



Design Guide

VLT® Decentral Drive FCD 302

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1 Introduction

1.1 How to Read the Design Guide

The Design Guide provides information required for integration of the frequency converter in a diversity of applications.

Additional resources available

- *Operating Instructions MG04F*, for information required to install and commission the frequency converter.
- *Programming Guide, MG04G*, for how to program the unit, including complete parameter descriptions.
- *Modbus RTU Operating Instructions, MG92B*, for the information required for controlling, monitoring and programming the drive via the built-in Modbus fieldbus
- *Profibus Operating Instructions, MG34N, Ethernet Operating Instructions, MG90J, and ProfiNet Operating Instructions, MG90U*, for information required for controlling, monitoring and programming the drive via a fieldbus.
- *MCB 102 manual*.
- *VLT Automation Drive FC 300 Resolver Option MCB 103, MI33I*.
- *Safe PLC Interface Option MCB 108 instruction, MI33J*.
- *Brake Resistor Design Guide, MG90O*.
- Approvals.

Technical literature and approvals are available online at www.danfoss.com/BusinessAreas/DrivesSolutions/Documentations/Technical+Documentation.

1.1.1 Definitions

Frequency converter:

Coast

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

I_{MAX}

The maximum output current.

I_N

The rated output current supplied by the frequency converter.

U_{MAX}

The maximum output voltage.

Input:

Control command

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

Functions are divided into two 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 the "Off" key.
Group 2	Start, Pulse start, Reversing, Start reversing, Jog and Freeze output

Table 1.1 Control Command Functions

Motor:

f_{JOG}

The motor frequency when the jog function is activated (via digital terminals).

f_M

Motor frequency. Output from the frequency converter. Output frequency is related to the shaft speed on motor depending on number of poles and slip frequency.

f_{MAX}

The maximum output frequency the frequency converter applies on its output. The maximum output frequency is set in limit par. 4-12, 4-13 and 4-19.

f_{MIN}

The minimum motor frequency from frequency converter. Default 0 Hz.

$f_{M,N}$

The rated motor frequency (nameplate data).

I_M

The motor current.

$I_{M,N}$

The rated motor current (nameplate data).

$n_{M,N}$

The rated motor speed (nameplate data).

n_s

Synchronous motor speed

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

$P_{M,N}$

The rated motor power (nameplate data).

$T_{M,N}$

The rated torque (motor).

U_M

The instantaneous motor voltage.

$U_{M,N}$

The rated motor voltage (nameplate data).

Break-away torque

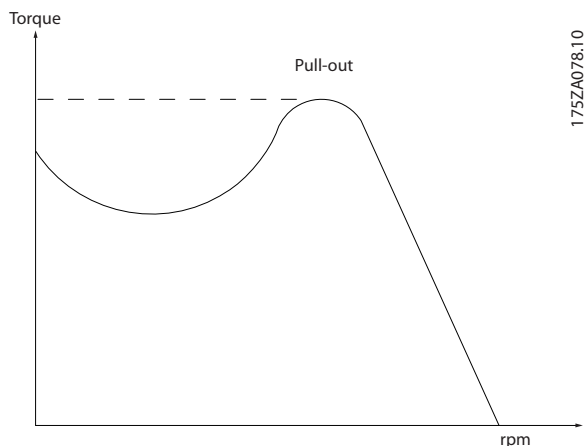


Illustration 1.1 Break-away Torque

η

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 this group.

Stop command

See Control commands.

References:

Analog Reference

An analog signal applied to input 53 or 54. The signal can be either voltage 0-10 V or -10 +10 V. Current signal is 0-20 mA or 4-20 mA.

Binary Reference

A signal applied to the serial communication port (RS-485 term 68-69).

Preset Reference

A defined preset reference, set between -100% and +100% of the reference range. Select eight preset references via the digital terminals.

Pulse Reference

A pulse reference applied to term 29 or 33, selected by par. 5-13 or 5-15 [32]. Scaling in par. group 5-5*.

Ref_{MAX}

Shows the relationship between the reference input at 100% full scale value (typically 10 V, 20 mA) and the resulting reference. Set the maximum reference value in 3-03 Maximum Reference.

Ref_{MIN}

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

Miscellaneous:

Analog Inputs

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

There are two types of analog inputs:

Current input, 0-20 mA and 4-20 mA

Voltage input, 0-10 V DC

Voltage input, -10 to +10 V DC.

Analog Outputs

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

Automatic Motor Adaptation, AMA

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

Brake Resistor

The brake resistor is a module capable of absorbing the brake power generated in regenerative braking. This regenerative 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 two Solid State outputs that can supply a 24 V DC (max. 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.

Hiperface®

Hiperface® is a registered trademark by Stegmann.

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 (LCP) comprises a complete interface for control and programming of the frequency converter. The LCP is detachable and can be installed up

to 3 metres from the frequency converter, i.e. in a front panel, using the installation kit option.

lsb

Least significant bit.

msb

Most significant bit.

MCM

Short for Mille Circular Mil, an American unit for measuring cable cross-section. 1 MCM=0.5067 mm².

On-line/Off-line Parameters

Changes to on-line parameters are activated immediately after the data value is changed. Changes to off-line parameters are activated upon entering [Ok] on the LCP.

Process PID

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

PCD

Process Data

Pulse Input/Incremental Encoder

An external digital sensor used for feedback information of motor speed and direction. Encoders are used for high speed accuracy feedback and in high dynamic applications. The encoder connection is either via term 32 and 32 or encoder option MCB 102.

RCD

Residual Current Device.

Set-up

It is possible to save parameter settings in four set-ups. Switch between the four parameter set-ups and edit one set-up, while another set-up is active.

SFAVM

Switching pattern called Stator Flux oriented Aynchronous Vector Modulation (14-00 Switching Pattern).

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. (Par. group 13-** *Smart Logic Control (SLC)*).

STW

Status Word

FC Standard Bus

Includes RS-485 bus with FC protocol or MC protocol. See 8-30 Protocol.

Thermistor:

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

THD

Total Harmonic Distortion state the total contribution of harmonic.

Trip

A state entered in fault situations, e.g. if the frequency converter is subject to an over-temperature or when the frequency converter 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. Trip may not be used 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. Trip may not be used for personal safety.

VT Characteristics

Variable torque characteristics used for pumps and fans.

VVC^{plus}

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

60° AVM

Switching pattern called 60° Aynchronous Vector Modulation (14-00 Switching Pattern).

Power Factor

The power factor is the relation between I₁ and I_{RMS}.

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

The power factor for 3-phase control:

$$= \frac{I_1 \times \cos\varphi}{I_{RMS}} = \frac{I_1}{I_{RMS}} \text{ since } \cos\varphi = 1$$

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.

Built-in DC coils in the DC link ensure a high power factor and reduce the THD on the main supply.

1.1.2 Symbols

The following symbols are used in this manual.

⚠ WARNING

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

⚠ CAUTION

Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury. It may also be used to alert against unsafe practices.

CAUTION

Indicates a situation that may result in equipment or property-damage-only accidents.

NOTE

Indicates highlighted information that should be regarded with attention to avoid mistakes or operate equipment at less than optimal performance.

* Indicates default setting

1.2 Safety Precautions

⚠ WARNING

The voltage of the frequency converter is dangerous whenever connected to mains. Correct planning of the installation of the motor, frequency converter and fieldbus is necessary. Follow the instructions in this manual, as well as national and local rules and safety regulations. Failure to follow design recommendations could result in death, serious personal injury or damage to the equipment once in operation.

⚠ WARNING

High Voltage

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

In planning, ensure that other voltage inputs can be disconnected, such as external 24 V DC, load sharing (linkage of DC intermediate circuit), as well as the 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 the valid safety regulations, e.g. law on mechanical tools, regulations for the prevention of accidents etc. Modifications on the frequency converters by means of the operating software are allowed.

Failure to follow design recommendations, could result in death or serious injury once the equipment is operation.

NOTE

Hazardous situations shall be identified by the machine builder/integrator who is responsible for taking necessary preventive means into consideration. Additional monitoring and protective devices may be included, always according to valid national safety regulations, e.g. law on mechanical tools, regulations for the prevention of accidents.

NOTE

Crane, Lifts and Hoists:

The controlling of external brakes must always be designed with a redundant system. The frequency converter can in no circumstances be the primary safety circuit. Comply with relevant standards, e.g.

Hoists and cranes: IEC 60204-32

Lifts: EN 81

Protection Mode

Once a hardware limit on motor current or DC link voltage is exceeded the frequency converter enters "Protection mode". "Protection mode" means a change of the PWM modulation strategy and a low switching frequency to minimize losses. This continues 10 s after the last fault and increases the reliability and the robustness of the frequency converter while re-establishing full control of the motor.

In hoist applications "Protection mode" is not usable because the frequency converter will usually not be able to leave this mode again and therefore it will extend the time before activating the brake – which is not recommendable. The "Protection mode" can be disabled by setting *14-26 Trip Delay at Inverter Fault* to zero which means that the frequency converter will trip immediately if one of the hardware limits is exceeded.

NOTE

It is recommended to disable protection mode in hoisting applications (14-26 Trip Delay at Inverter Fault=0)

1.3 Software Version

Check the software version in 15-43 Software Version.

1.4 CE Labelling

1.4.1 Conformity

The machinery directive (2006/42/EC)

Frequency converters do not fall under the machinery directive. However, if a frequency converter is supplied for use in a machine, Danfoss provide information on safety aspects relating to the frequency converter.

What is CE Conformity and Labelling?

The purpose of CE labelling is to avoid technical trade obstacles within EFTA and the EU. The EU has introduced the CE label as a simple way of showing whether a product complies with the relevant EU directives. The CE label says nothing about the specifications or quality of the product. Frequency converters are regulated by two EU directives:

The low-voltage directive (2006/95/EC)

Frequency converters must be CE labelled in accordance with the low-voltage directive of January 1, 1997. The directive applies to all electrical equipment and appliances used in the 50-1000 V AC and the 75-1500 V DC voltage ranges. Danfoss CE-labels in accordance with the directive and issues a declaration of conformity upon request.

The EMC directive (2004/108/EC)

EMC is short for electromagnetic compatibility. The presence of electromagnetic compatibility means that the mutual interference between different components/appliances does not affect the way the appliances work. The EMC directive came into effect January 1, 1996. Danfoss CE-labels in accordance with the directive and issues a declaration of conformity upon request. To carry out EMC-correct installation, see the instructions in this Design Guide. In addition, Danfoss specify which standards our products comply with. Danfoss offers the filters presented in the specifications and provides other types of assistance to ensure the optimum EMC result.

The frequency converter is most often used by professionals of the trade as a complex component forming part of a larger appliance, system or installation.

1.4.2 What Is Covered ?

The EU "Guidelines on the Application of Council Directive 2004/108/EC" outline three typical situations of using a frequency converter. See below for EMC coverage and CE labelling.

1. The frequency converter is sold directly to the end-user. The frequency converter is for example sold to a do-it-yourself market. The end-user is a layman, installing the frequency converter for use with a hobby machine, a kitchen appliance, etc. For such applications, the frequency converter must be CE labelled in accordance with the EMC directive.
2. The frequency converter is sold for installation in a plant. The plant is built up by professionals of the trade. It could be a production plant or a heating/ventilation plant designed and installed by professionals of the trade. Neither the frequency converter nor the finished plant has to be CE labelled under the EMC directive. However, the unit must comply with the basic EMC requirements of the directive. This is ensured by using components, appliances, and systems that are CE labelled under the EMC directive.
3. The frequency converter is sold as part of a complete system. The system is marketed as complete, for example an air-conditioning system. The complete system must be CE labelled in accordance with the EMC directive. The manufacturer can ensure CE labelling under the EMC directive either by using CE labelled components or by testing the EMC of the system. If only CE labelled components are used, it is unnecessary to test the entire system.

1.4.3 CE Labelling

CE labelling is a positive feature when used for its original purpose, i.e. to facilitate trade within the EU and EFTA.

However, CE labelling may cover many different specifications. Check what a given CE label specifically covers.

The specifications can vary greatly. A CE label may therefore give the installer a false sense of security when using a frequency converter as a component in a system or an appliance.

Danfoss CE labels the frequency converters in accordance with the low-voltage directive. This means that if the frequency converter is installed correctly, compliance with the low-voltage directive is achieved. Danfoss issues a

1

declaration of conformity that confirms CE labelling in accordance with the low-voltage directive.

The CE label also applies to the EMC directive, provided that the instructions for EMC-correct installation and filtering are followed. On this basis, a declaration of conformity in accordance with the EMC directive is issued.

The Design Guide offers detailed instructions for installation to ensure EMC-correct installation.

1.4.4 Compliance with EMC Directive 2004/108/EC

The frequency converter is mostly used by professionals of the trade as a complex component forming part of a larger appliance, system, or installation.

NOTE

The responsibility for the final EMC properties of the appliance, system or installation rests with the installer.

As an aid to the installer, Danfoss has prepared EMC installation guidelines for the Power Drive system. The standards and test levels stated for Power Drive systems are complied with, provided that the EMC-correct instructions for installation are followed, see 3.4.4 EMC.

1.4.5 Conformity

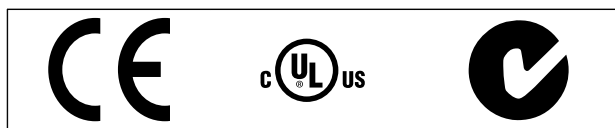


Table 1.2 FCD 302 Approvals

1.5 Disposal

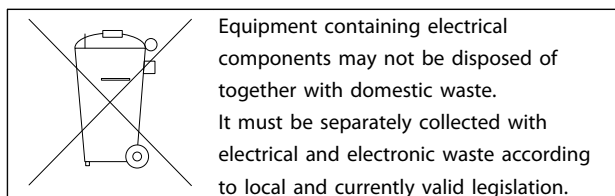


Table 1.3 Disposal Instruction

2 Product Overview

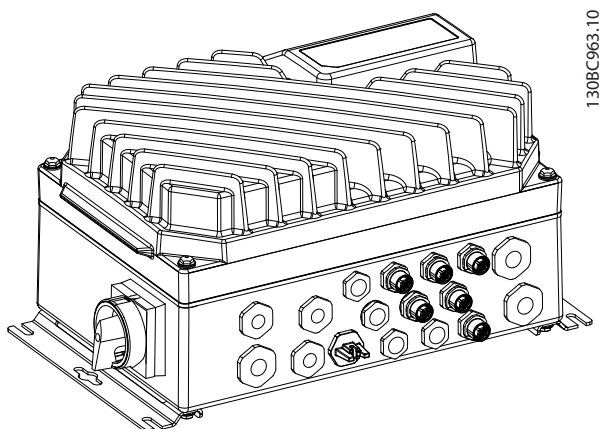


Illustration 2.1 Small Unit

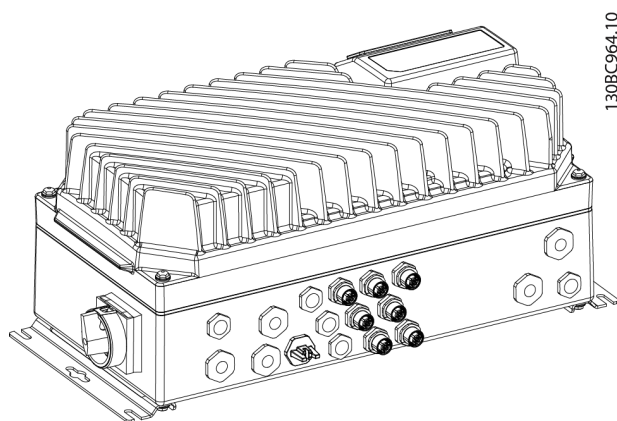


Illustration 2.2 Large Unit

2.1 Control

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

The FCD 302 frequency converter is designed for installations of multiple smaller drives, especially on conveyor applications, for example, in the food and beverage industries and materials handling. In installations where multiple motors are spread around a facility such as bottling plants, food preparation and packaging plants and airport baggage handling installations, there may be dozens, perhaps hundreds, of drives, working together but spread over a large physical area. In these cases cabling

costs alone outweigh the cost of the individual drives and it makes sense to get the control closer to the motors.

The frequency converter can control either the speed or the torque on the motor shaft.

Speed control

There are two types of speed control:

- Speed open loop control which does not require any feedback from motor (sensorless).
- Speed closed loop PID control, which requires a speed feedback to an input. A properly optimised speed closed loop control is more accurate than a speed open loop control.

Torque control

The torque control function is used in applications where the torque on motor output shaft is controlling the application as tension control.

- Closed loop in Flux mode with encoder feedback comprises motor control based on feedback signals from the system. It improves performance in all four quadrants and at all motor speeds.
- Open loop in VVC^{plus} mode. The function is used in mechanical robust applications, but the accuracy is limited. Open loop torque function works only in one speed direction. The torque is calculated on basis of current measurement internal in the frequency converter. See application example 4.5.1 *Control Structure in VVC^{plus} Advanced Vector Control*.

Speed/torque reference

The reference to these controls can either be a single reference or be the sum of various references including relatively scaled references. The handling of references is explained in detail in 2.3 *Reference Handling*.

2.1.1 Control Principle

The frequency converter is compatible with various motor control principles such as U/f special motor mode, VVC^{plus} or Flux Vector motor control.

In addition, the frequency converter is operable with Permanent Magnet Synchronous Motors (Brushless servo motors) as well as normal squirrel cage asynchronous motors.

The short circuit behaviour depends on the 3 current transducers in the motor phases and the desaturation protection with feedback from the brake.

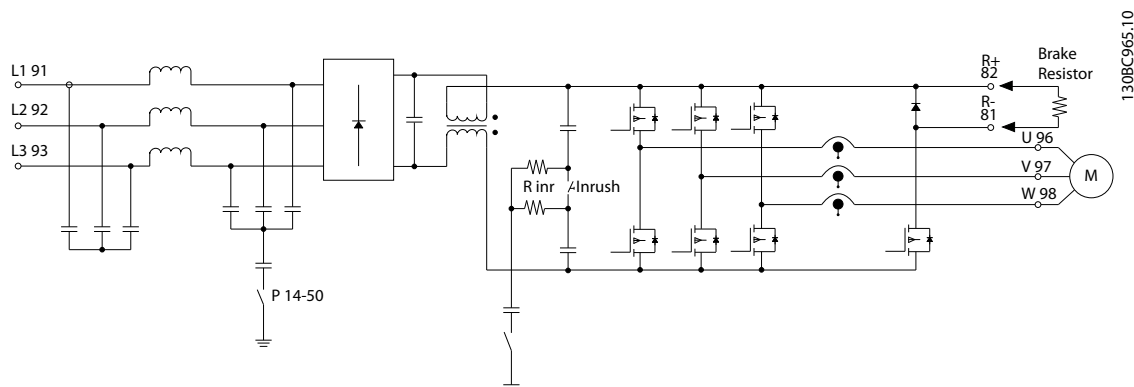


Illustration 2.3 Control Principle

2.1.2 Internal Current Control in VVC^{plus} 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, it reduces torque to below the preset torque limits as quickly as possible, without losing control of the motor.

Smart Logic Control (SLC) is essentially 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 illustrated in Illustration 2.4.

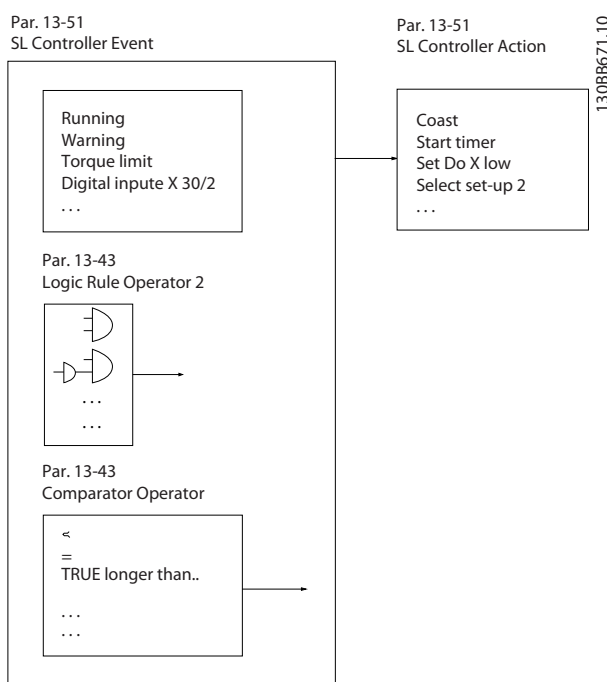


Illustration 2.4 Current Control Status/Event and Action

Events and actions are each numbered and linked together in pairs (states). This means that when [0] event is fulfilled (attains the value TRUE), [0] action is executed. After this, the conditions of [1] event will be evaluated and if evaluated TRUE, [1] action will be executed and so on. Only one event will be 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 will be evaluated. This means that when the SLC starts, it evaluates event [0] (and only [0] event) each scan interval. Only when [0] event is evaluated TRUE, will the SLC

execute [0] action and start evaluating event. It is possible to programme from 1 to 20 events and [1] actions. When the last event/action has been executed, the sequence starts over again from [0] event/[0] action. Illustration 2.5 shows an example with three event/actions.

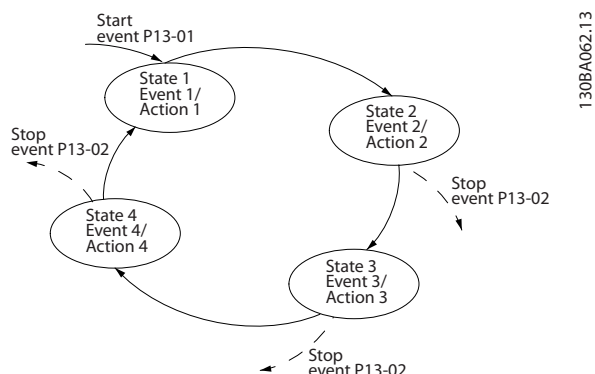


Illustration 2.5 Example - Internal Current Control

Comparators

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

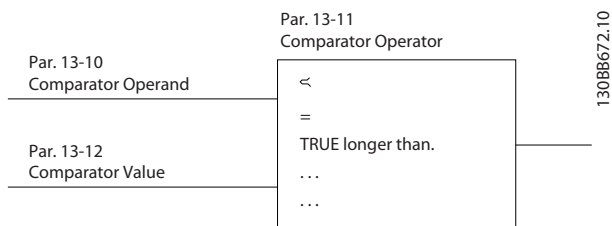


Illustration 2.6 Comparators

Logic Rules

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

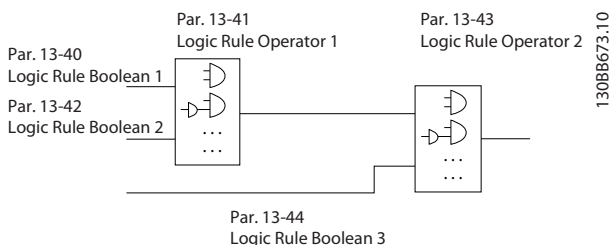


Illustration 2.7 Logic Rules

Application Example

Parameters	
Function	Setting
FC	13088839.10
+24 V 12	4-30 Motor Feedback Loss Function
+24 V 13	[1] Warning
D IN 18	4-31 Motor Feedback Speed Error
D IN 19	100 RPM
COM 20	4-32 Motor Feedback Loss Timeout
D IN 27	5 s
D IN 29	7-00 Speed PID Feedback Source
D IN 32	[2] MCB 102
D IN 33	17-11 Resolution (PPR)
D IN 37	1024*
+10 V 50	13-00 SL Controller Mode
A IN 53	[1] On
A IN 54	13-01 Start Event
COM 55	[19] Warning
A OUT 42	13-02 Stop Event
COM 39	[44] Reset key
R1 01	13-10 Comparat or Operand
R1 02	[21] Warning no.
R1 03	13-11 Comparat or Operator
R2 04	[1] ≈*
R2 05	13-12 Comparat or Value
R2 06	90
	13-51 SL Controller Event
	[22] Comparator 0
	13-52 SL Controller Action
	[32] Set digital out A low
	5-40 Function Relay
	[80] SL digital output A
	*=Default Value
	Notes/comments:
	If the limit in the feedback monitor is exceeded, Warning 90 is issued. The SLC monitors Warning 90 and in the case that Warning 90 becomes TRUE then Relay 1 is triggered. External equipment can indicate that service is required. If the feedback error goes below the limit again within 5 s then the drive continues and the warning disappears. Relay 1 remains triggered until pressing [Reset] on the LCP.

Table 2.1 Using SLC to Set a Relay

2

2.2 EMC

2.2.1 General Aspects of EMC Emissions

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 1 GHz is generated from the inverter, motor cable, and the motor.

As shown in *Illustration 2.8*, capacitive currents in the motor cable coupled with a high dU/dt from the motor voltage generate leakage currents.

The use of a screened motor cable increases the leakage current (see *Illustration 2.8*) because screened cables have higher capacitance to earth than unscreened cables. If the leakage current is not filtered, it will cause 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 will in principle only be a small electro-magnetic field (I_4) from the screened motor cable according to the below figure.

The screen reduces the radiated interference but increases the low-frequency interference on the mains. Connect the motor cable screen to the frequency converter and motor enclosures. Use integrated screen clamps to avoid twisted screen ends (pigtails). Twisted screen ends will increase the screen impedance at higher frequencies, which reduces the screen effect and increases the leakage current (I_4). When a screened cable is used for fieldbus relay, control cable, signal interface or brake, ensure the screen is mounted on the enclosure at both ends. In some situations, however, it will be necessary to break the screen to avoid current loops.

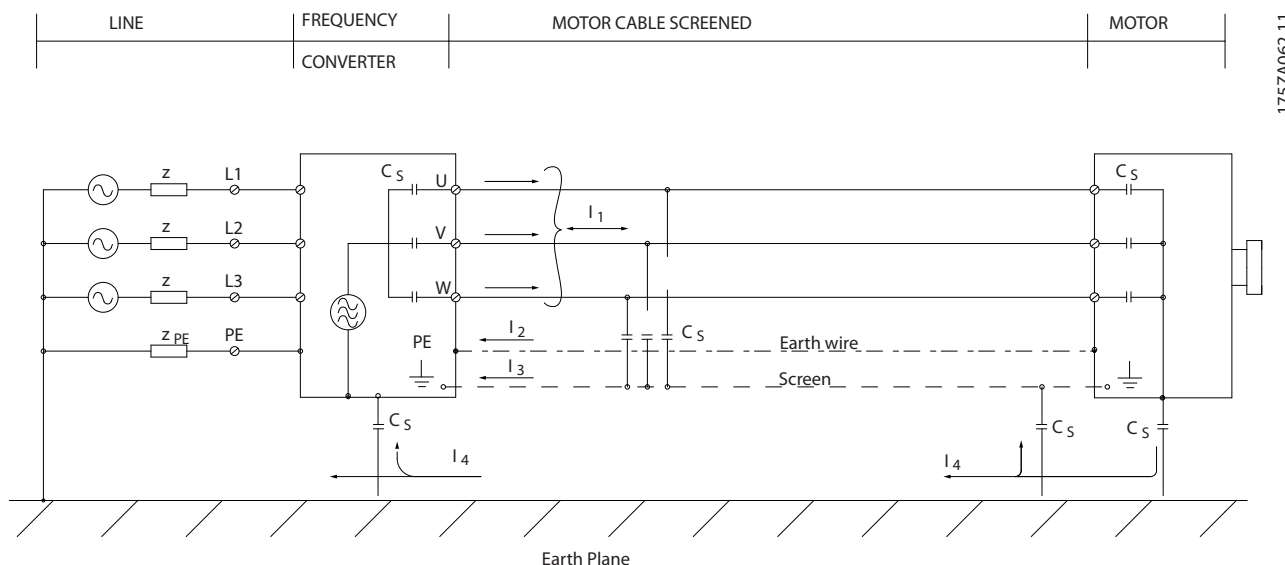


Illustration 2.8 Example - Leakage Current

Mounting plates, when used, must be constructed of metal, to ensure the screen currents are conveyed back to the unit. Ensure good electrical contact from the mounting plate through the mounting screws to the chassis of the frequency converter.

When unscreened cables are used, some emission requirements are not fulfilled. However the immunity requirements are observed.

In order to reduce the interference level from the entire system (unit+installation), make motor and brake cables as short as possible. Avoid placing cables with a sensitive

signal level alongside motor and brake cables. Radio interference frequency above 50 MHz (airborne) is generated by the control electronics in particular.

2.2.2 EMC Test Results

The following test results have been obtained using a system with a frequency converter (with options if relevant), a screened control cable, a control box with potentiometer, as well as a motor and motor screened cable.

RFI filter type		Conducted emission			Radiated emission	
		Class B	Class A Group 1	Class A Group 2	Class B	Class A Group 1
Standards and requirements	EN 55011	Housing, trades and light industries	Industrial environment	Industrial environment	Housing, trades and light industries	Industrial environment
	EN/IEC 61800-3	Category C1	Category C2	Category C3	Category C1	Category C2
		First environment Home and office	First environment Home and office	Second environment Industrial	First environment Home and office	First environment Home and office
H1						
FCD302	0.37-3 kW	No	10 m	10 m	No	Yes

Table 2.2 EMC Test Results (Emission, Immunity)

2.2.3 Emission Requirements

According to the EMC product standard for adjustable speed frequency converters EN/IEC 61800-3:2004 the EMC requirements depend on the intended use of the

frequency converter. Four categories are defined in the EMC product standard. The definitions of the 4 categories together with the requirements for mains supply voltage conducted emissions are given in *Table 2.3*.

Category	Definition	Conducted emission requirement according to the limits given in EN 55011
C1	Frequency converters installed in the first environment (home and office) with a supply voltage less than 1000 V.	Class B
C2	Frequency converters installed in the first environment (home and office) with a supply voltage less than 1000 V, which are neither plug-in nor movable and are intended to be installed and commissioned by a professional.	Class A Group 1
C3	Frequency converters installed in the second environment (industrial) with a supply voltage lower than 1000 V.	Class A Group 2
C4	Frequency converters installed in the second environment with a supply voltage equal to or above 1000 V or rated current equal to or above 400 A or intended for use in complex systems.	No limit line. An EMC plan should be made.

Table 2.3 Emission Requirements

When the generic emission standards are used the frequency converters are required to comply with the limits in *Table 2.4*

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

Table 2.4 Emission Limit Classes

2.2.4 Immunity Requirements

The immunity requirements for frequency converters depend on the environment where 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.

In order 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):** Incoming electromagnetic field radiation, 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 brought about by switching a contactor, relay or similar devices.
- **EN 61000-4-5 (IEC 61000-4-5):** Surge transients: Simulation of transients brought about e.g. by lightning that strikes near installations.
- **EN 61000-4-6 (IEC 61000-4-6):** RF Common mode: Simulation of the effect from radio-transmission equipment joined by connection cables.

See Table 2.5.

Voltage range: 200-240 V, 380-480 V					
Basic standard	Burst IEC 61000-4-4	Surge IEC 61000-4-5	ESD IEC 61000-4-2	Radiated electromagnetic field IEC 61000-4-3	RF common mode voltage IEC 61000-4-6
Acceptance criterion	B	B	B	A	A
Line	4 kV CM	2 kV/2 Ω DM 4kV/12 Ω CM	—	—	10 V _{RMS}
Motor	4 kV CM	4 kV/2 Ω ¹⁾	—	—	10 V _{RMS}
Brake	4 kV CM	4 kV/2 Ω ¹⁾	—	—	10 V _{RMS}
Load sharing	4 kV CM	4 kV/2 Ω ¹⁾	—	—	10 V _{RMS}
Control wires	2 kV CM	2 kV/2 Ω ¹⁾	—	—	10 V _{RMS}
Standard bus	2 kV CM	2 kV/2 Ω ¹⁾	—	—	10 V _{RMS}
Relay wires	2 kV CM	2 kV/2 Ω ¹⁾	—	—	10 V _{RMS}
Application and Fieldbus options	2 kV CM	2 kV/2 Ω ¹⁾	—	—	10 V _{RMS}
LCP cable	2 kV CM	2 kV/2 Ω ¹⁾	—	—	10 V _{RMS}
External 24 V DC	2 V CM	0.5 kV/2 Ω DM 1 kV/12 Ω CM	—	—	10 V _{RMS}
Enclosure	—	—	8 kV AD 6 kV CD	10 V/m	—

Table 2.5 EMC Immunity

1) Injection on cable shield

AD: Air Discharge

CD: Contact Discharge

CM: Common Mode

DM: Differential Mode

2.3 Reference Handling

Local Reference

The local reference is active when the frequency converter is operated with 'Hand On' button active. Adjust the reference by [▲]/[▼] and [◀]/[▶] arrows respectively.

Remote Reference

The reference handling system for calculating the remote reference is shown in *Illustration 2.9*.

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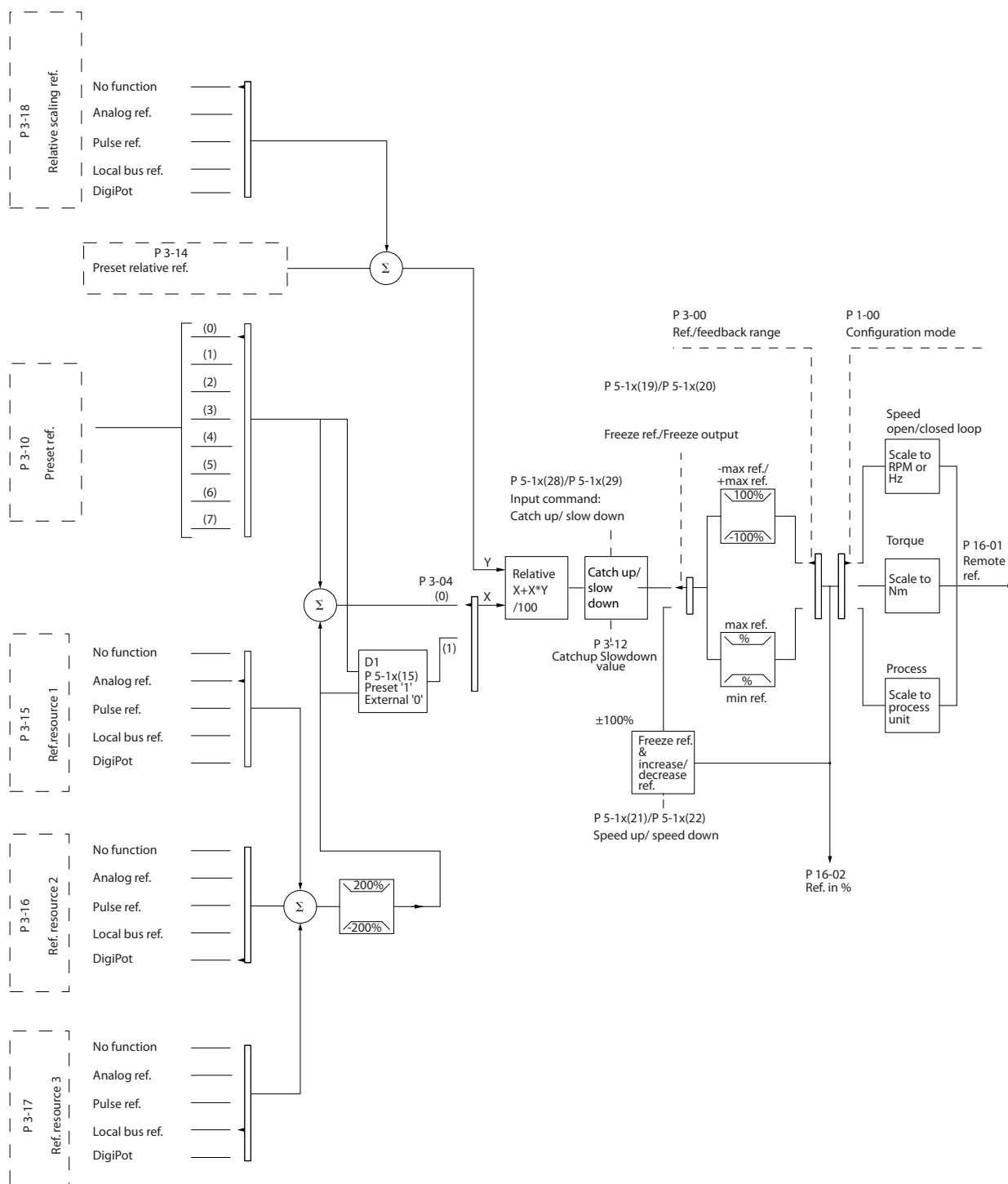


Illustration 2.9 Remote Reference

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

1. X (the external reference): A sum (see 3-04 Reference Function) of up to four externally selected references, comprising any combination (determined by the setting of 3-15 Reference Resource 1, 3-16 Reference Resource 2 and 3-17 Reference Resource 3) of a fixed preset reference (3-10 Preset Reference), variable analog references, variable digital pulse references, and various serial bus references in whatever unit the frequency converter is controlled ([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 two types of reference inputs are combined in the following formula: Remote reference= $X+X*Y/100\%$. If relative reference is not used 3-18 Relative Scaling Reference Resource must be set to No function and 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 Programming Guide.

The scaling of analog references are described in parameter groups 6-1* and 6-2*, and the scaling of digital pulse references are described in parameter group 5-5*. Reference limits and ranges are set in parameter group 3-0*.

2.3.1 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 are clamped when necessary. The relation between the resulting reference (after clamping) is shown in Illustration 2.10/Illustration 2.11 and the sum of all references is shown in Illustration 2.12.

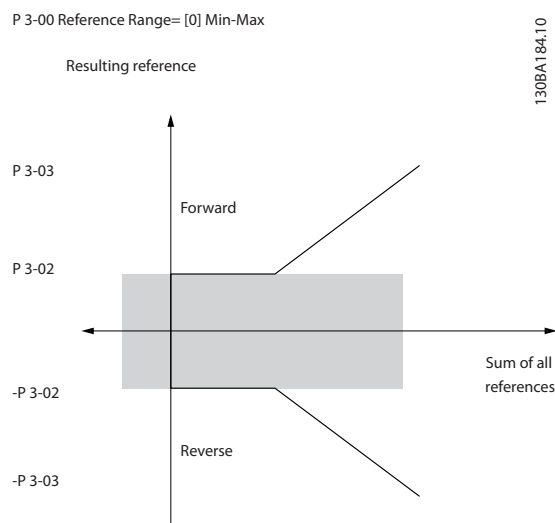


Illustration 2.10 Reference Range=[0] Min-Max

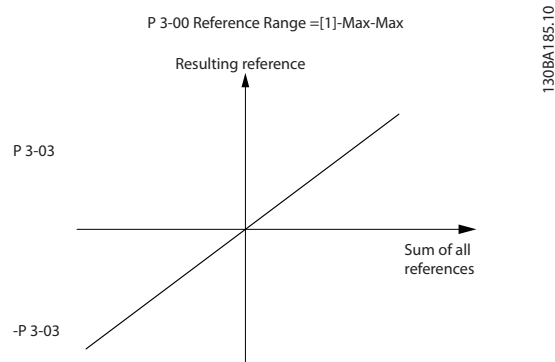


Illustration 2.11 Reference Range=[1] -Max-Max

The value of 3-02 Minimum Reference can not 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 2.12.

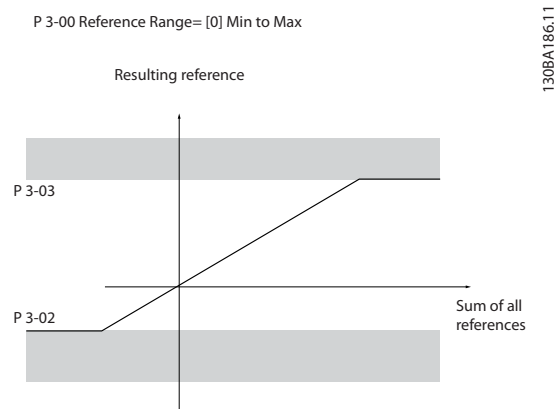


Illustration 2.12 Sum of all References

2.3.2 Scaling of Preset References and Bus References

Preset references are scaled according to the following rules:

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

Bus references are scaled according to the following rules:

- When 3-00 Reference Range: [0] Min to Max. To obtain max resolution on the bus reference the scaling on the bus is: 0% reference equals Min Reference and 100% reference equals Max reference.
- When 3-00 Reference Range: [1] -Max to +Max -100% reference equals -Max Reference 100% reference equals Max Reference.

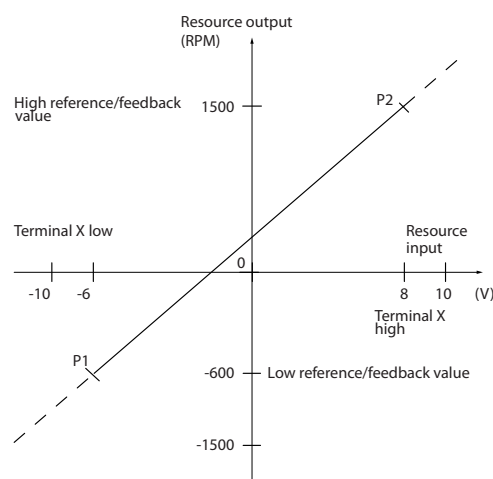


Illustration 2.14 Scaling of Reference Output

The endpoints P1 and P2 are defined by the following parameters depending on which analog or pulse input is used.

2.3.3 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 2.13) are clamped whereas a feedback above or below is not.

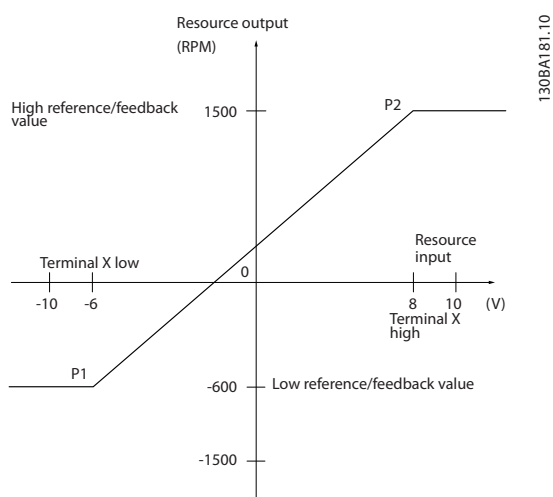


Illustration 2.13 Scaling of Analog and Pulse References and Feedback

	Analog 53 S201=OFF	Analog 53 S201=ON	Analog 54 S202=OFF	Analog 54 S202=ON	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 2.6 Input and Reference Endpoint Values

2.3.4 Dead Band Around Zero

In some cases the reference (in rare cases also the feedback) should have a dead band around zero (i.e. to make sure the machine is stopped when the reference is "near zero").

To make the dead band active and to set the amount of dead band, the following settings must be done:

- Either Minimum Reference Value (see Table 2.6 for relevant parameter) or Maximum Reference Value must be zero. In other words; Either P1 or P2 must be on the X-axis in the graph below.
- And 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 2.15.

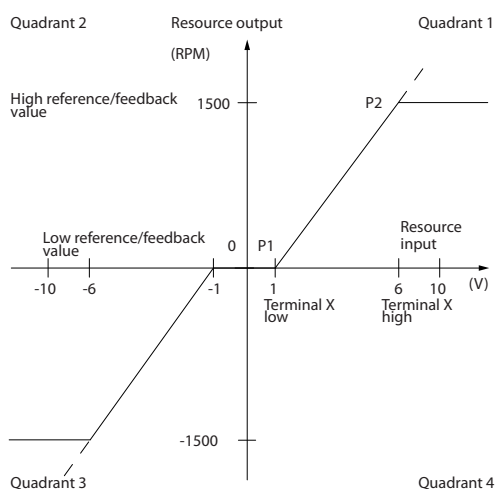


Illustration 2.15 Dead Band

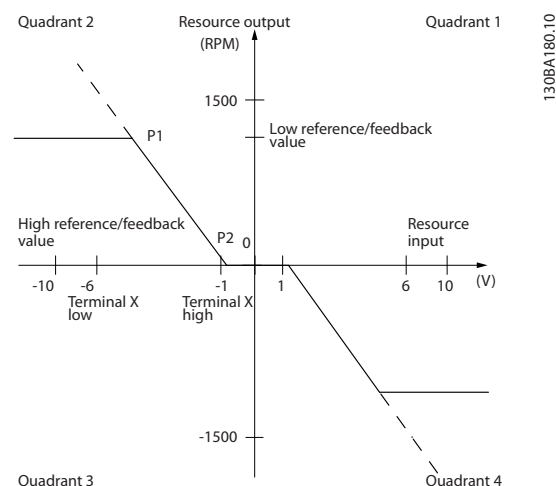


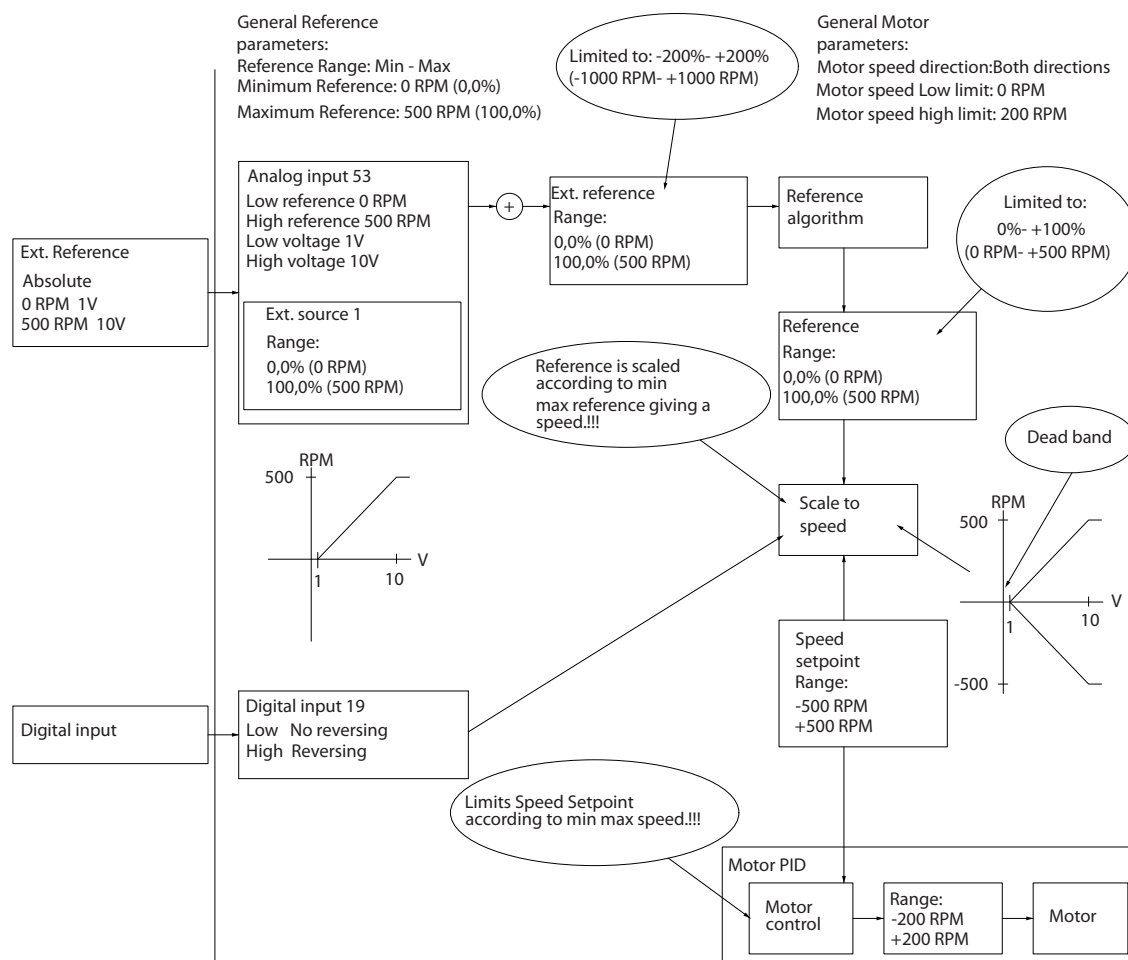
Illustration 2.16 Reverse Dead Band

Thus a reference endpoint of P1=(0 V, 0 RPM) will not result in any dead band, but a reference endpoint of e.g. P1=(1 V, 0 RPM) will result in a -1V to +1V dead band in this case provided that the end point P2 is placed in either Quadrant 1 or Quadrant 4.

Case 1: Positive Reference with Dead band, Digital input to trigger reverse

This case shows how reference input with limits inside Min to Max limits clamps.

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Illustration 2.17 Example 1 - Positive Reference

Case 2: Positive Reference with Dead band, Digital input to trigger reverse. Clamping rules.

This case shows how reference input with limits outside - Max to +Max limits clamps to the inputs low and high

limits before addition to external reference. And how the external reference is clamped to -Max to +Max by the reference algorithm.

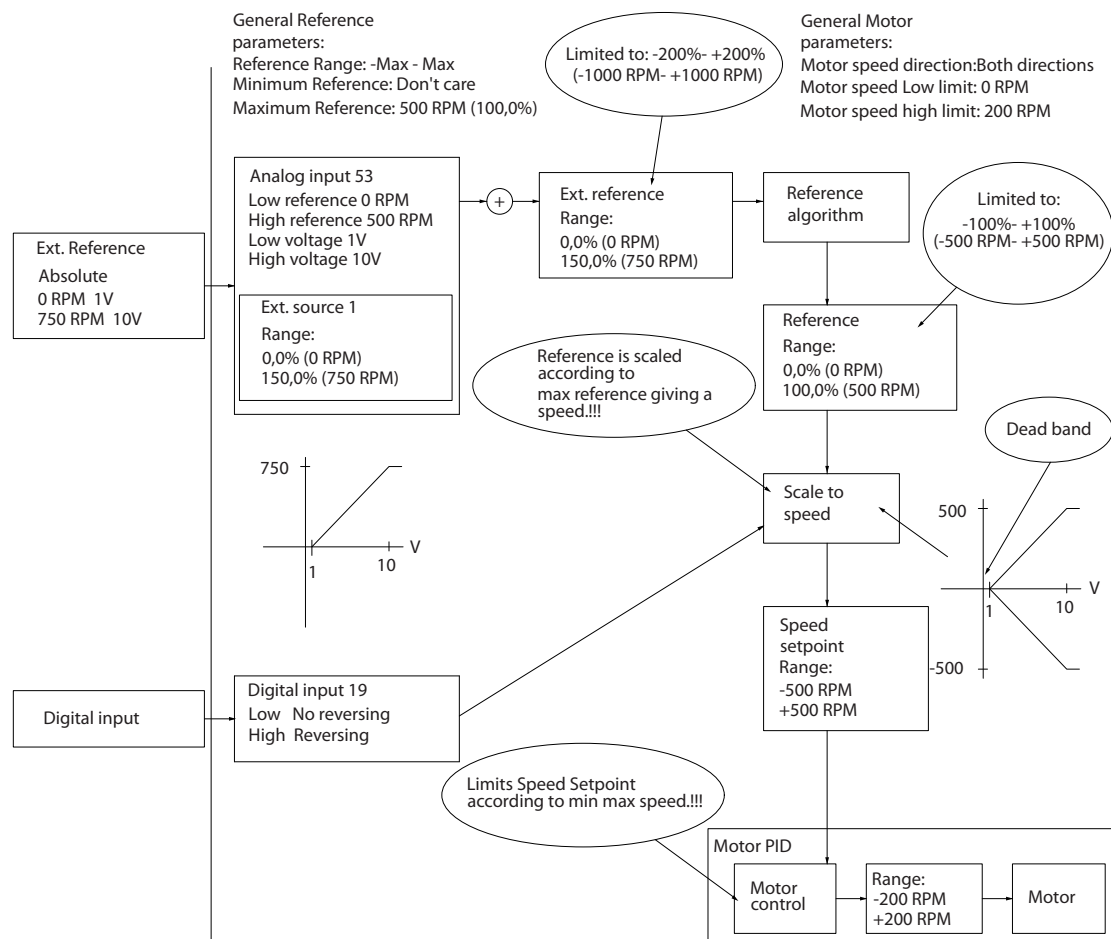


Illustration 2.18 Example 2 - Positive Reference

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**Case 3: Negative to positive reference with dead band,
Sign determines the direction, -Max to +Max**

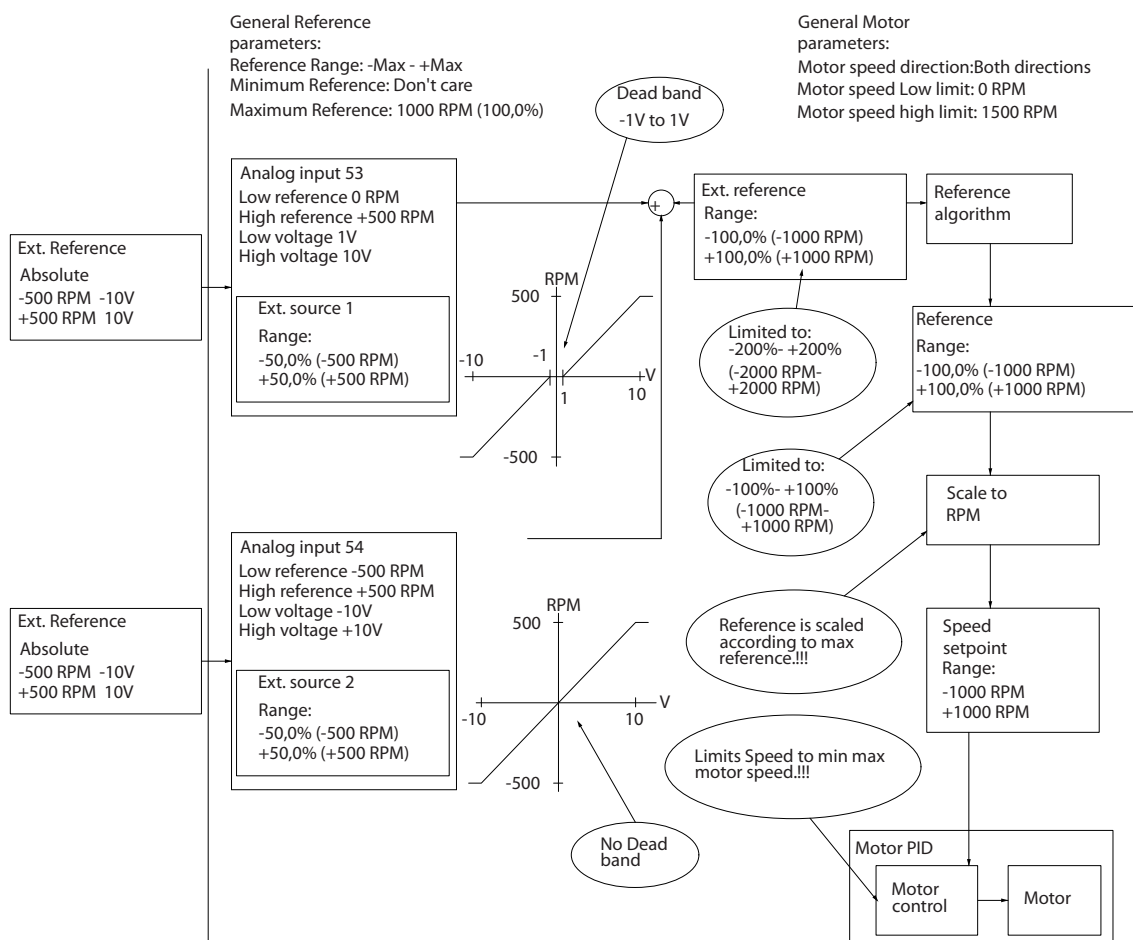


Illustration 2.19 Example 3 - Positive to Negative Reference

2.4.1 Earth Leakage Current

Follow national and local codes regarding protective earthing of equipment with a leakage current >3.5 mA. Frequency converter technology implies high frequency switching at high power. This will generate a leakage current in the earth 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 earth 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.

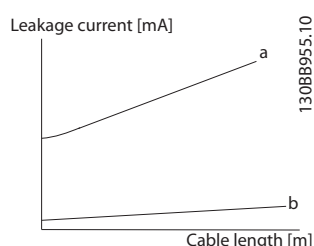


Illustration 2.20 Influence of Cable Length and Power Size on Leakage Current for $P_a > P_b$

The leakage current also depends on the line distortion

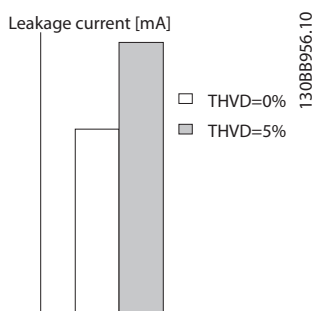


Illustration 2.21 Influence of Line Distortion on Leakage Current

NOTE

When a filter is used, turn off 14-50 RFI Filter when charging the filter, to avoid that a high leakage current makes the RCD switch.

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

- Earth ground wire (terminal 95) of at least 10 mm²
- Two separate earth ground wires both complying with the dimensioning rules

See EN/IEC61800-5-1 and EN50178 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 due to transient earth currents
- Dimension RCDs according to the system configuration and environmental considerations

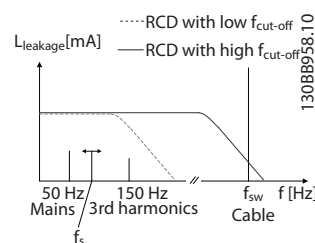


Illustration 2.22 Main Contributions to Leakage Current

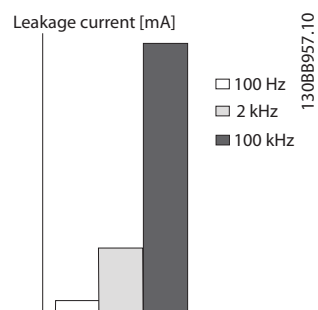


Illustration 2.23 Influence of Cut-off Frequency of the RCD

See also RCD Application Note, MN90G.

2.5 Galvanic Isolation (PELV)

2.5.1 PELV - Protective Extra Low Voltage

PELV offers protection by way of 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), with the exception of 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 described below, 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 six locations (see *Illustration 2.24*):

In order 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) incl. signal isolation of U_{DC} , indicating the voltage of intermediate DC Link circuit.
2. Gate drive that runs the IGBTs (trigger transformers/opto-couplers).
3. Current transducers.
4. Opto-coupler, brake module.
5. Internal inrush, RFI, and temperature measurement circuits.
6. Custom relays.
7. Mechanical brake.

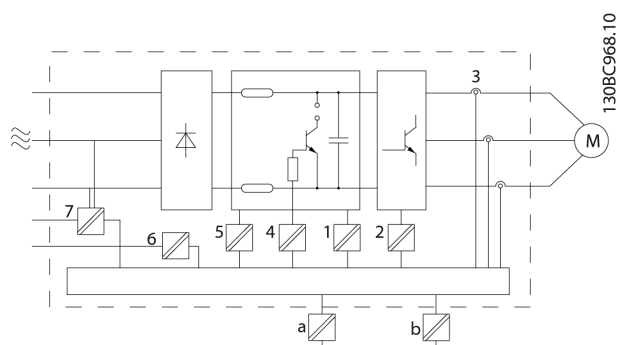


Illustration 2.24 Galvanic Isolation

The functional galvanic isolation (a and b on drawing) is for the 24 V back-up option and for the RS-485 standard bus interface.

⚠ WARNING

Installation at high altitude:

380-500 V: At altitudes above 2 km, contact Danfoss regarding PELV.

380-500 V: At altitudes above 3 km, contact Danfoss regarding PELV.

⚠ WARNING

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

Also make sure that other voltage inputs have been disconnected, such as load sharing (linkage of DC intermediate circuit), as well as the motor connection for kinetic back-up.

Before touching any electrical parts, wait at least the amount of time indicated in *Introduction, in FCD 302, Operating Instructions, MG04F*.

Shorter time is allowed only if indicated on the nameplate for the specific unit.

2.6 Mechanical Brake

2.6.1 Hoist Mechanical Brake

For an example of advanced mechanical brake control for hoisting applications, see *4 Application Examples*.

2.6.2 Brake Resistor Cabling

EMC (twisted cables/shielding)

To reduce the electrical noise from the wires between the brake resistor and the frequency converter, the wires must be twisted.

For enhanced EMC performance, use a metal screen.

2.7 Brake Functions

Braking function is applied for braking the load on the motor shaft, either as dynamic braking or static braking.

2.7.1 Mechanical Holding Brake

A mechanical holding brake mounted directly on the motor shaft normally performs static braking. In some applications the static holding torque is working as static holding of the motor shaft (usually synchronous permanent motors). A holding brake is either controlled by a PLC or directly by a digital output from the frequency converter (relay or solid state).

NOTE

When the holding brake is included in a safety chain: A frequency converter cannot provide a safe control of a mechanical brake. A redundancy circuitry for the brake control must be included in the total installation.

2.7.2 Dynamic Braking

Dynamic Brake established by:

- Resistor brake: A brake IGBT keep the overvoltage under a certain threshold by directing the brake energy from the motor to the connected brake resistor (2-10 Brake Function=[1]).
- 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 since this will overheat the motor (par. 2-10 Brake Function=[2]).
- DC brake: An over-modulated DC current added to the AC current works as an eddy current brake ($\neq 0$ s).

2.7.3 Selection of Brake Resistor

To handle higher demands by generatoric braking, a brake resistor is necessary. Using a brake resistor ensures that the energy is absorbed in the brake resistor and not in the frequency converter. For more information see the *Brake Resistor Design Guide, MG900*.

If the amount of kinetic energy transferred to the resistor in each braking period is not known, the average power

can be calculated based on the cycle time and braking time also called intermittent duty cycle. The resistor intermittent duty cycle is an indication of the duty cycle at which the resistor is active. *Illustration 2.25* shows a typical braking cycle.

NOTE

Motor suppliers often use S5 when stating the permissible load which is an expression of intermittent duty cycle.

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

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

T = cycle time in s

t_b is the braking time in s (of the cycle time)

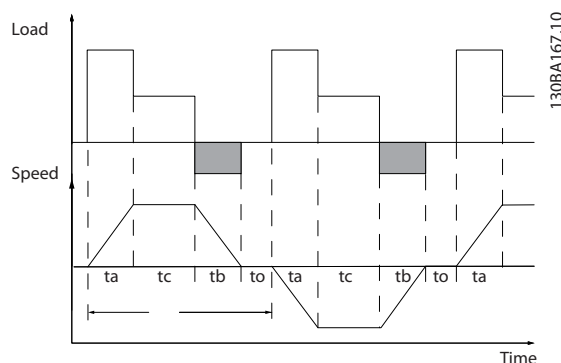


Illustration 2.25 Dynamic Braking Cycle Time

	Cycle time [s]	Braking duty cycle at 100% torque	Braking duty cycle at over torque (150/160%)
3x380-480 V			
PK37-P75K	120	Continuous	40%
P90K-P160	600	Continuous	10%
P200-P800	600	40%	10%

Table 2.7 Braking at High overload torque level

Brake resistors have a duty cycle of 5%, 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 will be used on dissipating excess heat.

NOTE

Ensure 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:

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

where

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

The brake resistance depends on the intermediate circuit voltage (U_{dc}).

The brake function is settled in four areas of mains.

Size	Brake active	Warning before cut out	Cut out (trip)
FCD 302 3x380-480 V	778 V	810 V	820 V

Table 2.8 Brake Limit Values

NOTE

Check that the brake resistor can cope with a voltage of 410 V, 820 V, 850 V, 975 V or 1130 V - unless brake resistors are used.

Danfoss recommends the brake resistance R_{rec} , i.e. one that guarantees that the frequency converter is able to brake at the highest braking torque ($M_{br(\%)}$) of 160%. The formula can be written as:

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

η_{motor} is typically at 0.90

η_{VLT} is typically at 0.98

For 200 V and 480 V frequency converters, R_{rec} at 160% braking torque is written as:

$$200 V : R_{rec} = \frac{107780}{P_{motor}} [\Omega]$$

$$480 V : R_{rec} = \frac{375300}{P_{motor}} [\Omega] 1)$$

$$480 V : R_{rec} = \frac{428914}{P_{motor}} [\Omega] 2)$$

1) For frequency converters ≤ 7.5 kW shaft output

2) For frequency converters 11-75 kW shaft output

NOTE

The resistor brake circuit resistance selected should not be higher than that recommended by Danfoss. If a brake resistor with a higher ohmic value is selected, the 160% braking torque may not be achieved because there is a risk that the frequency converter cuts out for safety reasons.

NOTE

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).

NOTE

Do not touch the brake resistor as it can get very hot while/after braking. The brake resistor must be placed in a secure environment to avoid fire risk

D-F size frequency converters contain more than one brake chopper. Consequently, use one brake resistor per brake chopper for those frame sizes.

2.7.4 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 against overloading in connection with a fault in the frequency converter.

In addition, the brake makes it possible to read out the momentary power and the mean power for the latest 120 seconds. The brake can also monitor the power energizing and make sure it does not exceed a limit selected in 2-12 Brake Power Limit (kW). In 2-13 Brake Power Monitoring, select the function to carry out when the power transmitted to the brake resistor exceeds the limit set in 2-12 Brake Power Limit (kW).

NOTE

Monitoring the brake power is not a safety function; a thermal switch is required for that purpose. The brake resistor circuit is not earth leakage protected.

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

OVC can not be activated when running a PM motor (when 1-10 Motor Construction is set to [1] PM non salient SPM).

3 System Integration

3

3.1 Introduction

3.1.1 Mounting

The FCD 302 consists of two parts: The installation box and the electronic part.

Stand alone mounting

- The holes on the rear of the installation box are used to fix mounting brackets
- Ensure that the strength of the mounting location can support the unit weight
- Make sure that the proper mounting screws or bolts are used

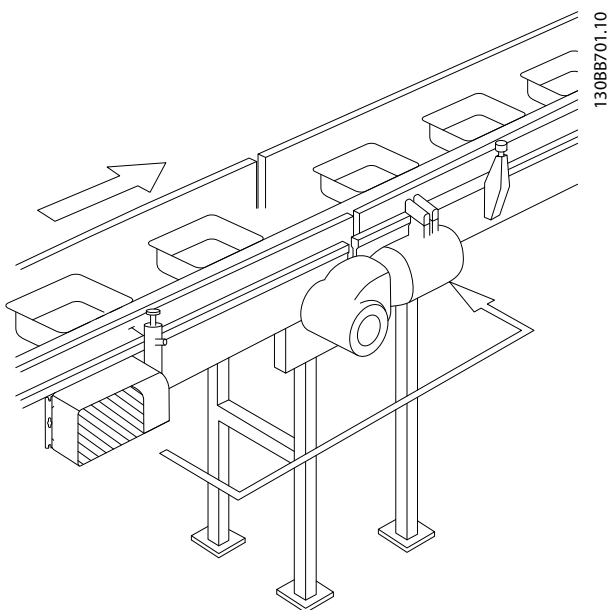


Illustration 3.1 FCD 302 Stand Alone Mounted with Mounting Brackets

Permitted mounting positions

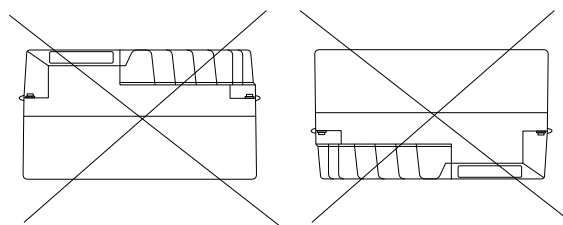
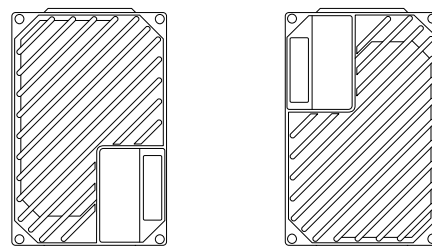
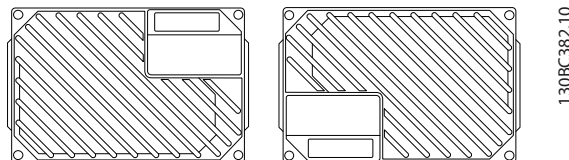


Illustration 3.2 Permitted Mounting Positions - Standard Applications

3.1.1.1 Hygienic Installation

The FCD 302 is designed according to the EHEDG guidelines, suitable for installation in environments with high focus on ease of cleaning.

Mount the FCD 302 vertically on a wall or machine frame, to ensure liquids drain off the enclosure. Orient the unit so the cable glands are located at the base.

Use cable glands designed to meet hygienic application requirements, for example Rittal HD 2410.110/120/130. Hygienic-purpose cable glands ensure optimal ease of cleaning in the installation.

NOTE

Only frequency converters configured as hygienic enclosure designation, FCD 302 P XXX T4 W69, have the EHEDG certification.

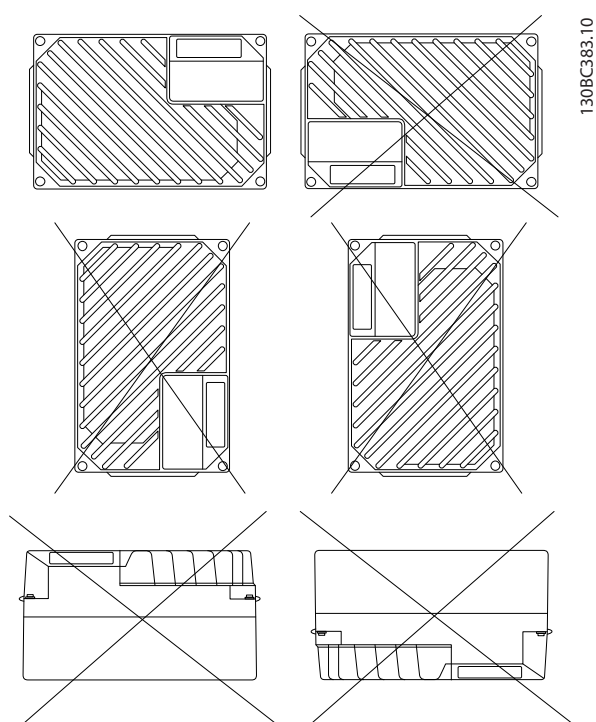


Illustration 3.3 Permitted Mounting Positions - Hygienic Applications

3.2 Input: Mains-side Dynamics

3.2.1 Connections

3.2.1.1 Cables General

NOTE

Cables General

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

3.2.1.2 Connection to Mains and Earthing

For installation instructions and location of terminals refer to *FCD 302 Operating Instructions, MG04F*.

Mains connection

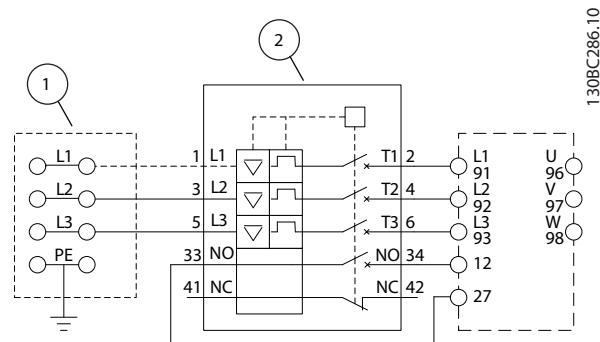


Illustration 3.4 Large Unit only: Circuit Breaker and Mains Disconnect

1	Looping terminals
2	Circuit breaker

Table 3.1 Legend

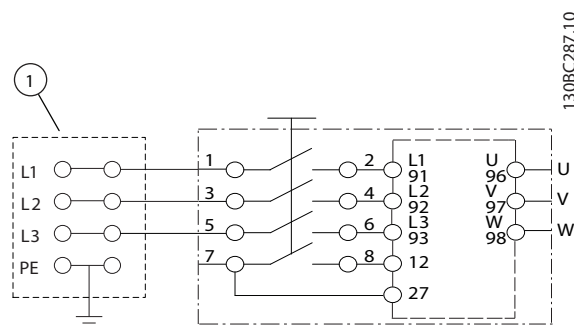
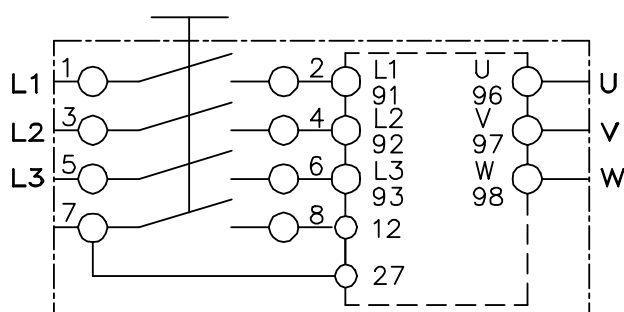
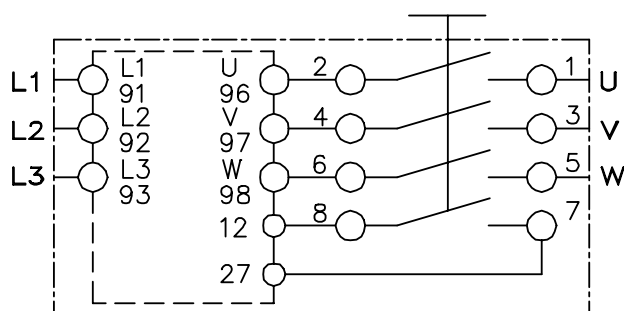


Illustration 3.5 Large Unit only: Service Switch at Mains with Looping Terminals

1	Looping terminals
---	-------------------

Table 3.2 Legend



195NA288.10

Illustration 3.6 Motor and Mains Connection with Service Switch

For both small and large unit, the service switch is optional. The switch is shown mounted on the motor side. Alternatively, the switch can be located on the mains side, or omitted.

For the large unit, the circuit breaker is optional. The large unit can be configured with either service switch or circuit breaker, not both. *Illustration 3.6* is not configurable in practice, but is displayed to show the respective positions of components only.

Usually the power cables for mains are unscreened cables.

3.2.1.3 Relay Connection

To set relay output, see parameter group 5-4* Relays.

No.	01-02	make (normally open)
	01-03	break (normally closed)
	04-05	make (normally open)
	04-06	break (normally closed)

Table 3.3 Relay Settings

For location of relay terminals, refer to *FCD 302 Operating Instructions, MG04F*.

3.2.2 Fuses and Circuit Breakers

3.2.2.1 Fuses

Fuses and/or circuit breakers are recommended protection on the supply side, in the event of component break-down inside the frequency converter (first fault).

NOTE

This is mandatory in order to ensure compliance with IEC 60364 for CE or NEC 2009 for UL.

⚠ WARNING

Personnel and property must be protected against the consequence of component break-down internally in the frequency converter.

Branch Circuit Protection

In order to protect the installation against electrical and fire hazard, all branch circuits in an installation, switch gear, machines etc., must be protected against short-circuit and over-current according to national/international regulations.

NOTE

The recommendations given do not cover Branch circuit protection for UL.

Short-circuit protection

Danfoss recommends using the fuses/circuit breakers mentioned below to protect service personnel and property in case of component break-down in the frequency converter.

3.2.2.2 Recommendations

⚠ WARNING

In the event of malfunction, failure to follow the recommendation may result in personnel risk and damage to the frequency converter and other equipment.

The following sections list the recommended rated current. Danfoss recommends fuse type gG and Danfoss CB (Danfoss - CTI-25) circuit breakers. Other types of circuit breaker may be used provide they limit the energy into the frequency converter to a level equal to or lower than the Danfoss CB types.

Follow the recommendations for fuses and circuit breakers to ensure any damage to the frequency converter is internal only.

For further information see Application Note *Fuses and Circuit Breakers, MN90T*.

3.2.2.3 CE Compliance

Use of fuses or circuit breakers is mandatory to comply with IEC 60364.

Danfoss recommends fuse size up to gG-25. This fuse size is suitable for use on a circuit capable of delivering 100,000 Arms (symmetrical), 480 V. With the proper fusing the frequency converter short circuit current rating (SCCR) is 100,000 Arms.

3.2.2.4 UL Compliance

Fuses or Circuit Breakers are mandatory to comply with NEC 2009. To meet UL/cUL requirements, use the pre-fuses in Table 6.3, and comply with the conditions listed in 6.2 Electrical Data and Wire Sizes.

3.3 Output: Motor-side Dynamics

3.3.1 Motor Connection

NOTE

To comply with EMC emission specifications, screened/armoured cables are recommended.

See 6.3 General Specifications for correct dimensioning of motor cable cross-section and length.

Screening of cables

Avoid installation with twisted screen ends (pigtailed). They spoil the screening effect at higher frequencies. If it is

necessary to break the screen to install a motor isolator or motor contactor, the screen must be continued at the lowest possible HF impedance.

Connect the motor cable screen to both the decoupling plate of the frequency converter and to the metal housing of the motor.

Make the screen connections with the largest possible surface area (cable clamp). This is done by using the supplied installation devices in the frequency converter. If it is necessary to split the screen to install a motor isolator or motor relay, the screen must be continued with the lowest possible HF impedance.

Cable-length and cross-section

The frequency converter has been tested with a given length of cable and a given cross-section of that cable. If the cross-section is increased, the cable capacitance - and thus the leakage current - may increase, and the cable length must be reduced correspondingly. Keep the motor cable as short as possible to reduce the noise level and leakage currents.

All types of three-phase asynchronous standard motors can be connected to the frequency converter. Normally, small motors are star-connected (230/400 V, Y). Large motors are normally delta-connected (400/690 V, Δ). Refer to the motor name plate for correct connection mode and voltage.

For installation of mains and motor cables refer to FCD 302 Operating Instructions, MG04F.

Term. no.	96	97	98	99	
	U	V	W	PE ¹⁾	Motor voltage 0-100% of mains voltage. 3 wires out of motor
	U1	V1	W1	PE ¹⁾	Delta-connected
	W2	U2	V2		6 wires out of motor
	U1	V1	W1	PE ¹⁾	Star-connected U2, V2, W2 U2, V2 and W2 to be interconnected separately.

Table 3.4 Motor Connection Terminals

¹⁾Protected Earth Connection

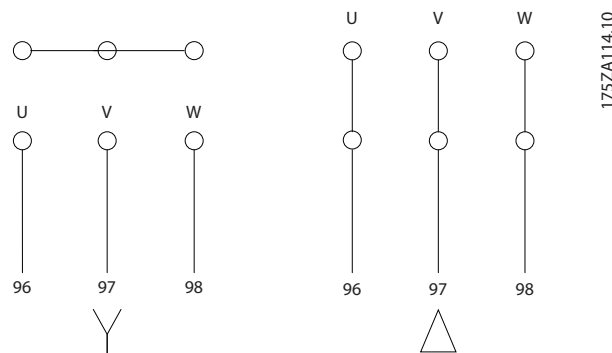
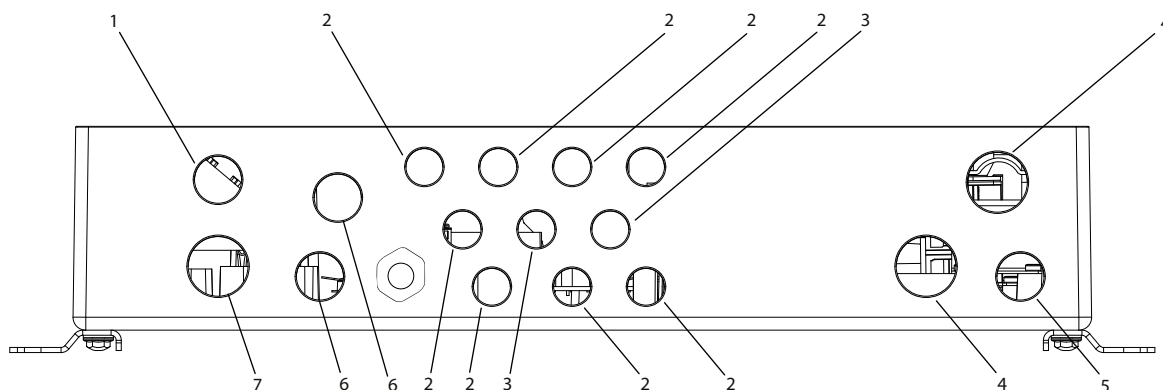


Illustration 3.7 Star - Delta Earth Connections

NOTE

In motors without phase insulation paper or other insulation reinforcement suitable for operation with voltage supply (such as a frequency converter), fit a Sine-wave filter on the output of the frequency converter.



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Illustration 3.8 Cable Entry Holes - Large Unit

1	Brake M20
2	8xM16
3	2xM20
4	Mains cables M25
5	M20
6	24 V M20
7	Motor M25

Table 3.5 Legend

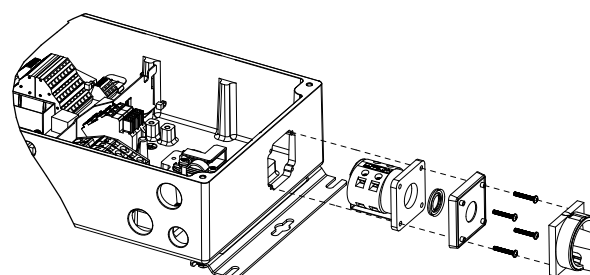
3.3.2 Mains Disconnectors

The frequency converter is available with optional

- service switch on mains side or motor side
- built-in circuit breaker on the mains side (large unit only)

Specify the requirement when ordering.

Illustration 3.9 and Illustration 3.10 show examples of configuration for the large unit.



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Illustration 3.9 Location of Service Switch, Mains Side, Large Unit, (IP66/Type 4X indoor)

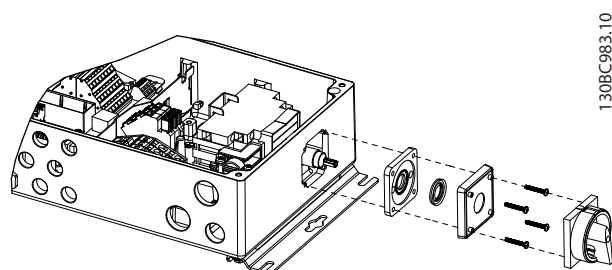


Illustration 3.10 Location of Circuit Breaker, Mains Side, Large Unit

3.3.3 Additional Motor Information

3.3.3.1 Motor Cable

The motor must be connected to terminals U/T1/96, V/T2/97, W/T3/98. Earth (Ground) to terminal 99. All types of three-phase asynchronous standard motors can be used with a frequency converter unit. The factory setting is for clockwise rotation with the frequency converter output connected as shown in *Table 3.6*:

Terminal No.	Function
96, 97, 98, 99	Mains U/T1, V/T2, W/T3 Earth (Ground)

Table 3.6 Motor Connection - Factory Setting

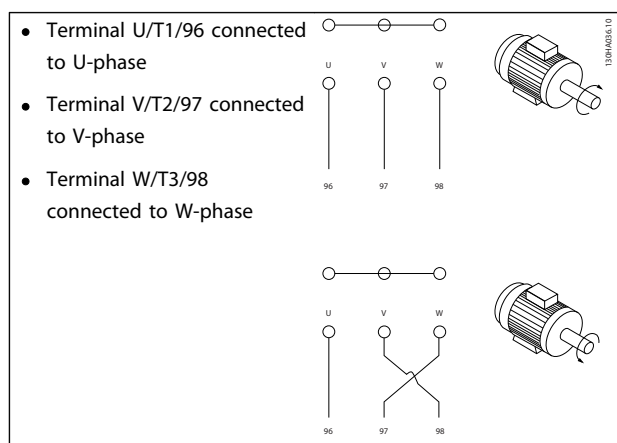


Table 3.7 Motor Connection - Direction of Rotation

The direction of rotation can be changed by switching two phases in the motor cable or by changing the setting of 4-10 Motor Speed Direction.

Motor rotation check can be performed using 1-28 Motor Rotation Check and following the steps shown in the display.

3.3.3.2 Motor Thermal Protection

The electronic thermal relay in the frequency converter has received UL-approval for single motor protection, when 1-90 Motor Thermal Protection is set for ETR Trip and

1-24 Motor Current is set to the rated motor current (see motor name plate).

3.3.3.3 Parallel Connection of Motors

The frequency converter can control several parallel-connected motors. When using parallel motor connection following must be observed:

- Recommended to run applications with parallel motors in U/F mode 1-01 Motor Control Principle [0]. Set the U/F graph in 1-55 U/f Characteristic - U and 1-56 U/f Characteristic - F.
- VCC⁺ mode may be used in some applications.
- The total current consumption of the motors must not exceed the rated output current I_{INV} for the frequency converter.
- If motor sizes are widely different in winding resistance, starting problems may arise due to too low motor voltage at low speed.
- The electronic thermal relay (ETR) of the frequency inverter cannot be used as motor protection for the individual motor. Provide further motor protection by e.g. thermistors in each motor winding or individual thermal relays. (Circuit breakers are not suitable as protection device).

NOTE

Installations with cables connected in a common joint as shown in the first example in the picture is only recommended for short cable lengths.

NOTE

When motors are connected in parallel, 1-02 Flux Motor Feedback Source cannot be used, and 1-01 Motor Control Principle must be set to Special motor characteristics (U/f).

The total motor cable length specified in 6 Specifications, is valid as long as the parallel cables are kept short (less than 10 m each).

3.3.3.4 Motor Insulation

For motor cable lengths \leq the maximum cable length listed in the 6.3 General Specifications, the following motor insulation ratings are recommended because the peak voltage can be up to twice the DC link voltage, 2.8 times the mains voltage, due to transmission line effects in the motor cable. If a motor has lower insulation rating it recommended to use a du/dt or sine wave filter.

Nominal Mains Voltage	Motor Insulation
$U_N \leq 420 \text{ V}$	Standard $U_{LL} = 1300 \text{ V}$
$420 \text{ V} < U_N \leq 500 \text{ V}$	Reinforced $U_{LL} = 1600 \text{ V}$

Table 3.8 Mains Voltage and Motor Insulation

3.3.3.5 Motor Bearing Currents

All motors installed with FC 302 90 kW or higher power drives should have NDE (Non-Drive End) insulated bearings installed to eliminate circulating bearing currents. To minimize DE (Drive End) bearing and shaft currents proper grounding of the drive, motor, driven machine, and motor to the driven machine is required.

Standard Mitigation Strategies

1. Use an insulated bearing
2. Apply rigorous installation procedures
 - Ensure the motor and load motor are aligned
 - Strictly follow the EMC Installation guideline
 - Reinforce the PE so the high frequency impedance is lower in the PE than the input power leads
 - Provide a good high frequency connection between the motor and the frequency converter for instance by screened cable which has a 360° connection in the motor and the frequency converter
 - Make sure that the impedance from frequency converter to building ground is lower than the grounding impedance of the machine. This can be difficult for pumps
 - Make a direct earth connection between the motor and load motor
3. Lower the IGBT switching frequency
4. Modify the inverter waveform, 60° AVM vs. SFAVM
5. Install a shaft grounding system or use an isolating coupling
6. Apply conductive lubrication
7. Use minimum speed settings if possible
8. Try to ensure the line voltage is balanced to ground. This can be difficult for IT, TT, TN-CS or Grounded leg systems
9. Use a dU/dt or sinus filter

3.3.4 Extreme Running Conditions

Short Circuit (Motor Phase – Phase)

The frequency converter is protected against short circuits with current measurement in each of the three motor phases or in the DC link. A short circuit between two output phases causes an overcurrent in the inverter. The inverter is turned off individually when the short circuit current exceeds the permitted value (Alarm 16 Trip Lock). To protect the frequency converter against a short circuit at the load sharing and brake outputs, see the design guidelines.

Switching on the Output

Switching on the output between the motor and the frequency converter is fully permitted. No damage to the frequency converter can occur by switching on the output. However, fault messages can appear.

Motor-generated Over-voltage

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

1. The load drives the motor (at constant output frequency from the frequency converter), that is, the load generates energy.
2. During deceleration, ("ramp-down") if the moment of inertia is high, the friction is low, and the ramp-down time is too short for the energy to be dissipated as a loss in the frequency converter, the motor, and the installation.
3. Incorrect slip compensation setting can cause higher DC link voltage.
4. Back-EMF from PM motor operation. When coasted at high rpm, the PM motor back-EMF can potentially exceed the maximum voltage tolerance of the frequency converter and cause damage. The frequency converter is designed to prevent the occurrence of back EMF: the value of *4-19 Max Output Frequency* is automatically limited based on an internal calculation based on the value of *1-40 Back EMF at 1000 RPM*, *1-25 Motor Nominal Speed* and *1-39 Motor Poles*. When motor overspeed is possible (for example, due to excessive windmilling effects), then a brake resistor is recommended.

NOTE

The frequency converter must be equipped with a break chopper.

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

The inverter 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.

NOTE

OVC cannot be activated when running a PM motor, that is, for parameter 1-10 Motor Construction set to [1] PM non salient SPM.

Mains Drop-out

During mains drop-out, the frequency converter keeps running until the intermediate circuit voltage drops below the minimum stop level. The minimum stop level is typically 15% below the lowest rated supply voltage of the frequency converter. The mains voltage prior to the drop-out, combined with the motor load, determines how long it takes for the inverter to coast.

Static Overload in VVC^{plus} mode

When the frequency converter is overloaded, the controls reduce the output frequency to reduce the load. Overload is defined as reaching the torque limit set in 4-16 Torque Limit Motor Mode/4-17 Torque Limit Generator Mode. For extreme overload, a current acts to ensure the frequency converter cuts 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.

3.3.4.1 Motor Thermal Protection

To protect the application from serious damage, the frequency converter offers several dedicated features

Torque Limit

The torque limit feature the motor is protected for being overloaded independent of the speed. Select torque limit settings 4-16 Torque Limit Motor Mode and or 4-17 Torque Limit Generator Mode. Set the time to trip for the torque limit warning in 14-25 Trip Delay at Torque Limit.

Current Limit

Set the current limit in 4-18 Current Limit. Set the time before the current limit warning trips in 14-24 Trip Delay at Current Limit.

Min Speed Limit

(4-11 Motor Speed Low Limit [RPM] or 4-12 Motor Speed Low Limit [Hz]) limit the operating speed range to for instance between 30 and 50/60 Hz. Max Speed Limit: (4-13 Motor Speed High Limit [RPM] or 4-19 Max Output Frequency) limit the max output speed the drive can provide.

ETR (Electronic Thermal relay)

The 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 3.11:

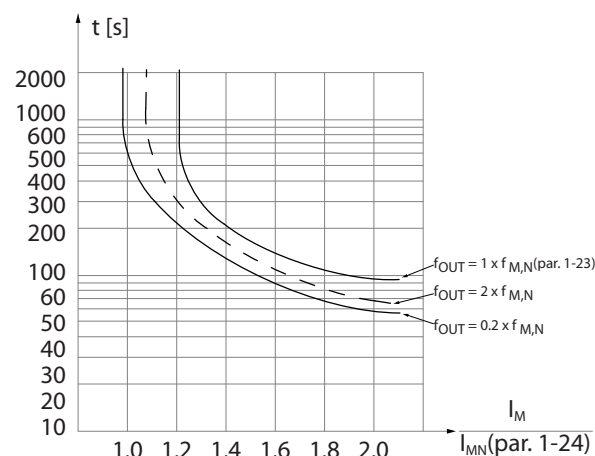


Illustration 3.11 ETR Functions

Illustration 3.11: The X-axis shows the ratio between I_{motor} and I_{motor} nominal. The Y-axis shows the time in seconds before the ETR cut of and trips the drive. The curves show the characteristic nominal speed, at twice the nominal speed and at 0.2 x the nominal speed.

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

3.4 Drive/Options Selections

3.4.1 Control Cables and Terminals

3.4.1.1 Control Cable Routing

24 V DC external supply can be used as low-voltage supply to the control card and any option cards installed. This enables full operation of the LCP (including parameter setting) without connection to mains.

NOTE

A warning of low voltage will be given when 24 V DC has been connected; however, there will be no tripping.

⚠ WARNING

Use 24 V DC supply of type PELV to ensure correct galvanic isolation (type PELV) on the control terminals of the frequency converter.

3.4.1.2 DIP Switches

- Analog input terminals 53 and 54 can select for either voltage (0-10 V) or current (0-20 mA) input signals
- Set switches S201 (terminal 53) and S202 (terminal 54) to select the signal type. ON is for current, OFF for voltage
- Terminal 53 default is for a speed reference in open loop
- Terminal 54 default is for a feedback signal in closed loop

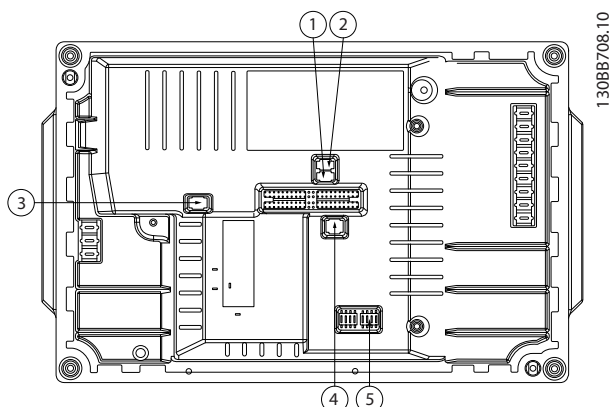


Illustration 3.12 Location of DIP Switches

1	S201 - terminal 53
2	S202 - terminal 54
3	S801 - standard bus termination
4	Profibus termination
5	Fieldbus address

Table 3.9 Legend

NOTE

Switches 4 and 5 are only valid for units fitted with fieldbus options.

3.4.1.3 Basic Wiring Example

Connect terminals 27 and 37 to +24 V terminals 12 and 13, as shown in *Illustration 3.13*.

Default settings:

27=Coast inverse 5-10 Terminal 18 Digital Input [2]

37=Safe torque off inverse

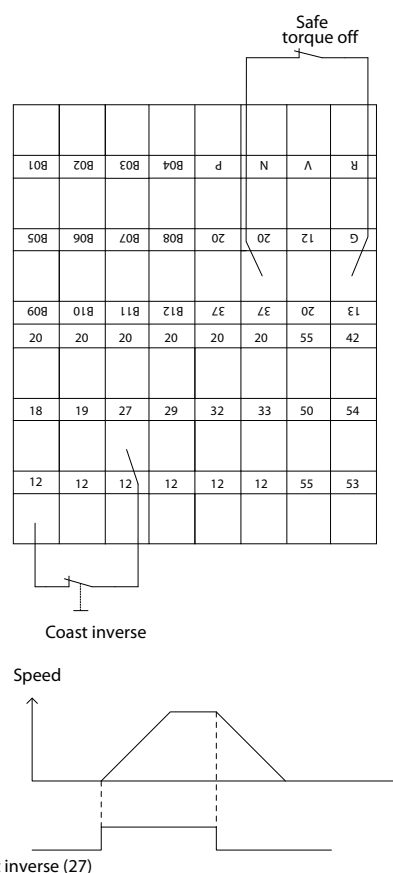


Illustration 3.13 Basic Wiring Example

3.4.1.4 Electrical Installation, Control Cables

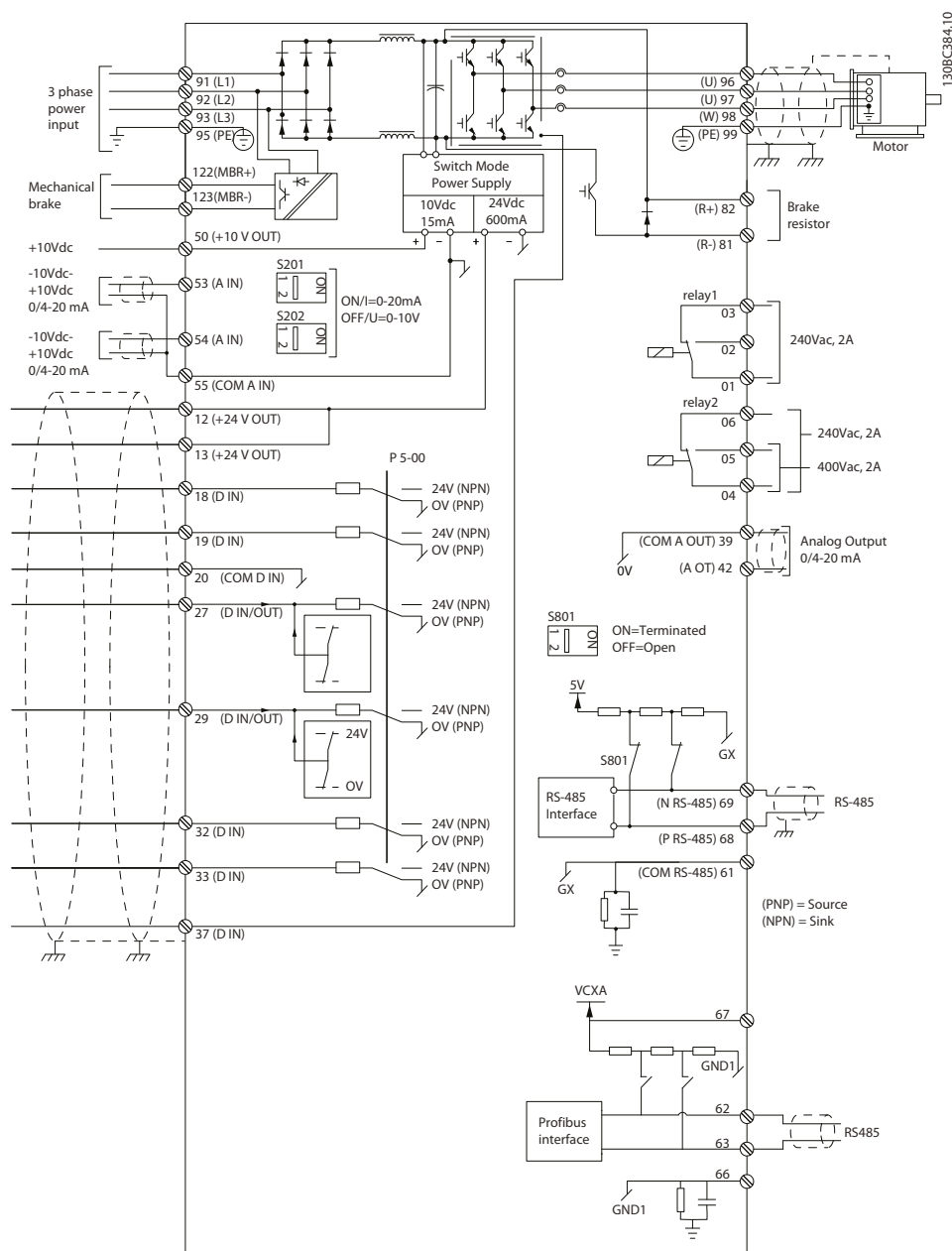


Illustration 3.14 Electrical Terminals without Options

A=analog, D=digital

Terminal 37 is used for Safe Stop.

Relay 2 has no function when the frequency converter has mechanical brake output.

Very long control cables and analogue signals may in rare cases result in 50/60 Hz earth loops due to noise from mains supply cables. If this occurs, it may be necessary to break the screen or insert a 100 nF capacitor between screen and chassis. Connect the digital and analogue inputs and outputs separately to the common inputs (terminal 20, 55, 39) to avoid ground currents from both groups affecting other groups. For example, switching on the digital input may disturb the analog input signal.

frequency converter. Code numbers can be found in 5.2.1 *Ordering Numbers: Accessories*.

3.4.2.1 Brake Resistors 10%

For frequency converters equipped with the dynamic brake option, one brake IGBT along with terminals 81 (R-) and 82 (R+) is included in each inverter module for connecting a brake resistor(s).

For internal brake resistor use:

Brake resistor 1750 Ω 10 W/100%	For mounting inside installation box below motor terminals
Brake resistor 350 Ω 10 W/100%	For mounting inside installation box below motor terminals

Table 3.10 Brake Resistors 10%

3.4.2.2 Brake Resistor 40%

Placing the brake resistor externally has the advantages of selecting the resistor based on application need, dissipating the energy outside of the control panel, and protecting the frequency converter from overheating if the brake resistor is overloaded.

No.	81 (optional function)	82 (optional function)	Brake resistor terminals
	R-	R+	

Table 3.11 Brake Resistors 40%

- The connection cable to the brake resistor must be screened/armoured. Connect the screen to the metal cabinet of the frequency converter and to the metal cabinet of the brake resistor with cable clamps.
- Dimension the cross-section of the brake cable to match the brake torque.

3.4.3 Special Conditions

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

3.4.3.1 Manual Derating

Manual derating must be considered for:

- Air pressure – relevant for installation at altitudes above 1 km
- Motor speed – at continuous operation at low RPM in constant torque applications

- Ambient temperature – relevant for ambient temperatures above 50 °C

Contact Danfoss for the application note for tables and elaboration. Only the case of running at low motor speeds is elaborated here.

3.4.3.2 Automatic Derating

The drive constantly checks for critical levels:

- Critical high temperature on the control card or heatsink
- High motor load
- High DC link voltage
- Low motor speed

As a response to a critical level, the frequency converter adjusts the switching frequency. For critical high internal temperatures and low motor speed, the drive can also force the PWM pattern to SFAVM.

NOTE

The automatic derating is different when 14-55 Output Filter is set to [2] Sine-Wave Filter Fixed.

3.4.3.3 Derating for Running at Low Speed

When a motor is connected to a frequency converter, it is necessary to check that the cooling of the motor is adequate.

The level of heating depends on the load on the motor, as well as the operating speed and time.

Constant torque applications (CT mode)

A problem may occur at low RPM values in constant torque applications. In a constant torque applications a motor may over-heat at low speeds due to less cooling air from the motor integral fan. Therefore, if the motor is to be run continuously at an RPM value lower than half of the rated value, the motor must be supplied with additional air-cooling (or a motor designed for this type of operation may be used). An alternative is to reduce the load level of the motor by choosing a larger motor. However, the design of the frequency converter puts a limit to the motor size.

Variable (Quadratic) torque applications (VT)

In VT applications such as centrifugal pumps and fans, the torque is proportional to the square of the speed and the power is proportional to the cube of the speed. In these applications there is no need for additional cooling or derating of the motor. In *Illustration 3.17*, the typical VT curve is below the maximum torque with de-rating and maximum torque with forced cooling at all speeds.

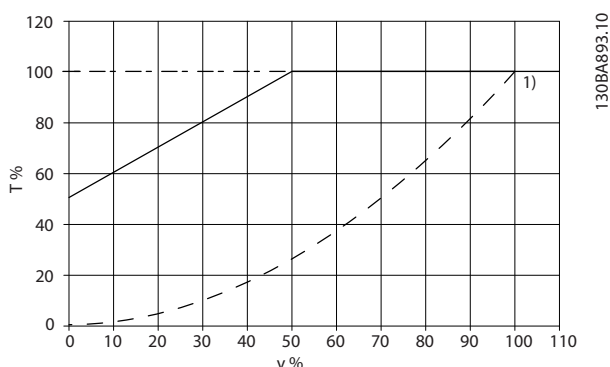


Illustration 3.17 VT Applications - Maximum Load for a Standard Motor at 40 °C

Item	Description
————	Maximum torque
-----	Typical torque at VT load

Table 3.12 Legend - VT Applications

NOTE

Over-synchronous speed operation will result in decrease of the available motor torque, inversely proportional to the increase in speed. This must be considered during the design phase to avoid over-loading of the motor.

3.4.4 EMC

3.4.4.1 EMC-correct Cables

The following is a guideline to good engineering practice when installing frequency converters. Follow these guidelines to comply with EN 61800-3 *First environment*. If the installation is in EN 61800-3 *Second environment*, i.e. industrial networks, or in an installation with its own transformer, deviation from these guidelines is allowed but not recommended. See also 1.4.3 *CE Labelling*, 2.2.1 *General Aspects of EMC Emissions* and 2.2.2 *EMC Test Results*.

Good engineering practice to ensure EMC-correct electrical installation:

- Use only braided screened/armoured motor cables and braided screened/armoured control

cables. The screen should provide a minimum coverage of 80%. The screen material must be metal, not limited to but typically copper, aluminium, steel or lead. There are no special requirements for the mains cable.

- Installations using rigid metal conduits are not required to use screened cable, but the motor cable must be installed in conduit separate from the control and mains cables. Full connection of the conduit from the drive to the motor is required. The EMC performance of flexible conduits varies a lot and information from the manufacturer must be obtained.
- Connect the screen/armour/conduit to earth at both ends for motor cables as well as for control cables. In some cases, it is not possible to connect the screen in both ends. If so, connect the screen at the frequency converter.
- Avoid terminating the screen/armour with twisted ends (pigtailed). It increases the high frequency impedance of the screen, which reduces its effectiveness at high frequencies. Use low impedance cable clamps or EMC cable glands instead.
- Avoid using unscreened/unarmoured motor or control cables inside cabinets housing the drive(s), whenever this can be avoided.

Leave the screen as close to the connectors as possible.

Illustration 3.18 shows an example of an EMC-correct electrical installation of an IP20 frequency converter. The frequency converter is connected to a PLC, which is installed in a separate cabinet. Other ways of doing the installation may have just as good an EMC performance, provided the above guidelines are followed.

If the installation is not carried out according to the guidelines, and if unscreened cables and control wires are used, then certain emission requirements will not be fulfilled, although the immunity requirements are fulfilled. See the section 2.2.2 *EMC Test Results*.

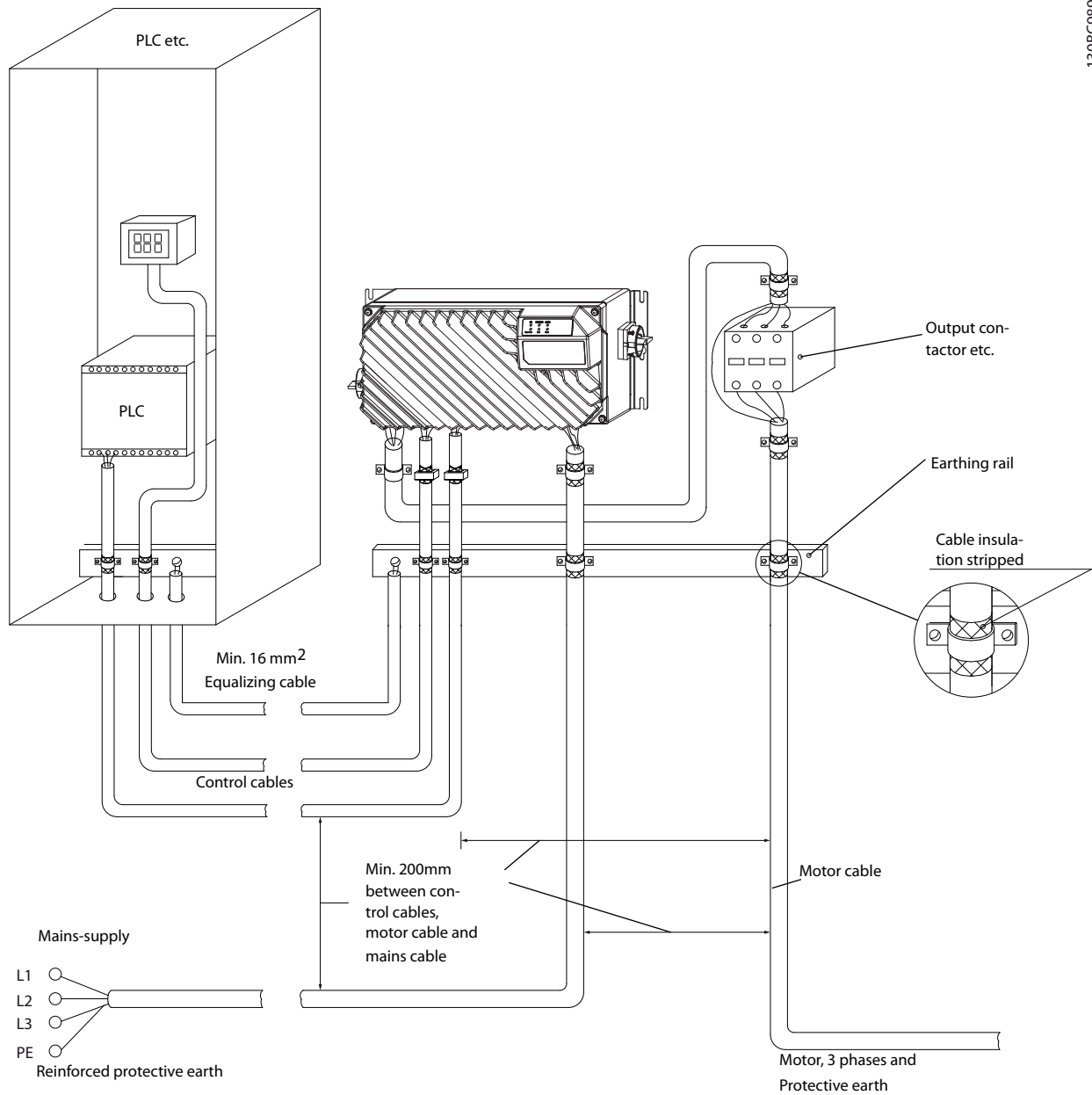


Illustration 3.18 EMC-correct Electrical Installation of a Frequency Converter

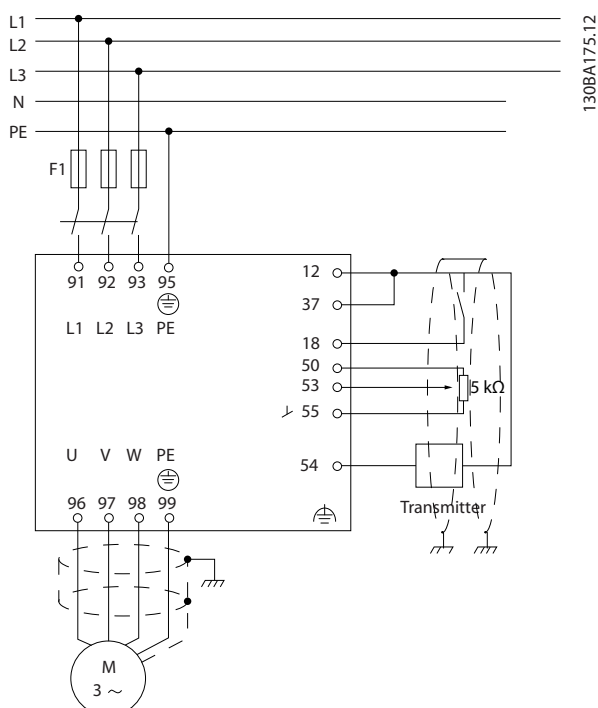


Illustration 3.19 Electrical Connection Diagram

3.4.4.2 Earthing of Screened Control Cables

Correct screening

The preferred method in most cases is to secure control and cables with screening clamps provided at both ends to ensure best possible high frequency cable contact. If the earth potential between the frequency converter and the PLC is different, electric noise may occur that will disturb the entire system. Solve this problem by fitting an equalizing cable next to the control cable. Minimum cable cross section: 16 mm².

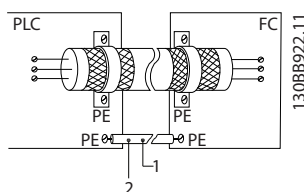


Illustration 3.20 Screening of Control Cables

1	Min. 16 mm ²
2	Equalizing cable

Table 3.13 Legend

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).

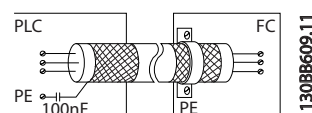


Illustration 3.21 Screening for 50/60 Hz Ground Loops

Avoid EMC noise on serial communication

This terminal is connected to earth via an internal RC link. Use twisted-pair cables to reduce interference between conductors. The recommended method is shown in Illustration 3.22.

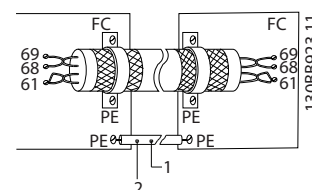


Illustration 3.22 Screening for EMC Noise Reduction, Serial Communication

1	Min. 16 mm ²
2	Equalizing cable

Table 3.14 Legend

Alternatively, the connection to terminal 61 can be omitted:

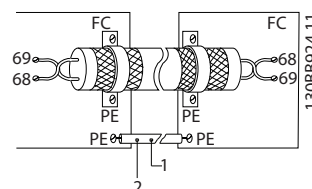


Illustration 3.23 Screening for EMC Noise Reduction, Serial Communication, without Terminal 61

1	Min. 16 mm ²
2	Equalizing cable

Table 3.15 Legend

3.4.4.3 RFI Switch

Mains supply isolated from earth

When the frequency converter is supplied from an isolated mains source (IT mains, floating delta and grounded delta) or TT/TN-S mains with grounded leg, set the RFI switch to [Off] via 14-50 RFI Filter on the drive.

Otherwise, set 14-50 RFI Filter to [On].

For further information, refer to:

- IEC 364-3
- Application note *VLT on IT mains, MN90C*. It is important to use isolation monitors that are capable for use together with power electronics (IEC 61557-8).

3.4.5 Mains Supply Interference/Harmonics

3.4.5.1 Mains Supply Interference/Harmonics

A frequency converter takes up a non-sinusoidal current from mains, which increases the input current I_{RMS} . A non-sinusoidal current is transformed by means of a Fourier analysis and split up into sine-wave currents with different frequencies, i.e. different harmonic currents I_N with 50 Hz as the basic frequency:

Harmonic currents	I_1	I_5	I_7
Hz	50 Hz	250 Hz	350 Hz

Table 3.16 Harmonic Currents

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

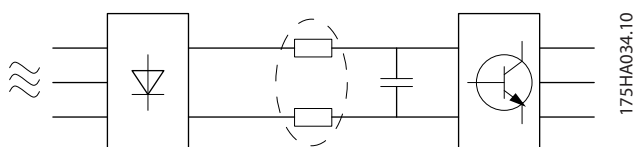


Illustration 3.24 Intermediate Circuit Coils

NOTE

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

	Input current
I_{RMS}	1.0
I_1	0.9
I_5	0.4
I_7	0.2
I_{11-49}	<0.1

Table 3.17 Harmonic Currents Compared to the RMS Input Current

To ensure low harmonic currents, the frequency converter is equipped with intermediate circuit coils as standard. DC-coils reduce the total harmonic distortion (THD) to 40%.

3.4.5.2 Effect of Harmonics in a Power Distribution System

In *Illustration 3.25* a transformer is connected on the primary side to a point of common coupling PCC1, on the medium voltage supply. The transformer has an impedance Z_{xfr} and feeds a number of loads. The point of common coupling where all loads are connected together is PCC2. Each load is connected through cables that have an impedance Z_1, Z_2, Z_3 .

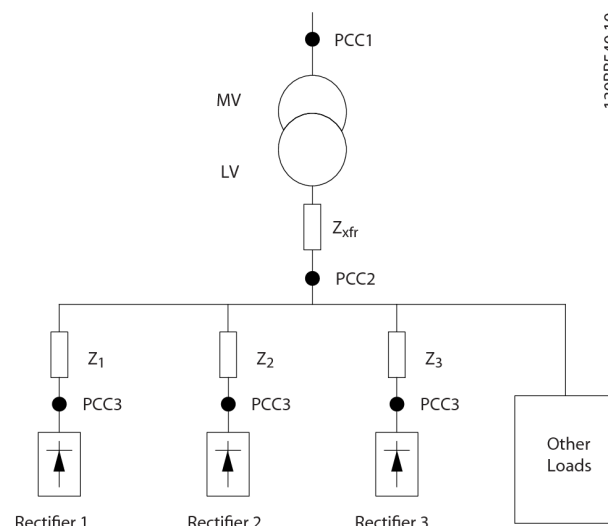


Illustration 3.25 Small Distribution System

Harmonic currents drawn by non-linear loads cause distortion of the voltage because of the voltage drop on the impedances of the distribution system. Higher impedances result in higher levels of voltage distortion.

Current distortion relates to apparatus performance and it relates to the individual load. Voltage distortion relates to system performance. It is not possible to determine the voltage distortion in the PCC knowing only the load's harmonic performance. In order to predict the distortion in the PCC the configuration of the distribution system and relevant impedances must be known.

A commonly used term for describing the impedance of a grid is the short circuit ratio R_{sce} , defined as the ratio between the short circuit apparent power of the supply at the PCC (S_{sc}) and the rated apparent power of the load (S_{equ}).

$$R_{sce} = \frac{S_{ce}}{S_{equ}}$$

$$\text{where } S_{sc} = \frac{U^2}{Z_{supply}} \text{ and } S_{equ} = U \times I_{equ}$$

The negative effect of harmonics is twofold

- Harmonic currents contribute to system losses (in cabling, transformer)
- Harmonic voltage distortion causes disturbance to other loads and increase losses in other loads

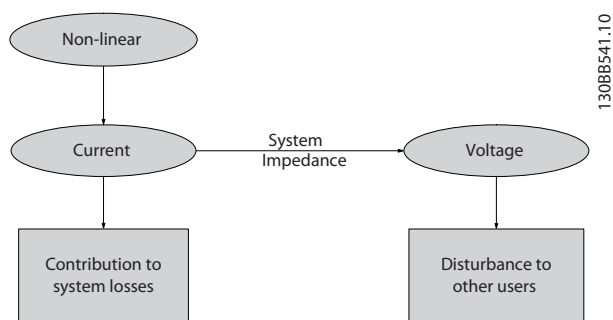


Illustration 3.26 Negative Effects of Harmonics

The choice of the right solution depends on several factors:

- The grid (background distortion, mains unbalance, resonance and type of supply (transformer/generator))
- Application (load profile, number of loads and load size)
- Local/national requirements/regulations (IEEE519, IEC, G5/4, etc.)
- Total cost of ownership (initial cost, efficiency, maintenance, etc.)

3.4.5.3 Harmonic Limitation Standards and Requirements

The requirements for harmonic limitation can be:

- Application specific requirements
- Standards that must be observed

The application specific requirements are related to a specific installation where there are technical reasons for limiting the harmonics.

Example: a 250 kVA transformer with two 110 kW motors connected is sufficient if one of the motors is connected directly on-line and the other is supplied through a frequency converter. However, the transformer will be undersized if both motors are frequency converter supplied. Using additional means of harmonic reduction within the installation or choosing low harmonic drive variants makes it possible for both motors to run with frequency converters.

There are various harmonic mitigation standards, regulations and recommendations. Different standards apply in different geographical areas and industries. The following standards are the most common:

- IEC61000-3-2
- IEC61000-3-12
- IEC61000-3-4
- IEEE 519
- G5/4

See the *Advanced Harmonic Filter Design Guide 005/010, MG80C* for specific details on each standard.

3.4.5.4 Harmonic Mitigation

In cases where additional harmonic suppression is required Danfoss offers a wide range of mitigation equipment. These are:

- VLT 12-pulse drives
- VLT AHF filters
- VLT Low Harmonic Drives
- VLT Active Filters

3.4.5.5 Harmonic Calculation

Determining the degree of voltage pollution on the grid and needed precaution is done with the Danfoss MCT31 calculation software. From www.danfoss.com the free tool VLT® Harmonic Calculation MCT 31 can be downloaded. The software is built with a focus on user-friendliness and limited to involve only system parameters that are normally accessible.

Use RCD relays, multiple protective earthing or earthing as extra protection, provided that local safety regulations are complied with.

If an earth fault appears, a DC content may develop in the faulty current.

If RCD relays are used, local regulations must be observed. Relays must be suitable for protection of 3-phase equipment with a bridge rectifier and for a brief discharge on power-up using RCDs see *2.4 Earth Leakage Current* for further information.

3.4.6 Final Test and Setup

3.4.6.1 High Voltage Test

Carry out a high voltage test by short-circuiting terminals U, V, W, L₁, L₂ and L₃. Energize maximum 2.15 kV DC for 380-500 V frequency converters, for one second between this short-circuit and the chassis.



When running high voltage tests of the entire installation, interrupt the mains and motor connection if the leakage currents are too high.

3.4.6.2 Earthing

The following basic issues need to be considered when installing a frequency converter, so as to obtain electro-magnetic compatibility (EMC).

- Safety earthing: note that the frequency converter has a high leakage current and must be earthed

appropriately for safety reasons. Apply local safety regulations.

- High-frequency earthing: Keep the earth wire connections as short as possible.

Connect the different earth systems at the lowest possible conductor impedance. The lowest possible conductor impedance is obtained by keeping the conductor as short as possible and by using the greatest possible surface area. The metal cabinets of the different devices are mounted on the cabinet rear plate using the lowest possible HF impedance. This avoids having different HF voltages for the individual devices and avoids the risk of radio interference currents running in connection cables that may be used between the devices. The radio interference will have been reduced.

In order to obtain a low HF impedance, use the fastening bolts of the devices as HF connection to the rear plate. It is necessary to remove insulating paint or similar from the fastening points.

3.4.6.3 Safety Earth Connection

The frequency converter has a high leakage current and must be earthed appropriately for safety reasons according to IEC 61800-5-1.

⚠ WARNING

The earth leakage current from the frequency converter exceeds 3.5 mA. To ensure a good mechanical connection from the earth cable to the earth connection (terminal 95), the cable cross-section must be at least 10 mm² or 2 rated earth wires terminated separately.

3.4.6.4 Final Setup Check

To check the setup and ensure that the frequency converter is running, follow these steps.

Step 1. Locate the motor name plate

NOTE

The motor is either star- (Y) or delta- connected (Δ). This information is located on the motor name plate data.

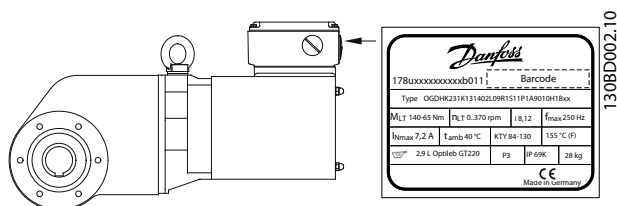


Illustration 3.27 Location of Motor Name Plate

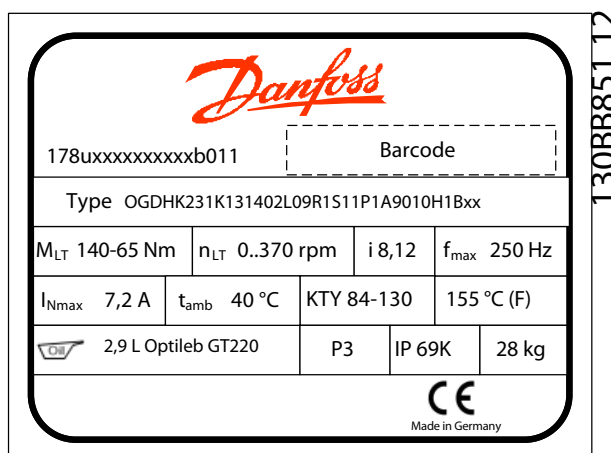


Illustration 3.28 Name Plate

Step 2. Check the motor name plate data in this parameter list.

To access this list first press the [Quick Menu] key on the LCP then select "Q2 Quick Setup".

- 1-20 Motor Power [kW]
1-21 Motor Power [HP]
- 1-22 Motor Voltage
- 1-23 Motor Frequency
- 1-24 Motor Current
- 1-25 Motor Nominal Speed

Step 3. Select OGD motor data

- Set 1-11 Motor Model to 'Danfoss OGD LA10'.

Step 4. Set speed limit and ramp times

Set up the desired limits for speed and ramp time:

- 3-02 Minimum Reference
- 3-03 Maximum Reference
- 4-11 Motor Speed Low Limit [RPM] or 4-12 Motor Speed Low Limit [Hz]
- 4-13 Motor Speed High Limit [RPM] or 4-14 Motor Speed High Limit [Hz]
- 3-41 Ramp 1 Ramp up Time
- 3-42 Ramp 1 Ramp Down Time

3.5 Ambient Conditions

3.5.1 Air Humidity

The frequency converter has been designed to meet the IEC/EN 60068-2-3 standard, EN 50178 pkt. 9.4.2.2 at 50 °C.

3.5.2 Aggressive Environments

A frequency converter contains a large number of mechanical and electronic components. All are to some extent vulnerable to environmental effects.

CAUTION

The frequency converter should not be installed in environments with airborne liquids, particles, or gases capable of affecting and damaging the electronic components. Failure to take the necessary protective measures increases the risk of stoppages, thus reducing the life of the frequency converter.

Degree of protection as per IEC 60529

The Safe Stop function may only be installed and operated in a control cabinet with degree of protection IP54 or higher (or equivalent environment). This is required to avoid cross faults and short circuits between terminals, connectors, tracks and safety-related circuitry caused by foreign objects.

Liquids can be carried through the air and condense in the frequency converter and may cause corrosion of components and metal parts. Steam, oil, and salt water may cause corrosion of components and metal parts. In such environments, use equipment with enclosure rating IP54/55. As an extra protection, coated printed circuit boards can be ordered as an option.

Airborne Particles such as dust may cause mechanical, electrical, or thermal failure in the frequency converter. A typical indicator of excessive levels of airborne particles is dust particles around the frequency converter fan. In very dusty environments, use equipment with enclosure rating IP54/55 or a cabinet for IP00/IP20/TYPE 1 equipment.

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

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

NOTE

Mounting frequency converters in aggressive environments increases the risk of stoppages and considerably reduces the life of the converter.

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

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

D and E enclosures have a stainless steel back-channel option to provide additional protection in aggressive environments. Proper ventilation is still required for the internal components of the frequency converter. Contact Danfoss for additional information.

3.5.3 Vibration and Shock

The frequency converter has been tested according to the procedure based on the shown standards:

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

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

3.5.4 Acoustic Noise

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

1. DC intermediate circuit coils.
2. Integral fan.
3. RFI filter choke.

Refer to 6 *Specifications* for acoustic noise data.

4 Application Examples

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

- Parameter settings are the regional default values unless otherwise indicated (selected in *0-03 Regional Settings*)
- Parameters associated with the terminals and their settings are shown next to the drawings
- Where switch settings for analog terminals A53 or A54 are required, these are also shown

A jumper wire may be required between terminal 12 (or 13) and terminal 27 for the frequency converter to operate when using factory default programming values. See *4.9.1.1 Terminal 37 Safe Stop Function* for details.

		Parameters	
FC		Function	Setting
+24 V	12	1-29 Automatic Motor Adaptation (AMA)	[1] Enable complete AMA
+24 V	13		
D IN	18		
D IN	19		
COM	20		
D IN	27	5-12 Terminal 27 Digital Input	[2]* Coast inverse
D IN	29	*=Default Value	
D IN	32		
D IN	33		
D IN	37		
+10 V	50		
A IN	53	Notes/comments: Parameter group 1-2* must be set according to motor	
A IN	54		
COM	55		
A OUT	42		
COM	39		

Table 4.1 AMA with T27 Connected

		Parameters	
FC		Function	Setting
+24 V	12	1-29 Automatic Motor Adaptation (AMA)	[1] Enable complete AMA
+24 V	13		
D IN	18		
D IN	19		
COM	20		
D IN	27	5-12 Terminal 27 Digital Input	[0] No operation
D IN	29		
D IN	32	*=Default Value	
D IN	33		
D IN	37	Notes/comments: Parameter group 1-2* must be set according to motor	
+10 V	50		
A IN	53		
A IN	54		
COM	55		
A OUT	42		
COM	39		

Table 4.2 AMA without T27 Connected

		Parameters	
FC		Function	Setting
+24 V	12	6-10 Terminal 53 Low Voltage	0.07 V*
+24 V	13		
D IN	18		
D IN	19		
COM	20		
D IN	27	6-11 Terminal 53 High Voltage	10 V*
D IN	29	6-14 Terminal 53 Low Ref./Feedb. Value	0 RPM
D IN	32		
D IN	33		
D IN	37	6-15 Terminal 53 High Ref./Feedb. Value	1500 RPM
		*=Default Value	
		Notes/comments:	

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Table 4.3 Analog Speed Reference (Voltage)

		Parameters	
FC		Function	Setting
+24 V	12		
+24 V	13		
D IN	18	6-12 Terminal 53	4 mA*
D IN	19	Low Current	
COM	20	6-13 Terminal 53	20 mA*
D IN	27	High Current	
D IN	29	6-14 Terminal 53	0 RPM
D IN	32	Low Ref./Feedb.	
D IN	33	Value	
D IN	37	6-15 Terminal 53	1500 RPM
		High Ref./Feedb.	
		Value	
+10 V	50	*=Default Value	
A IN	53	Notes/comments:	
A IN	54		
COM	55		
A OUT	42		
COM	39		

Table 4.4 Analog Speed Reference (Current)

		Parameters	
FC		Function	Setting
+24 V	12		
+24 V	13		
D IN	18	5-10 Terminal 18	[8] Start*
D IN	19	Digital Input	
COM	20	5-12 Terminal 27	[0] No operation
D IN	27	Digital Input	
D IN	29	5-19 Terminal 37	[1] Safe Stop
D IN	32	Safe Stop	
D IN	33	Alarm	
D IN	37	*=Default Value	
		Notes/comments:	
+10	50		
A IN	53		
A IN	54		
COM	55		
A OUT	42	If 5-12 Terminal 27 Digital Input is set to [0] No operation, a jumper wire to terminal 27 is not needed.	
COM	39		

Table 4.5 Start/Stop Command with Safe Stop

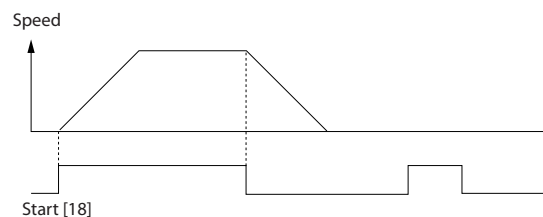


Illustration 4.1 Start/Stop Command with Safe Stop

		Parameters	
FC		Function	Setting
+24 V	12		
+24 V	13		
D IN	18	5-10 Terminal 18	[9] Latched
D IN	19	Digital Input	
COM	20	5-12 Terminal 27	[6] Stop
D IN	27	Digital Input	
D IN	29	*=Default Value	
D IN	32	Notes/comments:	
D IN	33		
D IN	37		
+10 V	50		
A IN	53		
A IN	54	If 5-12 Terminal 27 Digital Input is set to [0] No operation, a jumper wire to terminal 27 is not needed.	
COM	55		
A OUT	42		
COM	39		

Table 4.6 Pulse Start/Stop

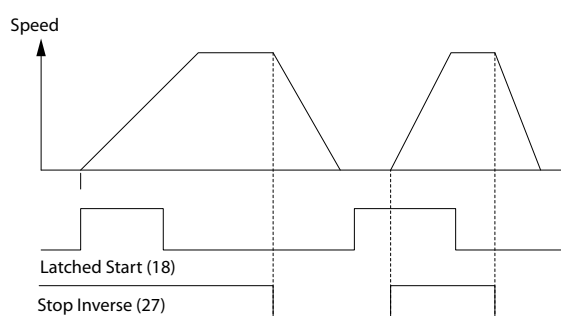


Illustration 4.2 Pulse Start/Stop

Parameters	
Function	Setting
5-10 Terminal 18 Digital Input	[8] Start
5-11 Terminal 19 Digital Input	[10] Reversing*
5-12 Terminal 27 Digital Input	[0] No operation
5-14 Terminal 32 Digital Input	[16] Preset ref bit 0
5-15 Terminal 33 Digital Input	[17] Preset ref bit 1
3-10 Preset Reference	
Preset ref. 0	25%
Preset ref. 1	50%
Preset ref. 2	75%
Preset ref. 3	100%
*=Default Value	
Notes/comments:	

Table 4.7 Start/Stop with Reversing and 4 Preset Speeds

Parameters	
Function	Setting
5-11 Terminal 19 Digital Input	[1] Reset
*=Default Value	
Notes/comments:	

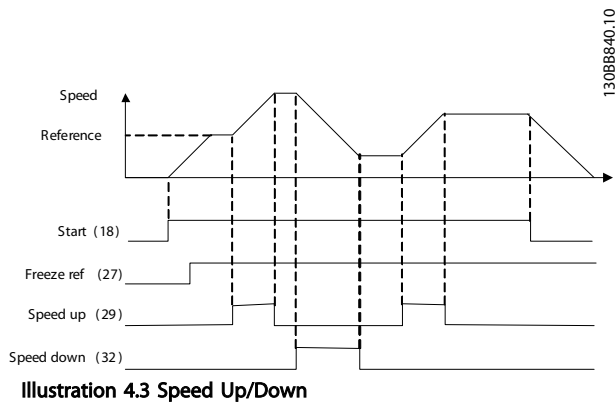
Table 4.8 External Alarm Reset

Parameters	
Function	Setting
6-10 Terminal 53 Low Voltage	0.07 V*
6-11 Terminal 53 High Voltage	10 V*
6-14 Terminal 53 Low Ref./Feedb. Value	0 RPM
6-15 Terminal 53 High Ref./Feedb. Value	1500 RPM
*=Default Value	
Notes/comments:	

Table 4.9 Speed Reference (using a manual potentiometer)

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 4.10 Speed Up/Down



Parameters	
Function	Setting
FC	
+24 V 12	
+24 V 13	
D IN 18	
D IN 19	
COM 20	
D IN 27	
D IN 29	
D IN 32	
D IN 33	
D IN 37	
+10 V 50	
A IN 53	
A IN 54	
COM 55	
A OUT 42	
COM 39	
R1 01	
R1 02	
R1 03	
R2 04	
R2 05	
R2 06	
61	
68	
69	
RS-485	

Notes/comments:
Select protocol, address and baud rate in the above mentioned parameters.

Table 4.11 RS-485 Network Connection

Parameters	
Function	Setting
FC	
+24 V 12	
+24 V 13	
D IN 18	
D IN 19	
COM 20	
D IN 27	
D IN 29	
D IN 32	
D IN 33	
D IN 37	
+10 V 50	
A IN 53	
A IN 54	
COM 55	
A OUT 42	
COM 39	
U - I	
A53	

Notes/comments:
If only a warning is desired, 1-90 Motor Thermal Protection should be set to [1] Thermistor warning.

Table 4.12 Motor Thermistor

CAUTION

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

		Parameters	
FC		Function	Setting
+24 V	12	4-30 Motor Feedback Loss Function	[1] Warning
+24 V	13		
D IN	18		
D IN	19		
COM	20		
D IN	27		
D IN	29		
D IN	32		
D IN	33	4-31 Motor Feedback Speed Error	100RPM
D IN	37		
		4-32 Motor Feedback Loss Timeout	5 s
+10 V	50	7-00 Speed PID Feedback Source	[2] MCB 102
A IN	53	17-11 Resolution (PPR)	1024*
A IN	54		
COM	55	13-00 SL Controller Mode	[1] On
A OUT	42		
COM	39	13-01 Start Event	[19] Warning
		13-02 Stop Event	[44] Reset key
		13-10 Comparator Operand	[21] Warning no.
		13-11 Comparator Operator	[1] ≈*
		13-12 Comparator Value	90
		13-51 SL Controller Event	[22] Comparator 0
		13-52 SL Controller Action	[32] Set digital out A low
		5-40 Function Relay	[80] SL digital output A
		*=Default Value	
		Notes/comments:	
		If the limit in the feedback monitor is exceeded, Warning 90 will be issued. The SLC monitors Warning 90 and in the case that Warning 90 becomes TRUE then Relay 1 is triggered. External equipment may then indicate that service may be required. If the feedback error goes below the limit again within 5 then the drive continues and the warning disappears. But Relay 1 will still be triggered until [Reset] on the LCP.	

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R1	01 02 03
R2	04 05 06

Table 4.13 Using SLC to Set a Relay

		Parameters		
FC		Function	Setting	
+24 V	12	5-40 Function Relay	[32] Mech. brake ctrl.	
+24 V	13			
D IN	18			
D IN	19			
COM	20	5-10 Terminal 18 Digital Input	[8] Start*	
D IN	27	5-11 Terminal 19 Digital Input	[11] Start reversing	
D IN	29			
D IN	32	1-71 Start Delay	0.2	
D IN	33	1-72 Start Function	[5] VVC ^{plus} /FLUX Clockwise	
D IN	37			
+10 V	50	1-76 Start Current	Im,n	
A IN	53			
A IN	54	2-20 Release Brake Current	App. dependent	
COM	55			
A OUT	42	2-21 Activate Brake Speed [RPM]	Half of nominal slip of the motor	
COM	39			
R1	01	*=Default Value		
	02			
	03			
R2	04	Notes/comments:		
	05			
	06			

Table 4.14 Mechanical Brake Control

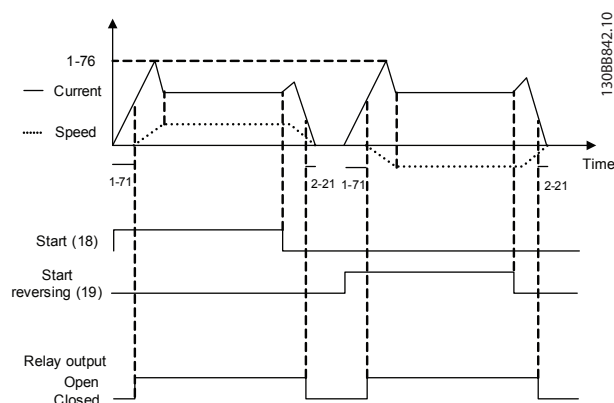


Illustration 4.4 Mechanical Brake Control

4.1 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 will be shown.

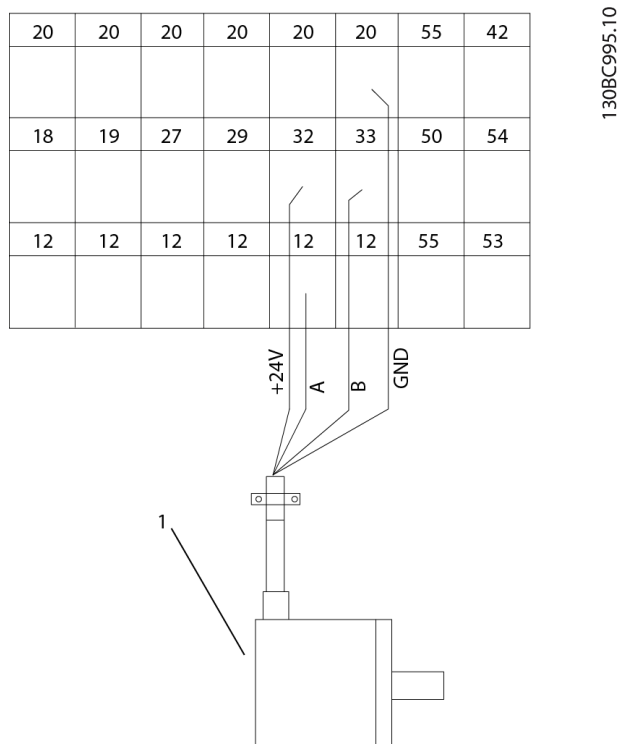


Illustration 4.5 Encoder Connection to the Frequency Converter

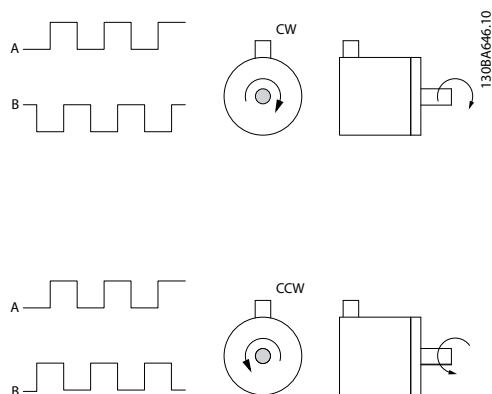


Illustration 4.6 24 V Incremental Encoder with Maximum Cable Length 5 m

4.2 Encoder Direction

The direction of encoder is determined by which order the pulses are entering the drive.

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 determined by looking into the shaft end.

4.3 Closed Loop Drive System

A closed loop drive system usually comprises elements such as:

- Motor
- Add (Gearbox) (Mechanical Brake)
- Frequency converter
- Encoder as feed-back system
- Brake resistor for dynamic braking
- Transmission
- Load

Applications demanding mechanical brake control will usually need a brake resistor.

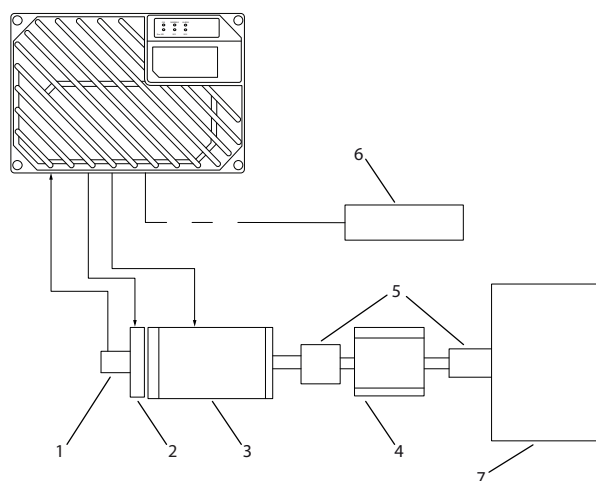


Illustration 4.7 Basic Set-up for Closed Loop Speed Control

Item	Description
1	Encoder
2	Mechanical brake
3	Motor
4	Gearbox
5	Transmission
6	Brake resistor
7	Load

Table 4.15 Legend

4.4 PID Control

4.4.1 Speed PID Control

1-00 Configuration Mode	1-01 Motor Control Principle			
	U/f	VVC ^{plus}	Flux Sensorless	Flux w/ enc. feedb
[0] Speed open loop	Not Active	Not Active	ACTIVE	N.A.
[1] Speed closed loop	N.A.	ACTIVE	N.A.	ACTIVE
[2] Torque	N.A.	N.A.	N.A.	Not Active
[3] Process		Not Active	ACTIVE	ACTIVE

Table 4.16 Control configurations where the Speed Control is active

"N.A." means that the specific mode is not available at all.

"Not Active" means that the specific mode is available but the Speed Control is not active in that mode.

NOTE

The Speed Control PID will work under the default parameter setting, but tuning the parameters is highly recommended to optimize the motor control performance. The two Flux motor control principles are particularly dependant on proper tuning to yield their full potential.

4.4.2 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.
30-83 Speed PID Proportional Gain	The higher the value - the quicker the control. However, too high value may lead to oscillations.
7-03 Speed PID Integral Time	Eliminates steady state speed error. Lower value means quick reaction. However, too low 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 zero 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 large filter time will deteriorate the dynamic performance of the Speed PID control.
	Practical settings of parameter 7-06 taken from the number of pulses per revolution on from encoder (PPR):
	Encoder PPR
	7-06 Speed PID Lowpass Filter Time
	512
	10 ms
	1024
	5 ms
	2048
	2 ms
	4096
	1 ms

Table 4.17 Parameters Relevant for the Speed Control

Example of how to Programme the Speed Control

In this case 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 (1024 pulses per revolution) connected to terminals 32 and 33.

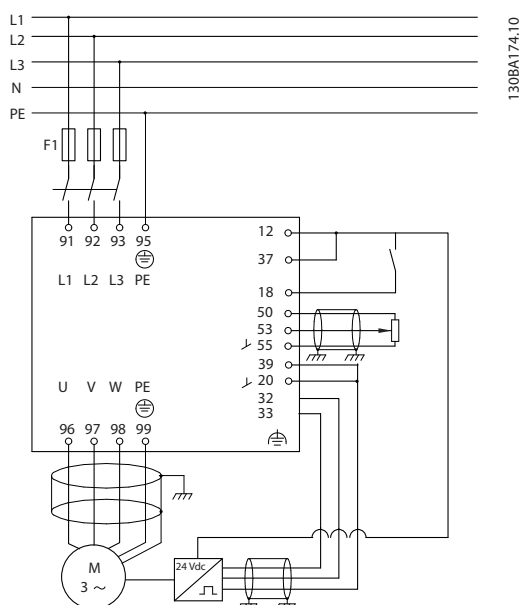


Illustration 4.8 Example - Speed Control Connections

The following must be programmed in order shown (see explanation of settings in the *FCD 302 Programming Guide, MG04G*)

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

Function	Parameter no.	Setting
1) Make sure the motor runs properly. Do the following:		
Set the motor parameters using name plate data	1-2*	As specified by motor name plate
Have the frequency converter makes an Automatic Motor Adaptation	1-29 <i>Automatic Motor Adaptation (AMA)</i>	[1] Enable complete AMA
2) Check the motor is running and the encoder is attached properly. Do the following:		
Press the "Hand On" LCP key. 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.
Go to <i>16-20 Motor Angle</i> . Turn the motor slowly in the positive direction. It must be turned so slowly (only a few RPM) that it can be determined if the value in <i>16-20 Motor Angle</i> is increasing or decreasing.	<i>16-20 Motor Angle</i>	N.A. (read-only parameter) Note: An increasing value overflows at 65535 and starts again at 0.
If <i>16-20 Motor Angle</i> is decreasing then change the encoder direction in <i>5-71 Term 32/33 Encoder Direction</i> .	<i>5-71 Term 32/33 Encoder Direction</i>	[1] Counter clockwise (if <i>16-20 Motor Angle</i> is decreasing)
3) Make sure the drive limits are set to safe values		
Set acceptable limits for the references.	3-02 Minimum Reference 3-03 Maximum Reference	0 RPM (default) 1500 RPM (default)
Check that the ramp settings are within drive capabilities and allowed application operating specifications.	3-41 Ramp 1 Ramp up Time 3-42 Ramp 1 Ramp Down Time	default setting default setting
Set acceptable limits for the motor speed and frequency.	4-11 Motor Speed Low Limit [RPM] 4-13 Motor Speed High Limit [RPM] 4-19 Max Output Frequency	0 RPM (default) 1500 RPM (default) 60 Hz (default 132 Hz)
4) Configure the Speed Control and select the Motor Control principle		
Activation of Speed Control	1-00 Configuration Mode	[1] Speed closed loop

Function	Parameter no.	Setting
Selection of Motor Control Principle	1-01 Motor Control Principle	[3] Flux w motor feedb
5) Configure and scale the reference to the Speed Control		
Set up Analog Input 53 as a reference Source	3-15 Reference Resource 1	Not necessary (default)
Scale Analog Input 53 0 RPM (0 V) to 1500 RPM (10 V)	6-1*	Not necessary (default)
6) Configure the 24V 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 5-15 Terminal 33 Digital Input	[0] No operation (default)
Choose terminal 32/33 as motor feedback	1-02 Flux Motor Feedback Source	Not necessary (default)
Choose terminal 32/33 as Speed PID feedback	7-00 Speed PID Feedback Source	Not necessary (default)
7) Tune the Speed Control PID parameters		
Use the tuning guidelines when relevant or tune manually	7-0*	See the guidelines below
8) Finished!		
Save the parameter setting to the LCP for safe keeping	0-50 LCP Copy	[1] All to LCP

Table 4.18 Speed Control Settings

4.4.3 Tuning PID Speed Control

The following tuning guidelines are relevant when using one of the Flux motor control principles in applications where the load is mainly inertial (with a low amount of friction).

The value of *30-83 Speed PID Proportional Gain* is dependent on the combined inertia of the motor and load, and the selected bandwidth can be calculated using the following formula:

$$Par. 7 - 02 = \frac{Total\ inertia [kgm^2] \times par. 1 - 25}{Par. 1 - 20 \times 9550} \times Bandwidth [rad / s]$$

NOTE

1-20 Motor Power [kW] is the motor power in [kW] (i.e. enter '4' kW instead of '4000' W in the formula).

A practical value for the Bandwidth is 20 rad/s. Check the result of the *30-83 Speed PID Proportional Gain* calculation against the following formula (not required if you are using a high resolution feedback such as a SinCos feedback):

$$Par. 7 - 02_{MAX} = \frac{0.01 \times 4 \times Encoder\ Resolution \times Par. 7 - 06}{2 \times \pi} \times Max\ torque\ ripple [\%]$$

A good start value for *7-06 Speed PID Lowpass Filter Time* is 5 ms (lower encoder resolution calls for a higher filter value). Typically a Max Torque Ripple of 3 % is acceptable. For incremental encoders the Encoder Resolution is found in either *5-70 Term 32/33 Pulses per Revolution* (24V HTL on

standard drive) or *17-11 Resolution (PPR)* (5V TTL on MCB102 Option).

Generally the practical maximum limit of *30-83 Speed PID Proportional Gain* is determined by the encoder resolution and the feedback filter time but other factors in the application might limit the *30-83 Speed PID Proportional Gain* to a lower value.

To minimize the overshoot, *7-03 Speed PID Integral Time* could be set to approx. 2.5 s (varies with the application).

7-04 Speed PID Differentiation Time should be set to 0 until everything else is tuned. If necessary finish the tuning by experimenting with small increments of this setting.

4.4.4 Process PID Control

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

Table 4.19 shows the control configurations where the Process Control is possible. When a Flux Vector motor control principle is used, take care also to tune the Speed Control PID parameters. Refer to the section about the Control Structure to see where the Speed Control is active.

1-00 Configuration Mode	1-01 Motor Control Principle			
	U/f	VVC ^{plus}	Flux Sensorless	Flux w/ enc. feedback
[3] Process	N.A.	Process	Process & Speed	Process & Speed

Table 4.19 Process PID Control Settings

NOTE

The Process Control PID will work under the default parameter setting, but tuning the parameters is highly recommended to optimise the application control performance. The two Flux motor control principles are specially dependant on proper Speed Control PID tuning (prior to tuning the Process Control PID) to yield their full potential.

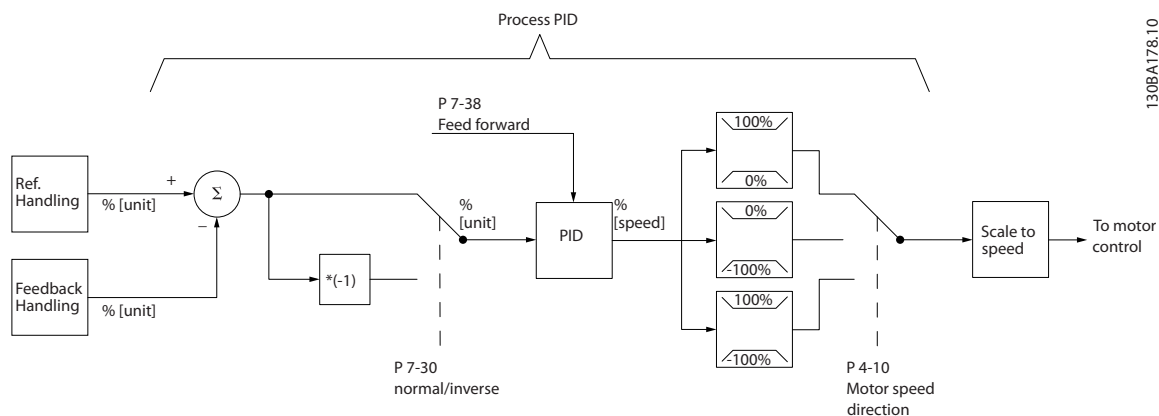


Illustration 4.9 Process PID Control Diagram

4.4.5 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 two feedback signals will be added together before being used in the Process PID Control.
7-30 Process PID Normal/ Inverse Control	Under [0] Normal operation the Process Control will respond with an increase of the motor speed if the feedback is getting lower than the reference. In the same situation, but under [1] Inverse operation, the Process Control will respond 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 will be set to a gain that corresponds to the actual frequency. This avoids integrating on an error that cannot in any case be compensated for by means of 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 very long time. In such applications it might 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 value may lead to oscillations.
7-34 Process PID Integral Time	Eliminates steady state speed error. Lower value means quick reaction. However, too small 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 zero 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 application 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.
5-54 Pulse Filter Time Constant #29 (Pulse term. 29), 5-59 Pulse Filter Time Constant #33 (Pulse term. 33), 6-16 Terminal 53 Filter Time Constant (Analog term 53), 6-26 Terminal 54 Filter Time Constant (Analog term. 54)	<p>If there are oscillations of the current/voltage feedback signal, these can be dampened by means of a low-pass filter. This 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 will be 10 RAD/s (the reciprocal of 0.1 s), corresponding to $(10/(2 \times \pi))=1.6$ Hz. This means that all currents/ voltages that vary by more than 1.6 oscillations per second will be damped by the filter. The control will only be 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 large filter time will deteriorate the dynamic performance of the Process PID Control.</p>

Table 4.20 Parameters are Relevant for the Process Control

4.4.6 Example of Process PID Control

Illustration 4.10 is an example of a Process PID Control used in a ventilation system.

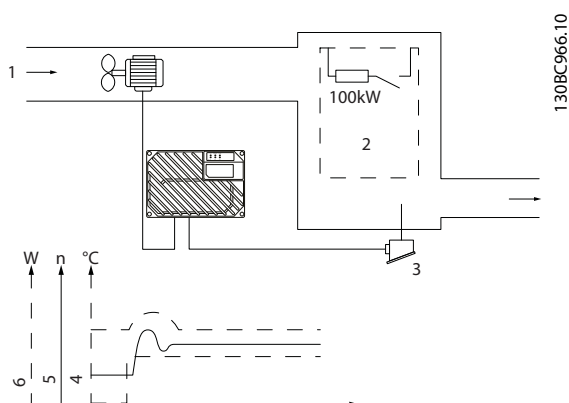


Illustration 4.10 Process PID Control in Ventilation System

Item	Description
1	Cold air
2	Heat generating process
3	Temperature transmitter
4	Temperature
5	Fan speed
6	Heat

Table 4.21 Legend

In a ventilation system, the temperature is to be settable from -5 to 35 °C with a potentiometer of 0 to 10 V. The task of the process control is to maintain temperature at a constant preset level.

The control is of the inverse type, which means that when the temperature increases, the ventilation speed is increased as well, so as 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. Min./Max. speed 300/1500 RPM.

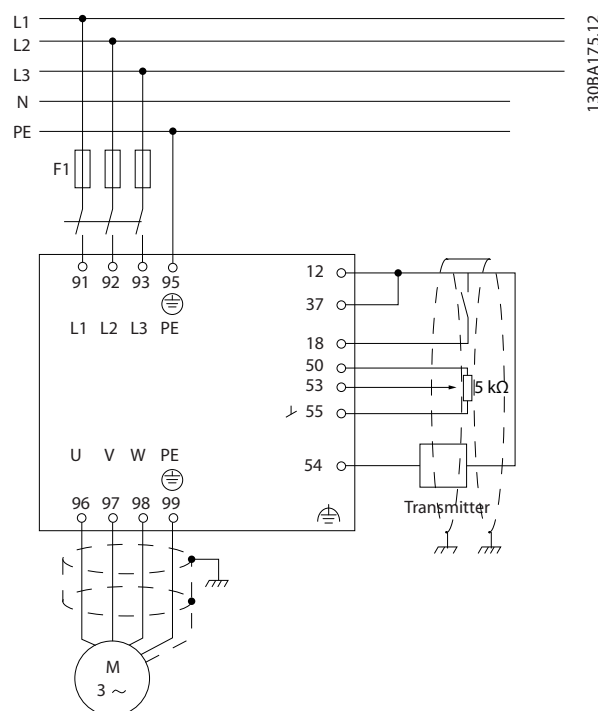


Illustration 4.11 Two-wire Transmitter

1. Start/Stop via switch connected to terminal 18.
2. Temperature reference via potentiometer (-5 to 35 °C, 0 to 10 V DC) connected to terminal 53.
3. Temperature feedback via transmitter (-10 to 40 °C, 4 to 20 mA) connected to terminal 54. Switch S202 set to ON (current input).

Function	Par. no.	Setting
Initialize the frequency converter	14-22	[2] Initialization - 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 right direction. When motor is connected to frequency converter with straight forward phase order as U - U; V- V; W - W motor shaft usually turns clockwise seen into shaft end.		
Press "Hand On" LCP key. Check shaft direction by applying a manual reference.		
If motor turns opposite of required direction: 1. Change motor direction in <i>4-10 Motor Speed Direction</i> 2. Turn off mains - wait for DC link to discharge - switch two of the motor phases	4-10	Select correct motor shaft direction
Set configuration mode	1-00	[3] Process
Set Local Mode Configuration	1-05	[0] Speed Open Loop
3) Set reference configuration, ie. the range for reference handling. Set scaling of analog input in par. 6-xx		
Set reference/feedback units	3-01	[60] °C Unit shown on display
Set min. reference (10° C)	3-02	-5 °C
Set max. reference (80° C)	3-03	35 °C
If set value is determined from a preset value (array parameter), set other reference sources to No Function	3-10	[0] 35% $Ref = \frac{Par. 3 - 10_{(0)}}{100} \times ((Par. 3 - 03) - (par. 3 - 02)) = 24,5^{\circ}C$ 3-14 Preset Relative Reference to 3-18 Relative Scaling Reference 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 min. speed limits	4-11	300 RPM
Set motor speed max. limit	4-13	1500 RPM
Set max. output frequency	4-19	60 Hz
Set S201 or S202 to wanted analog input function (Voltage (V) or milli-Amps (I))		
NOTE Switches are sensitive - Make a power cycling keeping default setting of V		
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 4.22 Example of Process PID Control Set-up

4.4.7 Optimisation of the Process Regulator

The basic settings have now been made; all that needs to be done is to 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, this can be done by following these guidelines:

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. Then reduce the value until the feedback signal has stabilised. Now 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 very fast-acting systems only (differentiation time). The typical value is four times the set integration time. The differentiator should only be used when the setting of the proportional gain and the integration time has been fully optimised. Make sure that oscillations on the feedback signal is sufficiently dampened by the lowpass filter on the feedback signal.

NOTE

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

4.4.8 Ziegler Nichols Tuning Method

In order to tune the PID controls of the frequency converter, several tuning methods can be used. One approach is to use a technique which was developed in the 1950s but which has stood the test of time and is still used today. This method is known as the Ziegler Nichols tuning method.

NOTE

The method described must not be used on 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. The proportional gain is increased until continuous oscillations are observed (as measured on the feedback), that is, until the system becomes marginally stable. The corresponding gain (K_u) is called the ultimate gain. The period of the oscillation (P_u)

(called the ultimate period) is determined as shown in Illustration 4.12.

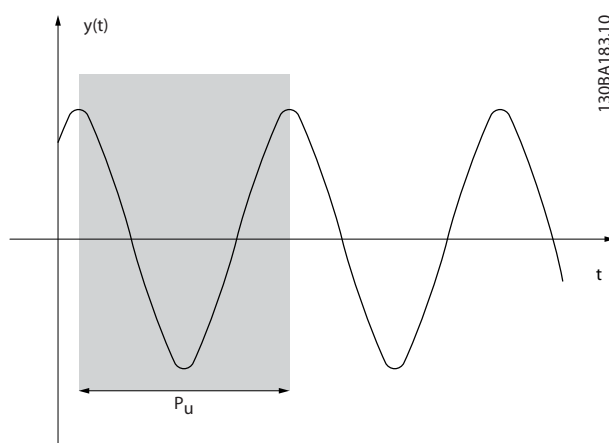


Illustration 4.12 Marginally Stable System

Measure P_u when the amplitude of oscillation is quite small. Then "back off" from this gain again, as shown in Table 4.23.

K_u is the gain at which the oscillation is obtained.

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 4.23 Ziegler Nichols Tuning for Regulator, based on a Stability Boundary.

Experience has shown that the control setting according to Ziegler Nichols rule provides a good closed loop response for many systems. The process operator can do the final tuning of the control iteratively to yield satisfactory control.

Step-by-step Description

Step 1: Select only proportional control, meaning that the Integral time is selected to the maximum value, while the differentiation time is selected to zero.

Step 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.

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

Step 4: Use Table 4.23 to calculate the necessary PID control parameters.

4.4.9 Example of Process PID Control

Illustration 4.10 is an example of a Process PID Control used in a ventilation system.

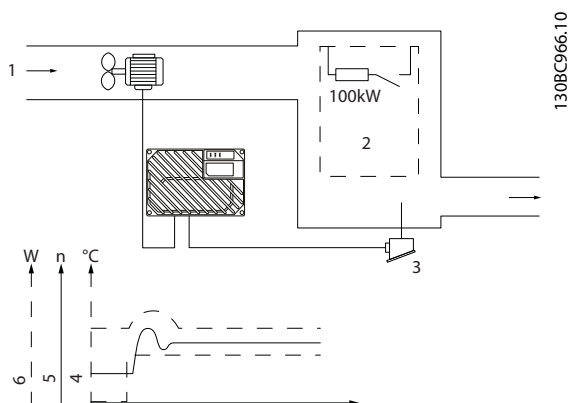


Illustration 4.13 Process PID Control in Ventilation System

Item	Description
1	Cold air
2	Heat generating process
3	Temperature transmitter
4	Temperature
5	Fan speed
6	Heat

Table 4.24 Legend

In a ventilation system, the temperature is to be settable from -5 to 35 °C with a potentiometer of 0 to 10 V. The task of the process control is to maintain temperature at a constant preset level.

The control is of the inverse type, which means that when the temperature increases, the ventilation speed is increased as well, so as 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. Min./Max. speed 300/1500 RPM.

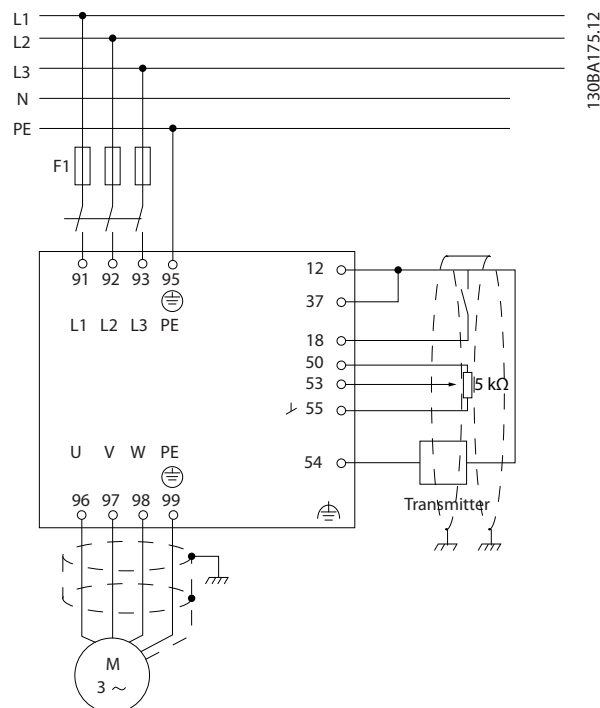


Illustration 4.14 Two-wire Transmitter

1. Start/Stop via switch connected to terminal 18.
2. Temperature reference via potentiometer (-5 to 35 °C, 0 to 10 V DC) connected to terminal 53.
3. Temperature feedback via transmitter (-10 to 40 °C, 4 to 20 mA) connected to terminal 54. Switch S202 set to ON (current input).

4.5 Control Structures

4.5.1 Control Structure in VVC^{plus} Advanced Vector Control

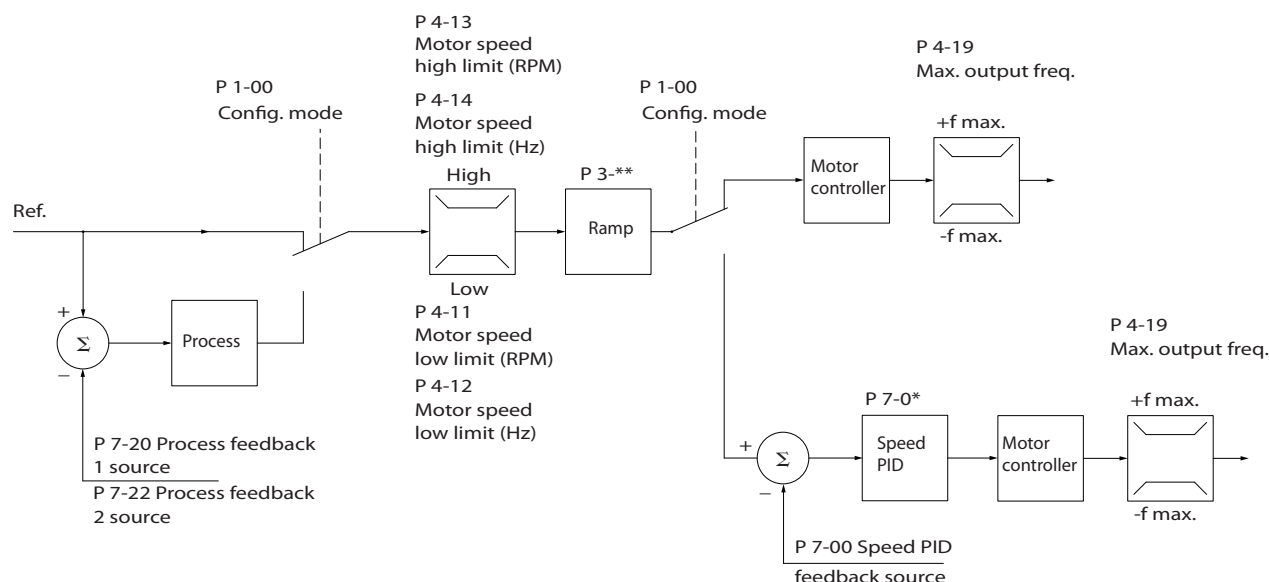


Illustration 4.15 Control Structure in VVC^{plus} Open Loop and Closed Loop Configurations

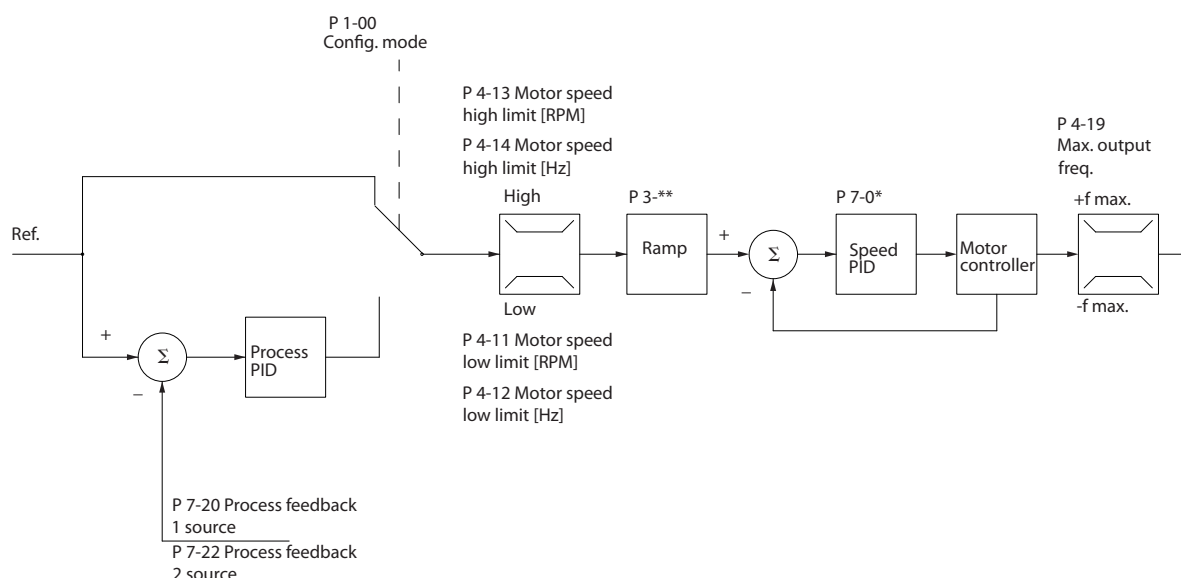
In the configuration shown in *Illustration 4.15*, 1-01 Motor Control Principle is set to [1] VVC^{plus} and 1-00 Configuration Mode is set to [0] Speed open loop. The resulting reference from the reference handling system is received and fed through the ramp limitation and speed limitation before being 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 passes from the ramp limitation and speed limitation into a speed PID control. The Speed PID control parameters are located in the parameter group 7-0*. 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 for example, speed or pressure in the controlled application. The Process PID parameters are located in parameter group 7-2* and 7-3*.

4.5.2 Control Structure in Flux Sensorless

Control structure in Flux sensorless open loop and closed loop configurations.



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Illustration 4.16 Control Structure in Flux Sensorless

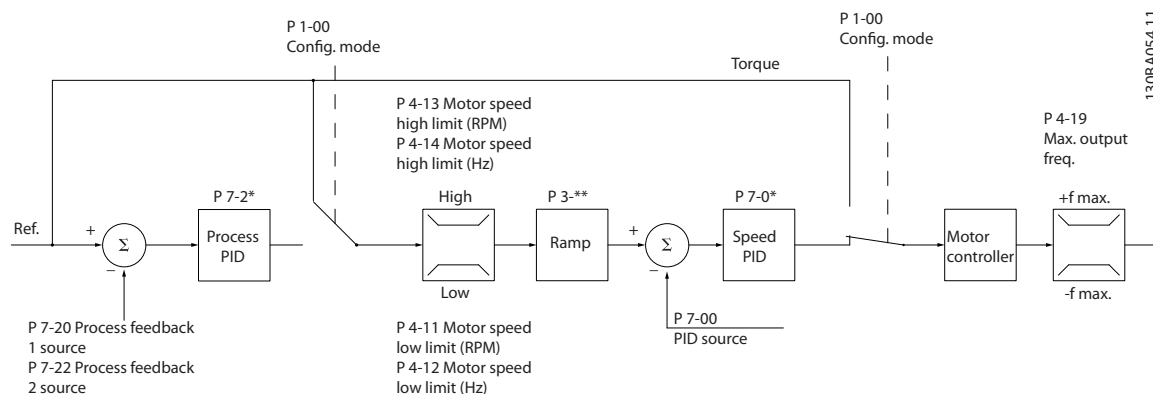
In the configuration shown, 1-01 Motor Control Principle is set to [2] Flux sensorless and 1-00 Configuration Mode is set to [0] Speed open loop. The resulting reference from the reference handling system is fed through the ramp and speed limitations as determined by the parameter settings indicated.

The Speed PID must be set with its P,I, and D parameters (parameter group 7-0*).

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 found in parameter group 7-2* and 7-3*.

An estimated speed feedback is generated to the Speed PID to control the output frequency.

4.5.3 Control Structure in Flux with Motor Feedback



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Illustration 4.17 Control Structure in Flux with Motor Feedback

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

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

The motor control in this configuration relies on a feedback signal from an encoder mounted directly on the motor (set in 1-02 Flux Motor Feedback Source).

Select [2] Torque in 1-00 Configuration Mode to use the resulting reference directly as a torque reference. Torque

control can only be selected in the *Flux with motor feedback (1-01 Motor Control Principle)* configuration. When this mode has been selected, the reference uses the Nm unit. It requires no torque feedback, since the actual torque is calculated based on the current measurement of the frequency converter.

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

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

The frequency converter can be operated manually via the local control panel (LCP) or remotely via analog and digital inputs and serial bus. If allowed in 0-40 [Hand on] Key on LCP, 0-41 [Off] Key on LCP, 0-42 [Auto on] Key on LCP, and 0-43 [Reset] Key on LCP, it is possible to start and stop the frequency converter via the LCP using the [Hand On] and [Off] keys. Alarms can be reset via the [Reset] key. After pressing the [Hand On] key, the frequency converter goes into Hand mode and follows (as default) the Local reference that can be set using arrow key on the LCP.

After pressing the [Auto On] key, the frequency converter goes into Auto mode and follows (as default) the remote reference. In this mode, it is possible to control the frequency converter via the digital inputs and various serial interfaces (RS-485, USB, or an optional fieldbus). See more about starting, stopping, changing ramps and parameter set-ups and so on, in parameter group 5-1* (digital inputs) or parameter group 8-5* (serial communication).

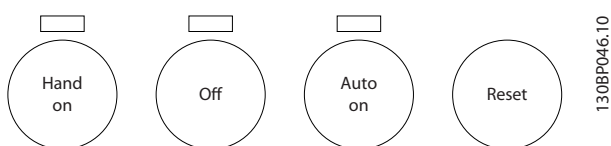


Illustration 4.18 LCP Keys

Active Reference and Configuration Mode

The active reference can be either the local reference or the remote reference.

In 3-13 *Reference Site* the local reference can be permanently selected by selecting [2] *Local*. For permanent setting of the remote reference, select [1] *Remote*. By selecting [0] *Linked to Hand/Auto* (default) the reference site links to the active mode. (Hand Mode or Auto Mode).

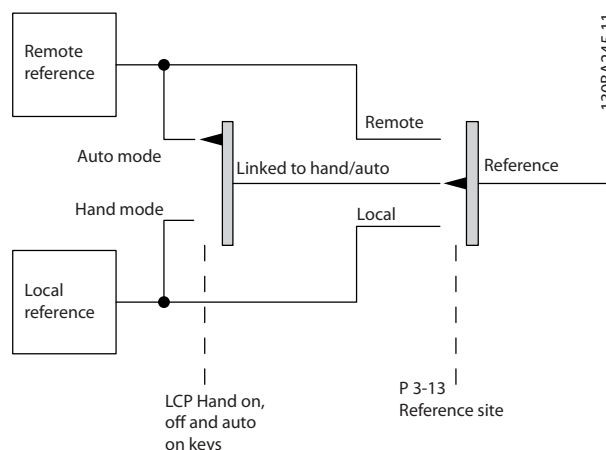


Illustration 4.19 Local Reference Handling

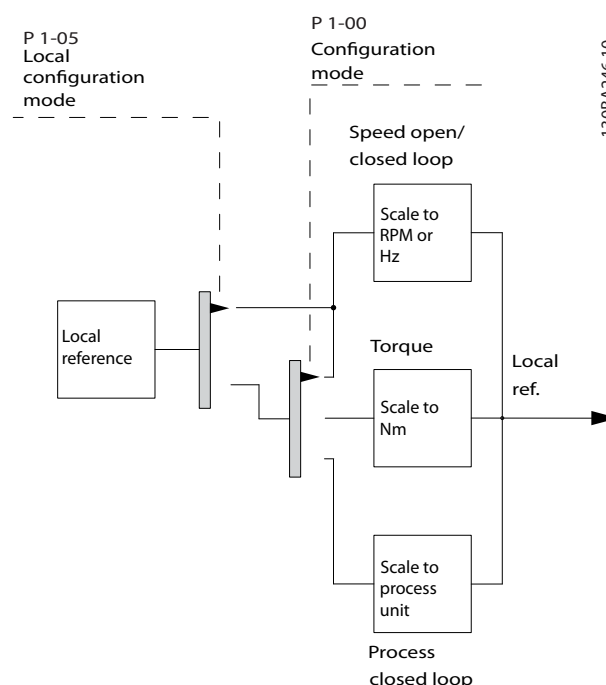


Illustration 4.20 Remote Reference Handling

LCP Keys	3-13 Reference Site	Active Reference
Hand	Linked to Hand/Auto	Local
Hand⇒Off	Linked to Hand/Auto	Local
Auto	Linked to Hand/Auto	Remote
Auto⇒Off	Linked to Hand/Auto	Remote
All keys	Local	Local
All keys	Remote	Remote

Table 4.25 Conditions for Local/Remote Reference Handling

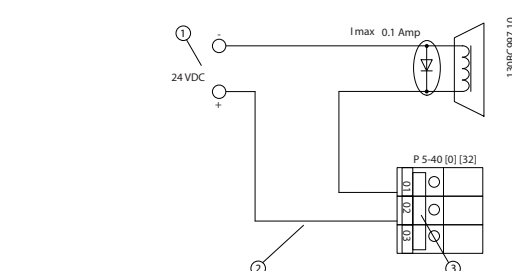


Illustration 4.21 Mechanical Brake Control

4.7 Programming of Torque Limit and Stop

In applications with an external electro-mechanical brake, such as hoisting applications, it is possible to stop the frequency converter via a 'standard' stop command and simultaneously activate the external electro-mechanical brake.

The example given below, illustrates the programming of frequency converter connections.

The external brake can be connected to relay 1 or 2.

Program terminal 27 to [2] Coast, inverse or [3] Coast and Reset, inverse , and program terminal 29 to Terminal mode 29 [1] Output and [27] Torque limit & stop.

Item	Description
1	External 24 V DC
2	Mechanical brake connection
3	Relay 1

Table 4.26 Legend

Description

If a stop command is active via terminal 18 and the frequency converter is not at the torque limit, the motor ramps down to 0 Hz.

If the frequency converter is at the torque limit and a stop command is activated, terminal 29 Output (programmed to Torque limit and stop [27]) is activated. The signal to terminal 27 changes from 'logic 1' to 'logic 0', and the motor starts to coast, thereby ensuring that the hoist stops even if the frequency converter itself cannot handle the required torque (i.e. due to excessive overload).

- Start/stop via terminal 18
5-10 Terminal 18 Digital Input [8] Start
- Quickstop via terminal 27
5-12 Terminal 27 Digital Input [2] Coasting Stop, Inverse
- Terminal 29 Output
5-02 Terminal 29 Mode [1] Terminal 29 Mode Output
5-31 Terminal 29 Digital Output [27] Torque Limit & Stop
- [0] Relay output (Relay 1)
5-40 Function Relay [32] Mechanical Brake Control

4.8 Mechanical Brake

5-31 Terminal 29 Digital Output

For hoisting applications, it is necessary to be able to control an electro-magnetic brake. For controlling the brake, a relay output (relay1 or relay2) or a programmed digital output (terminal 27 or 29) is required. Normally, this output must be closed for as long as the frequency converter is unable to 'hold' the motor, for example, because of excess load. For applications with an electro-magnetic brake, select [32] *mechanical brake control* in one of the following parameters:

5-40 Function Relay (Array parameter),

5-30 Terminal 27 Digital Output, or

When [32] *mechanical brake control* is selected, the mechanical brake relay stays closed during start until the output current is above a preset level. Select the preset level in 2-20 *Release Brake Current*. During stop, the mechanical brake closes when the speed is below the level selected in 2-21 *Activate Brake Speed [RPM]*. When the frequency converter is brought into an alarm condition (that is, an over-voltage situation), or during safe stop, the mechanical brake immediately cuts in.

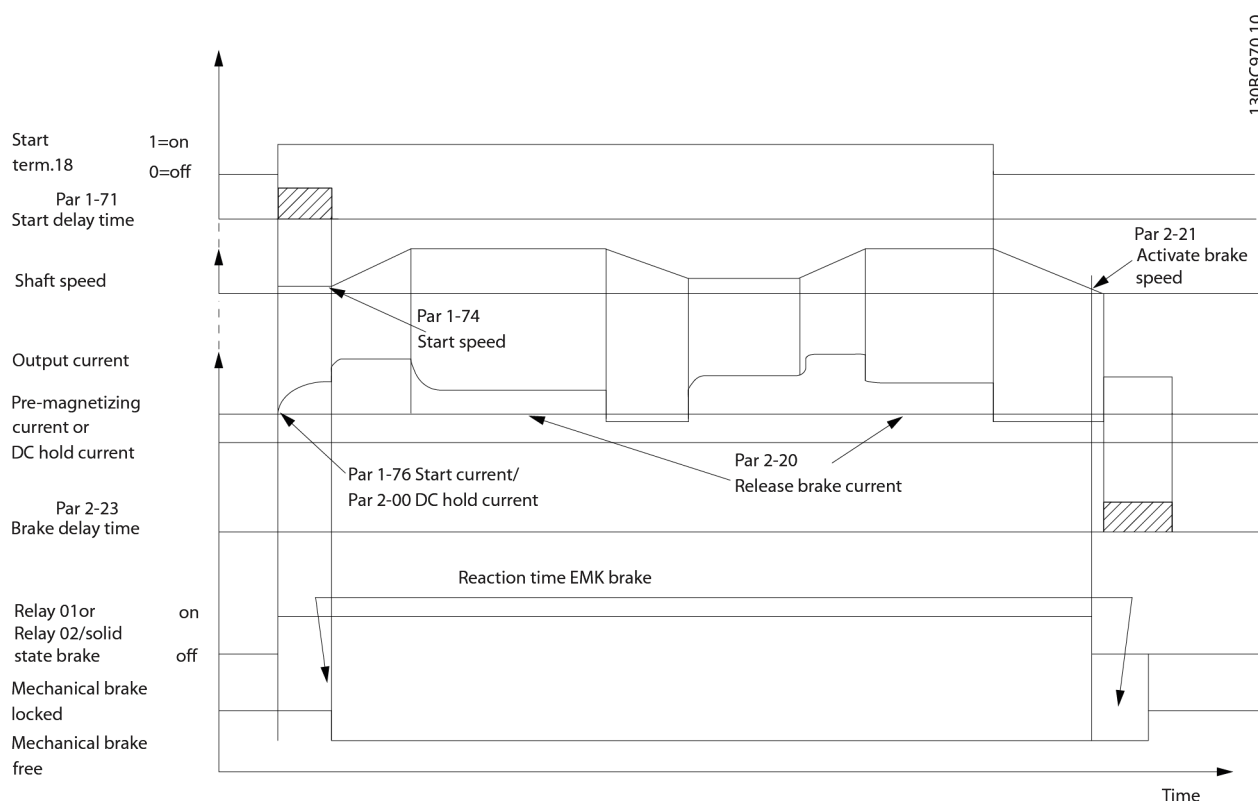


Illustration 4.22 Mechanical Brake Control for Hoisting Applications

In hoisting/lowering applications, it must be possible to control an electromechanical brake.

Step-by-step Description

- To control the mechanical brake, use any relay output, digital output (terminal 27 or 29) or solid-state brake voltage output (terminals 122 - 123). Use a suitable contactor when required.
- Ensure that the output is switched off as long as the frequency converter is unable to drive the motor. For example, due to the load being too heavy, or when the motor is not yet mounted.

- Select [32] *mechanical brake control* in parameter group 5-4* (or in parameter group 5-3*) before connecting the mechanical brake.
- The brake is released when the motor current exceeds the preset value in 2-20 *Release Brake Current*.
- The brake is engaged when the output frequency is lower than a preset limit. Set the limit in 2-21 *Activate Brake Speed [RPM]* or 2-22 *Activate Brake Speed [Hz]* and only if the frequency converter carries out a stop command.

NOTE

Recommendation: For vertical lifting or hoisting applications ensure that the load can be stopped in an emergency or a malfunction of a single part such as a contactor.

When the frequency converter enters alarm mode or an over voltage situation, the mechanical brake cuts in.

NOTE

For hoisting applications, make sure that the torque limit settings do not exceed the current limit. Set torque limits in *4-16 Torque Limit Motor Mode* and *4-17 Torque Limit Generator Mode*. Set current limit in *4-18 Current Limit*. Recommendation: Set *14-25 Trip Delay at Torque Limit* to [0], *14-26 Trip Delay at Inverter Fault* to [0] and *14-10 Mains Failure* to [3] *Coasting*.

4.9 Safe Stop

The frequency converter can perform the safety function *Safe Torque Off* (STO, as defined by EN IEC 61800-5-2¹⁾ and *Stop Category 0* (as defined in EN 60204-1²⁾).

Danfoss has named this functionality *Safe Stop*. Before integration and use of Safe Stop in an installation, perform a thorough risk analysis to determine whether the Safe Stop functionality and safety levels are appropriate and sufficient. Safe Stop is designed and approved suitable for the requirements of:

- Safety Category 3 in EN 954-1 (and EN ISO 13849-1)
- Performance Level "d" in EN ISO 13849-1:2008
- SIL 2 Capability in IEC 61508 and EN 61800-5-2
- SILCL 2 in EN 62061

1) Refer to EN IEC 61800-5-2 for details of Safe torque off (STO) function.

2) Refer to EN IEC 60204-1 for details of stop category 0 and 1.

Activation and Termination of Safe Stop

The Safe Stop (STO) function is activated by removing the voltage at Terminal 37 of the Safe Inverter. By connecting the Safe Inverter to external safety devices providing a safe delay, an installation for a safe Stop Category 1 can be obtained. The Safe Stop function can be used for asynchronous, synchronous, and permanent magnet motors.

⚠ WARNING

After installation of Safe Stop (STO), a commissioning test must be performed. A passed commissioning test is mandatory after first installation and after each change to the safety installation.

Safe Stop Technical Data

The following values are associated to the different types of safety levels:

Reaction time for T37

- Typical reaction time: 10 ms

Reaction time=delay between de-energizing the STO input and switching off the frequency converter output bridge.

Data for EN ISO 13849-1

- Performance Level "d"
- MTTF_d (Mean Time To Dangerous Failure): 24816 years
- DC (Diagnostic Coverage): 99%
- Category 3
- Lifetime 20 years

Data for EN IEC 62061, EN IEC 61508, EN IEC 61800-5-2

- SIL 2 Capability, SILCL 2
- PFH (Probability of Dangerous failure per Hour)=7e-10FIT=7e-19/h
- SFF (Safe Failure Fraction) >99%
- HFT (Hardware Fault Tolerance)=0 (1oo1 architecture)
- Lifetime 20 years

Data for EN IEC 61508 low demand

- PFDavg for one year proof test: 3, 07E-14
- PFDavg for three year proof test: 9, 20E-14
- PFDavg for five year proof test: 1, 53E-13

SISTEMA Data

Functional safety data is available via a data library for use with the SISTEMA calculation tool from the IFA (Institute for Occupational Safety and Health of the German Social Accident Insurance), and data for manual calculation. The library is permanently completed and extended.

Abbrev.	Ref.	Description
Cat.	EN 954-1	Category, level "B, 1-4"
FIT		Failure In Time: 1E-9 hours
HFT	IEC 61508	Hardware Fault Tolerance: HFT=n means, that n+1 faults could cause a loss of the safety function
MTTFd	EN ISO 13849-1	Mean Time To Failure - dangerous. Unit: years
PFH	IEC 61508	Probability of Dangerous Failures per Hour. Consider the PFH value when the safety device is operated in high demand (more often than once per year); or operated in continuous mode, where the frequency of demands for operation made on a safety-related system is greater than one per year.

Abbrev.	Ref.	Description
PL	EN ISO 13849-1	Discrete level used to specify the ability of safety-related parts of control systems to perform a safety function under foreseeable conditions. Levels a-e.
SFF	IEC 61508	Safe Failure Fraction [%]; Percentage part of safe failures and dangerous detected failures of a safety function or a subsystem related to all failures.
SIL	IEC 61508	Safety Integrity Level
STO	EN 61800-5-2	Safe Torque Off
SS1	EN 61800-5-2	Safe Stop 1

Table 4.27 Abbreviations Related to Functional Safety

The PFDavg value (Probability of Failure on Demand) Failure probability in the event of a request of the safety function.

4.9.1.1 Terminal 37 Safe Stop Function

The frequency converter is available with safe stop functionality via control terminal 37. Safe stop disables the control voltage of the power semiconductors of the frequency converter output stage. This in turn prevents generating the voltage required to rotate the motor. When the Safe Stop (T37) is activated, the frequency converter issues an alarm, trips the unit, and coasts the motor to a stop. Manual restart is required. The safe stop function can be used as an emergency stop for the frequency converter. In the normal operating mode when safe stop is not required, use the regular stop function instead. When automatic restart is used, ensure the requirements of ISO 12100-2 paragraph 5.3.2.5 are fulfilled.

Liability Conditions

It is the responsibility of the user to ensure personnel installing and operating the safe stop function:

- Read and understand the safety regulations concerning health and safety/accident prevention
- Understand the generic and safety guidelines given in this description and the extended description in this manual
- Have a good knowledge of the generic and safety standards applicable to the specific application

User is defined as: integrator, operator, service technician, maintenance technician.

Standards

Use of safe stop on terminal 37 requires that the user satisfies all provisions for safety including relevant laws, regulations and guidelines. The optional safe stop function complies with the following standards.

- EN 954-1: 1996 Category 3
- IEC 60204-1: 2005 category 0 – uncontrolled stop
- IEC 61508: 1998 SIL2
- IEC 61800-5-2: 2007 – safe torque off (STO) function
- IEC 62061: 2005 SIL CL2
- ISO 13849-1: 2006 Category 3 PL d
- ISO 14118: 2000 (EN 1037) – prevention of unexpected startup

The information and instructions of the instruction manual are not sufficient for a proper and safe use of the safe stop functionality. The related information and instructions of the relevant *Design Guide* must be followed.

Protective Measures

- Qualified and skilled personnel are required for installation and commissioning of safety engineering systems
- The unit must be installed in an IP54 cabinet or in an equivalent environment. In special applications a higher IP degree is required
- The cable between terminal 37 and the external safety device must be short circuit protected according to ISO 13849-2 table D.4
- When external forces influence the motor axis (for example, suspended loads), to eliminate potential hazards additional measures are required (for example, a safety holding brake)

Safe Stop Installation and Set-Up



SAFE STOP FUNCTION!

The safe stop function does NOT isolate mains voltage to the frequency converter or auxiliary circuits. Perform work on electrical parts of the frequency converter or the motor only after isolating the mains voltage supply and waiting the length of time specified under Safety in this manual. Failure to isolate the mains voltage supply from the unit and waiting the time specified could result in death or serious injury.

- It is not recommended to stop the frequency converter by using the Safe Torque Off function. If a running frequency converter is stopped by using the function, the unit trips and stops by coasting. If unacceptable or dangerous, use another stopping mode to stop the frequency converter and machinery, before using this function. Depending on the application a mechanical brake can be required.
- For synchronous and permanent magnet motor frequency converters, in a multiple IGBT power semiconductor failure: In spite of the activation of

the Safe torque off function, the system can produce an alignment torque which maximally rotates the motor shaft by $180/p$ degrees. p denotes the pole pair number.

- This function is suitable for performing mechanical work on the system or affected area of a machine only. It does not provide electrical safety. Do not use this function as a control for starting and/or stopping the frequency converter.

Follow these steps to perform a safe installation of the frequency converter:

1. Remove the jumper wire between control terminals 37 and 12 or 13. Cutting or breaking the jumper is not sufficient to avoid short-circuiting (see jumper on *Illustration 4.23*).
2. Connect an external Safety monitoring relay via a NO safety function to terminal 37 (safe stop) and either terminal 12 or 13 (24 V DC). Follow the instruction for the safety device. The Safety monitoring relay must comply with Category 3 (EN 954-1)/PL "d" (ISO 13849-1) or SIL 2 (EN 62061).

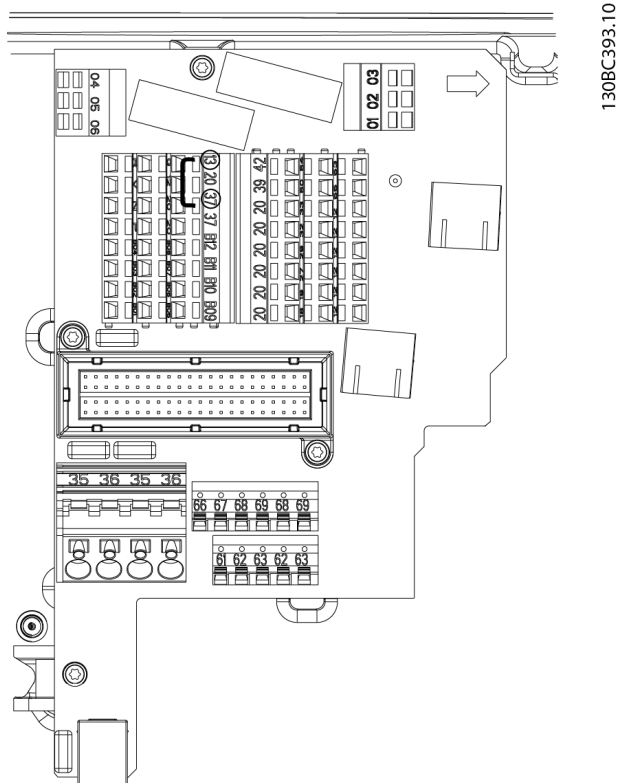


Illustration 4.23 Jumper between Terminal 12/13 (24 V) and 37

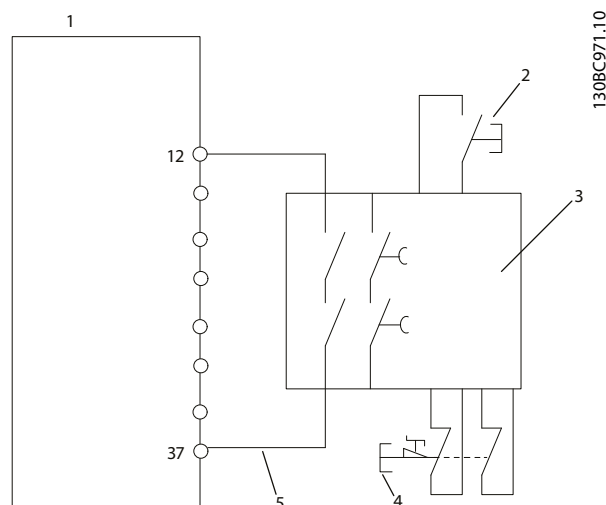


Illustration 4.24 Installation to Achieve a Stopping Category 0 (EN 60204-1) with Safety Cat. 3 (EN 954-1)/PL "d" (ISO 13849-1) or SIL 2 (EN 62061).

1	Frequency converter
2	Reset button
3	Safety relay (cat. 3, PL d or SIL2)
4	Emergency stop button
5	Short-circuit protected cable (if not inside installation IP54 cabinet)

Table 4.28 Legend

Safe Stop Commissioning Test

After installation and before first operation, perform a commissioning test of the installation using safe stop. Moreover, perform the test after each modification of the installation.

Example with STO

A safety relay evaluates the E-Stop button signals and triggers an STO function on the frequency converter in the event of an activation of the E-Stop button (See *Illustration 4.25*). This safety function corresponds to a category 0 stop (uncontrolled stop) in accordance with IEC 60204-1. If the function is triggered during operation, the motor runs down in an uncontrolled manner. The power to the motor is safely removed, so that no further movement is possible. It is not necessary to monitor plant at a standstill. If an external force effect can occur, provide additional measures to prevent any potential movement (for example, mechanical brakes).

NOTE

For all applications with Safe Stop it is important that short circuit in the wiring to T37 can be excluded. Exclude the short circuit as described in EN ISO 13849-2 D4 by the use of protected wiring, (shielded or segregated).

4

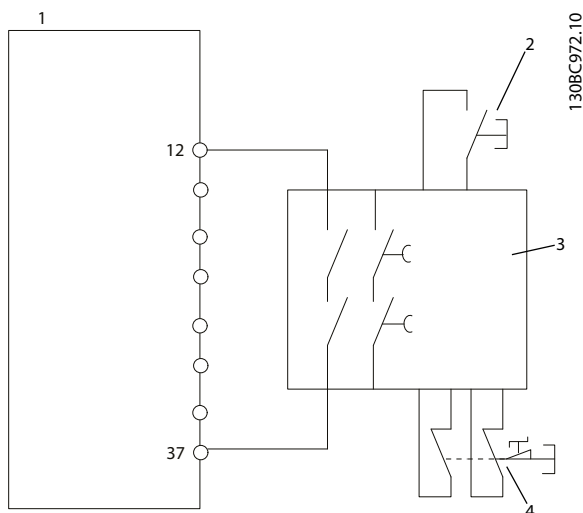


Illustration 4.25 STO Example

1	Frequency converter
2	[Reset] key
3	Safety relay
4	Emergency stop

Table 4.29 Legend

Example with SS1

SS1 correspond to a controlled stop, stop category 1 according to IEC 60204-1 (see *Illustration 4.26*). When activating the safety function the frequency converter performs a normal controlled stop. This can be activated through terminal 27. After the safe delay time has expired on the external safety module, the STO will be triggered and terminal 37 will be set low. Ramping down as configured in the frequency converter. If the frequency converter is not stopped after the safe delay time, the activation of STO will coast the frequency converter.

NOTE

When using the SS1 function, the brake ramp of the frequency converter is not monitored with respect to safety.

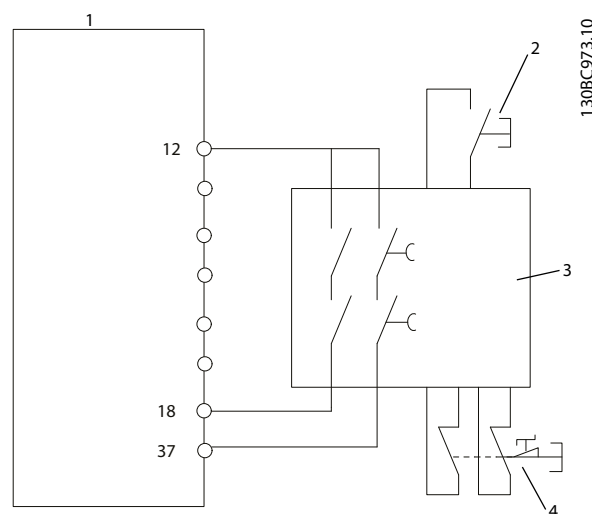


Illustration 4.26 SS1 Example

1	Frequency converter
2	[Reset] key
3	Safety relay
4	Emergency stop

Table 4.30 Legend

Example with Category 4/PL e application

Where the safety control system design requires two channels for the STO function to achieve Category 4/PL e, implement one channel via Safe Stop T37 (STO) and the other by a contactor. Connect the contactor in either the frequency converter input or output power circuits and controlled by the Safety relay (see *Illustration 4.27*). The contactor must be monitored through an auxiliary guided contact, and connected to the reset input of the Safety Relay.

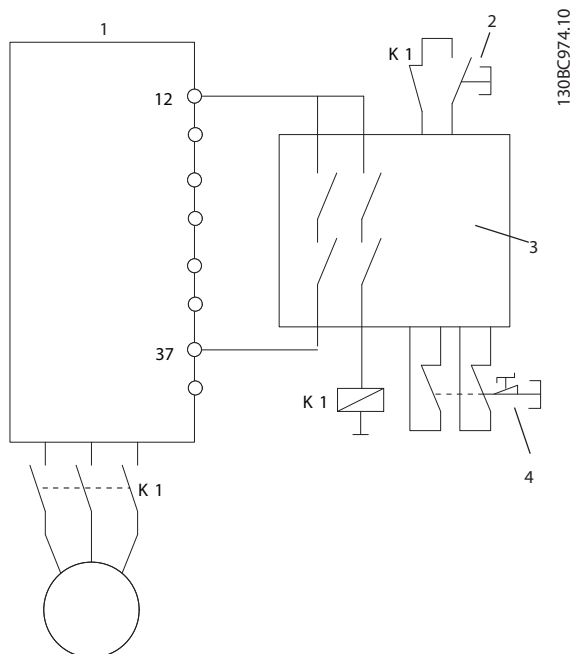


Illustration 4.27 STO Category 4 Example

1	Frequency converter
2	[Reset] key
3	Safety relay
4	Emergency stop

Table 4.31 Legend

Paralleling of Safe Stop input the one Safety Relay

Safe Stop inputs T37 (STO) may be connected directly together if it is required to control multiple frequency converters from the same control line via one Safety Relay (see *Illustration 4.28*). Connecting inputs together increases the probability of a fault in the unsafe direction. A fault in one frequency converter can result in all frequency converters becoming enabled. The probability of a fault for T37 is so low, that the resulting probability still meets the requirements for SIL2.

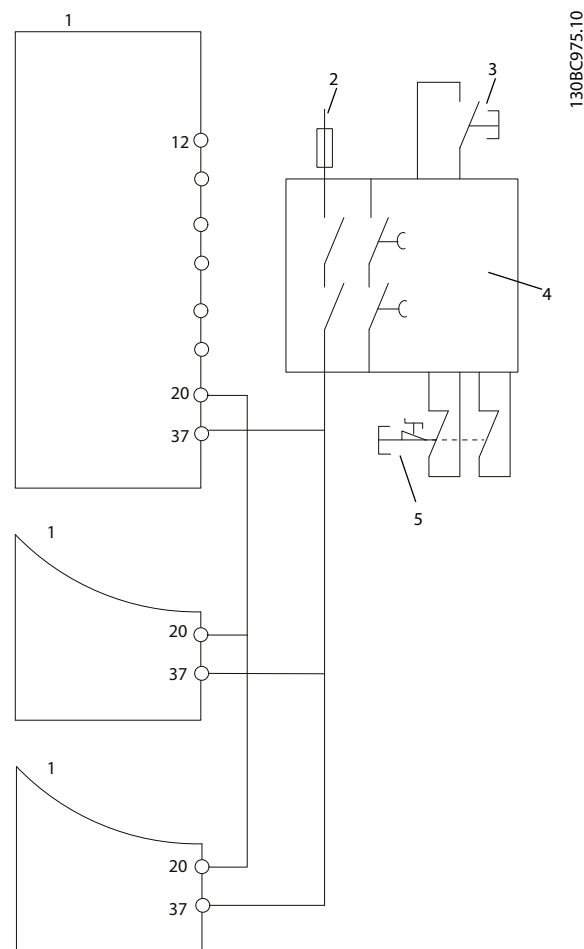


Illustration 4.28 Paralleling of Multiple Drives Example

1	Frequency converter
2	24 V DC
3	[Reset] key
4	Safety relay
5	Emergency stop

Table 4.32 Legend

⚠ WARNING

Safe Stop activation (that is, removal of 24 V DC voltage supply to terminal 37) does not provide electrical safety. The Safe Stop function itself is therefore not sufficient to implement the Emergency-Off function as defined by EN 60204-1. Emergency-Off requires measures of electrical isolation, for example, by switching off mains via an additional contactor.

1. Activate the Safe Stop function by removing the 24 V DC voltage supply to the terminal 37.
2. After activation of Safe Stop (that is, after the response time), the frequency converter coasts (stops creating a rotational field in the motor). The response time is typically less than 10ms.

The frequency converter is guaranteed not to restart creation of a rotational field by an internal fault (in accordance with Cat. 3 of EN 954-1, PL d acc. EN ISO 13849-1 and SIL 2 acc. EN 62061). After activation of Safe Stop, the display will show the text "Safe Stop activated". The associated help text says, "Safe Stop has been activated. This means that the Safe Stop has been activated, or that normal operation has not been resumed yet after Safe Stop activation".

NOTE

The requirements of Cat. 3 (EN 954-1)/PL "d" (ISO 13849-1) are only fulfilled while 24 V DC supply to terminal 37 is kept removed or low by a safety device which itself fulfills Cat. 3 (EN 954-1) PL "d" (ISO 13849-1). If external forces act on the motor, it must not operate without additional measures for fall protection. External forces can arise for example, in the event of vertical axis (suspended loads) where an unwanted movement, for example caused by gravity, could cause a hazard. Fall protection measures can be additional mechanical brakes.

By default the Safe Stop function is set to an Unintended Restart Prevention behaviour. Therefore, to resume operation after activation of Safe Stop,

1. reapply 24 V DC voltage to terminal 37 (text Safe Stop activated is still displayed)
2. create a reset signal (via bus, Digital I/O, or [Reset] key).

The Safe Stop function can be set to an Automatic Restart behaviour. Set the value of *5-19 Terminal 37 Safe Stop* from default value [1] to value [3].

Automatic Restart means that Safe Stop is terminated, and normal operation is resumed, as soon as the 24 V DC are applied to Terminal 37. No Reset signal is required.

WARNING

Automatic Restart Behaviour is permitted in one of the two situations:

1. The Unintended Restart Prevention is implemented by other parts of the Safe Stop installation.
2. A presence in the dangerous zone can be physically excluded when Safe Stop is not activated. In particular, *paragraph 5.3.2.5 of ISO 12100-2 2003* must be observed

4.9.1.2 Safe Stop Commissioning Test

After installation and before first operation, perform a commissioning test of an installation or application, using Safe Stop.

Perform the test again after each modification of the installation or application involving the Safe Stop.

NOTE

A passed commissioning test is mandatory after first installation and after each change to the safety installation.

The commissioning test (select one of cases 1 or 2 as applicable):

Case 1: Restart prevention for Safe Stop is required (that is, Safe Stop only where *5-19 Terminal 37 Safe Stop* is set to default value [1], or combined Safe Stop and MCB112 where *5-19 Terminal 37 Safe Stop* is set to [6] or [9]):

1.1 Remove the 24 V DC voltage supply to terminal 37 using the interrupt device while the frequency converter drives the motor (that is, mains supply is not interrupted). The test step is passed when

- the motor reacts with a coast, and
- the mechanical brake is activated (if connected)
- the alarm "Safe Stop [A68]" is displayed in the LCP, if mounted

1.2 Send Reset signal (via Bus, Digital I/O, or [Reset] key). The test step is passed if the motor remains in the Safe Stop state, and the mechanical brake (if connected) remains activated.

1.3 Reapply 24 V DC to terminal 37. The test step is passed if the motor remains in the coasted state, and the mechanical brake (if connected) remains activated.

1.4 Send Reset signal (via Bus, Digital I/O, or [Reset] key). The test step is passed when the motor becomes operational again.

The commissioning test is passed if all four test steps 1.1, 1.2, 1.3 and 1.4 are passed.

Case 2: Automatic Restart of Safe Stop is wanted and allowed (that is, Safe Stop only where *5-19 Terminal 37 Safe Stop* is set to [3], or combined Safe Stop and MCB112 where *5-19 Terminal 37 Safe Stop* is set to [7] or [8]):

2.1 Remove the 24 V DC voltage supply to terminal 37 by the interrupt device while the frequency converter drives the motor (that is, mains supply is not interrupted). The test step is passed when

- the motor reacts with a coast, and
- the mechanical brake is activated (if connected)
- the alarm "Safe Stop [A68]" is displayed in the LCP, if mounted

2.2 Reapply 24 V DC to terminal 37.

The test step is passed if the motor becomes operational again. The commissioning test is passed if both test steps 2.1 and 2.2 are passed.

NOTE

See warning on the restart behaviour in *Terminal 37 Safe Stop Function*.

NOTE

The Safe Stop function can be used for asynchronous, synchronous and permanent magnet motors. Two faults can occur in the power semiconductor of the frequency converter. When using synchronous or permanent magnet motors a residual rotation can result from the faults. The rotation can be calculated to $\text{Angle} = 360 / (\text{Number of Poles})$. The application using synchronous or permanent magnet motors must take this residual rotation into consideration and ensure that it does not pose a safety risk. This situation is not relevant for asynchronous motors.

5 Type Code and Selection Guide

5.1 Type Code Description

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

130BB797.10

Illustration 5.1 Type Code Description

5

Position	Description	Choices/options	
01-03	Product group	FCD	Decentral Drive
04-06	Frequency converter series	302	Advanced performance
07-10	Power size	PK37	0.37 kW/0.5 HP
		PK55	0.55 kW/0.75 HP
		PK75	0.75 kW/1.0 HP
		P1K1	1.1 kW/1.5 HP
		P1K5	1.5 kW/2.0 HP
		P2K2	2.2 kW/3.0 HP
		P3K0	3.0 kW/4.0 HP (large unit only)
		PXXX	Installation box only (without power section)
11-12	Phases, Mains voltage	T	Three phase
		4	380-480 V AC
13-15	Enclosure	B66	Standard Black - IP66/Type 4X
		W66	Standard White - IP66/Type 4X
		W69	Hygienic White - IP66K/Type 4X
16-17	RFI filter	H1	RFI filter class A1/C2
18	Brake	X	No brake
		S	Brake chopper + mechanical brake Supply
19	Hardware configuration	1	Complete product, small unit, stand alone mount
		3	Complete product, large unit, stand alone mount
		X	Drive part, small unit (No installation box)
		Y	Drive part, large unit (No installation box)
		R	Installation box, small unit, stand alone mount (No drive part)
		T	Installation box, large unit, stand alone mount (No drive part)
20	Brackets	X	No brackets
		E	Flat brackets
		F	40 mm brackets

Position	Description	Choices/options	
21	Threads	X	No installation box
		M	Metric threads
22	Switch option	X	No switch option
		E	Service switch on mains input
		F	Service switch on motor output
		H	Circuit breaker & mains disconnect, looping terminals (large unit only)
23	Display	X	No display connector (No installation box)
		C	With Display Connector
24	Sensor plugs	X	No sensor plugs
		E	Direct mount 4xM12: 4 digital inputs
		F	Direct mount 6xM12: 4 digital inputs, 2 relay outputs
25	Motor plug	X	No motor plug
26	Mains plug	X	No mains plug
27	Fieldbus plug	X	No fieldbus plug
		E	M12 Ethernet
		P	M12 Profibus
28	Reserved	X	For future use
29-30	A option	AX	No A option
		A0	Profibus DP
		AN	Ethernet IP
		AL	ProfiNet
31-32	B option	BX	No B option
		BR	Encoder option
		BU	Resolver option
		BZ	Safety PLC Interface
33-37	Reserved	XXXXX	For future use
38-39	D option	DX	No D option
		D0	24 V DC back-up input

Table 5.1 Type Code Description

Not all choices/options are available for each FCD 302 variant. To verify if the appropriate version is available, consult the Drive Configurator on the Internet:
<http://driveconfig.danfoss.com>.

NOTE

A and D options for FCD 302 are integrated into the control card. Therefore pluggable options for frequency converters cannot be used here. Future retrofit will require exchange of the entire control card. B options are pluggable, using the same concept as for frequency converters.

5.1.1 Drive Configurator

Design the frequency converter according to the application requirements by using the ordering number system.

Order standard drives and drives with integral options by sending a type code string describing the product to the local Danfoss sales office, for example:

FCD302P2K2T4B66H1X1XMXCXXXXXA0BXXXXXXDX

The meaning of the characters in the string can be located in the pages containing the ordering numbers in this chapter. In the example above, a Profibus DP V1 and a 24 V back-up option is included in the drive.

From the Internet based Drive Configurator, configure the right drive for the right application and generate the type code string. The Drive Configurator will automatically generate an eight-digit sales number to be delivered to the local sales office.

Furthermore, establish a project list with several products and send it to a Danfoss sales representative.

The Drive Configurator can be found on the global Internet site: www.danfoss.com/drives.

The frequency converter will automatically be delivered with a language package relevant to the region from which it is ordered.

To order a different language package, contact the local Danfoss sales office.

5.2 Ordering Numbers

5.2.1 Ordering Numbers: Accessories

Accessories	Description	Ordering No.
Mounting brackets extended	40 mm brackets	130B5771
Mounting brackets	Flat brackets	130B5772
LCP cable	Preconfectioned cable to be used between inverter and LCP	130B5776
Brake resistor 1750 Ω 10 W/100%	For mounting inside installation box below motor terminals	130B5778
Brake resistor 350 Ω 10 W/100%	For mounting inside installation box below motor terminals	130B5780
VLT Control Panel LCP 102	Graphical display for programming and read out	130B1078
Venting membrane, goretex	Preventing condensation inside enclosure	175N2116
PE termination, M20	Stainless Steel	175N2703
PE termination, M16	Stainless Steel	130B5833

Table 5.2 Ordering Numbers: Accessories

5.2.2 Ordering Numbers: Spare Parts

Spare parts	Description	Ordering No.
Protection cover	Plastic protection cover for inverter part	130B5770
Gasket	Gasket between installation box and inverter part	130B5773
Accessory bag	Spare cable clamps and screws for shield termination	130B5774
Service switch	Spare switch for mains or motor disconnect	130B5775
LCP plug	Spare plug for mounting in installation box	130B5777
Main termination board	For mounting in installation box	130B5779
M12 sensor plugs	Set of two M12 sensor plugs for mounting in cable gland hole	130B5411
Control card	Control card with 24 V backup	130b5783
Control card Profibus	Control card Profibus with 24 V backup	130b5781
Control card EtherNet	Control card EtherNet with 24 V backup	130b5788
Control card Profinet	Control card Profinet with 24 V backup	130b5794

Table 5.3 Ordering Numbers: Spare Parts

The packaging contains:

- Accessories bag, supplied only with order of installation box. Contents:
 - 2 cable clamps
 - bracket for motor/loads cables
 - elevation bracket for cable clamp
 - screw 4 mm 20 mm
 - thread forming 3.5 mm 8 mm
- Documentation

Depending on options fitted, the box will contain one or two bags and one or more booklets.

5.3 Options and Accessories

Danfoss offers a wide range of options and accessories for the frequency converter.

5.3.1 Fieldbus Options

Select the fieldbus option when ordering the frequency converter. All fieldbus options are included on the control card. No separate A option is available.

To change the fieldbus option later, change out the control card. The following control cards with different fieldbus options are available. All control cards have 24 V backup as standard.

Item	Ordering number
Control card PROFIBUS	130B5781
Control card EtherNet	130B5788
Control card PROFINET	130B5794

Table 5.4 Control Cards with Fieldbus Options

5.3.2 Encoder Option MCB 102

The encoder module can be used as feedback source for closed loop Flux control (*1-02 Flux Motor Feedback Source*) as well as closed loop speed control (*7-00 Speed PID Feedback Source*). Configure encoder option in parameter group 17-**

The encoder option MCB 102 is used for:

- VVC^{plus} closed loop
- Flux Vector Speed control
- Flux Vector Torque control
- Permanent magnet motor

Supported encoder types:

Incremental encoder: 5 V TTL type, RS422, max. frequency: 410 kHz

Incremental encoder: 1Vpp, sine-cosine

Hiperface® Encoder: Absolute and Sine-Cosine (Stegmann/SICK)

EnDat encoder: Absolute and Sine-Cosine (Heidenhain)

Supports version 2.1

SSI encoder: Absolute

Encoder monitor:

The 4 encoder channels (A, B, Z, and D) are monitored, open and short circuit can be detected. There is a green LED for each channel which lights up when the channel is OK.

NOTE

The LEDs are not visible when mounted in an FCD302 frequency converter. Reaction in case of an encoder error can be selected in *17-61 Feedback Signal Monitoring: None, Warning or Trip*.

The encoder option kit contains

- Encoder Option MCB 102
- Cable to connect customer terminals to control card

Connector Designation X31	Incremental Encoder (refer to Graphic A)	SinCos Encoder Hiperface® (refer to Graphic B)	EnDat Encoder	SSI Encoder	Description
1	NC			24 V*	24 V Output (21-25 V, I _{max} :125 mA)
2	NC	8 VCC			8 V Output (7-12 V, I _{max} : 200 mA)
3	5 VCC		5 VCC	5 V*	5 V Output (5 V ±5%, I _{max} : 200 mA)
4	GND		GND	GND	GND
5	A input	+COS	+COS		A input
6	A inv input	REFCOS	REFCOS		A inv input
7	B input	+SIN	+SIN		B input
8	B inv input	REFSIN	REFSIN		B inv input
9	Z input	+Data RS-485	Clock out	Clock out	Z input OR +Data RS-485
10	Z inv input	-Data RS-485	Clock out inv.	Clock out inv.	Z input OR -Data RS-485
11	NC	NC	Data in	Data in	Future use
12	NC	NC	Data in inv.	Data in inv.	Future use
Max. 5 V on X31.5-12					

Table 5.5 Encoder Option MCB 102 Connection Terminals

* Supply for encoder: see data on encoder

5

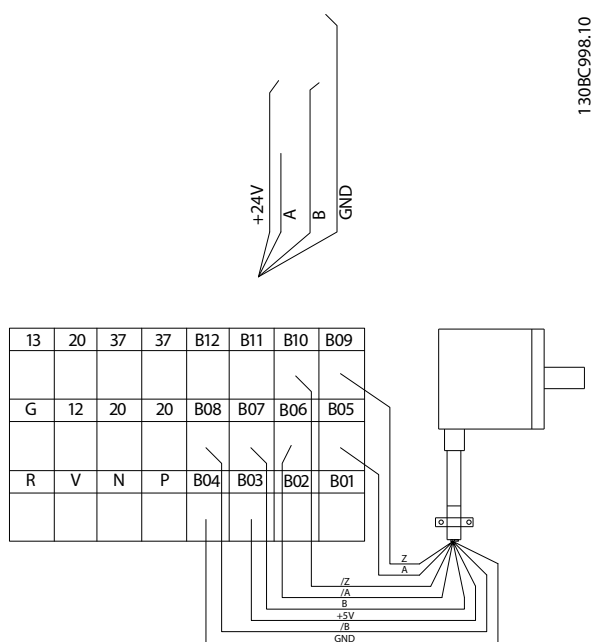


Illustration 5.2 Connections for 5 V Incremental Encoder

Max. cable length 10 m.

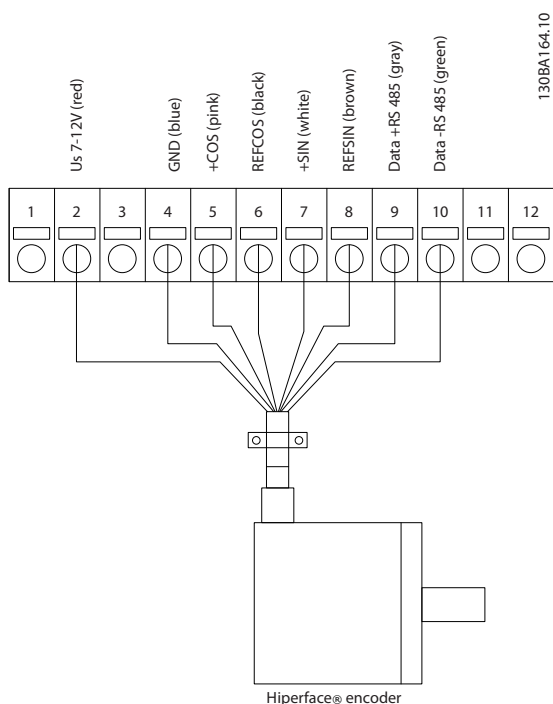


Illustration 5.3 Connections for Hiperface Encoder - 1

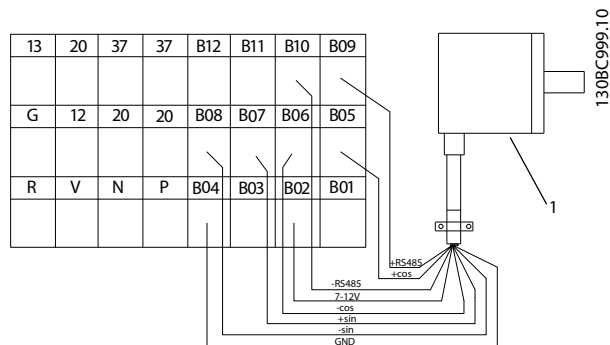


Illustration 5.4 Connections for Hiperface Encoder - 2

Item	Description
1	Hiperface encoder

Table 5.6 Legend

5.3.3 Resolver Option MCB 103

The MCB 103 Resolver Option is used for interfacing resolver motor feedback to the frequency converter. Resolvers are used basically as motor feedback device for permanent magnet brushless synchronous motors.

The resolver option kit comprises:

- MCB 103 Resolver Option
- Cable to connect customer terminals to control card

Selection of parameters: 17-5x resolver Interface.

MCB 103 Resolver Option supports a various number of resolver types.

Resolver Poles	17-50 Poles: 2 *2
Resolver Input Voltage	17-51 Input Voltage: 2.0–8.0 Vrms *7.0Vrms
Resolver Input Frequency	17-52 Input Frequency: 2–15 kHz *10.0 kHz
Transformation ratio	17-53 Transformation Ratio: 0.1–1.1 *0.5
Secondary input voltage	Max 4 Vrms
Secondary load	App. 10 kΩ

Table 5.7 Resolver Option MCB 103 Specifications

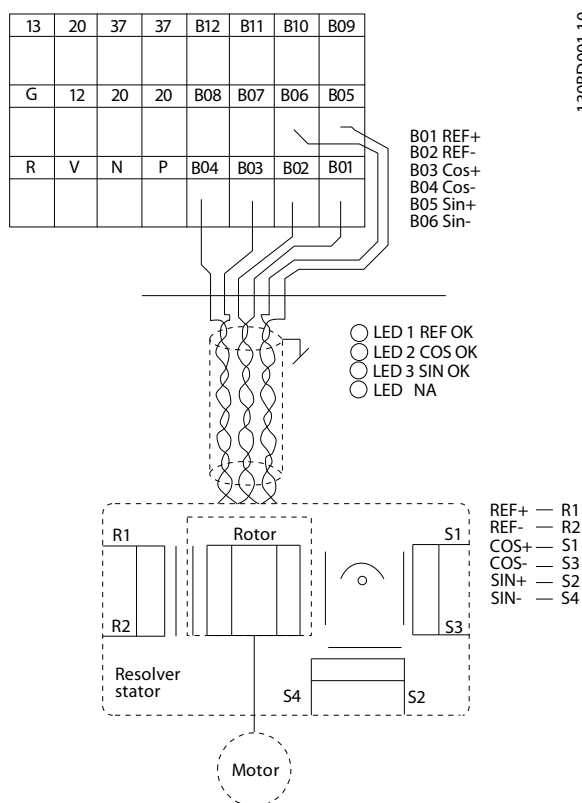


Illustration 5.5 Connections for MCB 103 Resolver Option

NOTE

The Resolver Option MCB 103 can only be used with rotor-supplied resolver types. Stator-supplied resolvers cannot be used.

NOTE

LED indicators are not visible at the resolver option.

LED indicators

LED 1 is on when the reference signal is OK to resolver

LED 2 is on when Cosinus signal is OK from resolver

LED 3 is on when Sinus signal is OK from resolver

The LEDs are active when 17-61 Feedback Signal Monitoring is set to Warning or Trip.

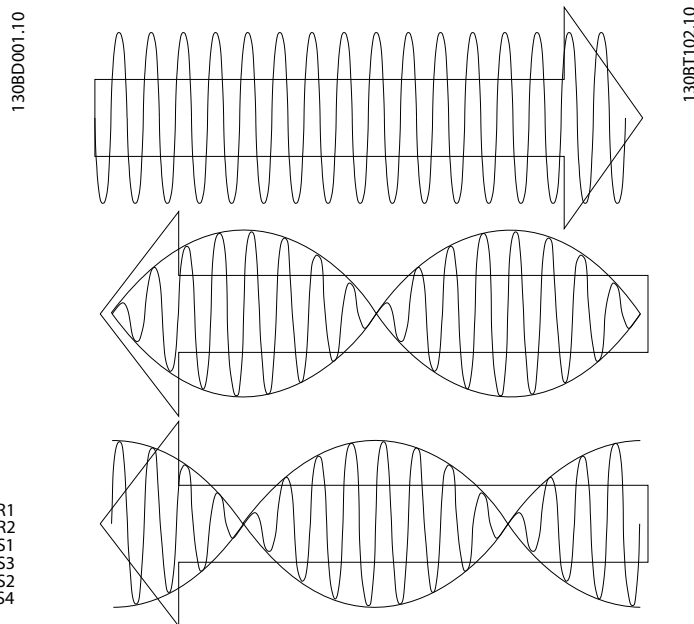


Illustration 5.6 Resolver Signals

Set-up example

In this example a Permanent Magnet (PM) Motor is used with resolver as speed feedback. A PM motor must usually operate in flux mode.

Wiring

The max cable length is 150 m when a twisted pair type of cable is used.

NOTE

Resolver cables must be screened and separated from the motor cables.

NOTE

The screen of the resolver cable must be correctly connected to the de-coupling plate and connected to chassis (earth) on the motor side.

NOTE

Always use screened motor cables and brake chopper cables.

1-00 Configuration Mode	[1] Speed closed loop
1-01 Motor Control Principle	[3] Flux with feedback
1-10 Motor Construction	[1] PM, non salient SPM
1-24 Motor Current	Nameplate
1-25 Motor Nominal Speed	Nameplate
1-26 Motor Cont. Rated Torque	Nameplate
AMA is not possible on PM motors	
1-30 Stator Resistance (Rs)	Motor data sheet
30-80 d-axis Inductance (Ld)	Motor data sheet (mH)
1-39 Motor Poles	Motor data sheet
1-40 Back EMF at 1000 RPM	Motor data sheet
1-41 Motor Angle Offset	Motor data sheet (Usually zero)
17-50 Poles	Resolver data sheet
17-51 Input Voltage	Resolver data sheet
17-52 Input Frequency	Resolver data sheet
17-53 Transformation Ratio	Resolver data sheet
17-59 Resolver Interface	[1] Enabled

Table 5.8 Adjust following Parameters

5.3.4 24 V Back-Up Option MCB 107

External 24 V DC Supply

An external 24 V DC supply can be installed for low-voltage supply to the control card and any option card installed. This enables full operation of the LCP (including the parameter setting) without connection to mains.

External 24 V DC supply specification

Input voltage range	24 V DC $\pm 15\%$ (max. 37 V in 10 s)
Max. input current	2.2 A
Average input current	0.9 A
Max cable length	75 m
Input capacitance load	<10 μ F
Power-up delay	<0.6 s
The inputs are protected.	

Terminal numbers

Terminal 35: - external 24 V DC supply.

Terminal 36: + external 24 V DC supply.

6 Specifications

6.1 Mechanical Dimensions

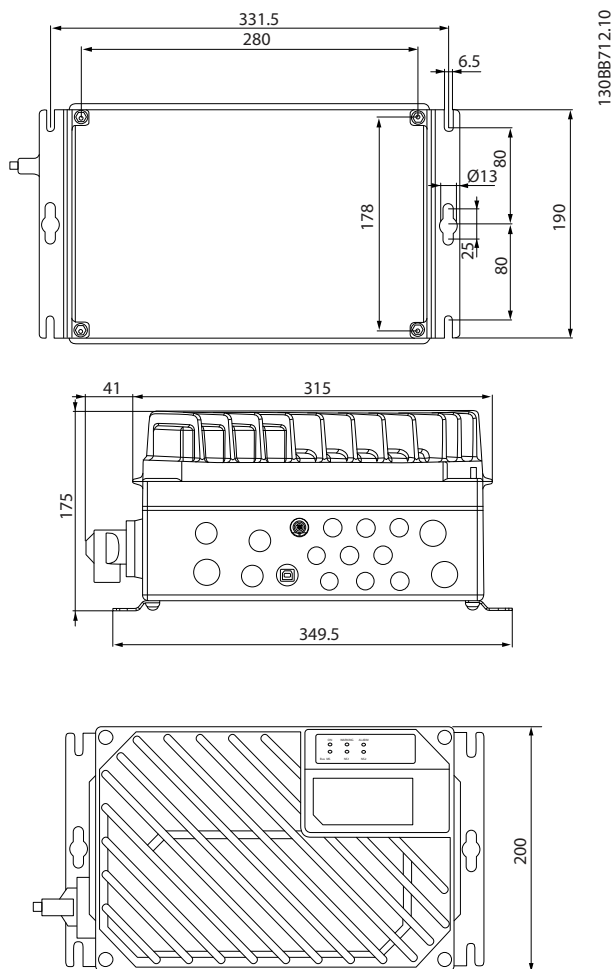


Illustration 6.1 Small Unit

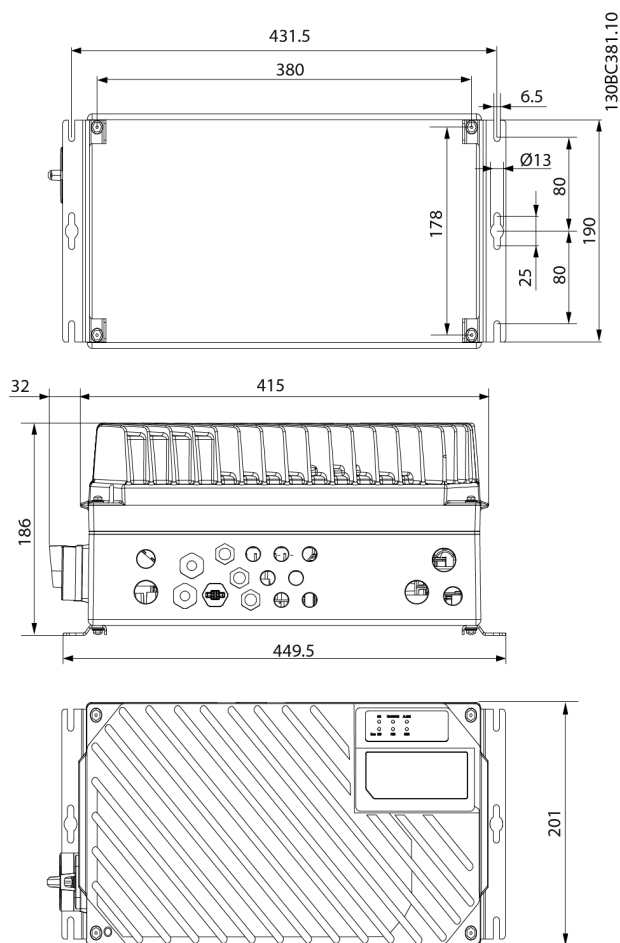


Illustration 6.2 Large Unit

Motor side	1xM20, 1xM25
Control side	2xM20, 9xM16 ¹⁾
Mains side	2xM25

Table 6.1 Legend

¹⁾ Also used for 4xM12/6xM12 sensor/actuator sockets.

6.2 Electrical Data and Wire Sizes

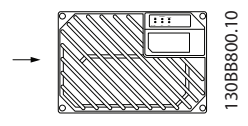
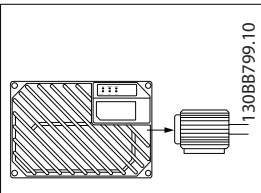
Mains Supply 3x380-480 V AC								
Frequency Converter		PK37	PK55	PK75	P1K1	P1K5	P2K2	P3K0
Rated Shaft Output [kW]		0.37	0.55	0.75	1.1	1.5	2.2	3.0
Rated Shaft Output [hp]		0.5	0.75	1.0	1.5	2.0	3.0	4.0
Max. input current								
	Continuous (3x380-440 V) [A]	1.2	1.6	2.2	2.7	3.7	5.0	6.5
	Intermittent (3x380-440 V) [A]	1.9	2.6	3.5	4.3	5.9	8.0	10.4
	Continuous (3x441-480 V) [A]	1.0	1.4	1.9	2.7	3.1	4.3	5.7
	Intermittent (3x441-480 V) [A]	1.6	2.2	3.0	4.3	5.0	6.9	9.1
	Recommended max. fuse size*	gG-25						
	Built-in circuit breaker (large unit)	CTI-25M Danfoss part no.: 047B3151						
	Recommended circuit breaker (small unit)	CTI-45MB Danfoss part no.: 047B3164						
	Power loss at max. load [W]	35	42	46	58	62	88	116
	Efficiency	0.93	0.95	0.96	0.96	0.97	0.97	0.97
	Weight, small unit [kg]	9.8						
Weight, large unit [kg]		13.9						
Output current								
	Continuous (3x380-440 V) [A]	1.3	1.8	2.4	3.0	4.1	5.2	7.2
	Intermittent (3x380-440 V) [A]	2.1	2.9	3.8	4.8	6.6	8.3	11.5
	Continuous (3x441-480 V) [A]	1.2	1.6	2.1	3.0	3.4	4.8	6.3
	Intermittent (3x441-480 V) [A]	1.9	2.6	3.4	4.8	5.4	7.7	10.1
	Continuous kVA (400 V AC) [kVA]	0.9	1.3	1.7	2.1	2.8	3.9	5.0
	Continuous kVA (460 V AC) [kVA]	0.9	1.3	1.7	2.4	2.7	3.8	5.0
	Max. cable size: (mains, motor, brake) [mm²/ AWG]	solid cable 6/10 flexible cable 4/12						

Table 6.2 FCD 302 Shaft Output, Output Current and Input Current

*To meet UL/cUL requirements, use the following pre-fuses.

- American Wire Gauge. Max. Cable cross section is the largest cable cross section that can be attached to the terminals. Always observe national and local regulations.
- Type gG pre-fuses must be used. To maintain UL/cUL, use pre-fuses of these type (see Table 6.3).
- Measured using a 10 m screened/armoured motor cable with a rated load and rated frequency.

Recommended maximum pre-fuse size 25 A

Brand	Fuse Type	UL File no.	UL Category (CCN code)
Bussmann	FWH-25	E91958	JFHR2
Bussmann	KTS-R25	E52273	RK1/JDDZ
Bussmann	JKS-25	E4273	J/JDDZ
Bussmann	JJS-25	E4273	T/JDDZ
Bussmann	FNW-R-25	E4273	CC/JDDZ
Bussmann	KTK-R-25	E4273	CC/JDDZ
Bussmann	LP-CC-25	E4273	CC/JDDZ
SIBA	5017906-025	E180276	RK1/JDDZ
LITTLE FUSE	KLS-R25	E81895	RK1/JDDZ
FERRAZ-SHAWMUT	ATM-R25	E163267/ E2137	CC/JDDZ
FERRAZ-SHAWMUT	A6K-25R	E163267/ E2137	RK1/JDDZ
FERRAZ-SHAWMUT	HSJ25	E2137	J/HSJ

Table 6.3 FCD 302 Pre-fuses Meeting UL/cUL Requirements

DC voltage level	380-480 V units (V DC)
Inverter undervoltage disable	373
Undervoltage warning	410
Inverter undervoltage re-enable (warning reset)	398
Overvoltage warning (without brake)	778
Dynamic brake turn on	778
Inverter overvoltage re-enable (warning reset)	795
Overvoltage warning (with brake)	810
Overvoltage trip	820

Table 6.4 FCD 302 DC Voltage Level
Fuses

The unit is suitable for use on a circuit capable of delivering not more than 100,000 RMS symmetrical Amperes, 500 V maximum.

Circuit breaker

The unit is suitable for use on a circuit capable of delivering not more than 10,000 RMS symmetrical Amperes, 500 V maximum.

6.3 General Specifications

Mains supply (L1, L2, L3)

Supply voltage	380-480 V $\pm 10\%$
----------------	----------------------

Mains voltage low / mains drop-out:

During low mains voltage or a mains drop-out, the frequency converter continues until the intermediate circuit voltage drops below the minimum stop level, which corresponds typically to 15% below the FC's lowest rated supply voltage. Power-up and 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 $\pm 5\%$
------------------	--------------------

Max. imbalance temporary between mains phases	3.0% of rated supply voltage
---	------------------------------

True Power Factor (λ)	≥ 0.9 nominal at rated load
---------------------------------	----------------------------------

Displacement Power Factor ($\cos \phi$)	near unity (> 0.98)
---	-------------------------

Switching on input supply L1, L2, L3 (power-ups)	maximum 2 times/min.
--	----------------------

The unit is suitable for use on a circuit capable of delivering not more than 100,000 RMS symmetrical Amperes, 480 V maximum.

Motor output (U, V, W)

Output voltage	0-100% of supply voltage
----------------	--------------------------

Output frequency	0-1000 Hz
------------------	-----------

Output frequency in Flux Mode	0-300 Hz
-------------------------------	----------

Switching on output	Unlimited
---------------------	-----------

Ramp times	0.01-3600 s
------------	-------------

Torque Characteristics

Starting torque (Constant torque)	maximum 160% for 60 s ¹⁾
-----------------------------------	-------------------------------------

Starting torque	maximum 180% up to 0.5 s ¹⁾
-----------------	--

Overload torque (Constant torque)	maximum 160% for 60 s ¹⁾
-----------------------------------	-------------------------------------

Starting torque (Variable torque)	maximum 110% for 60 s ¹⁾
-----------------------------------	-------------------------------------

Overload torque (Variable torque)	maximum 110% for 60 s ¹⁾
-----------------------------------	-------------------------------------

¹⁾ Percentage relates to the nominal torque.

Cable lengths and cross sections for control cables¹⁾

Max. motor cable length, screened	10 m
-----------------------------------	------

Max. motor cable length, unscreened, without fulfilling emission specification.	10 m
---	------

Maximum cross section to control terminals, flexible/ rigid wire without cable end sleeves	1.5 mm ² /16 AWG
--	-----------------------------

Maximum cross section to control terminals, flexible wire with cable end sleeves	1.5 mm ² /16 AWG
--	-----------------------------

Maximum cross section to control terminals, flexible wire with cable end sleeves with collar	1.5 mm ² /16 AWG
--	-----------------------------

Minimum cross section to control terminals	0.25 mm ² / 24 AWG
--	-------------------------------

¹⁾Power cables, see tables in 6.2 Electrical Data and Wire Sizes of the FCD 302 Design Guide, MG04H

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.
- 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).
- 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 constantly checks for critical levels of internal temperature, load current, high voltage on the intermediate circuit and low motor speeds. As a response to a critical level, the frequency converter can adjust the switching frequency and/ or change the switching pattern in order to ensure the performance of the drive.

Digital inputs

Programmable digital inputs	4 (6) ¹⁾
Terminal number	18, 19, 27 ¹⁾ , 29 ¹⁾ , 32, 33,
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 ²⁾	>19 V DC
Voltage level, logic '1' NPN ²⁾	<14 V DC
Maximum voltage on input	28 V DC
Pulse frequency range	0-110 kHz
(Duty cycle) Min. pulse width	4.5 ms
Input resistance, R _i	approx. 4 kΩ

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

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

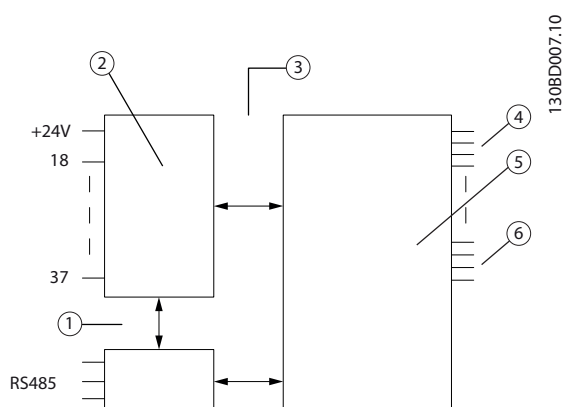
Safe stop Terminal 37 (Terminal 37 is fixed PNP logic)

Voltage level	0-24 V DC
Voltage level, logic '0' PNP	<4 V DC
Voltage level, logic '1' PNP	20 V DC
Nominal input current at 24 V	50 mA rms
Nominal input current at 20 V	60 mA rms
Input capacitance	400 nF

Analog inputs

Number of analog inputs	2
Terminal number	53, 54
Modes	Voltage or current
Mode select	Switch S201 and switch S202
Voltage mode	Switch S201/switch S202=OFF (U)
Voltage level	-10 to +10 V (scaleable)
Input resistance, R _i	approx. 10 kΩ
Max. voltage	±20 V
Current mode	Switch S201/switch S202=ON (I)
Current level	0/4 to 20 mA (scaleable)
Input resistance, R _i	approx. 200Ω
Max. current	30 mA
Resolution for analog inputs	10 bit (+ sign)
Accuracy of analog inputs	Max. 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.



Item	Description
1	Functional isolation
2	Control
3	PELV isolation
4	Mains
5	High voltage
6	Motor

Table 6.5 Legend

Illustration 6.3 Analog Inputs

Pulse/encoder inputs

Programmable pulse/encoder inputs	2/1
Terminal number pulse/encoder	29, 33 ¹⁾ /32 ²⁾ , 33 ²⁾
Max. frequency at terminal 29, 32, 33	110 kHz (Push-pull driven)
Max. frequency at terminal 29, 32, 33	5 kHz (open collector)
Min. frequency at terminal 29, 32, 33	4 Hz
Voltage level	see 6.3.1 Digital Inputs
Maximum voltage on input	28 V DC
Input resistance, R _i	approx. 4 kΩ
Pulse input accuracy (0.1 to 1 kHz)	Max. error: 0.1% of full scale
Encoder input accuracy (1 to 110 kHz)	Max. error: 0.05% of full scale

The pulse and encoder inputs (terminals 29, 32, 33) are galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

¹⁾ Pulse inputs are 29 and 33

²⁾ Encoder inputs: 32=A, and 33=B

Analog output

Number of programmable analog outputs	1
Terminal number	42
Current range at analog output	0/4 to 20 mA
Max. load GND - analog output less than	500 Ω
Accuracy on analog output	Max. error: 0.5% of full scale
Resolution on analog output	12 bit

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

Control card, RS-485 serial communication

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

The RS-485 serial communication circuit is functionally separated from other central circuits and galvanically isolated from the supply voltage (PELV).

Digital output

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

Specifications

VLT® Decentral Drive FCD 302

Resolution of frequency outputs 12 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, 13
Output voltage	24 V +1, -3 V
Max. load	600 mA

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

Relay outputs

Programmable relay outputs	2
Relay 01 Terminal number	1-3 (break), 1-2 (make)
Max. terminal load (AC-1) ¹⁾ on 1-3 (NC), 1-2 (NO) (Resistive load)	240 V AC, 2A
Max. terminal load (AC-15) ¹⁾ (Inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Max. terminal load (DC-1) ¹⁾ on 1-2 (NO), 1-3 (NC) (Resistive load)	48 V DC, 1A
Max. terminal load (DC-13) ¹⁾ (Inductive load)	24 V DC, 0.1A
Relay 02 Terminal number	4-6 (break), 4-5 (make)
Max. terminal load (AC-1) ¹⁾ on 4-5 (NO) (Resistive load) ²⁾³⁾ Overvoltage cat. II	240 V AC, 2 A
Max. terminal load (AC-15) ¹⁾ on 4-5 (NO) (Inductive load @ cosφ 0.4)	240 V AC, 0.2A
Max. terminal load (DC-1) ¹⁾ on 4-5 (NO) (Resistive load)	80 V DC, 2 A
Max. terminal load (DC-13) ¹⁾ on 4-5 (NO) (Inductive load)	24 V DC, 0.1A
Max. terminal load (AC-1) ¹⁾ on 4-6 (NC) (Resistive load)	240 V AC, 2 A
Max. terminal load (AC-15) ¹⁾ (Inductive load @ cosφ 0.4)	240 V AC, 0.2A
Max. terminal load (DC-1) ¹⁾ on 4-6 (NO), 4-5 (NC) (Resistive load)	48 V DC, 1A
Max. terminal load (DC-13) ¹⁾ (Inductive load)	24 V DC, 0.1 A
Min. terminal load on 1-3 (NC), 1-2 (NO), 4-6 (NC), 4-5 (NO)	24 V DC 10 mA, 24 V AC 20 mA

1) IEC 60947 part 4 and 5

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

2) Overvoltage Category II

3) UL applications 300 V AC 2A

Control card, 10 V DC output

Terminal number	±50
Output voltage	10.5 V ±0.5 V
Max. 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 0-1000 Hz	±0.003 Hz
Repeat accuracy of <i>Precise start/stop</i> (terminals 18, 19)	≤±0.1 ms
System response time (terminals 18, 19, 27, 29, 32, 33)	≤ 2 ms
Speed control range (open loop)	1:100 of synchronous speed
Speed control range (closed loop)	1:1000 of synchronous speed
Speed accuracy (open loop)	30-4000 rpm: error ±8 rpm
Speed accuracy (closed loop), depending on resolution of feedback device	0-6000 rpm: error ±0.15 rpm
Torque control accuracy (speed feedback)	max error ±5% of rated torque

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

Control card performance

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

Surroundings

Enclosure rating	IP66/Type 4X (indoor)
Vibration test for units with no circuit breaker	1.7 g RMS
Mounts unit with integrated circuit breaker on a level, vibration-proof and torsionally rigid support structure	
Max. relative humidity	5%-95% (IEC 60 721-3-3; Class 3K3 (non-condensing) during operation

Ambient temperature	Max. 40 °C (24-hour average maximum 35 °C)
Temperature during storage/transport	-25 to +65/70 °C
<i>Derating for high ambient temperature</i>	
Minimum ambient temperature during full-scale operation	0 °C
Minimum ambient temperature at reduced performance	-10 °C
Maximum altitude above sea level	1000 m
<i>Derating for high altitude</i>	
Control card, USB serial communication:	
USB standard	1.1 (Full speed)
USB plug	USB type B plug

Connection to PC is carried out via a standard host/device USB cable.

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

The USB ground connection is not galvanically isolated from protection earth. Use only an isolated laptop as PC connection to the USB connector on the frequency converter.

6

6.4 Efficiency

Contact Danfoss Hotline for efficiency data.

6.5.1 Acoustic Noise

Contact Danfoss Hotline for acoustic noise data.

6.6.1 dU/dt Conditions

NOTE

380-690 V

To avoid premature ageing of motors (without phase insulation paper or other insulation reinforcement) not designed for frequency converter operation, Danfoss strongly recommend to fit a dU/dt filter or a Sine-Wave filter on the output of the frequency converter. For further information about du/dt and Sine-Wave filters see the Output Filters Design Guide.

When a transistor in the inverter bridge switches, the voltage across the motor increases by a du/dt ratio depending on:

- the motor cable (type, cross-section, length screened or unscreened)
- 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, especially motors without phase coil insulation are affected. When the motor cable is short (a few metres), the rise time and peak voltage are lower.

Peak voltage on the motor terminals is caused by the switching of the IGBTs. The frequency converter complies with the demands of IEC 60034-25 regarding motors

designed to be controlled by frequency converters. The frequency converter also complies with IEC 60034-17 regarding Norm motors controlled by frequency converters. Contact Danfoss Hotline for measured values from laboratory tests.

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