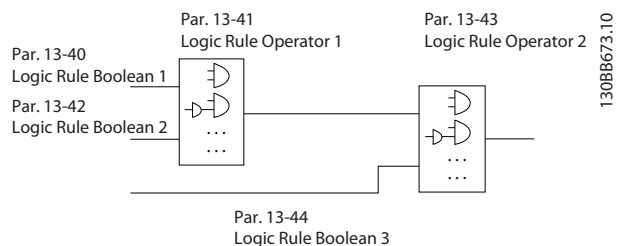


Illustration 2.39 Logic Rules

## 2.11 Extreme Running Conditions

### Short circuit (motor phase – phase)

The frequency converter is protected against short circuits by means of 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 frequency converter. The frequency converter is turned off individually when the short circuit current exceeds the permitted value (Alarm 16 Trip Lock).

### Switching on the output

Switching on the output between the motor and the frequency converter is fully permitted, and does not damage the frequency converter. However, fault messages may appear.

### Motor-generated overvoltage

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

1. The load drives the motor (at constant output frequency from the frequency converter).
2. If the moment of inertia 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 frequency converter, the motor and the installation.
3. Incorrect slip compensation setting may cause higher DC-link voltage.

The control unit may attempt to correct the ramp if possible (2-17 *Over-voltage Control*).

The frequency converter turns off to protect the transistors and the intermediate circuit capacitors when a certain voltage level is reached.

See 2-10 *Brake Function* and 2-17 *Over-voltage Control* to select the method used for controlling the intermediate circuit voltage level.

### Mains drop-out

During a mains drop-out, the frequency converter keeps running until the intermediate circuit 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<sup>+</sup> mode

When the frequency converter is overloaded (the torque limit in 4-16 *Torque Limit Motor Mode*/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 may occur that makes the frequency converter cut out after approximately 5–10 s.

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

## 2.11.1 Motor Thermal Protection

To protect the application from serious damage, VLT<sup>®</sup> AutomationDrive FC 360 offers several dedicated features.

### Torque limit

The torque limit protects the motor from being overloaded independent of the speed. Torque limit is controlled in 4-16 *Torque Limit Motor Mode* and or 4-17 *Torque Limit Generator Mode*, and the time before the torque limit

warning trips is controlled in 14-25 *Trip Delay at Torque Limit*.

### Current limit

The current limit is controlled in 4-18 *Current Limit*, and the time before the current limit warning trips is controlled in 14-24 *Trip Delay at Current Limit*.

### Minimum speed limit

(4-12 *Motor Speed Low Limit [Hz]*) sets the minimum output speed the frequency converter can provide.

### Maximum speed limit

(4-14 *Motor Speed High Limit [Hz]* or 4-19 *Max Output Frequency*) sets the maximum output speed the frequency converter can provide.

### ETR (Electronic Thermal relay)

The frequency converter ETR function measures actual current, speed, and time to calculate motor temperature and protect 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 *Illustration 2.40*

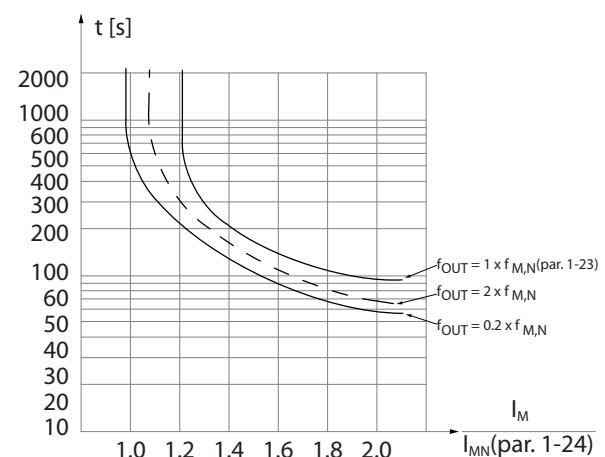


Illustration 2.40 ETR

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

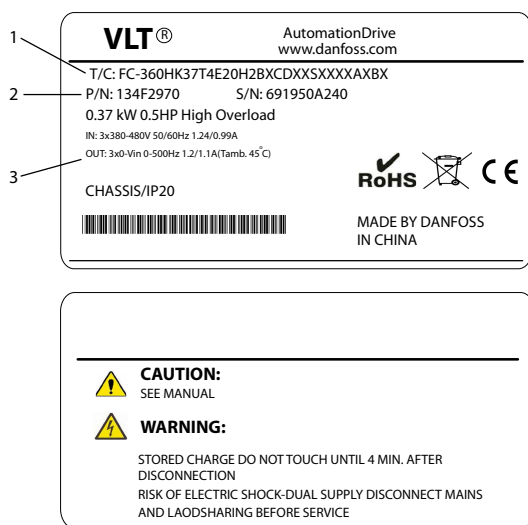
At lower speed, the ETR cuts off at lower heat due to less cooling of the motor. In that way, the motor is protected from being overheated even at low speed. The ETR feature calculates the motor temperature based on actual current and speed. The calculated temperature is visible as a readout parameter in 16-18 *Motor Thermal*.

### 3 Type Code and Selection

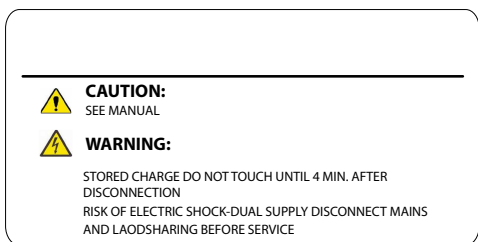
# 3

#### 3.1 Ordering

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



1308C435.11



1	Type code
2	Ordering number
3	Specifications

Illustration 3.1 Nameplate 1 and 2

1-6: Product Name	
7: Overload	H: Heavy Duty Q: Normal Duty <sup>1)</sup>
8-10: Power Size	0.37-75 kW e.g. K37: 0.37 kW <sup>2)</sup> 1K1: 1.1 kW 11K: 11 kW etc.
11-12: Voltage Class	T4: 380-480 V 3 phases
13-15: IP Class	E20: IP20
16-17: RFI	H2: C3 Class
18: Brake chopper	X: No B: Built-in <sup>3)</sup>
19: LCP	X: No
20: PCB Coating	C: 3C3
21: Mains terminals	D: Load sharing
29-30: Embedded Fieldbus	AX: No A0: Profibus AL: ProfiNet <sup>4)</sup>

Table 3.1 Type Code: Selection of Different Features and Options

For options and accessories, refer to the section Options and Accessories in Design Guide.

1) Only 11-75 kW for normal duty variants. Profibus and ProfiNet unavailable for normal duty.

2) For all power sizes, see chapter 4.1.1 Mains Supply 3x380-480 V AC.

3) 0.37-22 kW with built-in brake chopper. 30-75 kW with external brake chopper only.

4) Not available yet.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
F	C	-	3	6	0	H				T	4	E	2	0	H	2	X	X	C	D	X	X	S	X	X	X	X	A	X	B	X
						Q											B											A	0		
																												A	L		

1308C437.10

Illustration 3.2 Type Code String



### 3.2 Ordering Numbers: Options and Accessories

Description	Ordering numbers
VLT® control panel LCP 21	132B0254 <sup>1)</sup>
VLT® LCP remote mounting kit with 3 m cable	132B0102 <sup>2)</sup>
VLT® blind cover, FC 360	132B0262 <sup>1)</sup>
VLT® graphical LCP adapter	132B0281
VLT® control panel LCP 102	130B1107
VLT® encoder input MCB 102, FC 360	132B0282
VLT® resolver input MCB 103, FC 360	132B0283
VLT® terminal cover for MCB, J1, FC 360	132B0263
VLT® terminal cover for MCB, J2, FC 360	132B0265
VLT® terminal cover for MCB, J3, FC 360	132B0266
VLT® terminal cover for MCB, J4, FC 360	132B0267
VLT® terminal cover for MCB, J5, FC 360	132B0268
VLT® decoupling plate mounting kit, J1	132B0258
VLT® decoupling plate mounting kit, J2, J3	132B0259
VLT® decoupling plate mounting kit, J4, J5	132B0260
VLT® decoupling plate mounting kit, J6	132B0284
VLT® decoupling plate mounting kit, J7	132B0285

1) 2 kinds of packages, 6 pcs or 72 pcs

2) 2 pcs in one package

### 3.3 Ordering Numbers: Brake Resistors

Danfoss offers a wide variety of different resistors that are specially designed to our frequency converters. See *chapter 2.9.4 Control with Brake Function* for the dimensioning of brake resistors. This section lists the ordering numbers for the brake resistors.

**3**

#### 3.3.1 Ordering Numbers: Brake Resistors 10%

FC 360	P <sub>m</sub> (HO)	R <sub>min</sub>	R <sub>br. nom</sub>	R <sub>rec</sub>	P <sub>br avg</sub>	Code no.	Period	Cable cross section <sup>1)</sup>	Thermal relay	Maximum brake torque with R <sub>rec</sub>
T4	[kW]	[Ω]	[Ω]	[Ω]	[kW]	175Uxxxx	[s]	[mm <sup>2</sup> ]	[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

**Table 3.2 FC 360 - Mains: 380–480 V (T4), 10% Duty Cycle**

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

## 3.3.2 Ordering Numbers: Brake Resistors 40%

FC 360	P <sub>m</sub> (HO)	R <sub>min</sub>	R <sub>br. nom</sub>	R <sub>rec</sub>	P <sub>br avg</sub>	Code no.	Period	Cable cross section <sup>1)</sup>	Thermal relay	Maximum brake torque with R <sub>rec</sub>
T4	[kW]	[Ω]	[Ω]	[Ω]	[kW]	175Uxxxx	[s]	[mm <sup>2</sup> ]	[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

Table 3.3 FC 360 - Mains: 380–480 V (T4), 40% Duty Cycle

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

## 4 Specifications

### 4.1 Power-dependent Specifications

**4**

Frequency converter typical shaft output [kW]	HK37 0.37	HK55 0.55	HK75 0.75	H1K1 1.1	H1K5 1.5	H2K2 2.2	H3K0 3	H4K0 4	H5K5 5.5	H7K5 7.5
Enclosure IP20	J1	J1	J1	J1	J1	J1	J2	J2	J2	J3
<b>Output current</b>										
Shaft output [kW]	0.37	0.55	0.75	1.1	1.5	2.2	3	4	5.5	7.5
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
<b>Maximum input current</b>										
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
<b>Additional specifications</b>										
Maximum cable cross section (mains, motor, brake, and load sharing) [mm <sup>2</sup> /AWG]	4 mm <sup>2</sup>									
Estimated power loss at rated maximum load [W] <sup>2)</sup>	20.88	25.16	30.01	40.01	52.91	73.97	94.81	115.5	157.54	192.83
Weight, enclosure IP20	2.3	2.3	2.3	2.3	2.3	2.5	3.6	3.6	3.6	4.1
Efficiency [%] <sup>3)</sup>	96.2	97.0	97.2	97.4	97.4	97.6	97.5	97.6	97.7	98.0

 Table 4.1 Mains Supply 3x380–480 V AC - Heavy Duty<sup>1)</sup>

Frequency converter typical shaft output [kW]	H11K 11	H15K 15	H18K 18.5	H22K 22	H30K 30	H37K 37	H45K 45	H55K 55	H75K 75	
IP20	J4	J4	J5	J5	J6	J6	J6	J7	J7	
<b>Output current</b>										
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	
<b>Maximum input current</b>										
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	
<b>Additional specifications</b>										
Maximum cable size (mains, motor, brake) [mm <sup>2</sup> /AWG]	16 mm <sup>2</sup>			50 mm <sup>2</sup>				85 mm <sup>2</sup>		
Estimated power loss at rated maximum load [W] <sup>2)</sup>	289.53	393.36	402.83	467.52	630	848	1175	1250	1507	
Weight enclosure IP20 [kg]	9.4	9.5	12.3	12.5	22.4	22.5	22.6	37.3	38.7	
Efficiency [%] <sup>3)</sup>	97.8	97.8	98.1	97.9	98.1	98.0	97.7	98.0	98.2	

 Table 4.2 Mains Supply 3x380–480 V AC - Heavy Duty<sup>1)</sup>

Frequency converter typical shaft output [kW]	Q11K	Q15K	Q18K	Q22K	Q30K	Q37K	Q45K	Q55K	Q75K
IP20	J4	J4	J5	J5	J6	J6	J6	J7	J7
<b>Output current</b>									
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]	25.3	34.1	40.7	46.8	67.1	80.3	99	116.6	161.7
Continuous kVA (400 V AC) [kVA]	15.94	21.48	25.64	29.45	42.3	50.6	62.4	73.4	101.8
Continuous kVA (480 V AC) [kVA]	17.5	22.4	28.3	33.3	43.2	54.0	64.0	79.8	103.1
<b>Maximum input current</b>									
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]	24.3	32.9	38.7	45.7	62.7	77.3	92.6	113.2	154.3
<b>Additional specifications</b>									
Maximum cable size (mains, motor, brake) [mm <sup>2</sup> /AWG]	16 mm <sup>2</sup>			50 mm <sup>2</sup>				85 mm <sup>2</sup>	
Estimated power loss at rated maximum load [W] <sup>2)</sup>	289.53	393.36	402.83	467.52	630	848	1175	1250	1507
Weight enclosure IP20 [kg]	9.4	9.5	12.3	12.5	22.4	22.5	22.6	37.3	38.7
Efficiency [%] <sup>3)</sup>	97.8	97.8	98.1	97.9	98.1	98.0	97.7	98.0	98.2

**Table 4.3 Mains Supply 3x380–480 V AC - Normal Duty<sup>1)</sup>**

1) Heavy duty=150–160% current during 60 s, Normal duty=110% current during 60 s.

2) The typical power loss is at nominal load conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions).

Values are based on a typical motor efficiency (IE2/IE3 border line). Motors with lower efficiency add to the power loss in the frequency converter and motors with high efficiency reduce power loss.

Applies for dimensioning of frequency converter cooling. If the switching frequency is higher than the default setting, the power losses may rise. LCP and typical control card power consumptions are included. Further options and customer load may add up to 30 W to the losses (though typical only 4 W extra for a fully loaded control card, or field bus, or options for slot B).

For power loss data according to EN 50598-2, refer to [www.danfoss.com/vltenergyefficiency](http://www.danfoss.com/vltenergyefficiency).

3) Measured using 5 m screened motor cables at rated load and rated frequency for enclosure sizes J1–J5, and using 33 m screened motor cables at rated load and rated frequency for enclosure sizes J6 and J7. For energy efficiency class, see the Ambient Conditions section in chapter 4.2 General Specifications. For part load losses, see [www.danfoss.com/vltenergyefficiency](http://www.danfoss.com/vltenergyefficiency).

## 4.2 General Specifications

### Mains supply (L1, L2, L3)

Supply terminals	L1, L2, L3
Supply voltage	380–480 V: -15% (-25%) <sup>1)</sup> to +10%

1) The frequency converter can run at -25% input voltage with reduced performance. The maximum output power of the frequency converter is 75% in case of -25% input voltage and 85% in case of -15% input voltage.

Full torque cannot be expected at mains voltage lower than 10% below the frequency converter's lowest rated supply voltage.

Supply frequency	50/60 Hz ±5%
Maximum imbalance temporary between mains phases	3.0 % of rated supply voltage
True power factor ( $\lambda$ )	≥ 0.9 nominal at rated load
Displacement power factor (cos $\phi$ )	near unity (> 0.98)
Switching on input supply L1, L2, L3 (power-ups) ≤ 7.5 kW	maximum 2 times/minute
Switching on input supply L1, L2, L3 (power-ups) 11–75 kW	maximum 1 time/minute

The unit is suitable for use on a circuit capable of delivering less than 100,000 RMS symmetrical Amperes, 480 V maximum.

### Motor output (U, V, W)

Output voltage	0–100% of supply voltage
Output frequency	0–500 Hz
Output frequency in VVC <sup>+</sup> Mode	0–200 Hz
Switching on output	Unlimited
Ramp time	0.05–3600 s

### Torque characteristics

Starting torque (constant torque)	maximum 160% for 60 s <sup>1)</sup>
Overload torque (constant torque)	maximum 160% for 60 s <sup>1)</sup>
Starting torque (variable torque)	maximum 110% for 60 s <sup>1)</sup>
Overload torque (variable torque)	maximum 110% for 60 s
Starting current	maximum 200% for 1 s
Torque rise time in VVC <sup>+</sup> (independent of $f_{sw}$ )	10 ms

1) Percentage relates to the nominal torque.

2) The torque response time depends on application and load, but, as a general rule, the torque step from 0 to reference is 4–5 x torque rise time.

### Cable lengths and cross sections<sup>1)</sup>

Maximum motor cable length, screened	50 m
Maximum motor cable length, unscreened	0.37–22 kW: 75 m, 30–75 kW: 100 m
Maximum cross section to control terminals, flexible/rigid wire	2.5 mm <sup>2</sup> /14 AWG
Minimum cross section to control terminals	0.55 mm <sup>2</sup> / 30 AWG

1) For power cables, see Table 4.1 to Table 4.3.

### Digital inputs

Programmable digital inputs	7
Terminal number	18, 19, 27 <sup>1)</sup> , 29 <sup>1)</sup> , 32, 33, 31
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, $R_i$	approximately 4 k $\Omega$

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

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, $R_i$	approximately 10 k $\Omega$
Maximum voltage	-15 to +20 V
Current level	0/4 to 20 mA (scaleable)
Input resistance, $R_i$	approximately 200 $\Omega$
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.

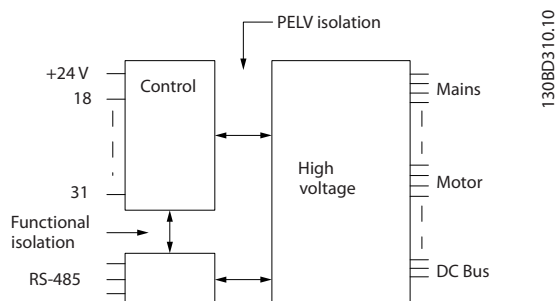


Illustration 4.1 Analog Inputs

Pulse inputs	
Programmable pulse inputs	2
Terminal number pulse	29, 33
Maximum frequency at terminal, 29, 33	32 kHz (Push-pull driven)
Maximum frequency at terminal, 29, 33	5 kHz (open collector)
Minimum frequency at terminal 29, 33	4 Hz
Voltage level	see section on digital input
Maximum voltage on input	28 V DC
Input resistance, $R_i$	approximately 4 k $\Omega$
Pulse input accuracy (0.1–1 kHz)	Maximum error: 0.1% of full scale
Pulse input accuracy (1–32 kHz)	Maximum error: 0.05% of full scale

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

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

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).

**Digital outputs**

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

1) Terminal 27 and 29 can also be programmed as input.

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

**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.

**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) <sup>1)</sup> on 01–02/04–05 (NO) (Resistive load)	250 V AC, 3 A
Maximum terminal load (AC-15) <sup>1)</sup> on 01–02/04–05 (NO) (Inductive load @ $\cos\phi$ 0.4)	250 V AC, 0.2 A
Maximum terminal load (DC-1) <sup>1)</sup> on 01–02/04–05 (NO) (Resistive load)	30 V DC, 2 A
Maximum terminal load (DC-13) <sup>1)</sup> on 01–02/04–05 (NO) (Inductive load)	24 V DC, 0.1 A
Maximum terminal load (AC-1) <sup>1)</sup> on 01–03/04–06 (NC) (Resistive load)	250 V AC, 3 A
Maximum terminal load (AC-15) <sup>1)</sup> on 01–03/04–06 (NC) (Inductive load @ $\cos\phi$ 0.4)	250 V AC, 0.2 A
Maximum terminal load (DC-1) <sup>1)</sup> 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.

**Control card, +10 V DC output**

Terminal number	50
Output voltage	10.5 V $\pm$ 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.

**Control characteristics**

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

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



**Ambient Conditions**

Enclosure sizes J1-J7	IP20
Vibration test, all enclosure sizes	1.0 g
Relative humidity	5-95% (IEC 721-3-3; Class 3K3 (non-condensing) during operation
Aggressive environment (IEC 60068-2-43) H <sub>2</sub> S test	class Kd
Test method according to IEC 60068-2-43 H <sub>2</sub> S (10 days)	
Ambient temperature (at 60 AVM switching mode)	
- with derating	maximum 55 °C <sup>1)</sup>
- at full continuous output current with some power size	maximum 50 °C
- at full continuous output current	maximum 45 °C
Minimum ambient temperature during full-scale operation	0 °C
Minimum ambient temperature at reduced performance	-10 °C
Temperature during storage/transport	-25 to +65/70 °C
Maximum altitude above sea level without derating	1000 m
Maximum altitude above sea level with derating	3000 m
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 EN 61800-3, EN 61000-6-1/2, EN 61000-4-2,
EMC standards, immunity	EN 61000-4-3, EN 61000-4-4, EN 61000-4-5, EN 61000-4-6
Energy efficiency class <sup>1)</sup>	IE2

1) Determined according to EN50598-2 at:

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

**Control card performance**

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

**Protection and features**

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

### 4.3 Fuses

#### 4.3.1 Introduction

Use fuses and/or circuit breakers on the supply side to protect service personnel and equipment from injuries and damage in case of component breakdown inside the frequency converter (first fault).

#### Branch circuit protection

All branch circuits in an installation, switch gear, machines etc. must be protected against short circuit and overcurrent according to national/international regulations.

#### **NOTICE**

The recommendations do not cover branch circuit protection for UL.

Table 4.4 lists the recommended fuses that have been tested.

If fuses are selected according to recommendations, possible damages can be limited to inside the frequency converter.

#### **⚠ WARNING**

Malfunction or failing to follow the recommendations may result in personal risk and damage to the frequency converter and other equipment.

### 4.3.2 CE Compliance

#### **NOTICE**

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

Danfoss recommends using the fuses in Table 4.4 on a circuit capable of delivering 100000 A<sub>rms</sub> (symmetrical), 380–480 V depending on the frequency converter voltage rating. With the proper fusing, the frequency converter short circuit current rating (SCCR) is 100000 A<sub>rms</sub>.

Enclosure size	Power [kW]	CE compliance fuse
J1	0.37–1.1	gG-10
	1.5	
	2.2	
J2	3.0	gG-25
	4.0	
	5.5	
J3	7.5	gG-32
J4	11–15	gG-50
J5	18.5	gG-80
	22	
J6	30	gG-125
	37	
	45	
J7	55	aR-250
	75	

Table 4.4 CE Fuse, 380–480 V, Enclosure Sizes J1–J7

### 4.4 Efficiency

#### Efficiency of the frequency converter ( $\eta_{VLT}$ )

The load on the frequency converter has little effect on its efficiency. In general, the efficiency is the same at the rated motor frequency  $f_{M,N}$ , even if the motor supplies 100% of the rated shaft torque or only 75%, i.e. in case of part loads.

This also means that the efficiency of the frequency converter 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. The efficiency is also slightly reduced if the mains voltage is 480 V, or if the motor cable is longer than 30 m.

#### Frequency converter efficiency calculation

Calculate the efficiency of the frequency converter at different loads based on *Illustration 4.2*. The factor in this graph must be multiplied with the specific efficiency factor listed in the specification tables:

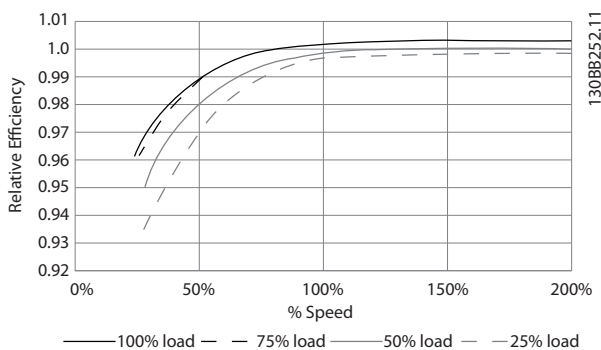


Illustration 4.2 Typical Efficiency Curves

#### Efficiency of the motor ( $\eta_{MOTOR}$ )

The efficiency of a motor connected to the frequency converter depends on the magnetising level. In general, the efficiency is just 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 it is controlled by the frequency converter and when it runs directly on mains.

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

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

#### Efficiency of the system ( $\eta_{SYSTEM}$ )

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

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

### 4.5 Acoustic Noise

The acoustic noise from the frequency converter comes from 3 sources:

- DC intermediate circuit coils.
- Integral fan.
- RFI filter choke.

The typical values measured at a distance of 1 m from the unit:

Enclosure size	50% fan speed [dBA]	Full fan speed [dBA]
J1 (0.37–2.2 kW)	N.A. <sup>1)</sup>	51
J2 (3.0–5.5 kW)	N.A. <sup>1)</sup>	55
J3 (7.5 kW)	N.A. <sup>1)</sup>	54
J4 (11–15 kW)	52	66
J5 (18.5–22 kW)	57.5	63
J6 (30–45 kW)	56	71
J7 (55–75 kW)	63	72

Table 4.5 Typical Measured Values

1) For J1–J3, the fan speed is fixed.

### 4.6 dU/dt Conditions

When a transistor in the frequency converter 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 screened or not.
- Inductance

The natural induction causes an overshoot  $U_{PEAK}$  in the motor voltage before it stabilises itself at a level depending on the voltage in the intermediate circuit. The rise time and the peak voltage  $U_{PEAK}$  affect the service life of the motor. 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.

Peak voltage on the motor terminals is caused by the switching of the IGBTs. The FC 360 complies with IEC 60034-25 regarding motors designed to be controlled by frequency converters. The FC 360 also complies with IEC 60034-17 regarding Norm motors controlled by frequency converters.

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

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

Table 4.6 dU/dt Data for FC 360, 2.2 kW

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

Table 4.7 dU/dt Data for FC 360, 5.5 kW

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

Table 4.8 dU/dt Data for FC 360, 7.5 kW

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

Table 4.9 dU/dt Data for FC 360, 15 kW

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

Table 4.10 dU/dt Data for FC 360, 22 kW

Cable length [m]	Mains voltage [V]	Rise time [ $\mu$ sec]	$U_{PEAK}$ [kV]	dU/dt [kV/ $\mu$ sec]
5	400	0.212	0.81	3.08
53	400	0.294	0.94	2.56
5	480	0.228	0.95	3.37
53	480	0.274	1.11	3.24

Table 4.11 dU/dt Data for FC 360, 37 kW

Cable length [m]	Mains voltage [V]	Rise time [ $\mu$ sec]	$U_{PEAK}$ [kV]	dU/dt [kV/ $\mu$ sec]
5	400	0.14	0.64	3.60
50	400	0.548	0.95	1.37
5	480	0.146	0.70	3.86
50	480	0.54	1.13	1.68

Table 4.12 dU/dt Data for FC 360, 45 kW

Cable length [m]	Mains voltage [V]	Rise time [ $\mu$ sec]	$U_{PEAK}$ [kV]	dU/dt [kV/ $\mu$ sec]
5	400	0.206	0.91	3.52
54	400	0.616	1.03	1.34
5	480	0.212	1.06	3.99
54	480	0.62	1.23	1.59

Table 4.13 dU/dt Data for FC 360, 55 kW

Cable length [m]	Mains voltage [V]	Rise time [ $\mu$ sec]	$U_{PEAK}$ [kV]	dU/dt [kV/ $\mu$ sec]
5	400	0.232	0.81	2.82
50	400	0.484	1.03	1.70
5	480	0.176	1.06	4.77
50	480	0.392	1.19	2.45

Table 4.14 dU/dt Data for FC 360, 75 kW

## 4.7 Special Conditions

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

### 4.7.1 Manual Derating

Manual derating must be considered for:

- Air pressure—for installation at altitudes above 1 km.
- Motor speed—at continuous operation at low RPM in constant torque applications.
- Ambient temperature—above 45 °C (for some types above 50 °C), for details, see *Table 4.15* and *Table 4.16*.

Enclosure size	Power size [kW]	Maximum output current at 45 °C	Maximum output current at 50 °C
J1	0.37	1.2	1.2
	0.55	1.7	1.7
	0.75	2.2	2.2
	1.1	3.0	3.0
	1.5	3.7	3.0
	2.2	5.3	4.1
J2	3	7.2	7.2
	4	9.0	9.0
	5.5	12.0	10.2
J3	7.5	15.5	13.1
J4	11	23.0	23.0
	15	31.0	26.0
J5	18.5	37.0	37.0
	22	42.5	40.0
J6	30	61	61
	37	73	73
	45	90	77
J7	55	106	106
	75	147	125

Table 4.15 Derating at 380 V

Enclosure size	Power size [kW]	Maximum output current at 45 °C	Maximum output current at 50 °C
J1	0.37	1.1	1.1
	0.55	1.6	1.6
	0.75	2.1	2.1
	1.1	3.0	2.8
	1.5	3.4	2.8
	2.2	4.8	3.8
J2	3	6.3	6.3
	4	8.2	8.2
	5.5	11.0	9.4
J3	7.5	14.0	11.9
J4	11	21.0	21.0
	15	27.0	22.6
J5	18.5	34.0	34.0
	22	40.0	37.7
J6	30	52	52
	37	65	65
	45	77	76
J7	55	96	96
	75	124	117

Table 4.16 Derating at 480 V

### 4.7.2 Automatic Derating

The frequency converter constantly checks for critical levels:

- Critical high temperature on the control card or heatsink.
- 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 frequency converter adjusts the switching frequency.

## 5 RS485 Installation and Set-up

### 5.1 Introduction

#### 5.1.1 Overview

RS485 is a 2-wire bus interface compatible with multi-drop network topology, that is, nodes can be connected as a bus, or via drop cables from a common trunk line. A total of 32 nodes can be connected to one network segment. Repeaters divide network segments, see *Illustration 5.1*.

5

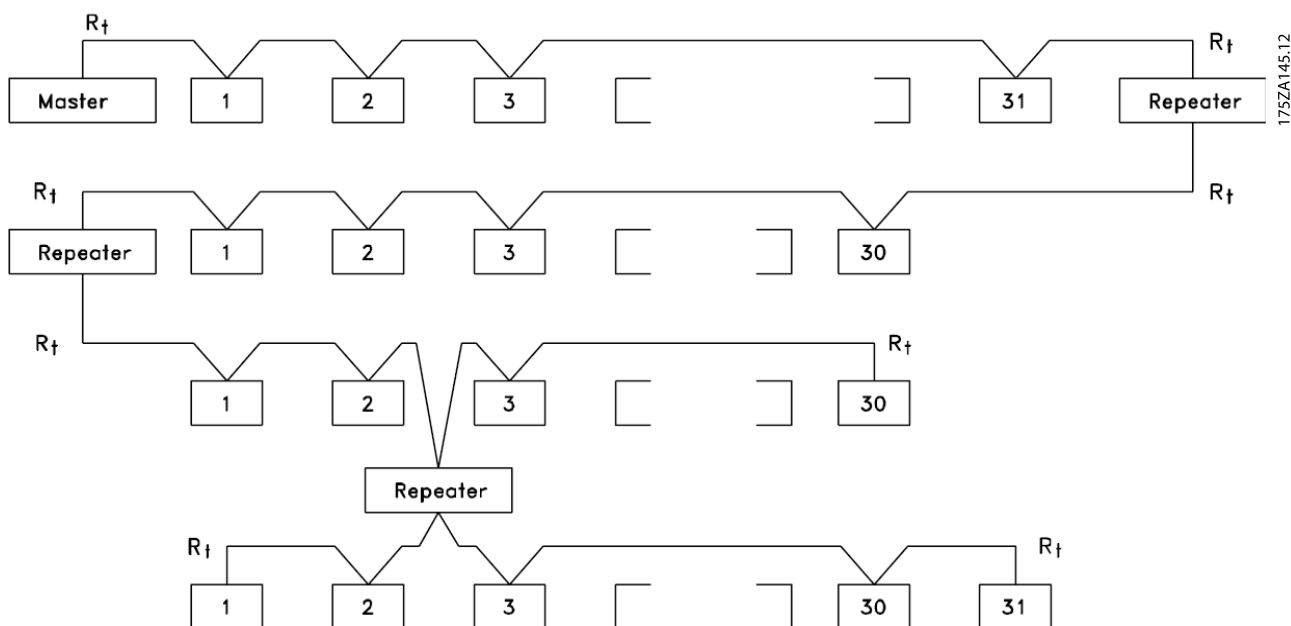


Illustration 5.1 RS485 Bus Interface

#### **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 frequency converters or a biased termination resistor network. Always use screened twisted pair (STP) cable for bus cabling, and follow good common installation practice.

Low-impedance ground connection of the screen at every node is important, including at high frequencies. Thus, connect a large surface of the screen to ground, for example with a cable clamp or a conductive cable gland. It may be necessary to apply potential-equalising 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 frequency converter, always use screened motor cable.

Cable	Screened twisted pair (STP)
Impedance [ $\Omega$ ]	120
Cable length [m]	Max. 1200 (including drop lines) Max. 500 station-to-station

Table 5.1 Cable Specifications

## 5.1.2 Network Connection

Connect the frequency converter to the RS485 network as follows (see also *Illustration 5.2*):

1. Connect signal wires to terminal 68 (P+) and terminal 69 (N-) on the main control board of the frequency converter.
2. Connect the cable screen to the cable clamps.

### **NOTICE**

Screened, twisted-pair cables are recommended to reduce noise between conductors.

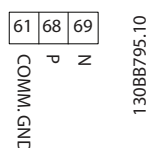


Illustration 5.2 Network Connection

## 5.1.3 Hardware Set-up

Use the terminator switch on the main control board of the frequency converter to terminate the RS485 bus.

The factory setting for the switch is OFF.

## 5.1.4 Parameter Settings for Modbus Communication

Parameter	Function
8-30 Protocol	Select the application protocol to run for the RS485 interface.
8-31 Address	Set the node address. <b>NOTICE</b> The address range depends on the protocol selected in 8-30 Protocol.
8-32 Baud Rate	Set the baud rate. <b>NOTICE</b> The default baud rate depends on the protocol selected in 8-30 Protocol.
8-33 Parity / Stop Bits	Set the parity and number of stop bits. <b>NOTICE</b> The default selection depends on the protocol selected in 8-30 Protocol.
8-35 Minimum Response Delay	Specify a minimum delay time between receiving a request and transmitting a response. This function is for overcoming modem turnaround delays.

Parameter	Function
8-36 Maximum Response Delay	Specify a maximum delay time between transmitting a request and receiving a response.
8-37 Maximum Inter-char delay	If transmission is interrupted, specify a maximum delay time between 2 received bytes to ensure time-out. <b>NOTICE</b> The default selection depends on the protocol selected in 8-30 Protocol.

Table 5.2 Modbus Communication Parameter Settings

## 5.1.5 EMC Precautions

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

### **NOTICE**

Observe relevant national and local regulations, for example regarding protective earth connection. 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 inches) 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°.

## 5.2 FC Protocol

### 5.2.1 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 serial bus.

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 message 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 utilising the RS485 port built into the frequency converter. 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.

### 5.2.2 FC with Modbus RTU

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

The control word allows the Modbus master to control several important functions of the frequency converter.

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

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

### 5.3 Network Configuration

Set the following parameters to enable the FC protocol for the frequency converter.

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

Table 5.3 Parameters to Enable the Protocol

### 5.4 FC Protocol Message Framing Structure

#### 5.4.1 Content of a Character (byte)

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

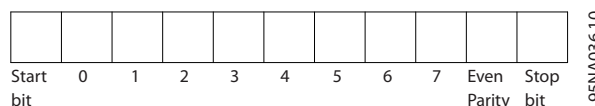


Illustration 5.3 Content of a Character

#### 5.4.2 Telegram Structure

Each telegram has the following structure:

1. Start character (STX)=02 hex.
2. A byte denoting the telegram length (LGE).
3. A byte denoting the frequency converter address (ADR).

A number of data bytes (variable, depending on the type of telegram) follows.

A data control byte (BCC) completes the telegram.



Illustration 5.4 Telegram Structure

#### 5.4.3 Telegram Length (LGE)

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

4 data bytes	LGE=4+1+1=6 bytes
12 data bytes	LGE=12+1+1=14 bytes
Telegrams containing texts	10 <sup>1</sup> +n bytes

Table 5.4 Length of Telegrams

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



### 5.4.4 Frequency Converter Address (ADR)

#### Address format 1-126

- Bit 7=1 (address format 1-126 active).
- Bit 0-6=frequency converter address 1-126.
- Bit 0-6=0 Broadcast.

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

### 5.4.5 Data Control Byte (BCC)

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

### 5.4.6 The Data Field

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

The 3 types of telegram are:

#### Process block (PCD)

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

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

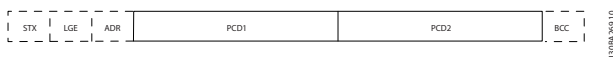


Illustration 5.5 Process Block

#### Parameter block

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



Illustration 5.6 Parameter Block

#### Text block

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

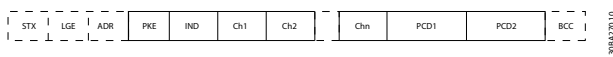


Illustration 5.7 Text Block

### 5.4.7 The PKE Field

The PKE field contains 2 subfields:

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

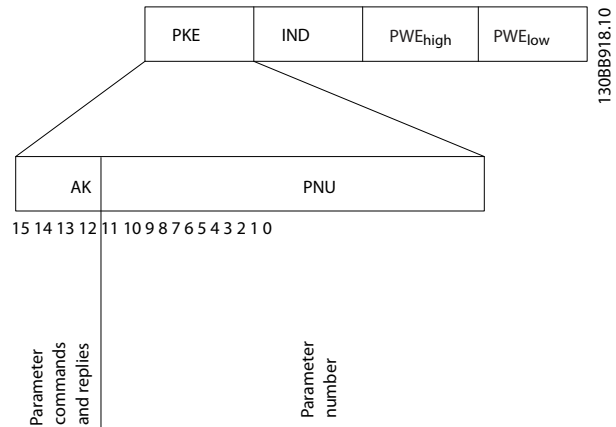


Illustration 5.8 PKE Field

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

Parameter commands master⇒slave				
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 5.5 Parameter Commands

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

Table 5.6 Response

If the command cannot be performed, the slave sends this response *0111 Command cannot be performed* and issues the following fault report in *Table 5.7*.

Error code	FC Specification
0	Illegal parameter number.
1	Parameter cannot be changed.
2	Upper or lower limit is exceeded.
3	Subindex is corrupted.
4	No array.
5	Wrong data type.
6	Not used.
7	Not used.
9	Description element is not available.
11	No parameter write access.
15	No text available.
17	Not applicable while running.
18	Other errors.
100	–
>100	–
130	No bus access for this parameter.
131	Write to factory set-up is not possible.
132	No LCP access.
252	Unknown viewer.
253	Request is not supported.
254	Unknown attribute.
255	No error.

Table 5.7 Slave Report

### 5.4.8 Parameter Number (PNU)

Bits 0–11 transfer parameter numbers. The function of the relevant parameter is defined in the parameter description in the *VLT® AutomationDrive FC 360 Programming Guide*.

### 5.4.9 Index (IND)

The index is used with the parameter number to read/write access parameters with an index, for example, *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.

### 5.4.10 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 slave.

When a slave responds to a parameter request (read command), the present parameter value in the PWE block is transferred and returned to the master. If a parameter contains several data options, e.g. *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).

*15-40 FC Type* to *15-53 Power Card Serial Number* contain data type 9.

For example, read the unit size and mains voltage range in *15-40 FC Type*. When a text string is transferred (read), the length of the telegram is variable, and the texts are of different lengths. The telegram length is defined in the second 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.

### 5.4.11 Data Types Supported by the Frequency Converter

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

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

Table 5.8 Data Types

### 5.4.12 Conversion

The various attributes of each parameter are displayed in the chapter *Parameter Lists* in the *Programming Guide*. Parameter values are transferred as whole numbers only. Conversion factors are used to transfer decimals.

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

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

Table 5.9 Conversion

### 5.4.13 Process Words (PCD)

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

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

Table 5.10 Process Words (PCD)

## 5.5 Examples

### 5.5.1 Writing a Parameter Value

Change 4-14 Motor Speed High Limit [Hz] to 100 Hz. Write the data in EEPROM.

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

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

Data value 1000, corresponding to 100 Hz, see chapter 5.4.12 Conversion.

The telegram looks like Illustration 5.9.

E19E	H	0000	H	0000	H	03E8	H
PKE		IND		PWE <sub>high</sub>		PWE <sub>low</sub>	

Illustration 5.9 Telegram

130BA092.10

## NOTICE

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

The response from the slave to the master is shown in Illustration 5.10.

119E	H	0000	H	0000	H	03E8	H
PKE		IND		PWE <sub>high</sub>		PWE <sub>low</sub>	

Illustration 5.10 Response from Master

130BA093.10

### 5.5.2 Reading a Parameter Value

Read the value in 3-41 Ramp 1 Ramp Up Time

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

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

1155	H	0000	H	0000	H	0000	H
PKE		IND		PWE <sub>high</sub>		PWE <sub>low</sub>	

Illustration 5.11 Telegram

130BA094.10

If the value in 3-41 Ramp 1 Ramp Up Time is 10 s, the response from the slave to the master is shown in Illustration 5.12.

1155	H	0000	H	0000	H	03E8	H
PKE		IND		PWE <sub>high</sub>		PWE <sub>low</sub>	

Illustration 5.12 Response

130BA267.10

3E8 hex corresponds to 1000 decimal. The conversion index for 3-41 Ramp 1 Ramp Up Time is -2, that is, 0.01. 3-41 Ramp 1 Ramp Up Time is of the type Unsigned 32.

## 5.6 Modbus RTU

### 5.6.1 Prerequisite Knowledge

Danfoss assumes that the installed controller supports the interfaces in this document, and strictly observes all requirements and limitations stipulated in the controller and frequency converter.

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

### 5.6.2 Overview

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

During communications over a Modbus RTU network, the protocol:

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

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

Controllers communicate using a master-slave technique in which only the master can initiate transactions (called queries). Slaves respond by supplying the requested data to the master, or by taking the action requested in the query.

The master can address individual slaves, or initiate a broadcast message to all slaves. Slaves 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's 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 slave's response message is also constructed using Modbus protocol. It contains fields confirming the action taken, any data to be returned, and an error-checking field.

If an error occurs in receipt of the message, or if the slave is unable to perform the requested action, the slave constructs an error message, and send it in response, or a time-out occurs.

### 5.6.3 Frequency Converter with Modbus RTU

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

The control word allows the modbus master to control several important functions of the frequency converter:

- Start.
- Various stops:
  - Coast stop.
  - Quick stop.
  - DC brake stop.
  - Normal (ramp) stop.
- Reset after a fault trip.
- Run at a variety of preset speeds.
- Run in reverse.
- Change the active set-up.
- Control the frequency converter's built-in relay.

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

## 5.7 Network Configuration

To enable Modbus RTU on the frequency converter, set the following parameters:

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

Table 5.11 Network Configuration

## 5.8 Modbus RTU Message Framing Structure

### 5.8.1 Introduction

The controllers are set up to communicate on the Modbus network using RTU (remote terminal unit) mode, with each byte in a message containing 2 4-bit hexadecimal characters. The format for each byte is shown in *Table 5.12*.

Start bit	Data byte						Stop/parity	Stop

Table 5.12 Format for Each Byte

Coding system	8-bit binary, hexadecimal 0-9, A-F. 2 hexadecimal characters contained in each 8-bit field of the message.
Bits per byte	<ul style="list-style-type: none"> <li>• 1 start bit.</li> <li>• 8 data bits, least significant bit sent first.</li> <li>• 1 bit for even/odd parity; no bit for no parity.</li> <li>• 1 stop bit if parity is used; 2 bits if no parity.</li> </ul>
Error check field	Cyclical redundancy check (CRC).

Table 5.13 Byte Details

### 5.8.2 Modbus RTU Message Structure

The transmitting device places a Modbus RTU message into a frame with a known beginning and ending point. This allows receiving devices to begin at the start of the message, read the address portion, determine which device is addressed (or all devices, if the message is broadcast), and to recognise when the message is completed. Partial messages are detected and errors set as a result. Characters for transmission must be in hexadecimal 00 to FF format in each field. The frequency converter continuously monitors the network bus, also during 'silent' intervals. When the first field (the address field) is received, each frequency converter or device decodes it to determine which device is being addressed. Modbus RTU messages addressed to 0 are broadcast messages. No response is permitted for broadcast messages. A typical message frame is shown in *Table 5.14*.

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

Table 5.14 Typical Modbus RTU Message Structure

### 5.8.3 Start/Stop Field

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

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

### 5.8.4 Address Field

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

### 5.8.5 Function Field

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

For a normal response, the slave simply echoes the original function code. For an exception response, the slave returns a code that is equivalent to the original function code with its most significant bit set to logic 1. In addition, the slave places a unique code into the data field of the response message. This tells the master what kind of error occurred, or the reason for the exception. Also refer to *chapter 5.8.10 Function Codes Supported by Modbus RTU* and *chapter 5.8.11 Modbus Exception Codes*.

## 5.8.6 Data Field

The data field is constructed using sets of 2 hexadecimal digits, in the range of 00 to FF hexadecimal. These are made up of one RTU character. The data field of messages sent from a master to slave device contains additional information which the slave must use to take the action defined by the function code. This can include items such as coil or register addresses, the quantity of items to be handled, and the count of actual data bytes in the field.

## 5.8.7 CRC Check Field

Messages include an error-checking field, operating based on a cyclical redundancy check (CRC) method. The CRC field checks the contents of the entire message. It is applied regardless of any parity check method used for the individual characters of the message. The CRC value is calculated by the transmitting device, which appends the CRC as the last field in the message. The receiving device recalculates a CRC during receipt of the message and compares the calculated value to the actual value received in the CRC field. If the 2 values are unequal, a bus time-out results. The error-checking field contains a 16-bit binary value implemented as 2 8-bit bytes. When this is done, the low-order byte of the field is appended first, followed by the high-order byte. The CRC high-order byte is the last byte sent in the message.

## 5.8.8 Coil Register Addressing

In Modbus, all data is organised 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 messages are referenced to 0. The first 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 message. Coil 127 decimal is addressed as coil 007Ehex (126 decimal).

Holding register 40001 is addressed as register 0000 in the data address field of the message. The function code field already specifies a 'holding register' operation. Therefore, the '4XXXX' reference is implicit. Holding register 40108 is addressed as register 006Bhex (107 decimal).

Coil Number	Description	Signal Direction
1-16	Frequency converter control word (see Table 5.16)	Master to slave
17-32	Frequency converter speed or set-point reference Range 0x0-0xFFFF (-200% ... ~200%)	Master to slave
33-48	Frequency converter status word (see Table 5.17 )	Slave to master
49-64	Open loop mode: Frequency converter output frequency Closed loop mode: Frequency converter feedback signal	Slave to master
65	Parameter write control (master to slave)	Master to slave
	0 Parameter changes are written to the RAM of the frequency converter	
	1 Parameter changes are written to the RAM and EEPROM of the frequency converter.	
66-65536	Reserved	

Table 5.15 Coil Register

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 5.16 Frequency Converter Control Word (FC Profile)

Coil	0	1
33	Control not ready	Control ready
34	Frequency converter not ready	Frequency converter ready
35	Coasting stop	Safety closed
36	No alarm	Alarm
37	Not used	Not used
38	Not used	Not used
39	Not used	Not used
40	No warning	Warning
41	Not at reference	At reference
42	Hand mode	Auto mode
43	Out of 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 5.17 Frequency Converter Status Word (FC Profile)**

Bus address	Bus register <sup>1)</sup>	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 (p12-28 and 12-29 - stored in Eeprom etc.).
6	7	40007	Last error code	Read only	Error code received from parameter database, refer to WHAT 38295 for details.
7	8	40008	Last error register	Read only	Address of register with which last error occurred, refer to WHAT 38296 for details.
8	9	40009	Index pointer	Read/Write	Sub index of parameter to be accessed. Refer to WHAT 38297 for details.
9	10	40010	FC par. 0-01	Dependent on parameter access	Parameter 0-01 (Modbus Register=10 parameter number 20 bytes space reserved pr parameter in Modbus map.
19	20	40020	FC par. 0-02	Dependent on parameter access	Parameter 0-02 20 bytes space reserved pr parameter in Modbus map.
29	30	40030	FC par. xx-xx	Dependent on parameter access	Parameter 0-03 20 bytes space reserved pr parameter in Modbus map.

**Table 5.18 Adress/Registers**

1) Value written in Modbus RTU telegram must be one or less than register number. E.g. Read Modbus Register 1 by writing value 0 in telegram.

## 5.8.9 How to Control the Frequency Converter

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

## 5.8.10 Function Codes Supported by Modbus RTU

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

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

Table 5.19 Function Codes

Function	Function Code	Sub-function code	Sub-function
Diagnostics	8	1	Restart communication
		2	Return diagnostic register
		10	Clear counters and diagnostic register
		11	Return bus message count
		12	Return bus communication error count
		13	Return slave error count
		14	Return slave message count

Table 5.20 Function Codes

## 5.8.11 Modbus Exception Codes

For a full explanation of the structure of an exception code response, refer to *chapter 5.8.5 Function Field*.

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

Table 5.21 Modbus Exception Codes

## 5.9 How to Access Parameters

### 5.9.1 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 *3-12 Catch up/slow Down Value* (16bit): The holding register 3120 holds the parameters value. A value of 1352 (Decimal), means that the parameter is set to 12.52%



Reading 3-14 *Preset Relative Reference* (32bit): The holding registers 3410 & 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 converting index, consult the programming guide.

### 5.9.2 Storage of Data

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

### 5.9.3 IND (Index)

Some parameters in the frequency converter are array parameters e.g. 3-10 *Preset Reference*. Since the Modbus does not support arrays in the holding registers, the frequency converter 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.

### 5.9.4 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.

### 5.9.5 Conversion Factor

A parameter value can only be transferred as a whole number. Use a conversion factor to transfer decimals.

### 5.9.6 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).

## 5.10 Examples

The following examples illustrate various Modbus RTU commands.

### 5.10.1 Read Coil Status (01 hex)

#### Description

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

#### Query

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

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

Field name	Example (hex)
Slave address	01 (frequency converter 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)	–

Table 5.22 Query

#### Response

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

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

Field name	Example (hex)
Slave address	01 (frequency converter 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)	-

Table 5.23 Response

## NOTICE

Coils and registers are addressed explicitly with an offset of -1 in Modbus.

i.e. Coil 33 is addressed as coil 32.

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

#### Description

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

#### Query

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

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

Table 5.24 Query

#### Response

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

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

Table 5.25 Response

### 5.10.3 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 slaves.

#### Query

The query message specifies the coils 17 to 32 (speed set-point) to be forced.

Field name	Example (hex)
Slave address	01 (frequency converter address)
Function	0F (write multiple coils)
Coil address HI	00
Coil address LO	10 (coil address 17)
Quantity of coils HI	00
Quantity of coils LO	10 (16 coils)
Byte count	02
Force data HI (Coils 8-1)	20
Force data LO (Coils 16-9)	00 (ref.=2000 hex)
Error check (CRC)	-

Table 5.26 Query

#### Response

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

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

Table 5.27 Response

### 5.10.4 Read Holding Registers (03 hex)

#### Description

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

#### Query

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

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

Field name	Example (hex)
Slave address	01
Function	03 (Read holding registers)
Starting address HI	0B (Register address 3029)
Starting address LO	D5 (Register address 3029)
Number of points HI	00
Number of points LO	02 - (3-03 <i>Maximum Reference</i> is 32 bits long, i.e. 2 registers)
Error xheck (CRC)	-

Table 5.28 Query

### Response

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

Example: hex 000088B8=35.000=35 Hz.

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

Table 5.29 Response

### 5.10.5 Preset Single Register (06 hex)

#### Description

This function presets a value into a single holding register.

#### Query

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

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

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

Table 5.30 Query

#### Response

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

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

Table 5.31 Response

### 5.10.6 Preset Multiple Registers (10 hex)

#### Description

This function presets values into a sequence of holding registers.

#### Query

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

Field name	Example (hex)
Slave address	01
Function	10
Starting address HI	04
Starting address LO	07
Number of registers HI	00
Number of registers LO	02
Byte count	04
Write data HI (Register 4: 1049)	00
Write data LO (Register 4: 1049)	00
Write data HI (Register 4: 1050)	02
Write data LO (Register 4: 1050)	E2
Error check (CRC)	-

Table 5.32 Query

#### Response

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

Field name	Example (hex)
Slave 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)	-

Table 5.33 Response

## 5.11 Danfoss FC Control Profile

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

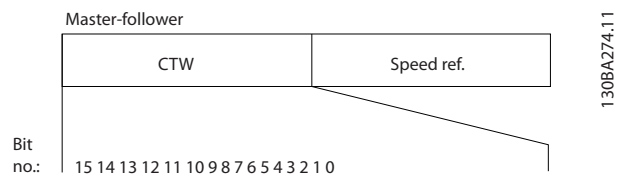


Illustration 5.13 Control Word According to FC Profile

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

Table 5.34 Control Word According to FC Profile

#### Explanation of the control bits

##### Bits 00/01

Bits 00 and 01 are used to select among the 4 reference values, which are pre-programmed in 3-10 Preset Reference according to the Table 5.35.

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

Table 5.35 Control Bits

### NOTICE

Make a selection in 8-56 Preset Reference Select to define how Bit 00/01 gates with the corresponding function on the digital inputs.

#### Bit 02, DC brake

Bit 02=0 leads to DC braking and stop. Set braking current and duration in 2-01 DC Brake Current and 2-02 DC Braking Time.

Bit 02=1 leads to ramping.

#### Bit 03, Coasting

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

Bit 03=1: The frequency converter starts the motor if the other starting conditions are met.

Make a selection in 8-50 Coasting Select to define how Bit 03 gates with the corresponding function on a digital input.

#### Bit 04, Quick stop

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

#### Bit 05, Hold output frequency

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

### NOTICE

If freeze output is active, the frequency converter can only be stopped by one of the following:

- Bit 03 Coasting stop.
- Bit 02 DC braking.
- Digital input (5-10 Terminal 18 Digital Input to 5-13 Terminal 29 Digital Input) programmed to DC braking=5, Coasting stop=2, or Reset and coasting stop=3.

#### Bit 06, Ramp stop/start

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

Bit 06=1: Permits the frequency converter to start the motor, if the other starting conditions are met.

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

#### Bit 07, Reset

Bit 07=0: No reset.

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

#### Bit 08, Jog

Bit 08=1: The output frequency is determined by 3-11 Jog Speed [Hz].

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

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

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

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

Tell the frequency converter 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. Turn off the control word if not needed for it when updating or reading parameters.

**Bit 11, Relay 01**

Bit 11=0: Relay not activated.

Bit 11=1: Relay 01 activated provided that Control word bit 11=36 is selected in 5-40 Function Relay.

**Bit 12, Relay 02**

Bit 12=0: Relay 02 is not activated.

Bit 12=1: Relay 02 is activated provided that Control word bit 12=37 is chosen in 5-40 Function Relay.

**Bit 13, Selection of set-up**

Use bit 13 to select from the 2 menu set-ups according to Table 5.36.

Set-up	Bit 13
1	0
2	1

Table 5.36 Menu Set-ups

The function is only possible when Multi Set-Ups=9 is selected in 0-10 Active Set-up.

Use 8-55 Set-up Select to define how bit 13 gates with the corresponding function on the digital inputs.

**Bit 15 Reverse**

Bit 15=0: No reversing.

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

**5.11.2 Status Word According to FC Profile (STW) (8-30 Protocol = FC profile)**

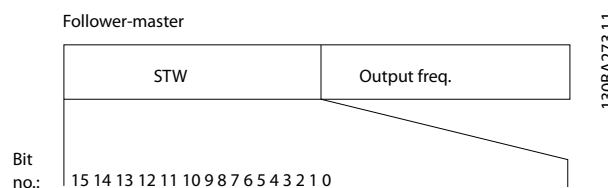


Illustration 5.14 Status Word

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

Table 5.37 Status Word According to FC Profile

**Explanation of the status bits**

**Bit 00, Control not ready/ready**

Bit 00=0: The frequency converter trips.

Bit 00=1: The frequency converter controls are ready but the power component does not necessarily receive any power supply (in case of external 24 V supply to controls).

**Bit 01, Drive ready**

Bit 01=0: The frequency converter is not ready.

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

**Bit 02, Coasting stop**

Bit 02=0: The frequency converter releases the motor.

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

**Bit 03, No error/trip**

Bit 03=0: The frequency converter is not in fault mode. Bit 03=1: The frequency converter trips. To re-establish operation, press [Reset].

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

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

Bit 04=1: The frequency converter 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 frequency converter is not in fault mode.

Bit 06=1: The frequency converter 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, for example, be the case 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 *local control* in 3-13 *Reference Site* is selected. It is not possible to control the frequency converter via serial communication.

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

**Bit 10, Out of frequency limit**

Bit 10=0: The output frequency has reached the value in 4-12 *Motor Speed Low Limit [Hz]* or 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 frequency converter has a start signal without coast.

**Bit 12, Drive OK/stopped, autostart**

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

Bit 12=1: The frequency converter stops because of overtemperature but the unit does not trip and resumes operation once the overtemperature normalises.

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

Bit 13=0: There are no voltage warnings.

Bit 13=1: The DC voltage in the frequency converter's intermediate circuit 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 4-18 *Current Limit*.

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

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

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

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

### 5.11.3 Bus Speed Reference Value

Speed reference value is transmitted to the frequency converter in a relative value in %. The value is transmitted in the form of a 16-bit word; in integers (0–32767) the value 16384 (4000 hex) corresponds to 100%. Negative figures are formatted by 2's complement. The actual output frequency (MAV) is scaled in the same way as the bus reference.

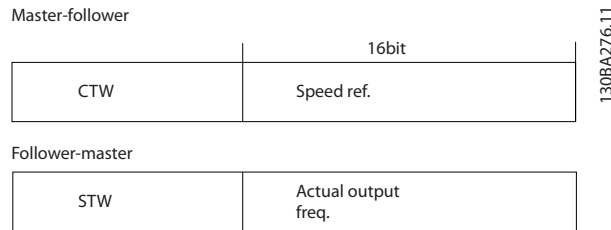


Illustration 5.15 Actual Output Frequency (MAV)

The reference and MAV are scaled as follows:

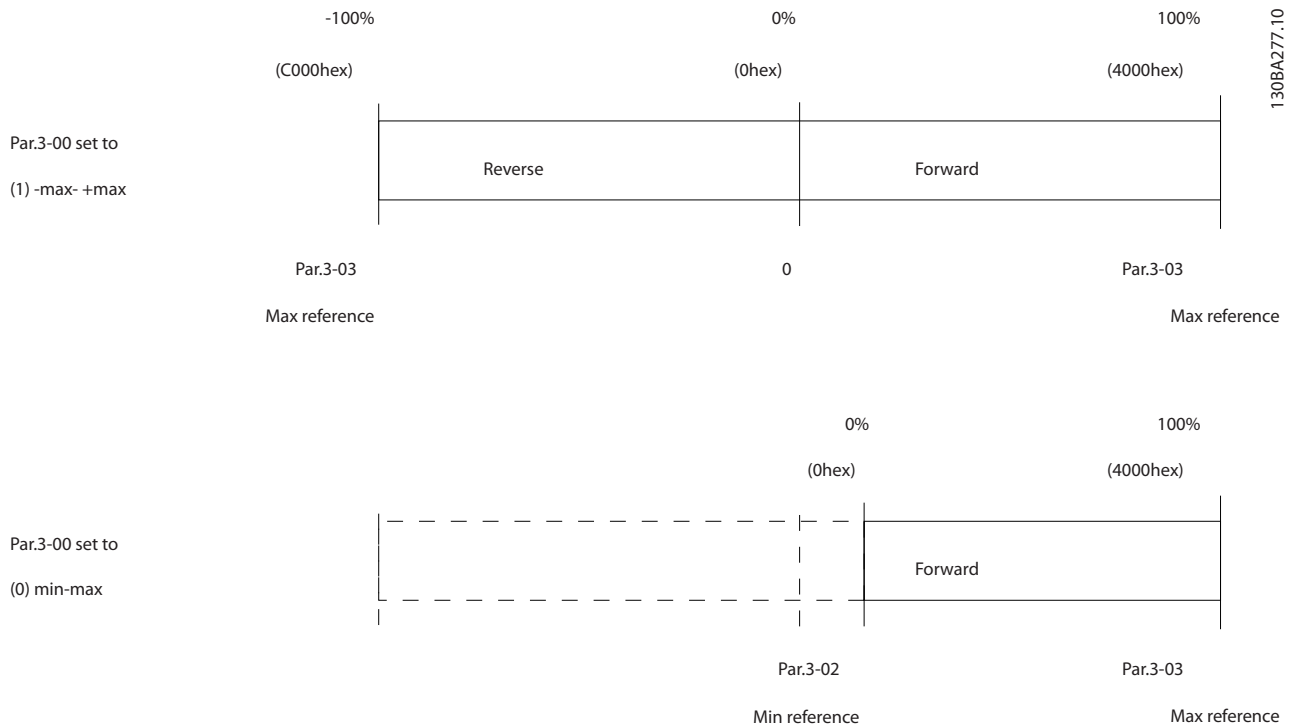


Illustration 5.16 Reference and MAV

# 6 Application Examples

## 6.1 Introduction

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

6

		Parameters	
FC		Function	Setting
+24 V	12	1-29 Automatic Motor Adaptation (AMA)	[1] Enable complete AMA
D IN	18		
D IN	19	5-12 Terminal 27 Digital Input	[2]* Coast inverse
COM	20		
D IN	27	* = Default value	
D IN	29	Notes/comments: Parameter group 1-2* Motor Data must be set according to motor	
D IN	32	<b>NOTICE</b>	
D IN	33	If terminal 12 and 27 are not connected, set 5-12 to [0]	
D IN	31		
+10 V	50		
A IN	53		
A IN	54		
COM	55		
A OUT	42		
A OUT	45		

Table 6.1 AMA with T27 Connected

		Parameters	
FC		Function	Setting
+24 V	12	6-10 Terminal 53 Low Voltage	0.07 V*
D IN	18	6-11 Terminal 53 High Voltage	10 V*
D IN	19		
COM	20	6-14 Terminal 53 Low Ref./Feedb. Value	0
D IN	27		
D IN	29	6-15 Terminal 53 High Ref./Feedb. Value	1500
D IN	32		
D IN	33	6-19 Terminal 53 mode	[1] Voltage
D IN	31		
+10 V	50	* = Default value	
A IN	53	Notes/comments:	
A IN	54		
COM	55		
A OUT	42		
A OUT	45		

Table 6.2 Analog Speed Reference (Voltage)

		Parameters	
FC		Function	Setting
+24 V	12	6-12 Terminal 53 Low Current	4 mA*
D IN	18		
D IN	19	6-13 Terminal 53 High Current	20 mA*
COM	20		
D IN	27	6-14 Terminal 53 Low Ref./Feedb. Value	0
D IN	29		
D IN	32	6-15 Terminal 53 High Ref./Feedb. Value	1500
D IN	33		
D IN	31	6-19 Terminal 53 mode	[0] current
+10 V	50		
A IN	53	* = Default value	
A IN	54	Notes/comments:	
COM	55		
A OUT	42		
A OUT	45		

Table 6.3 Analog Speed Reference (Current)

		Parameters		
FC		Function	Setting	
+24 V	12	5-10 Terminal 18 Digital Input	[8] Start	
D IN	18			
D IN	19	5-11 Terminal 19 Digital Input	[10] Reversing*	
COM	20			
D IN	27	5-12 Terminal 27 Digital Input	[0] No operation	
D IN	29			
D IN	32	5-14 Terminal 32 Digital Input	[16] Preset ref bit 0	
D IN	33			
D IN	31	5-15 Terminal 33 Digital Input	[17] Preset ref bit 1	
+10 V	50			
A IN	53	3-10 Preset Reference	Preset ref. 0 25%	
A IN	54			Preset ref. 1 50%
COM	55			Preset ref. 2 75%
A OUT	42			Preset ref. 3 100%
A OUT	45	* = Default value		
Notes/comments:				

Table 6.4 Start/Stop with Reversing and 4 Preset Speeds



		Parameters	
FC		Function	Setting
+24 V	12	5-11 Terminal 19	[1] Reset
D IN	18	Digital Input	
D IN	19	* = Default value	
COM	20	<b>Notes/comments:</b>	
D IN	27		
D IN	29		
D IN	32		
D IN	33		
D IN	31		
+10 V	50		
A IN	53		
A IN	54		
COM	55		
A OUT	42		
A OUT	45		

Table 6.5 External Alarm Reset

		Parameters	
FC		Function	Setting
+24 V	12	6-10 Terminal 53	0.07 V*
D IN	18	6-11 Terminal 53	10 V*
D IN	19	6-14 Terminal 53	0
COM	20	Low Ref./Feedb. Value	
D IN	27	6-15 Terminal 53	1500
D IN	29	High Ref./Feedb. Value	
D IN	32	6-19 Terminal 53	[1] voltage
D IN	33	* = Default value	
D IN	31	<b>Notes/comments:</b>	
+10 V	50		
A IN	53		
A IN	54		
COM	55		
A OUT	42		
A OUT	45		

Table 6.6 Speed Reference (Using a Manual Potentiometer)

		Parameters	
FC		Function	Setting
+24 V	12	4-30 Motor	[1] Warning
D IN	18	Feedback Loss	
D IN	19	Function	
COM	20	4-31 Motor	
D IN	27	Feedback Speed	100
D IN	29	Error	
D IN	32	4-32 Motor	
D IN	33	Feedback Loss	5 s
D IN	31	Timeout	
+10 V	50	7-00 Speed PID	
A IN	53	Feedback Source	[2] MCB 102
A IN	54	17-11 Resolution (PPR)	1024*
COM	55	13-00 SL	
A OUT	42	Controller Mode	[1] On
A OUT	45	13-01 Start Event	[19] Warning
		13-02 Stop Event	[44] Reset key
		13-10 Comparato	[21] Warning
		r Operand	no.
		13-11 Comparato	[1] ~*
		r Operator	
		13-12 Comparato	90
		r Value	
		13-51 SL	[22]
		Controller Event	Comparator 0
		13-52 SL	[32] Set
		Controller Action	digital out A
		low	
		5-40 Function	[80] SL digital
		Relay	output A
		* = Default value	
		<b>Notes/comments:</b>	
		If the limit in the feedback monitor is exceeded, warning 90 is issued. The SLC monitors warning 90. If warning 90 becomes true, relay 1 is triggered.	
		External equipment may then indicate that service is required.	
		If the feedback error goes below the limit again within 5 s, the frequency converter continues and the warning disappears. But relay 1 persists until [Off/Reset] is pressed.	

Table 6.7 Using SLC to Set a Relay

		Parameters	
		Function	Setting
		5-10 Terminal 18 Digital Input	[8] Start*
		5-12 Terminal 27 Digital Input	[19] Freeze Reference
		5-13 Terminal 29 Digital Input	[21] Speed Up
		5-14 Terminal 32 Digital Input	[22] Speed Down
		* = Default value	
		Notes/comments:	

Table 6.8 Speed Up/Down

		Parameters	
		Function	Setting
		1-90 Motor Thermal Protection	[2] Thermistor trip
		1-93 Thermistor Source	[1] Analog input 53
		6-19 Terminal 53 mode	[1] Voltage
		* = Default value	
		Notes/comments:	
		If only a warning is desired, 1-90 Motor Thermal Protection should be set to [1] Thermistor warning.	

Table 6.9 Motor Thermistor

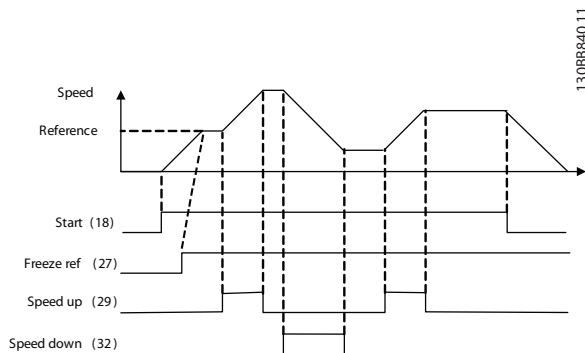


Illustration 6.1 Speed Up/Down

**CAUTION**

Thermistors must use reinforced or double insulation to meet PELV insulation requirements.

### 6.1.1 Encoder Connection

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

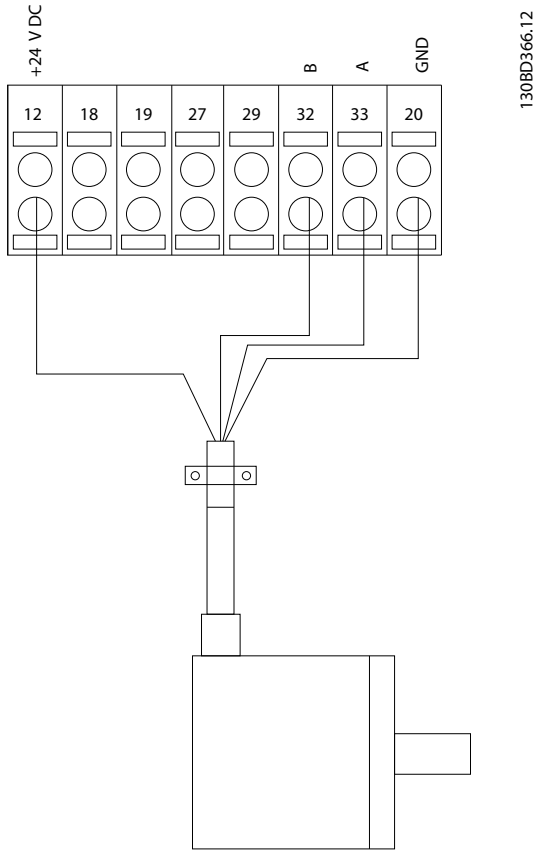


Illustration 6.2 24 V or 10-30 V Encoder

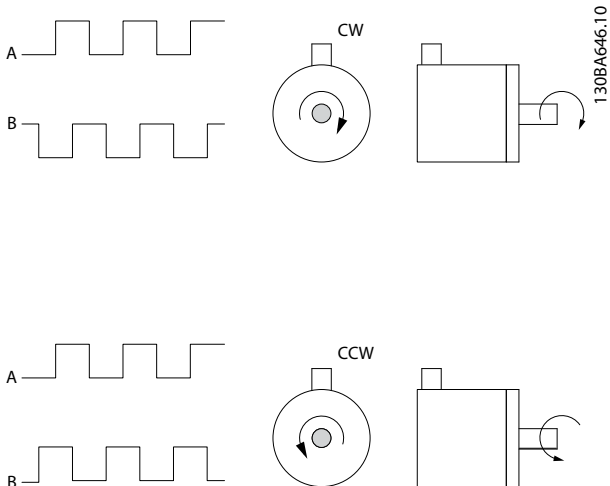


Illustration 6.3 24 V Incremental Encoder, Maximum Cable Length 5 m

### 6.1.2 Encoder Direction

The direction of the encoder is determined by which order the pulses are entering the frequency converter. Clockwise direction means channel A is 90 electrical degrees before channel B. Counter Clockwise direction means channel B is 90 electrical degrees before A. The direction is determined by looking into the shaft end.

### 6.1.3 Closed Loop Drive System

A drive system usually consists of more elements such as:

- Motor
- Brake (Gearbox) (Mechanical Brake).
- Frequency converter.
- Encoder as feedback system.
- Brake resistor for dynamic braking.
- Transmission.
- Load.

Applications demanding mechanical brake control usually need a brake resistor.

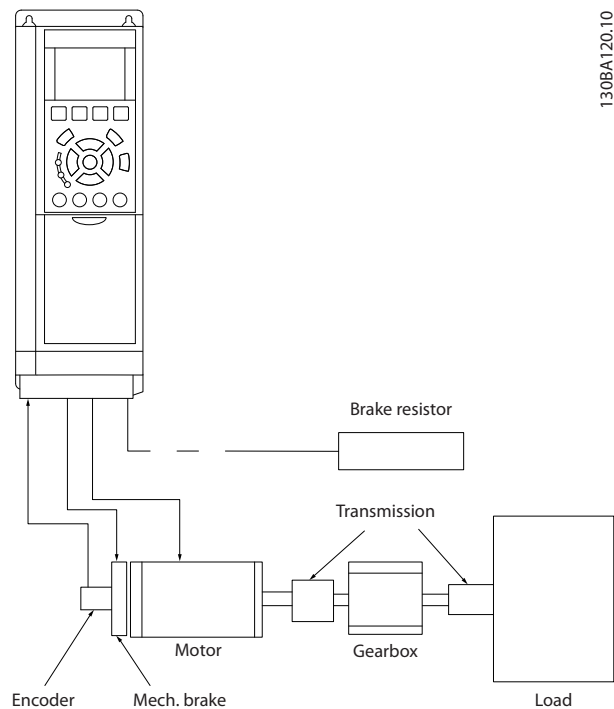


Illustration 6.4 Basic Set-up for Closed-loop Speed Control

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