



# Design Guide

## VLT<sup>®</sup> Micro Drive FC 51





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# 1 Introduction

## 1.1 Available Literature

This design guide contains the basic information necessary for installing and running the frequency converter.

- VLT® Micro Drive FC 51 Quick Guide
- VLT® Micro Drive FC 51 Programming Guide
- VLT® Micro Drive FC 51 LCP Mounting Instruction
- VLT® Micro Drive FC 51 De-coupling Plate Mounting Instruction
- VLT® Micro Drive FC 51 Remote Mounting Kit Mounting Instruction
- VLT® Micro Drive FC 51 DIN Rail Kit Mounting Instruction
- VLT® Micro Drive FC 51 IP21 Kit Mounting Instruction
- VLT® Micro Drive FC 51 Nema1 Kit Mounting Instruction
- VLT® Micro Drive FC 51 Line Filter MCC 107 Installation Instruction

## 1.2 Manual and Software Version

This manual is regularly reviewed and updated. All suggestions for improvement are welcome. Table 1.1 shows the manual version and the corresponding software version.

Edition	Remarks	Software version
MG02K4XX	Miscellaneous minor updates.	3.1X

Table 1.1 Manual and Software Version

## 1.3 Abbreviations

°C	Degrees celsius
A	Ampere/AMP
AC	Alternating current
AMT	Automatic motor tuning
AWG	American wire gauge
DC	Direct current
EMC	Electro magnetic compatibility
ETR	Electronic thermal relay
FC	Frequency converter
$f_{M,N}$	Nominal motor frequency
g	Gram
Hz	Hertz
$I_{INV}$	Rated inverter output current
$I_{LIM}$	Current limit
$I_{M,N}$	Nominal motor current
$I_{VLT,MAX}$	The maximum output current
$I_{VLT,N}$	The rated output current supplied by the frequency converter
kHz	Kilohertz
LCP	Local control panel
m	Meter
mA	Milliampere
MCT	Motion control tool
mH	Millihenry inductance
min	Minute
ms	Millisecond
nF	Nanofarad
Nm	Newton meters
$n_s$	Synchronous motor speed
$P_{M,N}$	Nominal motor power
PCB	Printed circuit board
PELV	Protective extra low voltage
RPM	Revolutions per minute
Regen	Regenerative terminals
s	Second
$T_{LIM}$	Torque limit
$U_{M,N}$	Nominal motor voltage
V	Volt

Table 1.2 Abbreviations

1

## 1.4 Definitions

### 1.4.1 Frequency Converter

**$I_{VLT,MAX}$**

The maximum output current.

**$I_{VLT,N}$**

The rated output current supplied by the frequency converter.

**$U_{VLT,MAX}$**

The maximum output voltage.

### 1.4.2 Input

#### Control command

The connected motor can be started and stopped with LCP and the digital inputs.

Functions are divided into 2 groups.

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

Group 1	Reset, coast stop, reset and coast stop, quick stop, DC brake, stop, and the [Off] key.
Group 2	Start, pulse start, reversing, start reversing, jog, and freeze output.

Table 1.3 Function Groups

### 1.4.3 Motor

**$f_{JOG}$**

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

**$f_M$**

The motor frequency.

**$f_{MAX}$**

The maximum motor frequency.

**$f_{MIN}$**

The minimum motor frequency.

**$f_{M,N}$**

The rated motor frequency (nameplate data).

**$I_M$**

The motor current.

**$I_{M,N}$**

The rated motor current (nameplate data).

**$n_{M,N}$**

The nominal motor speed (nameplate data).

**$P_{M,N}$**

The rated motor power (nameplate data).

**$U_M$**

The instant motor voltage.

**$U_{M,N}$**

The rated motor voltage (nameplate data).

#### Break-away torque

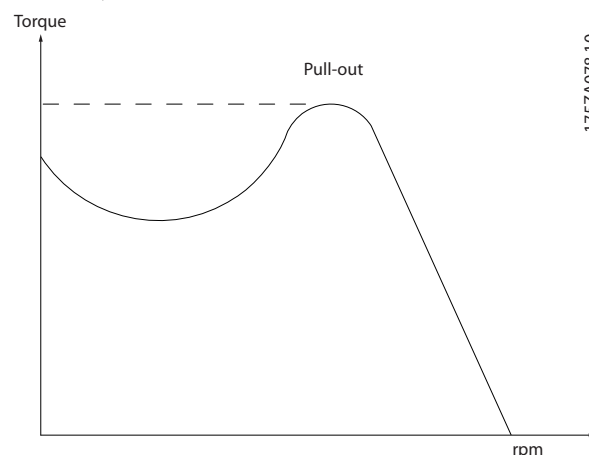


Illustration 1.1 Break-away Torque

**$\eta_{VLT}$**

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

#### Start-disable command

A stop command belonging to the group 1 control commands, see Table 1.3.

#### Stop command

See Table 1.3.

### 1.4.4 References

#### Analog reference

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

#### Bus reference

A signal transmitted to the serial communication port (FC port).

#### Preset reference

A defined preset reference to be set from -100% to +100% of the reference range. Selection of 8 preset references via the digital terminals.

**$Ref_{MAX}$**

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

**$Ref_{MIN}$**

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

## 1.4.5 Miscellaneous

### Analog inputs

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

There are 2 types of analog inputs:

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

### Analog outputs

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

### Automatic Motor Tuning, AMT

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

### Brake resistor

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

### CT characteristics

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

### Digital inputs

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

### Relay outputs

The frequency converter features 2 programmable relay outputs.

### ETR

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

### Initializing

If initializing is carried out (*parameter 14-22 Operation Mode*), the programmable parameters of the frequency converter return to their default settings.

Initializing *parameter 14-22 Operation Mode* does not initialize communication parameters.

### 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 none-periodic duty.

### LCP

The local control panel makes up a complete interface for control and programming of the frequency converter. The control panel is detachable and can be installed up to 3 m from the frequency converter, that is, in a front panel with the installation kit option.

### lsb

Least significant bit.

### MCM

Short for Mille Circular Mil, an American measuring unit for cable cross-section. 1 MCM  $\equiv$  0.5067 mm<sup>2</sup>.

### msb

Most significant bit.

### On-line/Off-line parameters

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

### PI controller

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

### RCD

Residual current device.

### Set-up

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

### 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 SLC.

### Thermistor

A temperature-dependent resistor.

### STW

Status word.

### FC standard bus

Includes RS485 bus with FC protocol.

### Trip

A state entered in fault situations, for example, if the frequency converter is subject to an overtemperature 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 canceled by activating reset or, sometimes, by being programmed to reset automatically. Do not use trip for personal safety.

### Trip lock

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

1

## VT characteristics

Variable torque characteristics used for pumps and fans.

### VVC<sup>+</sup>

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

## 1.5 Power Factor

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

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

The power factor for 3-phase control:

$$\text{Power factor} = \frac{I_1 \times \cos\phi_1}{I_{RMS}} = \frac{I_1}{I_{RMS}} \text{ since } \cos\phi_1 = 1$$

The power factor indicates to which extent the frequency converter imposes a load on the 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.



## 2 Safety and Conformity

### 2.1 Safety

The following symbols are used in this manual:

#### **⚠ WARNING**

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

#### **⚠ CAUTION**

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

#### **NOTICE**

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

#### 2.1.1 Safety Precautions

#### **⚠ WARNING**

##### HIGH VOLTAGE

Frequency converters contain high voltage when connected to AC mains input, DC supply, or load sharing. Failure to perform installation, start-up, and maintenance by qualified personnel can result in death or serious injury.

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

#### **⚠ WARNING**

##### UNINTENDED START

When the frequency converter is connected to AC mains, DC supply, or load sharing, the motor may start at any time. Unintended start during programming, service, or repair work can result in death, serious injury, or property damage. The motor can start with an external switch, a fieldbus command, an input reference signal from the LCP or LOP, via remote operation using MCT 10 Set-up Software, or after a cleared fault condition.

To prevent unintended motor start:

- Press [Off/Reset] on the LCP before programming parameters.
- Disconnect the frequency converter from the mains.
- Completely wire and assemble the frequency converter, motor, and any driven equipment before connecting the frequency converter to AC mains, DC supply, or load sharing.

#### **⚠ WARNING**

##### DISCHARGE TIME

The frequency converter contains DC-link capacitors, which can remain charged even when the frequency converter is not powered. High voltage can be present even when the warning LED indicator lights are off. Failure to wait the specified time after power has been removed before performing service or repair work can result in death or serious injury.

- Stop the motor.
- Disconnect AC mains and remote DC-link power supplies, including battery back-ups, UPS, and DC-link connections to other frequency converters.
- Disconnect or lock PM motor.
- Wait for the capacitors to discharge fully. The minimum duration of waiting time is specified in *Table 2.1*.
- Before performing any service or repair work, use an appropriate voltage measuring device to make sure that the capacitors are fully discharged.

Size	Minimum waiting time (minutes)
M1, M2, and M3	4
M4 and M5	15

Table 2.1 Discharge Time

## ⚠ WARNING

### LEAKAGE CURRENT HAZARD

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

- Ensure the correct grounding of the equipment by a certified electrical installer.

## ⚠ WARNING

### EQUIPMENT HAZARD

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

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

## ⚠ WARNING

### UNINTENDED MOTOR ROTATION WINDMILLING

Unintended rotation of permanent magnet motors creates voltage and can charge the unit, resulting in death, serious injury, or equipment damage.

- Ensure that permanent magnet motors are blocked to prevent unintended rotation.

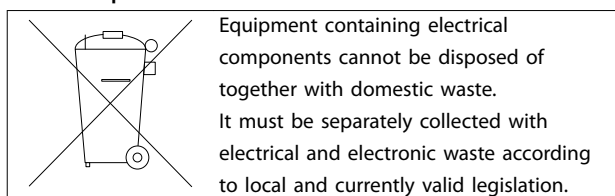
## ⚠ CAUTION

### INTERNAL FAILURE HAZARD

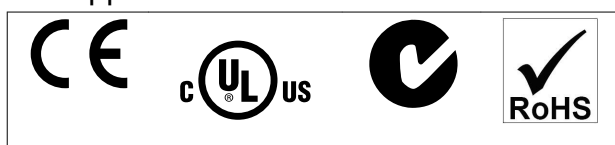
An internal failure in the frequency converter can result in serious injury when the frequency converter is not properly closed.

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

## 2.2 Disposal Instruction



## 2.3 Approvals



The frequency converter complies with UL 508C thermal memory retention requirements. For more information refer to *chapter 3.5.1 Motor Thermal Protection*.

## 2.4 CE Labeling

### 2.4.1 CE Conformity and Labeling

#### What is CE conformity and labeling?

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 3 EU directives:

#### The Machinery Directive (98/37/EEC)

All machines with critical moving parts are covered by the machinery directive of January 1, 1995. Since a frequency converter is largely electrical, it does not fall under the machinery directive. However, if a frequency converter is supplied for use in a machine, Danfoss provides information on safety aspects relating to the frequency converter. Danfoss does this with a manufacturer's declaration.

#### The Low Voltage Directive (73/23/EEC)

Frequency converters must be CE labeled 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 on 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 after request. To carry out EMC-correct installation, see the instructions in this design guide. In addition, Danfoss specifies which standards our products comply with. Danfoss offers the filters presented in the specifications and provide 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. Note that the responsibility for the final EMC properties of the appliance, system or installation rests with the installer.

## 2.4.2 What is Covered

The EU *Guidelines on the Application of Council Directive 89/336/EEC* outline 3 typical situations of using a frequency converter. See *chapter 2.4.3 Danfoss Frequency Converter and CE Labelling* for EMC coverage and CE labelling.

- The frequency converter is sold directly to the end-consumer. The frequency converter is for example sold to a DIY market. The end-consumer is a layman. The end-consumer installs the frequency converter himself for use with a hobby machine, a kitchen appliance, and so on. For such applications, the frequency converter must be CE labeled in accordance with the EMC directive.
- 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 labeled 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 labeled under the EMC directive.
- The frequency converter is sold as part of a complete system. The system is being marketed as complete and could for example, be an air-conditioning system. The complete system must be CE labeled in accordance with the EMC directive. The manufacturer can ensure CE labelling under the EMC directive either by using CE labeled components or by testing the EMC of the system. It is not necessary to test the entire system if only CE labeled components are selected.

### 2.4.3 Danfoss Frequency Converter and CE Labelling

CE labelling is a positive feature when used for its original purpose, that is, 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 covered specifications can be different and a CE label may therefore give the installer a false feeling 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, Danfoss

guarantees compliance with the Low Voltage Directive. Danfoss issues a declaration of conformity that confirms our CE labelling in accordance with the Low Voltage Directive.

The CE label also applies to the EMC directive if 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. Furthermore, Danfoss specifies which our different products comply with.

Danfoss provides other types of assistance that can help to obtain the best EMC result.

### 2.4.4 Compliance with EMC Directive 2004/108/EC

As mentioned, 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 that 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. If the EMC-correct instructions for installation are followed, the standards and test levels stated for power drive systems are complied with.

## 2.5 Air Humidity

The frequency converter has been designed to meet the IEC/EN 60068-2-3 standard, EN 50178 9.4.2.2 at 50 °C (122 °F).

## 2.6 Aggressive Environments

A frequency converter contains many mechanical and electronic components. All are to some extent vulnerable to environmental effects.

### **CAUTION**

**Do not install the frequency converter in environments with airborne liquids, particles, or gases that may affect or damage the electronic components. Failure to take necessary protective measures increases the risk of stoppages, potentially causing equipment damage and personnel injury.**

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

2

IP54. As an extra protection, coated printed circuit boards can be ordered as an option (standard on some power sizes).

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

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

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.

## 2.7 Vibration and Shock

The frequency converter has been tested according to the procedure based on the shown standards, *Table 2.2*.

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

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

Table 2.2 Standards

## 2.8 Advantages

### 2.8.1 Why use a Frequency Converter for Controlling Fans and Pumps?

A frequency converter takes advantage of the fact that centrifugal fans and pumps follow the laws of proportionality for such fans and pumps. For further information, see *chapter 2.8.3 Example of Energy Savings*.

### 2.8.2 The Clear Advantage - Energy Savings

The clear advantage of using a frequency converter for controlling the speed of fans or pumps lies in the electricity savings.

When comparing with alternative control systems and technologies, a frequency converter is the optimum energy control system for controlling fan and pump systems.

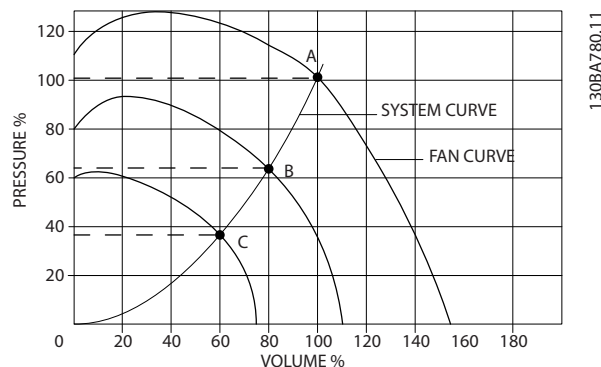
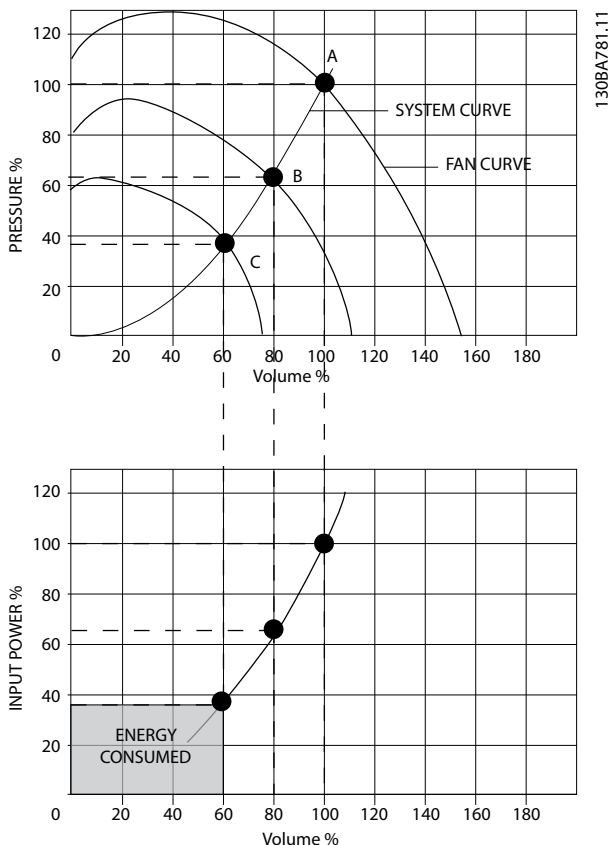


Illustration 2.1 Fan Curves (A, B, and C) for Reduced Fan Volumes



**Illustration 2.2 Energy Savings with Frequency Converter Solution**

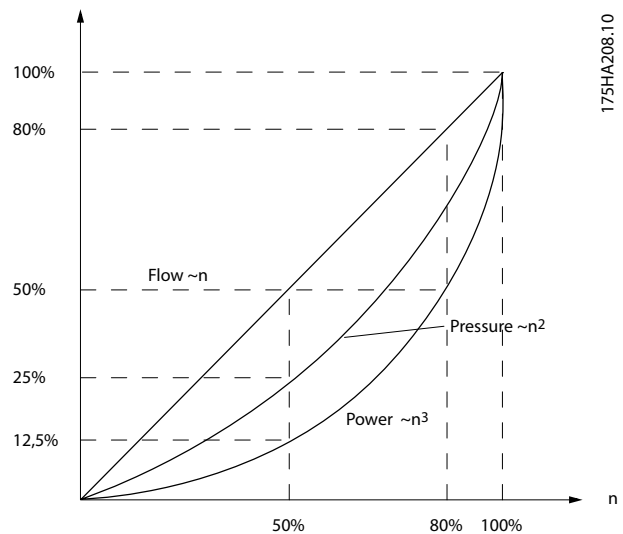
When using a frequency converter to reduce fan capacity to 60% - more than 50% energy savings may be obtained in typical applications.

### 2.8.3 Example of Energy Savings

As shown in *Illustration 2.3*, the flow is controlled by changing the RPM. By reducing the speed by only 20% from the rated speed, the flow is also reduced by 20%. This is because the flow is directly proportional to the RPM. The consumption of electricity, however, is reduced by 50%.

If the system in question only needs to be able to supply a flow that corresponds to 100% a few days in a year, while the average is below 80% of the rated flow for the remainder of the year, the amount of energy saved is even more than 50%.

*Illustration 2.3* describes the dependence of flow, pressure, and power consumption on RPM.



**Illustration 2.3 Laws of Proportionality**

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

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

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

Q=Flow	P=Power
Q <sub>1</sub> =Rated flow	P <sub>1</sub> =Rated power
Q <sub>2</sub> =Reduced flow	P <sub>2</sub> =Reduced power
H=Pressure	n=Speed control
H <sub>1</sub> =Rated pressure	n <sub>1</sub> =Rated speed
H <sub>2</sub> =Reduced pressure	n <sub>2</sub> =Reduced speed

**Table 2.3 The Laws of Proportionality**

### 2.8.4 Comparison of Energy Savings

The Danfoss frequency converter solution offers major savings compared with traditional energy saving solutions such as discharge damper solution and inlet guide vanes (IGV) solution. This is because the frequency converter is able to control fan speed according to thermal load on the system, and the frequency converter has a built-in facility that enables the frequency converter to function as a building management system, BMS.

*Illustration 2.3* shows typical energy savings obtainable with 3 well-known solutions when fan volume is reduced to 60%.

As the graph shows, more than 50% energy savings can be achieved in typical applications.

2

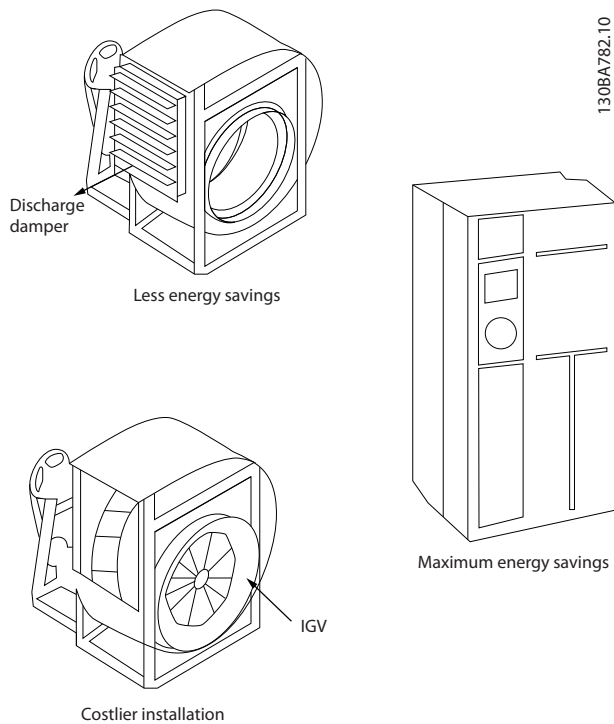


Illustration 2.4 The 3 Common Energy Saving Systems

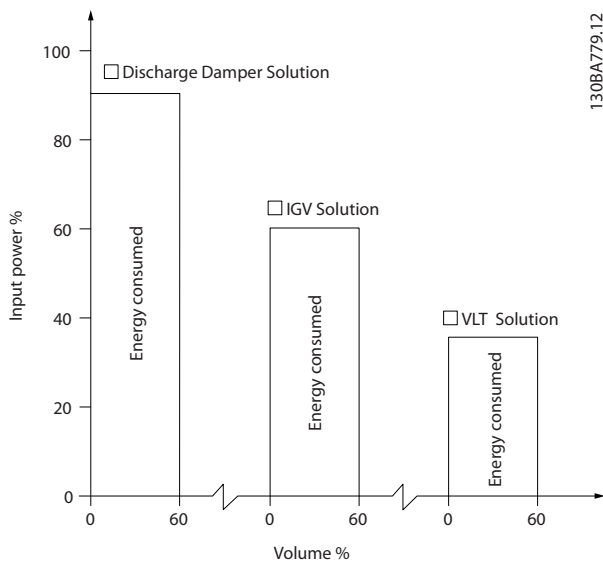


Illustration 2.5 Energy Savings

Discharge dampers reduce power consumption. Inlet guide vanes offer a 40% reduction, but are expensive to install. The Danfoss frequency converter solution reduces energy consumption with more than 50% and is easy to install. It also reduces noise, mechanical stress and wear-and-tear, and extends the life span of the entire application.

## 2.8.5 Example with Varying Flow over 1 Year

This example is calculated based on pump characteristics obtained from a pump datasheet.

The result obtained shows energy savings more than 50% at the given flow distribution over a year. The payback period depends on the price per kWh and the price of frequency converter. In this example, it is less than a year when compared with valves and constant speed.

### Energy savings

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

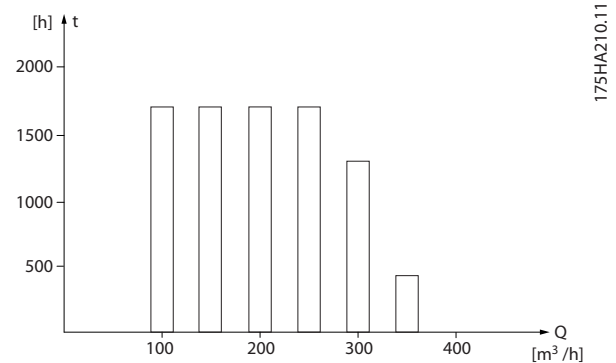


Illustration 2.6 Flow Distribution over 1 Year



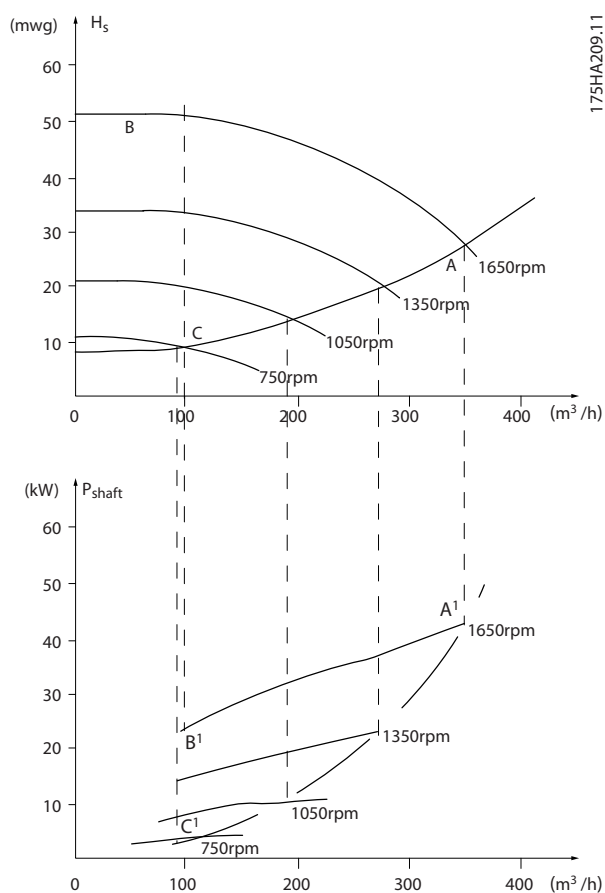


Illustration 2.7 Energy

m³/h	Distribution		Valve regulation		Frequency converter control	
	%	Hours	Power	Consumption	Power	Consumption
			A <sub>1</sub> - B <sub>1</sub>	kWh	A <sub>1</sub> - C <sub>1</sub>	kWh
350	5	438	42.5	18.615	42.5	18.615
300	15	1314	38.5	50.589	29.0	38.106
250	20	1752	35.0	61.320	18.5	32.412
200	20	1752	31.5	55.188	11.5	20.148
150	20	1752	28.0	49.056	6.5	11.388
100	20	1752	23.0	40.296	3.5	6.132
<b>Σ</b>	100	8760		275.064		26.801

Table 2.4 Result

## 2.8.6 Better Control

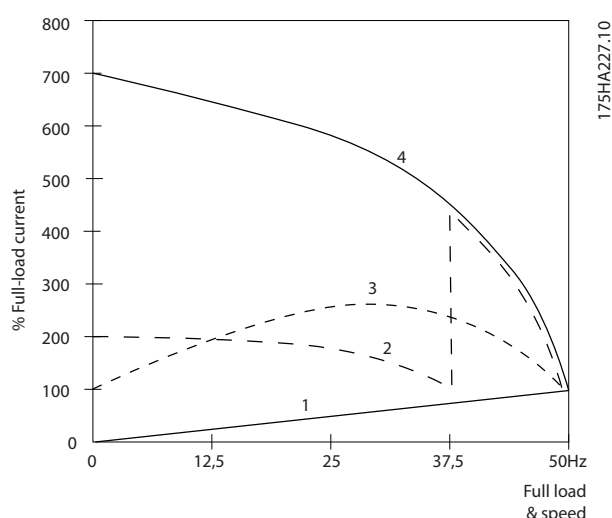
If a frequency converter is used for controlling the flow or pressure of a system, improved control is obtained. A frequency converter can vary the speed of the fan or pump, obtaining variable control of flow and pressure. Furthermore, a frequency converter can quickly adapt the speed of the fan or pump to new flow or pressure conditions in the system.

Simple control of process (flow, level, or pressure) utilizing the built-in PI control.

## 2.8.7 Star/Delta Starter or Soft Starter not Required

When larger motors are started, it is necessary in many countries to use equipment that limits the start-up current. In more traditional systems, a star/delta starter or soft starter is widely used. Such motor starters are not required if a frequency converter is used.

As illustrated in *Illustration 2.8*, a frequency converter does not consume more than rated current.



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

Illustration 2.8 Current

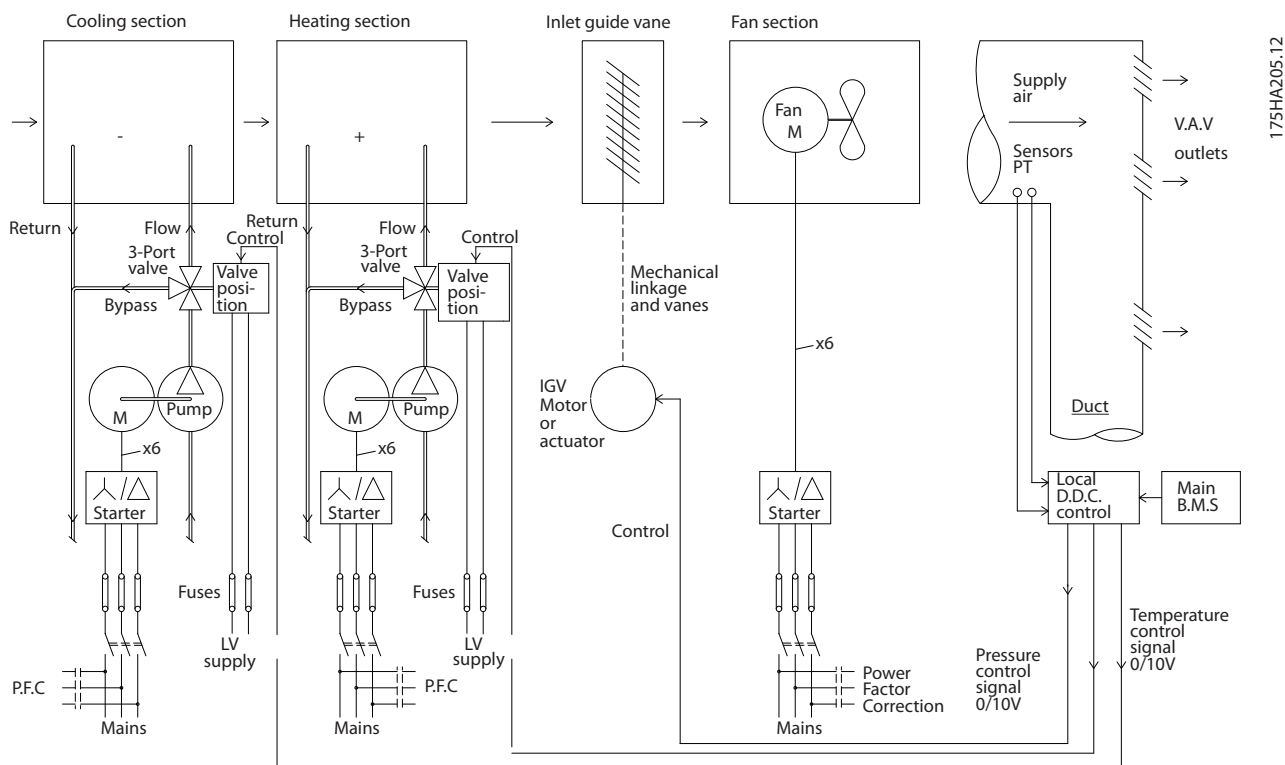
## 2.8.8 Using a Frequency Converter Saves Money

The example in *chapter 2.8.9 Without a Frequency Converter* shows that a frequency converter replaces other equipment. It is possible to calculate the cost of installing the 2 different systems. In the example, the 2 systems can be established at roughly the same price.

Use the VLT® Energy Box software that is introduced in *chapter 1.1 Available Literature* to calculate the cost savings that can be achieved by using a frequency converter.

## 2.8.9 Without a Frequency Converter

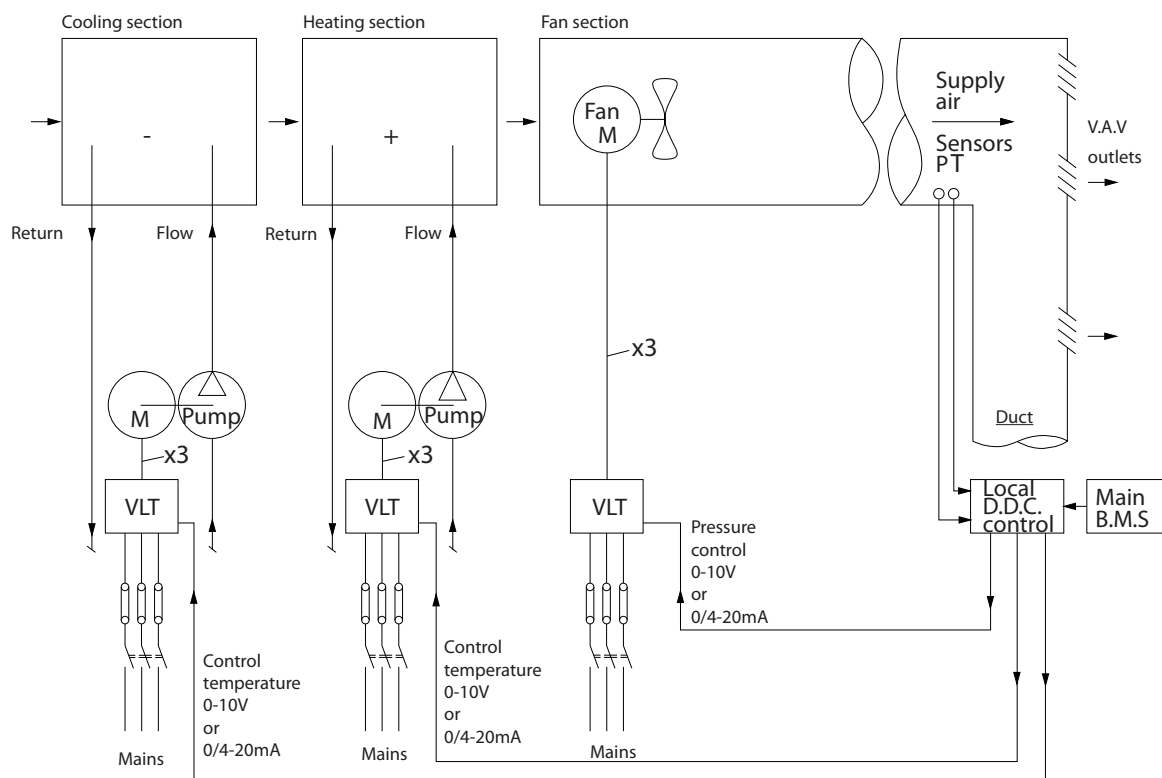
2



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

Illustration 2.9 Traditional Fan System

## 2.8.10 With a Frequency Converter



175HA206.11

2

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

Illustration 2.10 Fan System Controlled by Frequency Converters

## 3 Product Overview

### 3.1 Control Structures

Select the configuration mode in *parameter 1-00 Configuration Mode*.

#### 3.1.1 Control Structure Open Loop

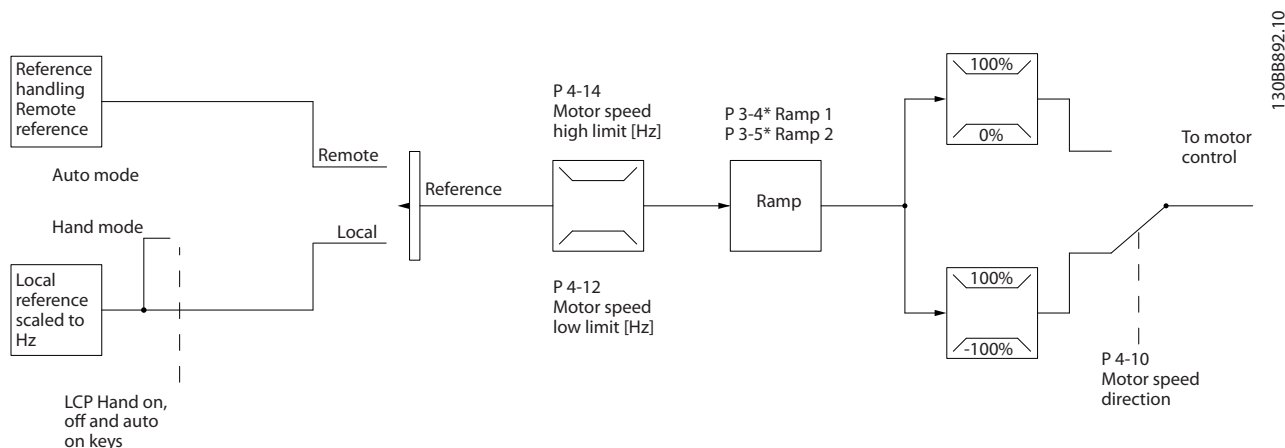


Illustration 3.1 Open-loop Structure

In the configuration shown in *Illustration 3.1*, *parameter 1-00 Configuration Mode* is set to [0] *Open loop*. The resulting reference from the reference handling system or the local reference is received and fed through the ramp limitation and speed limitation before being sent to the motor control. The output from the motor control is then limited by the maximum frequency limit.

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

The frequency converter can be operated manually via the local control panel (LCP) or remotely via analog/digital inputs or fieldbus. If allowed in *parameter 0-40 [Hand on] Key on LCP*, *parameter 0-44 [Off/Reset] Key on LCP*, and *parameter 0-42 [Auto on] Key on LCP*, it is possible to start and stop the frequency converter by pressing the [Hand On] and [Off/Reset] keys. Alarms can be reset via the [Off/Reset] key. After pressing the [Hand On] key, the frequency converter goes into hand mode and follows (by default) the local reference set using the LCP potentiometer (LCP 12) or [▲]/[▼] (LCP 11). The potentiometer can be disabled using *parameter 6-80 LCP Potmeter Enable*. If the potentiometer is disabled, use the navigation keys for adjusting reference.

After pressing the [Auto On] key, the frequency converter goes into auto mode and follows (by default) the remote reference. In this mode, it is possible to control the

frequency converter via the digital inputs and RS485. 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*.

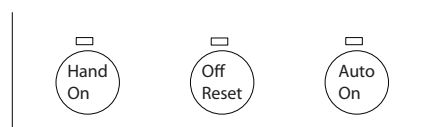


Illustration 3.2 LCP Control Keys

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

Local reference is restored at power-down.

#### 3.1.3 Control Structure Closed Loop

The internal controller allows the frequency converter to become a part of the controlled system. The frequency converter receives a feedback signal from a sensor in the system. It then compares this feedback to a setpoint reference value and determines the error, if any, between these 2 signals. It then adjusts the speed of the motor to correct this error.

For example, consider a pump application where the speed of a pump is to be controlled so that the static pressure in a pipe is constant. The static pressure value is supplied to the frequency converter as the setpoint reference. A static pressure sensor measures the actual static pressure in the pipe and supplies this data to the frequency converter as a feedback signal. If the feedback signal is greater than the

setpoint reference, the frequency converter slows the pump down to reduce the pressure. In a similar way, if the pipe pressure is lower than the setpoint reference, the frequency converter automatically speeds the pump up to increase the pressure provided by the pump.

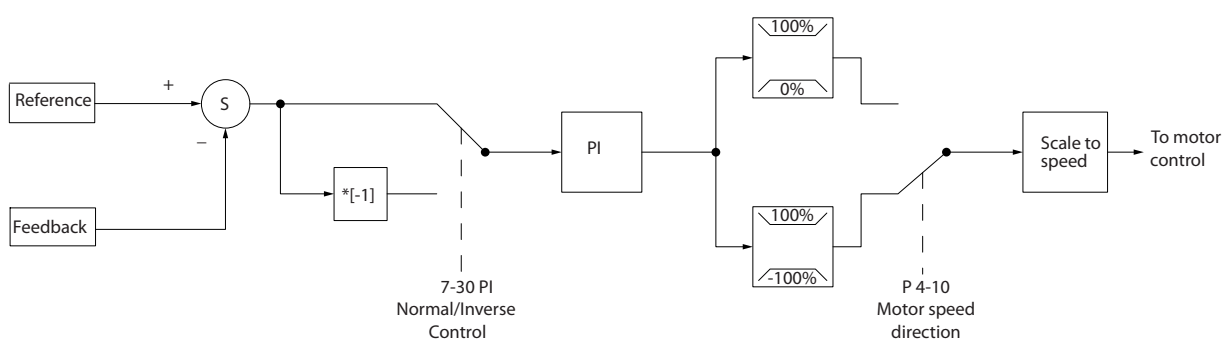


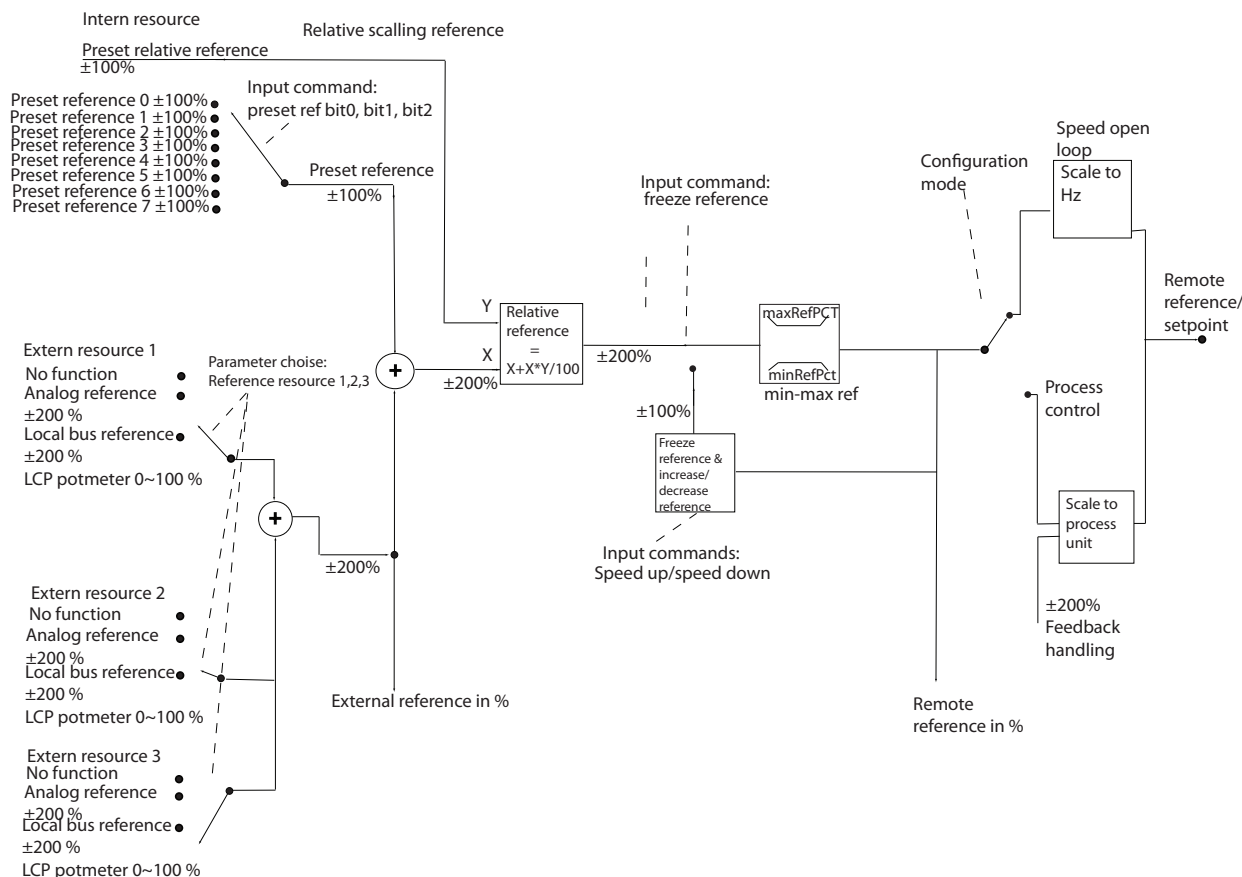
Illustration 3.3 Control Structure Closed Loop

While the default values for the closed-loop controller of the frequency converter often provide satisfactory performance, the control of the system can often be optimized by adjusting parameters.

### 3.1.4 Reference Handling

Details for open-loop and closed-loop operation.

3



1308B900.13

Illustration 3.4 Block Diagram Showing Remote Reference

The remote reference consists of:

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

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

active reference. Finally, this reference can be scaled using *parameter 3-14 Preset Relative Reference*.

The scaled reference is calculated as follows:

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

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

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



## 3.2 General Aspects of EMC

### 3.2.1 General Aspects of EMC Emissions

Frequency converters (and other electrical devices) generate electronic or magnetic fields that may interfere with their environment. The electromagnetic compatibility (EMC) of these effects depends on the power and the harmonic characteristics of the devices.

Uncontrolled interaction between electrical devices in a system can degrade compatibility and impair reliable operation. Interference may take the form of mains harmonics distortion, electrostatic discharges, rapid voltage fluctuations, or high frequency interference. Electrical devices generate interference along with being affected by interference from other generated sources.

Electrical interference usually occurs at frequencies in the range 150 kHz to 30 MHz. Airborne interference from the frequency converter system in the range 30 MHz to 1 GHz is generated from the inverter, motor cable, and the motor. Capacitive currents in the motor cable coupled with a high  $dU/dt$  from the motor voltage generate leakage currents, as shown in *Illustration 3.5*.

The use of a shielded motor cable increases the leakage current (see *Illustration 3.5*) because shielded cables have higher capacitance to ground than unshielded cables. If the leakage current is not filtered, it causes greater interference on the mains in the radio frequency range below approximately 5 MHz. Since the leakage current ( $I_1$ ) is carried back to the unit through the shield ( $I_3$ ), there is, in principle, only a small electro-magnetic field ( $I_4$ ) from the shielded motor cable according to *Illustration 3.5*.

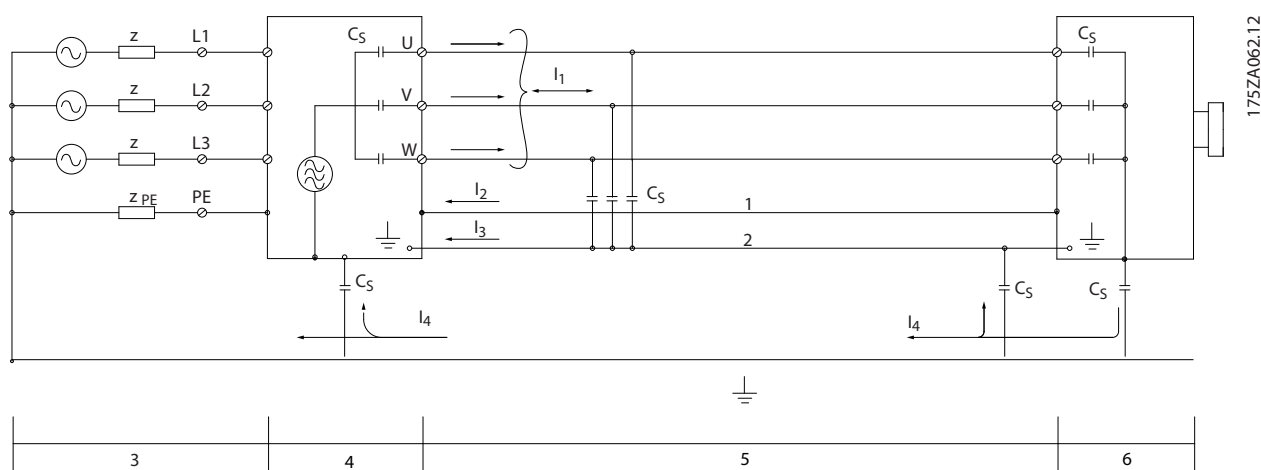
The shield reduces the radiated interference, but increases the low-frequency interference on the mains. Connect the motor cable shield to the frequency converter enclosure and to the motor enclosure. Use the integrated shield clamps to avoid twisted-pair ends (pigtails). Pigtails increase the shield impedance at higher frequencies, which reduces the shield effect and increases the leakage current ( $I_4$ ).

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

When placing the shield on a mounting plate for the frequency converter, ensure that the mounting plate is made of metal, to convey the shield currents back to the unit. Ensure good electrical contact from the mounting plate through the mounting screws to the frequency converter chassis.

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

To reduce the interference level from the entire system (unit+installation), make motor and brake cables as short as possible. Avoid placing cables with a sensitive signal level alongside motor cables and brake cables. The control electronics generate radio interference at frequencies higher than 50 MHz (airborne).



1	Ground wire	3	AC mains supply	5	Shielded motor cable
2	Shield	4	Frequency converter	6	Motor

Illustration 3.5 Generation of Leakage Currents

### 3.2.2 Emission Requirements

The EMC product standard for frequency converters defines 4 categories (C1, C2, C3, and C4) with specified requirements for emission and immunity. *Table 3.1* states the definition of the 4 categories and the equivalent classification from EN 55011.

Category	Definition	Equivalent emission class 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 not plug-in and not movable, and must 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

Category	Definition	Equivalent emission class in EN 55011
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. Make an EMC plan.

Table 3.1 Correlation between IEC 61800-3 and EN 55011

When the generic (conducted) emission standards are used, the frequency converters are required to comply with the limits in *Table 3.2*.

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

Table 3.2 Correlation between Generic Emission Standards and EN 55011

### 3.2.3 EMC Test Results (Emission)

FC type	Conducted emission. Maximum shielded cable length [m]						Radiated emission			
	Industrial environment				Housing, trades, and light industries		Industrial environment			
	EN 55011 Class A2		EN 55011 Class A1		EN 55011 Class B		EN 55011 Class A2		EN 55011 Class A1	
	Without external filter	With external filter	Without external filter	With external filter	Without external filter	With external filter	Without external filter	With external filter	Without external filter	With external filter
≤2.2 kW. Single-phase, 230 V	25	–	15	50	5	15	Yes	–	No	Yes
≤7.5 kW. Up to 500 V AC, 3-phase	25	–	15	50	–	15	Yes	–	No	Yes
11–22 kW. Up to 500 V AC, 3-phase	25	–	15	50	–	15	Yes	–	No	Yes

Table 3.3 EMC Test Result

### 3.2.4 Harmonics Emission Requirements

Equipment connected to the public supply network

#### **NOTICE**

Without a power option, the frequency converter may not comply with harmonics emission requirements.

Options	Definition
1	IEC/EN 61000-3-2 Class A for 3-phase balanced equipment (for professional equipment only up to 1 kW total power).
2	IEC/EN 61000-3-12 Equipment 16 A-75 A and professional equipment as from 1 kW up to 16 A phase current.

Table 3.4 Harmonics Emission Requirements

### 3.2.5 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 therefore comply also with the lower requirements for home and office environment with a large safety margin.

### 3.3 Galvanic Isolation (PELV)

PELV offers protection through extra low voltage. Protection against electric shock is ensured when the electrical supply is of the PELV type and the installation is made as described in local/national regulations on PELV supplies.

All control terminals and relay terminals 01-03/04-06 comply with PELV (protective extra low voltage) (does not apply to grounded delta leg above 440 V).

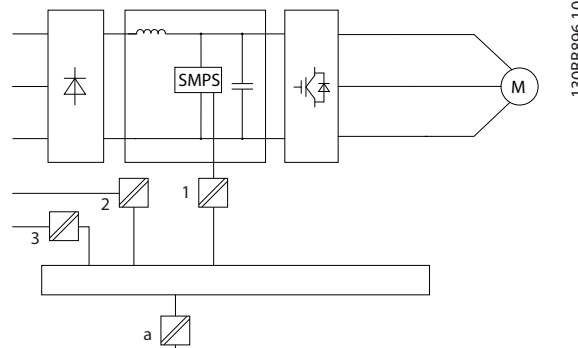
Galvanic (ensured) isolation is obtained by fulfilling requirements for higher isolation and by providing the relevant creepage/clearance distances. These requirements are described in the EN 61800-5-1 standard.

The components that make up the electrical isolation, as described, also comply with the requirements for higher isolation and the relevant test as described in EN 61800-5-1.

The PELV galvanic isolation can be shown in *Illustration 3.7*.

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

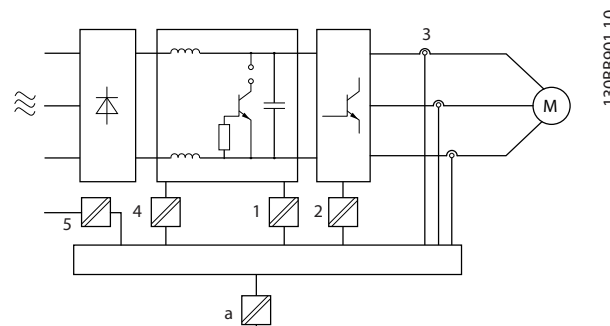
#### 0.25–22 kW (0.34–30 hp)



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

Illustration 3.6 Galvanic Isolation

#### 30–90 kW (40–120 hp)



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

Illustration 3.7 Galvanic Isolation

The functional galvanic isolation (see *Illustration 3.6*) is for the RS485 standard bus interface.

## ⚠ CAUTION

### INSTALLATION AT HIGH ALTITUDE

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

## 3.4 Ground Leakage Current

## ⚠ WARNING

### DISCHARGE TIME

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), and the motor connection for kinetic back-up.

Before touching any electrical parts, wait at least the amount of time indicated in *Table 2.1*.

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

## ⚠ WARNING

### LEAKAGE CURRENT HAZARD

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

- Ensure the correct grounding of the equipment by a certified electrical installer.

## ⚠ WARNING

### RESIDUAL CURRENT DEVICE PROTECTION

This product can cause a DC current in the protective conductor. Where a residual current device (RCD) is used for protection in case of direct or indirect contact, only an RCD of Type B is allowed on the supply side of this product. Otherwise, apply another protective measure, such as separation from the environment by double or reinforced insulation, or isolation from the supply system by a transformer. See also application note *Protection against Electrical Hazards*.

Protective grounding of the frequency converter and the use of RCDs must always follow national and local regulations.

## 3.5 Extreme Running Conditions

### Short circuit (motor phase-phase)

Current measurement in each of the 3 motor phases or in the DC-link, protects the frequency converter against short circuits. A short circuit between 2 output phases causes an overcurrent in the inverter. The inverter is turned off individually when the short circuit current exceeds the allowed value (*Alarm 16 Trip Lock*).

For information about protecting the frequency converter against a short circuit at the load sharing and brake outputs, see *chapter 6.6 Fuses*.

### Switching on the output

Switching on the output between the motor and the frequency converter is fully permitted. The frequency converter is not damaged in any way by switching on the output. However, fault messages may appear.

### Motor-generated overvoltage

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

- The load drives the motor (at constant output frequency from the frequency converter), that is the load generates energy.
- During deceleration (ramp-down) if the inertia moment is high, the friction is low, and the ramp-down time is too short for the energy to be dissipated as a loss in the frequency converter, the motor, and the installation.
- Incorrect slip compensation setting (*parameter 1-62 Slip Compensation*) may cause higher DC-link voltage.

The control unit may attempt to correct the ramp if *parameter 2-17 Over-voltage Control* is enabled.

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

### Mains drop-out

During a mains drop-out, the frequency converter keeps running until the DC-link voltage drops below the minimum stop level, which is typically 15% below the frequency converter's lowest rated supply voltage. The mains voltage before the drop-out and the motor load determines how long it takes for the frequency converter to coast.

## 3.5.1 Motor Thermal Protection

Motor thermal protection can be provided in 2 ways.

Using a motor thermistor, via 1 of the following:

- Thermistor input on a standard AI.
- VLT® Sensor Input MCB 114.
- VLT® PTC Thermistor Card MCB 112.

The frequency converter monitors motor temperature as the speed and load vary to detect overheating conditions.

The other method calculates motor temperature by measuring current, frequency, and operating time. The frequency converter shows the thermal load on the motor in percentage and can issue a warning at a programmable

overload setpoint. Programmable options at the overload allow the frequency converter to stop the motor, reduce output, or ignore the condition. Even at low speeds, the frequency converter meets I2t Class 20 electronic motor overload standards.

This method is called electronic thermal relay (ETR).

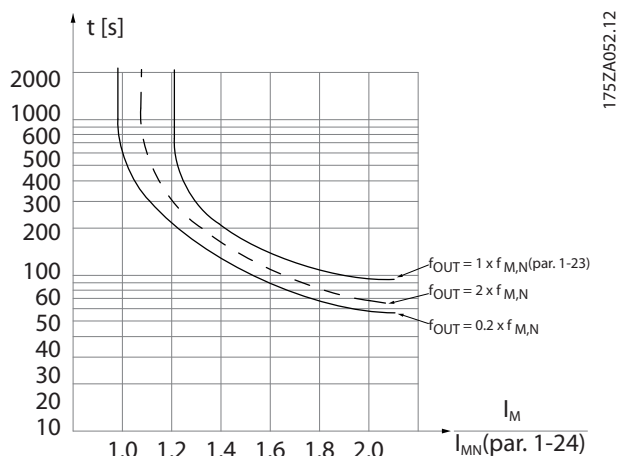


Illustration 3.8 ETR Characteristics

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

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

A special version of the ETR is also available for EX-e motors in ATEX areas. This function makes it possible to enter a specific curve to protect the Ex-e motor. The *Programming Guide* takes the user through the set-up.

## 4 Selection

### 4.1 Options and Accessories

#### 4.1.1 Local Control Panel (LCP)

For detailed information on programming, see *VLT® Micro Drive FC 51 Programming Guide*.

#### **NOTICE**

The frequency converter can also be programmed from a PC via RS485 port by installing the MCT 10 Set-up Software.

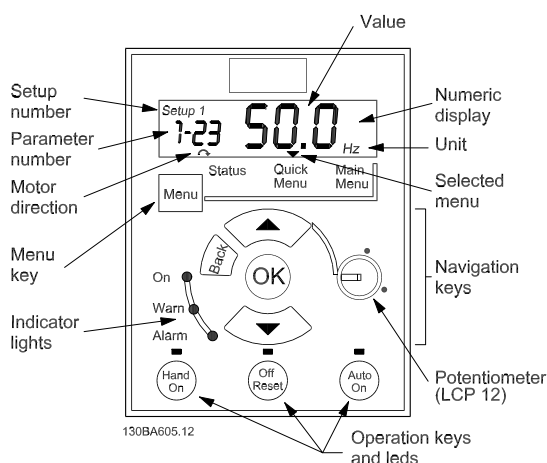


Illustration 4.1 Description of LCP Keys and Display

Press [Menu] to select one of the following menus:

#### **Status**

For readouts only.

#### **Quick Menu**

For access to Quick Menus 1 and 2.

#### **Main Menu**

For access to all parameters.

#### **Navigation keys**

[Back]: For moving to the previous step or layer in the navigation structure.

[▲] [▼]: For maneuvering between parameter groups, parameters and within parameters.

[OK]: For selecting a parameter and for accepting changes to parameter settings.

#### **Operation keys**

A yellow indicator light above the operation keys indicates the active key.

[Hand On]: Starts the motor and enables control of the frequency converter via the LCP.

[Off/Reset]: Stops the motor (off). If in alarm mode, the alarm is reset.

[Auto On]: The frequency converter is controlled either via control terminals or serial communication.

[Potentiometer] (LCP 12): The potentiometer works in 2 ways:

In *auto mode* the potentiometer acts as an extra programmable analog input.

In *hand-on mode*, the potentiometer controls local reference.

#### 4.1.2 Remote Mounting Kit for LCP

The LCP can be moved to the front of a cabinet by using the remote built-in kit. The enclosure is IP55.

Enclosure	IP55 front
Maximum cable length between LCP and unit	3 m
Communication standard:	RS485
Ordering number	132B0102

Table 4.1 Technical Data

#### 4.1.3 FC 51 Remote Mounting Kit Mounting Instruction

##### **Step 1**

Fit the gasket on the LCP in the frequency converter.

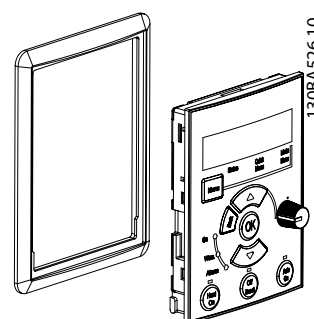


Illustration 4.2 Fit Gasket on LCP



### Step 2

Place the LCP on the panel - see dimensions of the hole in *Illustration 4.3*.

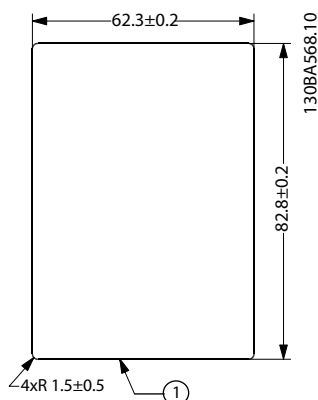


Illustration 4.3 Dimensions of Hole

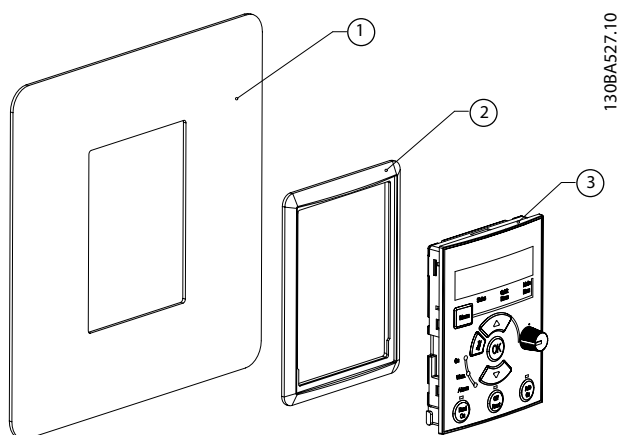


Illustration 4.4 Panel, Gasket, and LCP

### Step 3

Place the bracket on the back of the LCP, then slide down. Tighten screws and connect the cable to the LCP.

#### **NOTICE**

Use the provided thread cutting screws to fasten the connector to the LCP. Tightening torque: 1.3 Nm (11.5 in-lb).

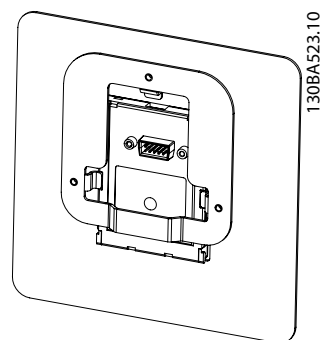


Illustration 4.5 Place the Bracket on LCP

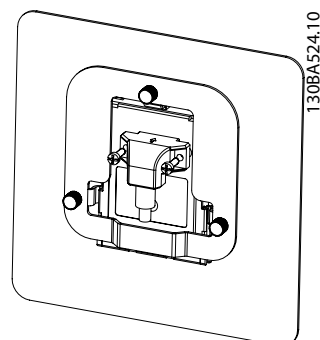


Illustration 4.6 Tighten Screws and Connect Cable to LCP

### Step 4

Connect the cable to the frequency converter.

#### **NOTICE**

Use the provided thread cutting screws to fasten connector to the frequency converter. Tightening torque: 1.3 Nm (11.5 in-lb).

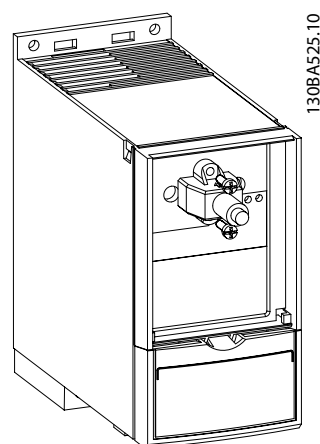


Illustration 4.7 Connect Cable to the Frequency Converter

#### 4.1.4 IP21/TYPE 1 Enclosure Kit

Frame	IP class	Power [kW]			Height [mm] A	Width [mm] B	Depth [mm] C	Ordering number
		1x200–240 V	3x200–240 V	3x380–480 V				
M1	IP21	0.18–0.75	0.25–0.75	0.37–0.75	219.3	73	155.9	132B0108
M2	IP21	1.5	1.5	1.5–2.2	245.6	78	175.4	132B0109
M3	IP21	2.2	2.2–3.7	3.0–7.5	297.5	95	201.4	132B0110
M4	IP21	–	–	11–15	–	–	–	–
M5	IP21	–	–	18.5–22	–	–	–	–

Table 4.2 IP21/TYPE 1 Enclosure Kit

#### 4.1.5 Type 1 (NEMA)

Frame	IP class	Power [kW]			Height [mm] A	Width [mm] B	Depth [mm] C	Ordering number
		1x200–240 V	3x200–240 V	3x380–480 V				
M1	IP20	0.18–0.75	0.25–0.75	0.37–0.75	194.3	70.0	155.9	132B0103
M2	IP20	1.5	1.5	1.5–2.2	220.6	75.0	175.4	132B0104
M3	IP20	2.2	2.2–3.7	3.0–7.5	282.5	90.0	201.3	132B0105
M4	IP20	–	–	11–15	345.6	125.0	248.5	132B0120
M5	IP20	–	–	18.5–22	385.5	165.0	248.2	132B0121

Table 4.3 Type 1 (NEMA)

#### 4.1.6 Decoupling Plate

Frame	IP class	Power [kW]			Height [mm] A	Width [mm] B	Depth [mm] C	Ordering number
		1x200–240 V	3x200–240 V	3x380–480 V				
M1	IP20	0.18–0.75	0.25–0.75	0.37–0.75	204.2	70.0	155.9	132B0106
M2	IP20	1.5	1.5	1.5–2.2	230.0	75.0	175.4	132B0106
M3	IP20	2.2	2.2–3.7	3.0–7.5	218.5	90.0	201.3	132B0107
M4	IP20	–	–	11–15	347.5	125.0	248.5	132B0122
M5	IP20	–	–	18.5–22	387.5	165.0	248.2	132B0122

Table 4.4 Decoupling Plate

#### 4.1.7 FC 51 Type 1 Kit Mounting Instruction for M1, M2 and M3

##### Step 1

Mount metal plate on frequency converter and tighten the screws. Tightening torque: 2 Nm (18 in-lb).

M1	4 x ½"
M2	5 x ½"
M3	2 x ½"
	3 x ¾"

Table 4.5 Conduit Sizes

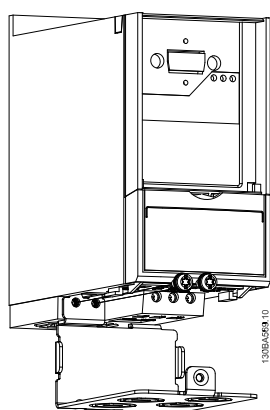


Illustration 4.8 Mount Metal Plate on Frequency Converter

##### Step 2

Fit base cover on frequency converter and tighten screw.

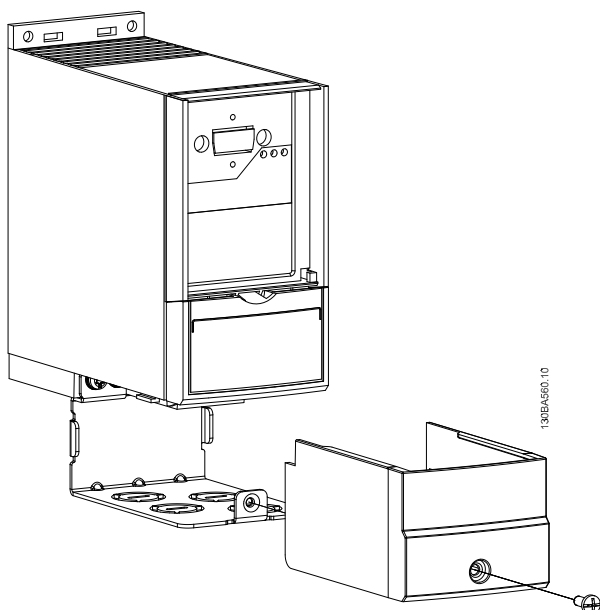


Illustration 4.9 Fit Base Cover on Frequency Converter

#### 4.1.8 FC 51 Type 1 Kit Mounting Instruction for M4 and M5

##### Step 1

Mount metal plate on frequency converter and tighten the screws. Tightening torque: 2 Nm (18 in-lb).

M4	3x½"
M5	3x1"

Table 4.6 Conduit Sizes

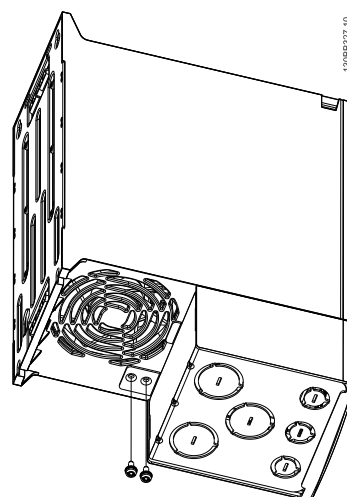


Illustration 4.10 Mount Metal Plate on Frequency Converter

##### Step 2

Fit base cover on frequency converter and tighten screw.

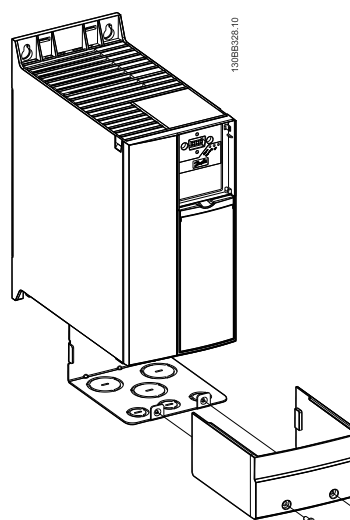


Illustration 4.11 Fit Base Cover on Frequency Converter

### 4.1.9 FC 51 IP21 Kit Mounting Instruction

#### Step 1

Fit top cover on frequency converter.

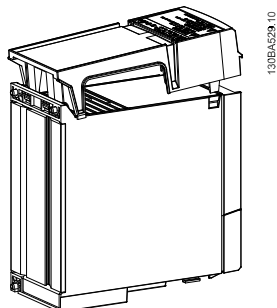


Illustration 4.12 Fit Top Cover on Frequency Converter

#### Step 2

Remove knockouts on metal plate and fit rubber grommets.

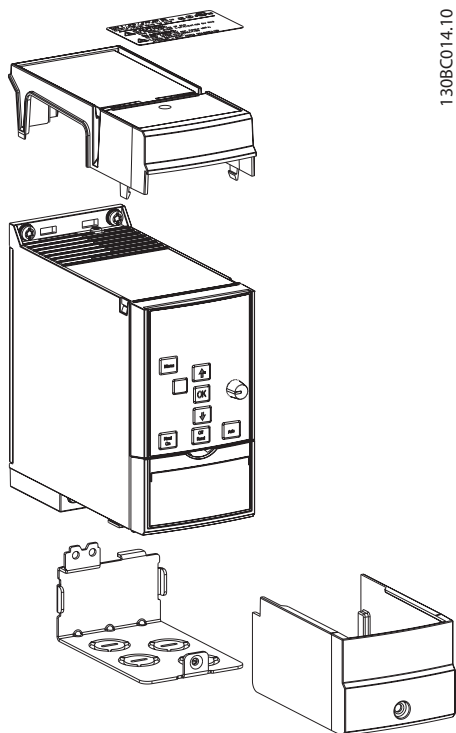


Illustration 4.13 Remove Knockouts and Fit Rubber Grommets

#### Step 3

Mount metal plate on frequency converter and tighten screws. Tightening torque: 2 Nm (18 in-lb).

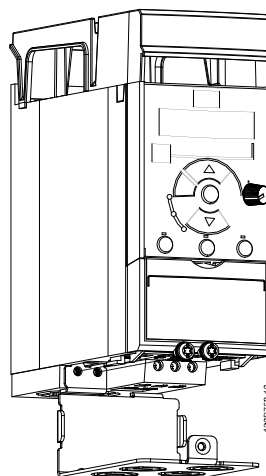


Illustration 4.14 Mount Metal Plate on Frequency Converter

#### Step 4

Fit base cover on frequency converter and tighten screw.

#### **NOTICE**

IP21 is only achieved with LCP 11 or LCP 12 mounted.

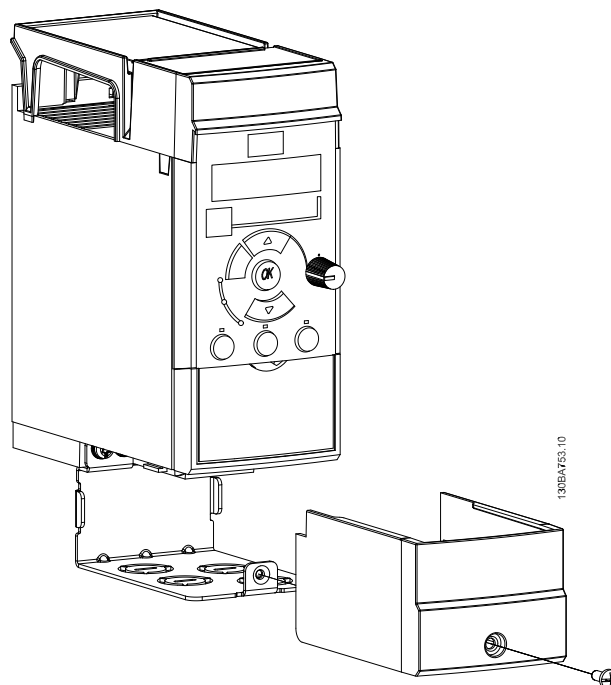


Illustration 4.15 Fit Base Cover on Frequency Converter

#### 4.1.10 FC 51 Decoupling Plate Mounting Instruction for M1 and M2

##### Step 1

Mount metal plate on frequency converter and fasten with two screws. Tightening torque: 2 Nm (18 in-lb).

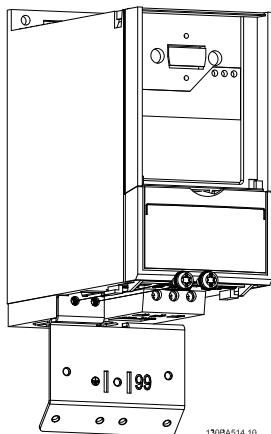


Illustration 4.16 Mount Metal Plate

##### Step 2

Mount bracket on decoupling plate.

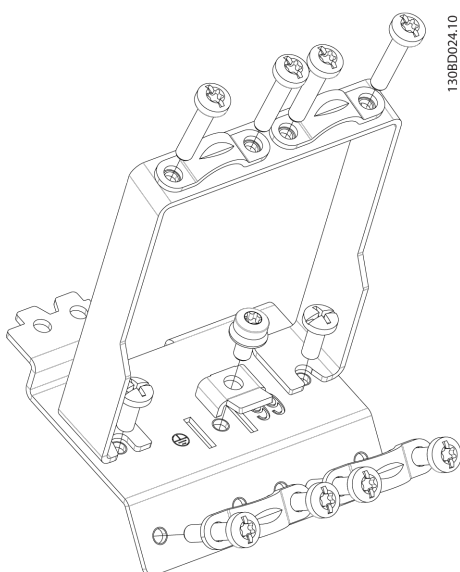


Illustration 4.17 Mount Bracket

##### Step 3

Decoupling plate mounted.

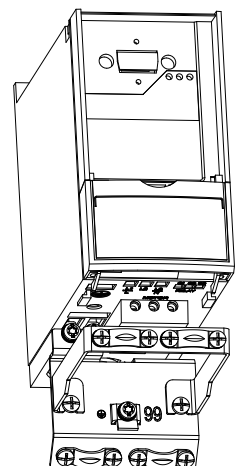


Illustration 4.18 Decoupling Plate Mounted

#### 4.1.11 FC 51 Decoupling Plate Mounting Instruction for M3

##### Step 1

Mount decoupling plate on frequency converter and fasten with 2 screws. Tightening torque: 2 Nm (18 in-lb).

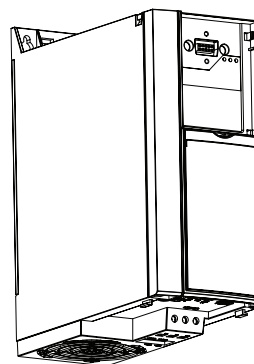


Illustration 4.19 Mount Decoupling Plate

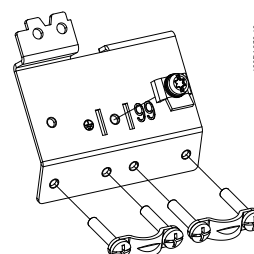


Illustration 4.20 Fasten with Screws

4

**Step 2**

Decoupling plate mounted.

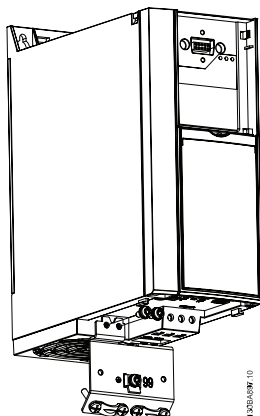


Illustration 4.21 Decoupling Plate Mounted

**Step 2**

Decoupling plate mounted.

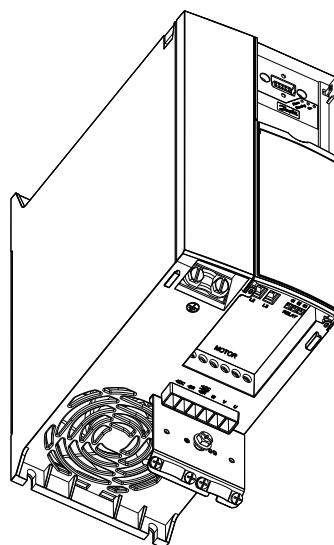


Illustration 4.23 Decoupling Plate Mounted

**4.1.12 FC 51 Decoupling Plate Mounting  
Instruction for M4 and M5**

**Step 1**

Mount metal plate on frequency converter and fasten with 2 screws. Tightening torque: 2 Nm (18 in-lb).

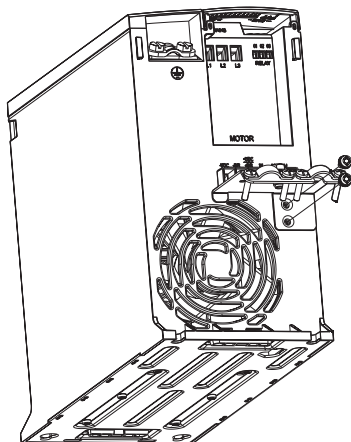


Illustration 4.22 Mount Metal Plate

**Step 3**

Mount bracket on decoupling plate.

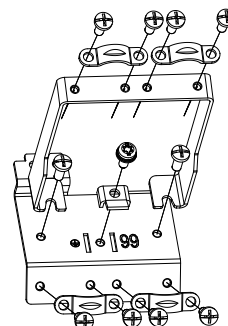


Illustration 4.24 Mount Bracket

#### 4.1.13 FC 51 DIN Rail Kit Mounting Instruction

##### Step 1

Mount plastic part on frequency converter.

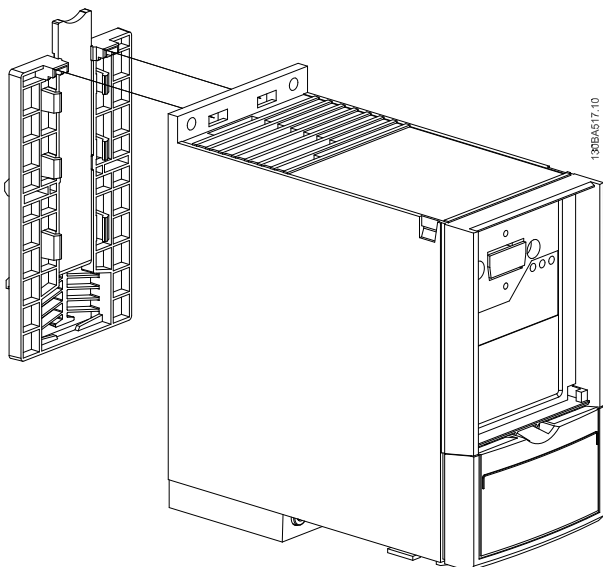


Illustration 4.25 Mount Plastic Part

##### Step 2

Fit frequency converter on DIN rail (DIN rail kit is only for M1 and M2).

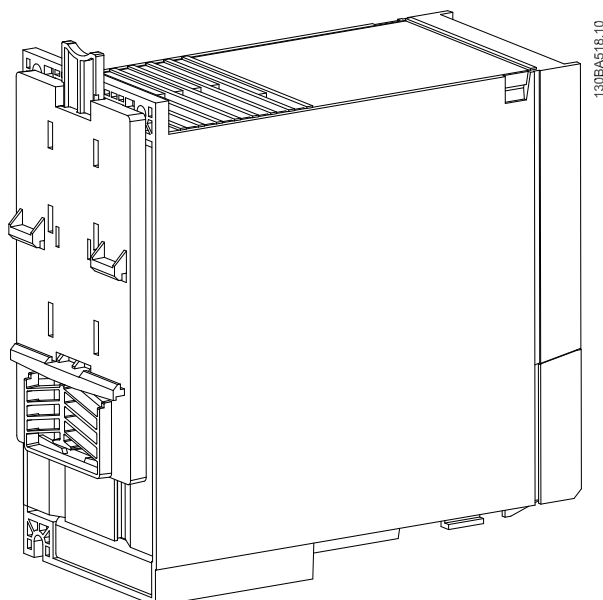
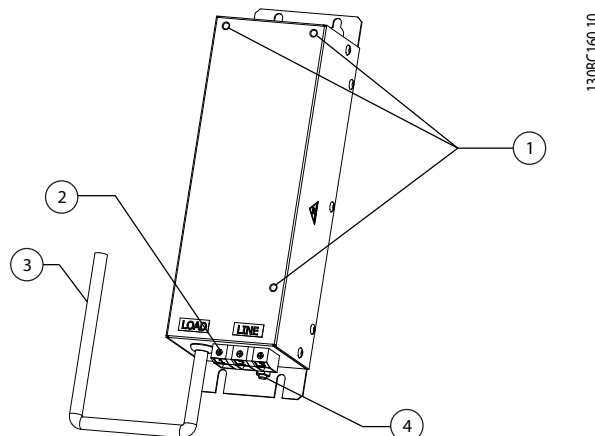


Illustration 4.26 Fit Frequency Converter on DIN Rail

#### 4.1.14 Line Filter MCC 107 Installation Instructions

Line filters of the type MCC 107 combine a harmonic filter and an EMC filter. The line filters improve performance of the line current to the frequency converter. The 3 different line filter enclosure sizes correspond to the VLT® Micro Drive enclosure types M1, M2 and M3.



1	Mounting holes for frequency converter
2	Input terminal
3	Output line
4	Protective earth (PE)

Illustration 4.27 Line Filter MCC 107 with VLT® Micro Drive FC 51

### CAUTION

#### HOT SURFACES

The surface of the line filter can get hot during operation.

- Do not touch the line filter during operation or wear protective gloves.

### WARNING

#### HIGH VOLTAGE

Frequency converters contain high voltage when connected to AC mains input, DC supply, or load sharing. Failure to perform installation, start-up, and maintenance by qualified personnel can result in death or serious injury.

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

### NOTICE

Always replace defective filters, never repair them.

#### 4.1.15 Mounting

There are 2 options for mounting the line filter correctly:

##### Front mounting

- Mount the filter in a vertical position with the terminals at the bottom.
- Mount the frequency converter on the front of the line filter using 3 M4 bolts.

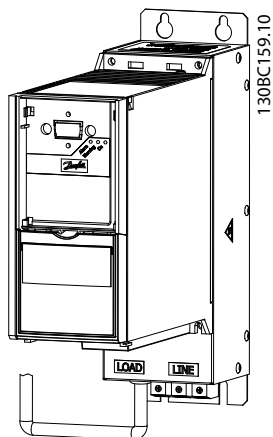


Illustration 4.28 Line Filter with Frequency Converter

- Ensure metal-to-metal contact between filter and frequency converter.

##### NOTICE

Metal-to-metal contact improves EMC performance and enables the base plate of the frequency converter to function as heat sink for the line filter.

##### Side mounting

- Mount the filter side-by-side with the frequency converter. There is no requirement for spacing between filter and frequency converter.
- Mount the back of the line filter to a cooling surface, such as a metal wall. Alternatively, derate the line filter by 1 size: For example, use a 0.75 kW (1 hp) line filter with a 0.37 kW (0.5 hp) frequency converter.

##### CAUTION

##### HIGH TEMPERATURES

Risk of fire or device damage.

- Do not mount the line filter close to heat-sensitive material (such as wood).

#### 4.1.16 Wiring

##### WARNING

##### LEAKAGE CURRENT HAZARD

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

- Ensure the correct grounding of the equipment by a certified electrical installer.

1. Connect line filter to protective earth (PE). Use a cabinet mounting panel or similar to achieve optimum grounding conditions.
2. Connect input terminal to mains power (cable not supplied).
3. Connect output cable to the input terminals of the frequency converter.
4. Ensure solid electrical contact between line filter and frequency converter (high frequency grounding).

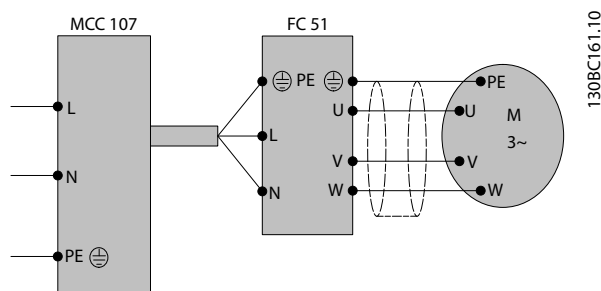


Illustration 4.29 Line 1

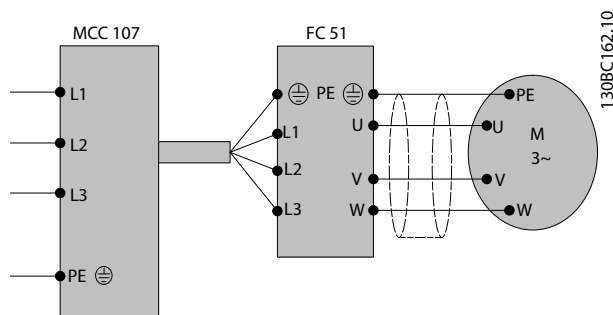


Illustration 4.30 Line 2



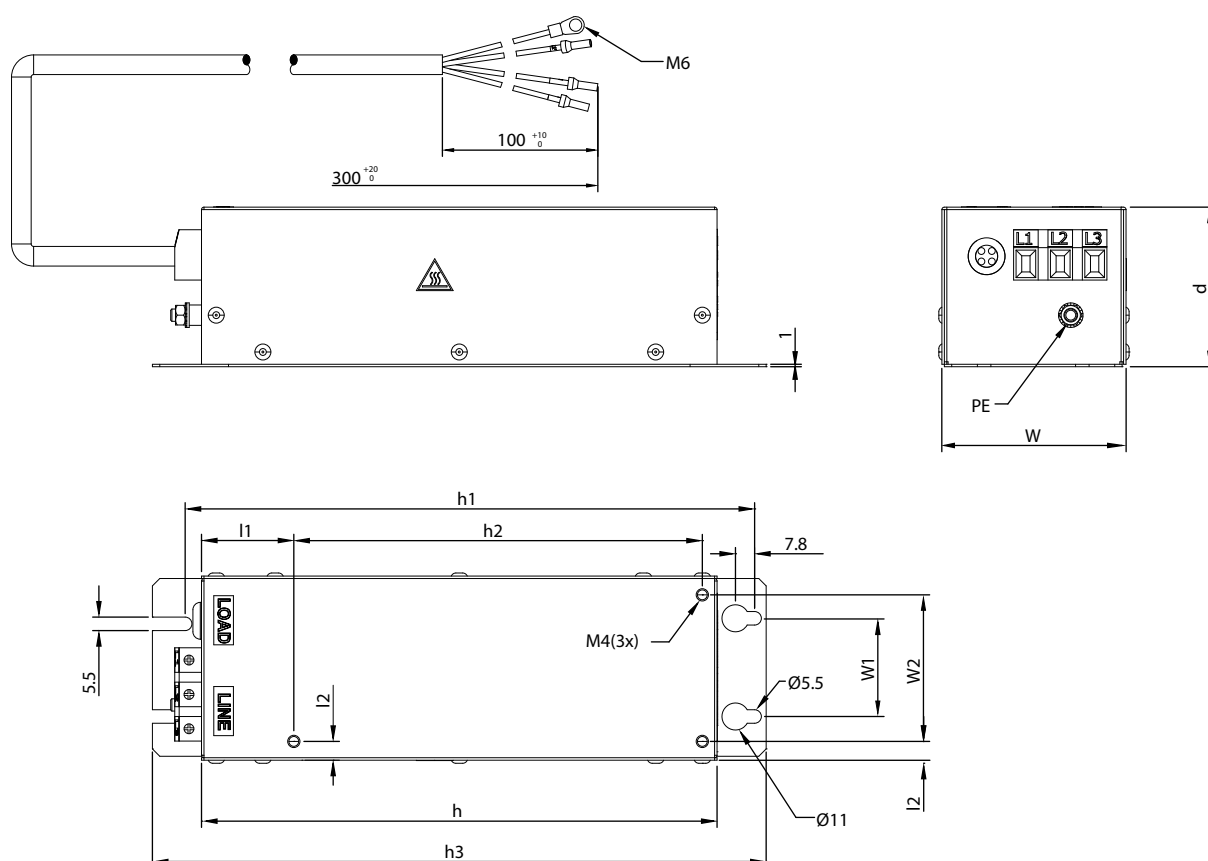
**NOTICE**

- Reduce common mode interferences by establishing a low impedance current path to the frequency converter.
- To ensure optimum EMC performance, use a decoupling plate kit (ordering numbers 132B0106 or 132B0107)

For voltage rating, wire size, and fuse selection, see the VLT® Micro Drive FC 51 Quick Guide.

4

4.1.17 Dimensions



1308C163.10

Frame	M1	M2	M3
w [mm]	70	75	90
d [mm]	55	65	69
h [mm]	190	210	300
h3 [mm]	230	250	340
w1 [mm]	40	40	55.6
h1 [mm]	213	233	323
w2 [mm]	55	59	69
h2 [mm]	140	166.5	226
l1 [mm]	45	38.5	68
l2 [mm]	7.6	8	9.3
PE (metric)	M6	M6	M6
Weight [kg]	2	3	5

Illustration 4.31 Dimensions

## 4.2 Special Conditions

### 4.2.1 Purpose of Derating

Consider the purpose of derating when using the frequency converter at low air pressure (heights), at low speeds, with long motor cables, cables with a large cross-section, or at high ambient temperature. The required action is described in this section.

### 4.2.2 Derating for Ambient Temperature

Derating for ambient temperature and IGBT switching.

The ambient temperature measured over 24 hours should be at least 5 °C lower than the maximum ambient temperature. If the frequency converter is operated at high ambient temperature, decrease the constant output current. The frequency converter has been designed for operation at maximum 50 °C ambient temperature with 1 motor size smaller than nominal. Continuous operation at full load at 50 °C ambient temperature reduces the lifetime of the frequency converter.

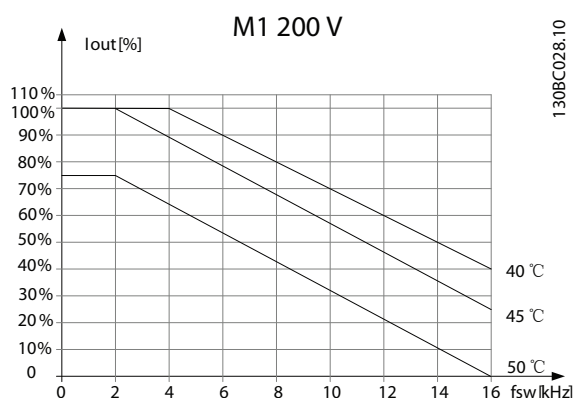


Illustration 4.32 M1 200 V

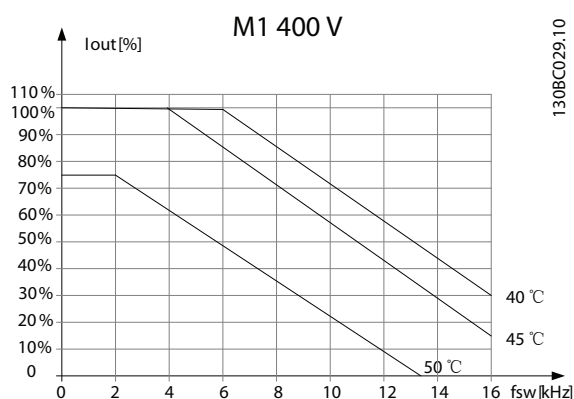


Illustration 4.33 M1 400 V

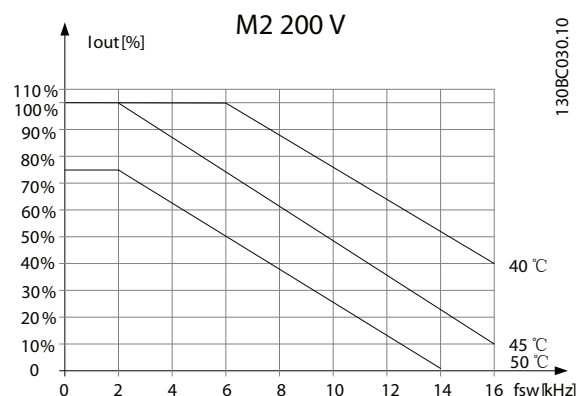


Illustration 4.34 M2 200 V

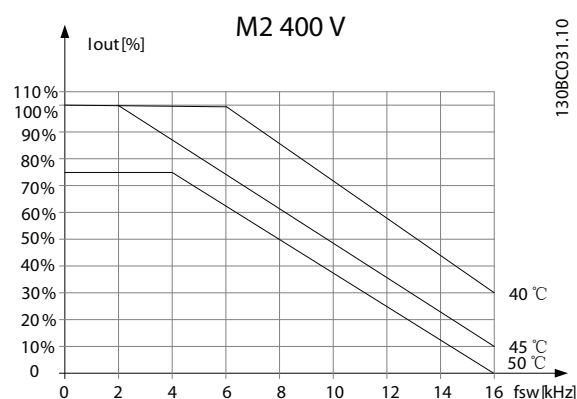


Illustration 4.35 M2 400 V

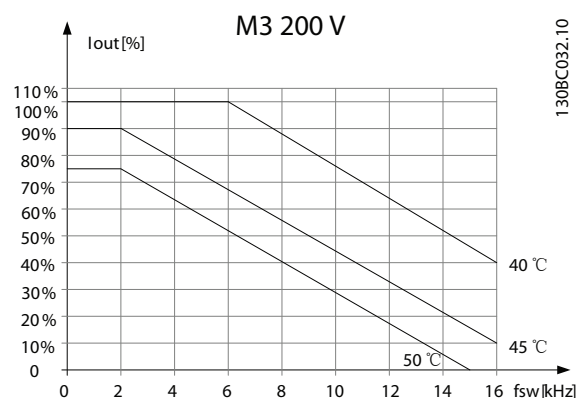


Illustration 4.36 M3 200 V

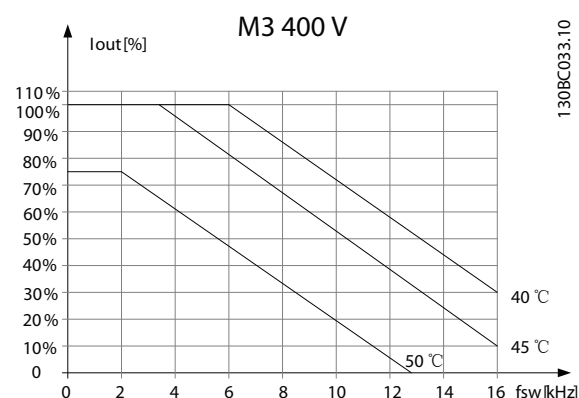


Illustration 4.37 M3 400 V

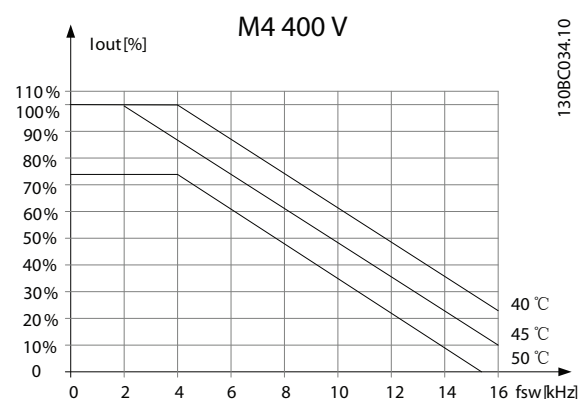


Illustration 4.38 M4 200 V

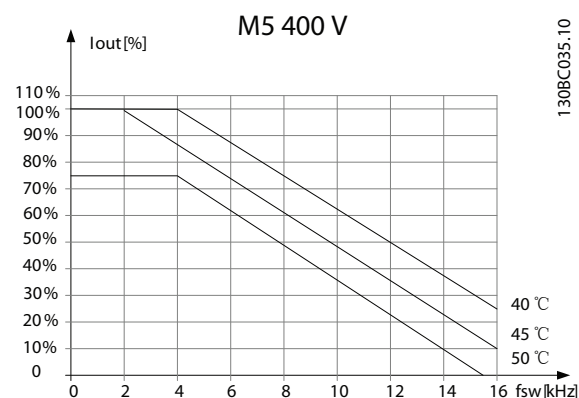


Illustration 4.39 M4 400 V

### 4.2.3 Derating for Low Air Pressure

The cooling capability of air is decreased at low air pressure.

#### **CAUTION**

#### INSTALLATION AT HIGH ALTITUDE

For altitudes above 2000 m (6560 ft), contact Danfoss regarding PELV.

Below 1000 m (3280 ft) altitude, no derating is necessary, but above 1000 m (3280 ft), decrease the ambient temperature or the maximum output current. Decrease the output by 1% per 100 m (328 ft) altitude above 1000 m (3280 ft), or reduce the maximum ambient temperature by 1 °C per 200 m (656 ft).

### 4.2.4 Automatic Adaptations to Ensure Performance

The frequency converter constantly checks for critical levels of:

- Internal temperature.
- Load current.
- High voltage on the DC link.
- Low motor speeds.

As a response to a critical level, the frequency converter can adjust the switching frequency and/or change the switching pattern to ensure the performance of the frequency converter. The capability for automatic output current reduction extends the acceptable operating conditions even further.

### 4.2.5 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 application, a motor may overheat at low speeds due to less cooling air from the motor integral fan.

Therefore, if the motor runs continuously at an RPM value lower than half of the rated value, supply the motor with extra air-cooling (or use a motor designed for this type of operation).

An alternative is to reduce the load level of the motor by using a larger motor. However, the design of the frequency converter puts a limit to the motor size.

## 5 How to Order

### 5.1 Drive Configurator

It is possible to design a frequency converter according to the application requirements by using the ordering number system.

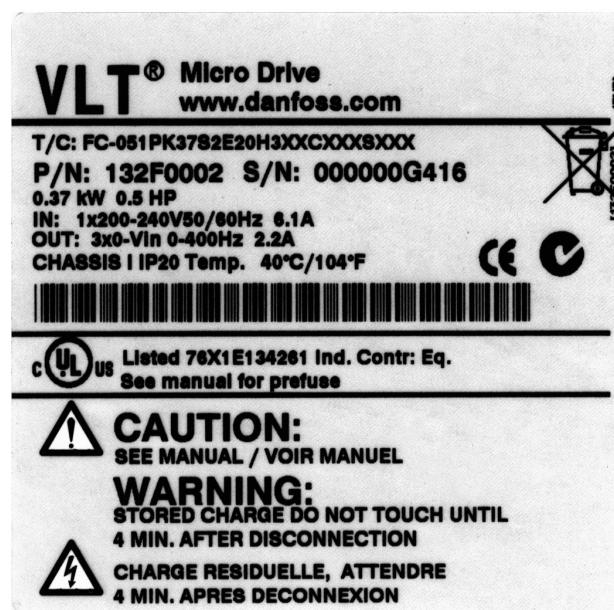
To order standard frequency converters and frequency converters with integral options, send a type code string describing the product to the Danfoss sales office. An example type code:

FC051PXXXXXXXXXXXXXXXXXXXX

Use the web-based Drive Configurator to configure the right frequency converter for the right application and generate the type code string. The Drive Configurator automatically generates an 8-digit sales number (either for 1 product or a project list with several products) to be delivered to your local sales office.

### 5.2 FC Identification

The nameplate sticker is located on the top of each frequency converter and shows the ratings, serial number, warnings catalog number, and other relevant data for each unit. See *Table 5.2* for details, how to read the type code string.



130BA505

Illustration 5.1 Nameplate Sticker

### 5.3 Type Code

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
FC-		0	5	1	P									H						X	X	X	S	X	X	X
130BA589.10																										

Table 5.1 Type Code

Description	Pos.	Possible option
Product group	1-3	Adjustable frequency converters
Series and product type	4-6	Micro Drive
Power size	7-10	0.18-22 kW (0.24-30 hp)
Mains voltage	11-12	S2: Single-phase 200-240 V AC T2: 3-phase 200-240 V AC T4: 3-phase 380-480 V AC
Enclosure	13-15	IP20/Chassis
RFI filter	16-17	H3: RFI filter A1/B (reduced cable length)
Brake	18	B: Brake chopper included (from 1.5 kW (2 hp) and up) X: No brake chopper included
Display	19	X: No local control panel N: Numerical local control panel (LCP) P: Numerical local control panel (LCP) with potentiometer
Coating PCB	20	C: Coated PCB X: No coated PCB
Mains option	21	X: No mains option
Adaptation A	22	X: No adaptation
Adaptation B	23	X: No adaptation
Software release	24-27	SXXX: Latest release - std. software

Table 5.2 Type Code Description

5

## 5.4 Ordering Numbers

	200–240 V			380–480 V	
Power [kW]	Current [I <sub>nom</sub> ]	Single-phase	3-phase	Current [I <sub>nom</sub> ]	3 ph.
0.18	1.2	132F0001			
0.25	1.5		132F0008		
0.37	2.2	132F0002	132F0009	1.2	132F0017
0.75	4.2	132F0003	132F0010	2.2	132F0018
1.5	6.8	132F0005	132F0012	3.7	132F0020
2.2	9.6	132F0007	132F0014	5.3	132F0022
3.0				7.2	132F0024
3.7	15.2		132F0016		
4.0	Frequency converters from 1.5 kW (2 hp) and up have built-in brake chopper.			9.0	132F0026
5.5				12.0	132F0028
7.5				15.5	132F0030
11.0				23.0	132F0058
15.0				31.0	132F0059
18.5				37.0	132F0060
22.0				43.0	132F0061

Table 5.3 Ordering Numbers

## 5.5 Options

Ordering number	Description
132B0100	VLT® Control Panel LCP 11 w/o potentiometer
132B0101	VLT® Control Panel LCP 12 with potentiometer
132B0102	Remote mounting kit for LCP incl. 3 m cable IP55 with LCP 11, IP21 with LCP 12
132B0103	Nema type 1 kit for M1 enclosure
132B0104	Type 1 kit for M2 enclosure
132B0105	Type 1 kit for M3 enclosure
132B0106	Decoupling plate kit for M1 and M2 enclosures
132B0107	Decoupling plate kit for M3 enclosure
132B0108	IP21 for M1 enclosure
132B0109	IP21 for M2 enclosure
132B0110	IP21 for M3 enclosure
132B0111	DIN rail mounting kit for M1 and M2 enclosure
132B0120	Type 1 kit for M4 enclosure
132B0121	Type 1 kit for M5 enclosure
132B0122	Decoupling plate kit for M4 and M5 enclosures
130B2522	Line Filter MCC 107 for 132F0001
130B2522	Line Filter MCC 107 for 132F0002
130B2533	Line Filter MCC 107 for 132F0003
130B2525	Line Filter MCC 107 for 132F0005
130B2530	Line Filter MCC 107 for 132F0007
130B2523	Line Filter MCC 107 for 132F0008
130B2523	Line Filter MCC 107 for 132F0009
130B2523	Line Filter MCC 107 for 132F0010
130B2526	Line Filter MCC 107 for 132F0012
130B2531	Line Filter MCC 107 for 132F0014
130B2527	Line Filter MCC 107 for 132F0016
130B2523	Line Filter MCC 107 for 132F0017
130B2523	Line Filter MCC 107 for 132F0018
130B2524	Line Filter MCC 107 for 132F0020

Ordering number	Description
130B2526	Line Filter MCC 107 for 132F0022
130B2529	Line Filter MCC 107 for 132F0024
130B2531	Line Filter MCC 107 for 132F0026
130B2528	Line Filter MCC 107 for 132F0028
130B2527	Line Filter MCC 107 for 132F0030

Table 5.4 Options for VLT® Micro Drive FC 51

## NOTICE

Danfoss line filters and brake resistors are available upon request.

## 6 How to Install

### 6.1 Before Starting

#### 6.1.1 Checklist

When unpacking the frequency converter, make sure that the unit is undamaged and complete. Check that the packaging contains the following:

- VLT® Micro Drive FC 51
- Quick Guide

Optional: LCP and/or decoupling plate.

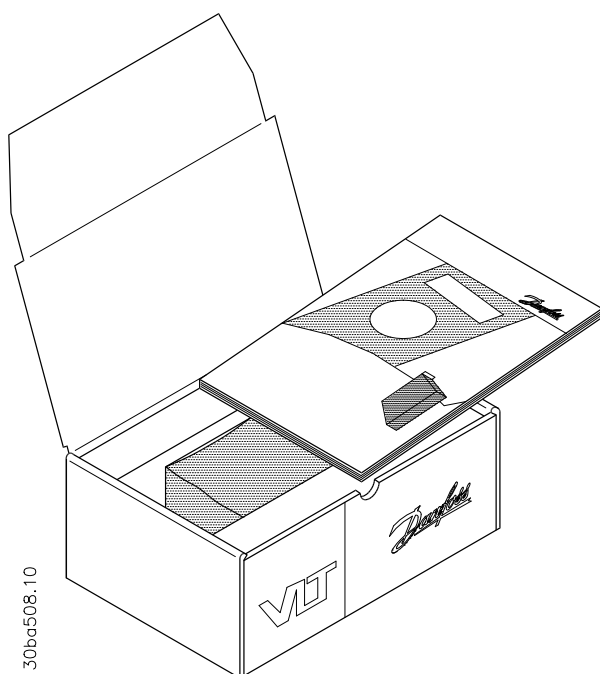


Illustration 6.1 Content of Box

### 6.2 Side-by-Side Installation

The frequency converter can be mounted side-by-side for IP20 rating units and requires 100 mm (3.94 in) clearance above and below for cooling. Regarding surroundings in general, see *chapter 9 Specifications*.

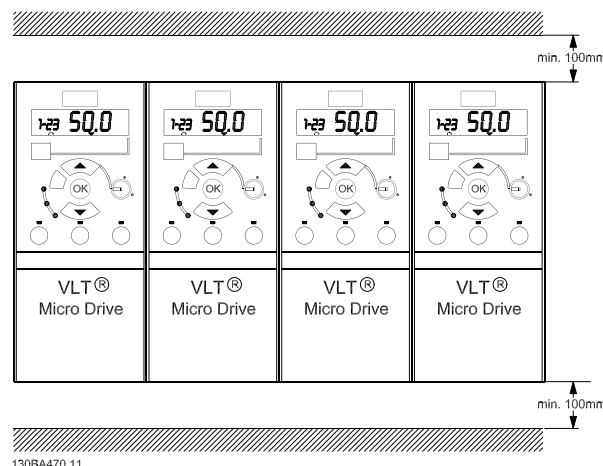


Illustration 6.2 Side-by-side Installation

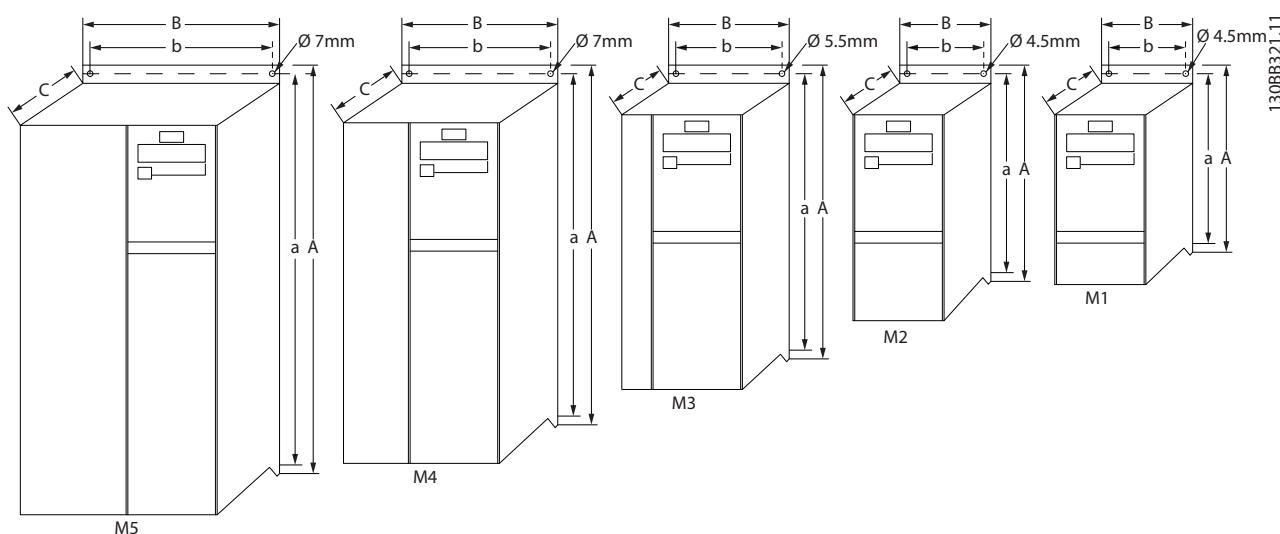
### 6.3 Before Commencing Repair Work

1. Disconnect the FC 51 from mains (and external DC supply, if present).
2. Wait for 4 minutes (M1, M2, and M3) and 15 minutes (M4 and M5) for discharge of the DC-link. See *Table 2.1*.
3. Disconnect the DC bus terminals and the brake terminals (if present).
4. Remove the motor cable.

### 6.4 Mechanical Dimensions

A template for drilling is on the flap of the packaging.





Enclosure	Power [kW]			Height [mm]			Width [mm]		Depth <sup>1)</sup> [mm]	Maximum weight
	1X200–240 V	3X200–240 V	3X380–480 V	A	A (including decoupling plate)	a	B	b	C	[kg]
M1	0.18–0.75	0.25–0.75	0.37–0.75	150	205	140.4	70	55	148	1.1
M2	1.5	1.5	1.5–2.2	176	230	166.4	75	59	168	1.6
M3	2.2	2.2–3.7	3.0–7.5	239	294	226	90	69	194	3.0
M4	–	–	11.0–15.0	292	347.5	272.4	125	97	241	6.0
M5	–	–	18.5–22.0	335	387.5	315	165	140	248	9.5

1) For LCP with potentiometer, add 7.6 mm (0.3 in).

Illustration 6.3 Mechanical Dimensions

## 6.5 Electrical Installation in General

### NOTICE

All cabling must comply with national and local regulations on cable cross-sections and ambient temperature. Copper conductors required, (60–75 °C) recommended.

Enclosure	Power [kW]			Torque [Nm]					
	1x200–240 V	3x200–240 V	3x380–480 V	Line	Motor	DC connection/brake	Control terminals	Ground	Relay
M1	0.18–0.75	0.25–0.75	0.37–0.75	0.8	0.7	Spade <sup>1)</sup>	0.15	3	0.5
M2	1.5	1.5	1.5–2.2	0.8	0.7	Spade <sup>1)</sup>	0.15	3	0.5
M3	2.2	2.2–3.7	3.0–7.5	0.8	0.7	Spade <sup>1)</sup>	0.15	3	0.5
M4	–	–	11.0–15.0	1.3	1.3	1.3	0.15	3	0.5
M5	–	–	18.5–22.0	1.3	1.3	1.3	0.15	3	0.5

1) Spade connectors (6.3 mm (0.25 in) Faston plugs)

Table 6.1 Tightening of Terminals

## 6.6 Fuses

### Branch circuit protection

To protect the installation against electrical and fire hazards, protect all branch circuits in an installation, switch gear, machines, and so on, against short circuits and overcurrent according to national/international regulations.

### Short-circuit protection

Use the fuses mentioned in *Table 6.2* to protect service personnel or other equipment if there is an internal failure in the unit or short circuit on DC-link. If there is a short circuit on the motor or brake output, the frequency converter provides full short-circuit protection.

### Overcurrent protection

To avoid overheating of the cables in the installation, provide overload protection. Always carry out overcurrent protection according to national regulations. Fuses must be designed for protection in a circuit capable of supplying a maximum of 100000 A<sub>rms</sub> (symmetrical), 480 V maximum.

### Non-UL compliance

If UL/cUL is not to be complied with, use the fuses mentioned in *Table 6.2*, which ensure compliance with EN50178/IEC61800-5-1:

If there is a malfunction, not following the fuse recommendation may result in damage to the frequency converter and the installation.

6

FC 51	Maximum fuses UL						Maximum fuses non-UL
	Bussmann	Bussmann	Bussmann	Littelfuse	Ferraz Shawmut	Ferraz Shawmut	
<b>1x200–240 V</b>							
kW	Type RK1	Type J	Type T	Type RK1	Type CC	Type RK1	Type gG
0K18-0K37	KTN-R15	JKS-15	JJN-15	KLN-R15	ATM-R15	A2K-15R	16A
0K75	KTN-R25	JKS-25	JJN-25	KLN-R25	ATM-R25	A2K-25R	25A
1K5	KTN-R35	JKS-35	JJN-35	KLN-R35	–	A2K-35R	35A
2K2	KTN-R50	JKS-50	JJN-50	KLN-R50	–	A2K-50R	50A
<b>3x200–240 V</b>							
0K25	KTN-R10	JKS-10	JJN-10	KLN-R10	ATM-R10	A2K-10R	10A
0K37	KTN-R15	JKS-15	JJN-15	KLN-R15	ATM-R15	A2K-15R	16A
0K75	KTN-R20	JKS-20	JJN-20	KLN-R20	ATM-R20	A2K-20R	20A
1K5	KTN-R25	JKS-25	JJN-25	KLN-R25	ATM-R25	A2K-25R	25A
2K2	KTN-R40	JKS-40	JJN-40	KLN-R40	ATM-R40	A2K-40R	40A
3K7	KTN-R40	JKS-40	JJN-40	KLN-R40	–	A2K-40R	40A
<b>3x380–480 V</b>							
0K37-0K75	KTS-R10	JKS-10	JJS-10	KLS-R10	ATM-R10	A6K-10R	10A
1K5	KTS-R15	JKS-15	JJS-15	KLS-R15	ATM-R15	A2K-15R	16A
2K2	KTS-R20	JKS-20	JJS-20	KLS-R20	ATM-R20	A6K-20R	20A
3K0	KTS-R40	JKS-40	JJS-40	KLS-R40	ATM-R40	A6K-40R	40A
4K0	KTS-R40	JKS-40	JJS-40	KLS-R40	ATM-R40	A6K-40R	40A
5K5	KTS-R40	JKS-40	JJS-40	KLS-R40	–	A6K-40R	40A
7K5	KTS-R40	JKS-40	JJS-40	KLS-R40	–	A6K-40R	40A
11K0	KTS-R60	JKS-60	JJS-60	KLS-R60	–	A6K-60R	63A
15K0	KTS-R60	JKS-60	JJS-60	KLS-R60	–	A6K-60R	63A
18K5	KTS-R60	JKS-60	JJS-60	KLS-R60	–	A6K-60R	80A
22K0	KTS-R60	JKS-60	JJS-60	KLS-R60	–	A6K-60R	80A

Table 6.2 Fuses

## 6.7 Mains Connection

Step 1: Mount ground cable.

Step 2: Mount wires in terminals L1/L, L2, and L3/N and tighten.

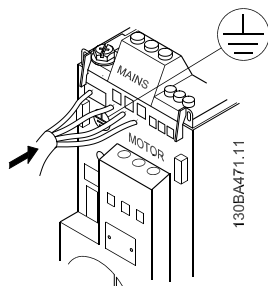


Illustration 6.4 Mounting of Ground Cable and Mains Wires

For 3-phase connection, connect wires to all 3 terminals. For single-phase connection, connect wires to terminals L1/L and L3/N.

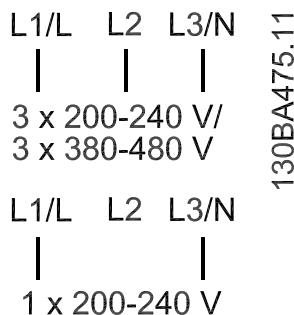


Illustration 6.5 3-phase and Single-phase Wire Connections

## 6.8 Motor Connection

### 6.8.1 How to Connect the Motor

See *chapter 9 Specifications* for correct dimensioning of motor cable cross-section and length.

- Use a shielded/armored motor cable to comply with EMC emission specifications, and connect this cable to both the decoupling plate and the motor metal.
- Keep the motor cable as short as possible to reduce the noise level and leakage currents.

For further details on mounting of the decoupling plate, see *VLT® Micro Drive FC 51 Decoupling Plate Mounting Instruction for M1 and M2*.

All types of 3-phased asynchronous standard motors can be connected to the frequency converter. Normally, small motors are star-connected (230/400 V,  $\Delta/Y$ ). Large motors are delta-connected (400/690 V,  $\Delta/Y$ ). Refer to the motor nameplate for correct connection and voltage.

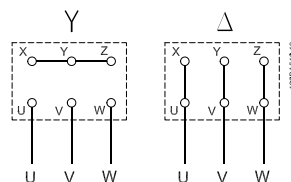


Illustration 6.6 Star and Delta Connections

Step 1: Mount the ground cable.

Step 2: Connect wires to terminals either in star or delta connection. See the motor nameplate for further information.

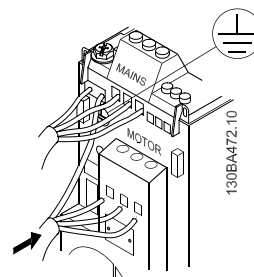


Illustration 6.7 Mounting of Ground Cable and Motor Wires

For EMC-correct installation, use optional decoupling plate, see *chapter 5.5 Options*.

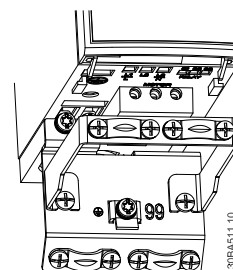


Illustration 6.8 Frequency Converter with Decoupling Plate

## 6.8.2 Motor Cables

See *chapter 9 Specifications* for maximum dimensioning of motor cable cross-section and length.

- Use a shielded/armored motor cable to comply with EMC emission specifications.
- Keep the motor cable as short as possible to reduce the noise level and leakage currents.
- Connect the motor cable shield to both the decoupling plate of the frequency converter and to the metal cabinet of the motor.
- Make the shield connections with the largest possible surface area (cable clamp). This is done by using the supplied installation devices in the frequency converter.
- Avoid mounting with twisted shield ends (pigtailes), which spoils high frequency shielding effects.
- If it is necessary to split the shield to install a motor isolator or motor relay, the shield must be continued with the lowest possible HF impedance.

## 6.8.3 Electrical Installation of Motor Cables

### Shielding of cables

Avoid installation with twisted shield ends (pigtailes). They spoil the shielding effect at higher frequencies.

If it is necessary to break the shield to install a motor isolator or motor contactor, the shield must be continued at 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.

### Switching frequency

When frequency converters are used together with sine-wave filters to reduce the acoustic noise from a motor, the switching frequency must be set according to the sine-wave filter instruction in *parameter 14-01 Switching Frequency*.

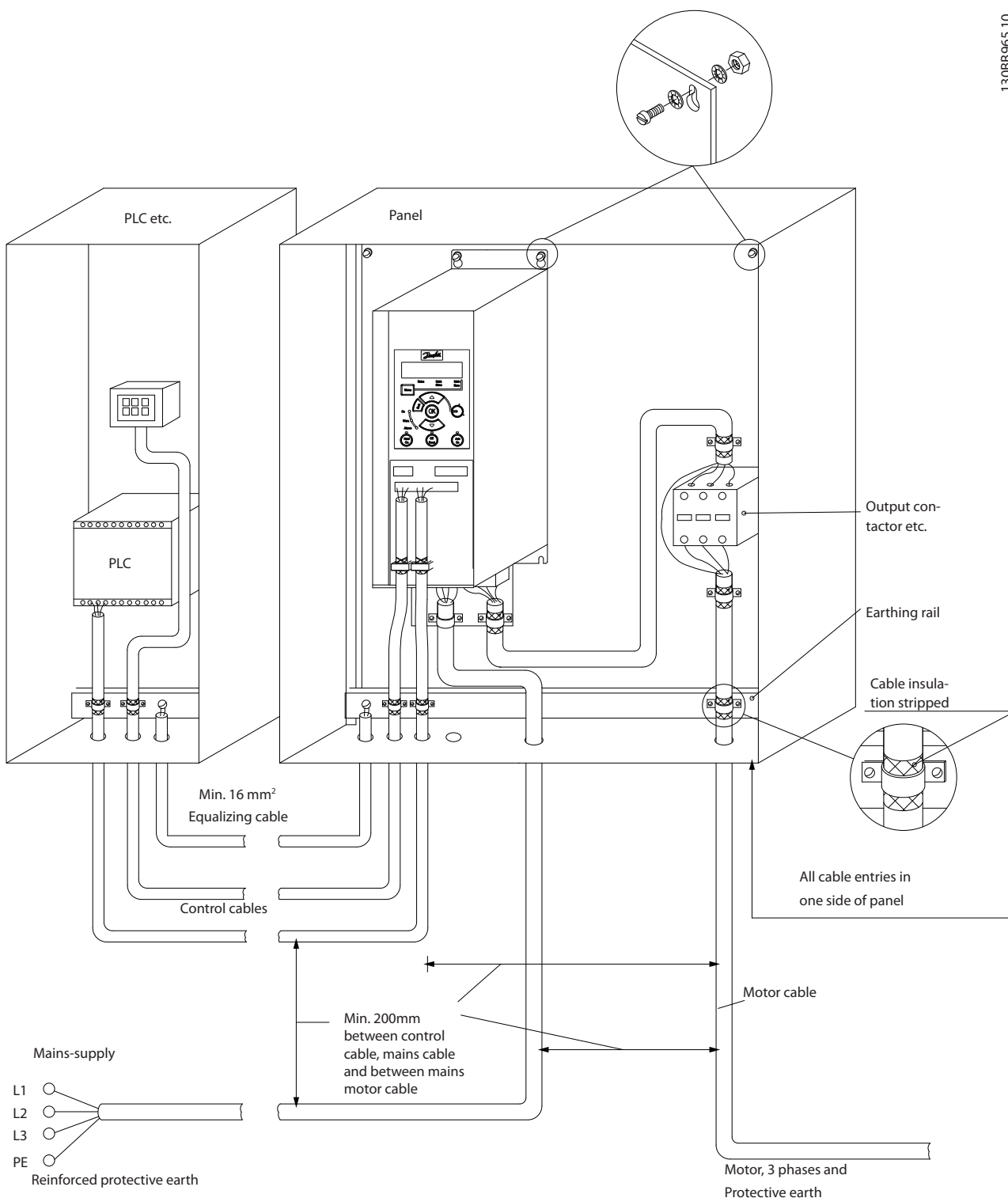
### Aluminum conductors

Aluminum conductors are not recommended. When using aluminum conductors, ensure that the conductor surface is clean and the oxidation is removed and sealed by a neutral acid-free grease before connecting the conductor. Retighten the terminal screw after 2 days due to the softness of aluminum. It is crucial to keep the connection a gas-tight joint, otherwise the aluminum surface oxidizes again.

## 6.8.4 EMC-correct Electrical Installation

General points to be observed to ensure EMC-correct electrical installation.

- Use only shielded/armored motor cables and shielded/armored control cables.
- Connect the shield to ground at both ends.
- Avoid installation with twisted shield ends (pigtailes), since this ruins the shielding effect at high frequencies. Use the cable clamps provided instead.
- It is important to ensure good electrical contact from the installation plate through the installation screws to the metal cabinet of the frequency converter.
- Use star washers and galvanically conductive installation plates.
- Do not use unshielded/unarmored motor cables in the installation cabinets.



6

Illustration 6.9 EMC-correct Electrical Installation

## NOTICE

For North America use metal conduits instead of shielded cables.

www.famcocorp.com  
E-mail: info@famcocorp.com  
@famco\_group

Tel: ۰۲۱-۴۸۰۰۰۰۴۹  
Fax: ۰۲۱-۴۴۹۹۴۶۴۲

تهران، کیلومتر ۲۱ بزرگراه لشگری (جاده مخصوص کرج)  
روبروی پالایشگاه نفت پارس، پلاک ۱۲

## 6.9 Use of EMC-Correct Cables

Danfoss recommends braided shielded/armored cables to optimize EMC immunity of the control cables and the EMC emission from the motor cables.

The ability of a cable to reduce the ingoing and outgoing radiation of electric noise depends on the transfer impedance ( $Z_T$ ). The shield of a cable is normally designed to reduce the transfer of electric noise; however, a shield with a lower transfer impedance ( $Z_T$ ) value is more effective than a shield with a higher transfer impedance ( $Z_T$ ).

Transfer impedance ( $Z_T$ ) is rarely stated by cable manufacturers, but it is often possible to estimate transfer impedance ( $Z_T$ ) by assessing the physical design of the cable.

**Transfer impedance ( $Z_T$ ) can be assessed based on the following factors:**

- The conductivity of the shield material.
- The contact resistance between the individual shield conductors.
- The shield coverage, that is, the physical area of the cable covered by the shield - often stated as a percentage value.
- Shield type, that is, braided or twisted pattern.
  - Aluminum-clad with copper wire.
  - Twisted copper wire or armored steel wire cable.
  - Single-layer braided copper wire with varying percentage shield coverage. This is the typical Danfoss reference cable.
  - Double-layer braided copper wire.
  - Twin layer of braided copper wire with a magnetic, shielded/armored intermediate layer.
  - Cable that runs in copper tube or steel tube.
  - Lead cable with 1.1 mm (0.04 in) wall thickness.

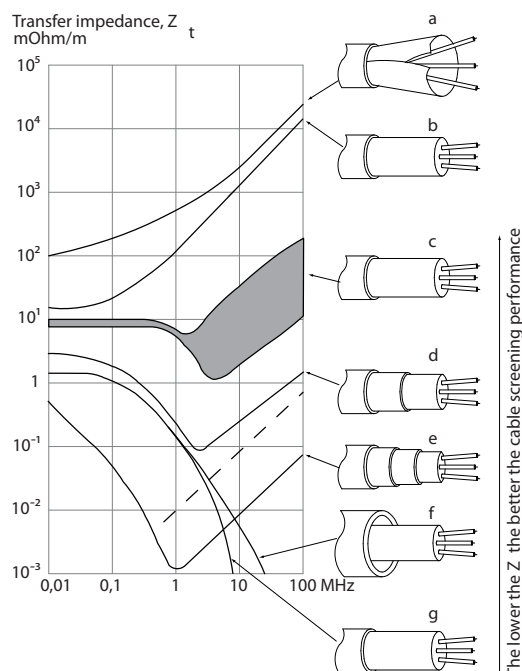
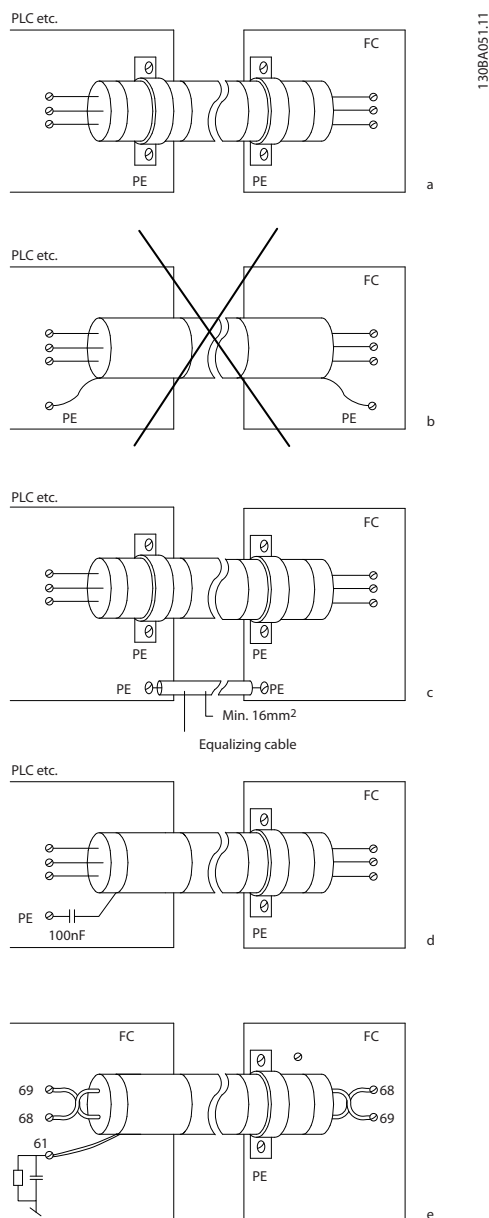


Illustration 6.10 Transfer Impedance of Different Wires

## 6.10 Grounding of Shielded/Armored Control Cables

Braid and shield/armor the control cables. Connect the shield to the metal cabinet of the unit with a cable clamp at both ends. *Illustration 6.11* shows correct grounding examples.



a	Correct grounding
b	Incorrect grounding
c	Protection from potential between PLC and frequency converter
d	50/60 Hz ground loops
e	Cables for serial communication

Illustration 6.11 Grounding Examples

- Correct grounding**  
Control cables and cables for serial communication are fitted with cable clamps at both ends to ensure the best possible electrical contact.
- Incorrect grounding**  
Do not use twisted cable ends (pigtails). They increase the shield impedance at high frequencies.
- Protection from potential between PLC and frequency converter**  
If the ground potential between the frequency converter and the PLC is different, electric noise that disturbs the entire system is possible. Fit an equalizing cable, next to the control cable. Minimum cable cross-section: 16 mm<sup>2</sup> (4 AWG).
- For 50/60 Hz ground loops**  
Long control cables sometimes causes 50/60 Hz ground loops. Connect 1 end of the shield to ground via a 100 nF capacitor (keeping leads short).
- Cables for serial communication**  
Eliminate low-frequency noise currents between 2 frequency converters by connecting 1 end of the shield to terminal 61. This terminal is connected to ground via an internal RC link. Use twisted-pair cables to reduce the differential mode interference between the conductors.

## 6.11 Residual Current Device

If local safety regulations are complied with, use RCD relays, multiple protective grounding, or grounding as extra protection.

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

If RCD relays are used, observe local regulations. Relays must be suitable for protection of 3-phase equipment with a bridge rectifier and for a brief discharge on power-up, see *chapter 3.4 Ground Leakage Current* for further information.

## 6.12 Electrical Overview

### 6.12.1 Power Circuit - Overview

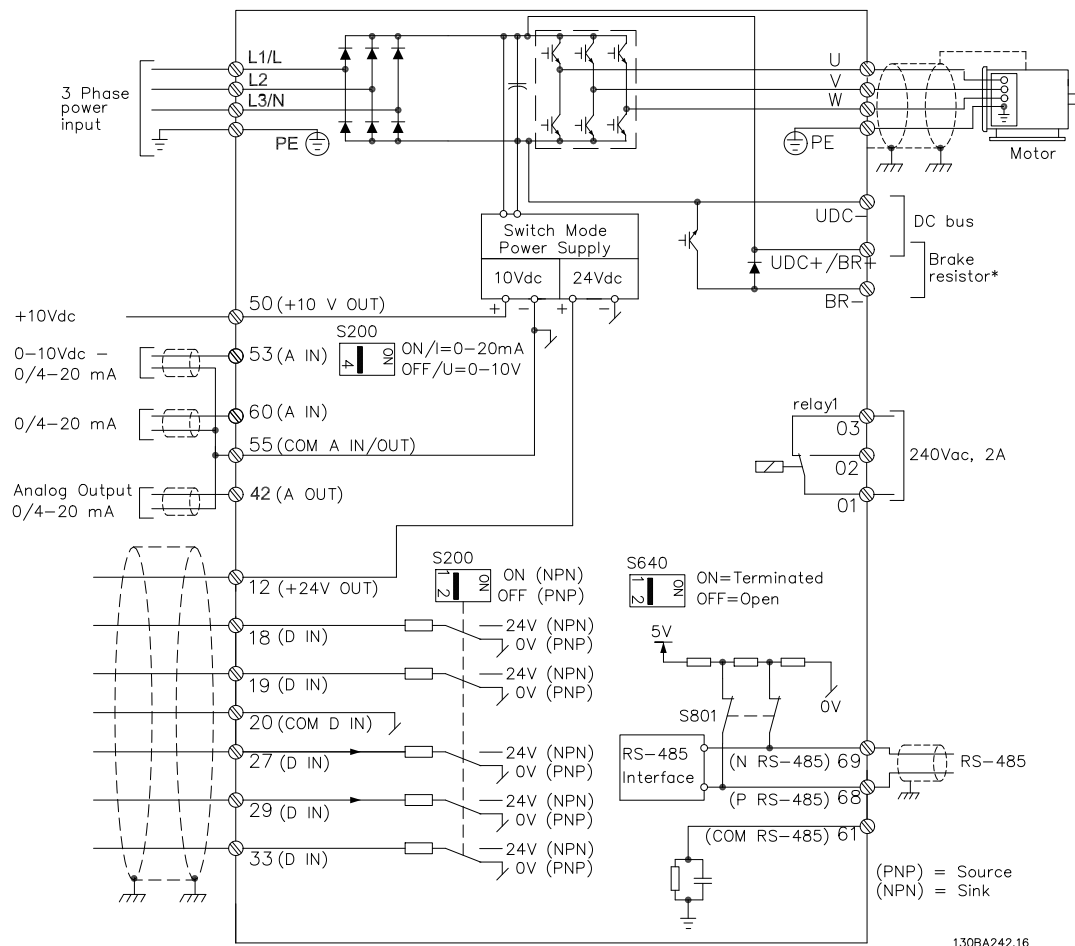


Illustration 6.12 Diagram Showing all Electrical Terminals

\* Brakes (BR+ and BR-) are not applicable for enclosure size M1.

For information about brake resistors, see *VLT® Brake Resistor MCE 101 Design Guide*.

Improved power factor and EMC performance can be achieved by installing optional Danfoss line filters.

Danfoss power filters can also be used for load sharing. For more information about load sharing, see *VLT® FC 51 Micro Drive Load Sharing* application note.



## 6.13 Electrical Installation and Control Cables

Terminal number	Terminal description	Parameter number	Factory default
1+2+3	Relay1	5-40	No operation
12	DC 24 V supply	–	+24 V DC
18	Digital input	5-10	Start
19	Digital input	5-11	Reversing
20	Common digital ground	–	Common
27	Digital input	5-12	Reset
29	Digital input	5-13	Jog
33	Digital input	5-15	Preset ref bit 0
42	Analog output/digital output	6-9*	No operation
50	Supply for analog input	–	+10 V DC
53	Analog input (voltage or current)	3-15/6-1*	Reference
55	Common analog ground	–	Common
60	Current input	3-16/6-2*	Reference

Table 6.3 Terminal Connections

Long control cables and analog signals may, in rare cases and depending on installation, result in 50/60 Hz ground loops due to noise from mains supply cables.

If this occurs, break the shield or insert a 100 nF capacitor between shield and chassis.

### NOTICE

To separate common terminals 20, 39, and 55, connect the common of digital/analog inputs and outputs. This avoids ground current interference among groups. For example, it avoids switching on digital inputs disturbing analog inputs.

### NOTICE

Control cables must be shielded/armored.

## 6.14 Control Terminals

### 6.14.1 Access to Control Terminals

All control cable terminals are located underneath the terminal cover in front of the frequency converter. Remove the terminal cover using a screwdriver.

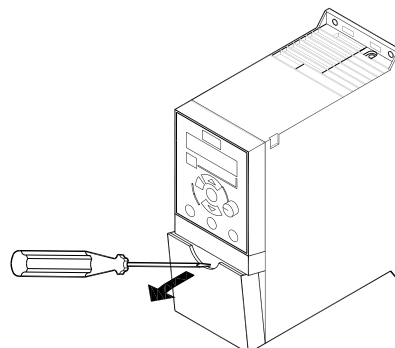


Illustration 6.13 Removing Terminal Cover

### NOTICE

See back of terminal cover for outlines of control terminals and switches.

## 6.14.2 Connecting to Control Terminals

Illustration 6.14 shows all control terminals of the frequency converter. Applying start (terminal 18) and an analog reference (terminals 53 or 60) make the frequency converter run.

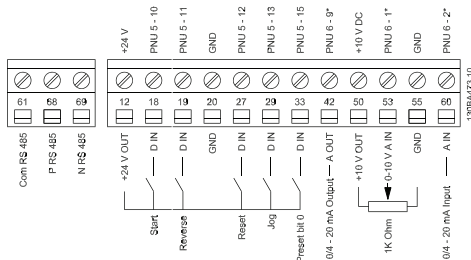
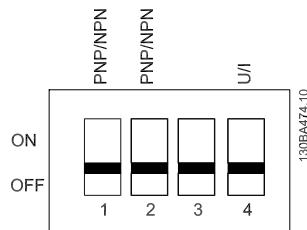


Illustration 6.14 Overview of Control Terminals in PNP-configuration and Factory Setting

## S200 Switches 1-4



Switch 1	*Off=PNP terminals 29 On=NPN terminals 29
Switch 2	*Off=PNP terminal 18, 19, 27, and 33 On=NPN terminal 18, 19, 27, and 33
Switch 3	No function
Switch 4	*Off=Terminal 53 0-10 V On=Terminal 53 0/4-20 mA

\*=default setting

Illustration 6.16 S200 Switches 1-4

## 6.15 Switches

### NOTICE

Do not operate switches with power on the frequency converter.

### Bus termination

Switch *BUS TER* position ON terminates the RS485 port, terminals 68, 69. See Illustration 6.15.

Default setting = Off

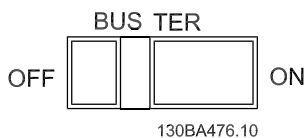


Illustration 6.15 S640 Bus Termination

### NOTICE

Set parameter 6-19 Terminal 53 Mode according to switch 4 position.

## 6.16 Final Set-Up and Test

To test the set-up and ensure that the frequency converter is running, follow these steps.

### Step 1. Locate the motor nameplate

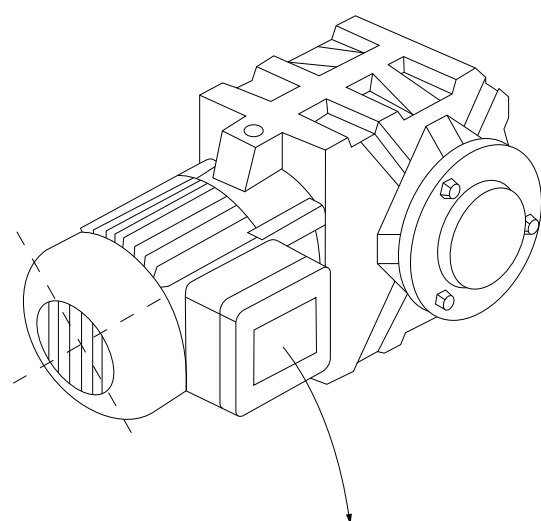
The motor is either star- (Y) or delta-connected (Δ). This information is on the motor nameplate data.

### Step 2. Enter the motor nameplate data in this parameter list

To access this list, press the [Quick Menu] key and select Q2 Quick Setup.

	Motor Power [kW] or Motor Power [HP]	Parameter 1-20 Motor Power [kW] Parameter 1-21 Motor Power [HP]
1	Motor Voltage	Parameter 1-22 Motor Voltage
2	Motor Frequency	Parameter 1-23 Motor Frequency
3	Motor Current	Parameter 1-24 Motor Current
4	Motor Nominal Speed	Parameter 1-25 Motor Nominal Speed

Table 6.4 Parameters for Quick Set-up



130BT307.10

BAUER D-7 3734 ESLINGEN				
3~ MOTOR NR. 1827421 2003				
S/E005A9				
	1,5	KW		
n <sub>2</sub> 31,5	/min.	400	Y	V
n <sub>1</sub> 1400	/min.		50	Hz
COS $\theta$ 0,80			3,6	A
1,7L				
B	IP 65	H1/1A		

Illustration 6.17 Motor Nameplate Example

### Step 3. Activate the automatic motor tuning (AMT)

Performing an AMT ensures optimum performance. The AMT measures the values from the motor model equivalent diagram.

1. Connect terminal 27 to terminal 12 or set parameter 5-12 Terminal 27 Digital Input to [0] No function.
2. Activate the AMT 1-29 Automatic Motor Tuning (AMT).
3. Select between complete or reduced AMT. If an LC filter is mounted, run only the reduced AMT, or remove the LC filter during the AMT procedure.
4. Press [OK]. The display shows *Press [Hand On] to start*.
5. Press [Hand On]. A progress bar indicates if the AMT is in progress.

### Stop the AMT during operation

1. Press [Off] - the frequency converter enters into alarm mode and the display shows that the user terminated the AMT.

### Successful AMT

1. The display shows *Press [OK] to finish AMT*.
2. Press [OK] to exit the AMT state.

### Unsuccessful AMT

1. The frequency converter enters into alarm mode. A description of the alarm can be found in the *Troubleshooting* section in *VLT® Micro Drive FC 51 Programming Guide*.
2. Report value in the [Alarm Log] shows the last measuring sequence carried out by the AMT, before the frequency converter entered alarm mode. This number along with the description of the alarm helps with troubleshooting. Contact Danfoss Service and make sure to mention number and alarm description.

Unsuccessful AMT is often caused by incorrectly registered motor nameplate data or too big difference between the motor power size and the frequency converter power size.

### Step 4. Set speed limit and ramp time

Set up the limits for speed and ramp time.

Minimum reference	Parameter 3-02 Minimum Reference
Maximum reference	Parameter 3-03 Maximum Reference

Table 6.5 Reference Limit Parameters

Motor speed low limit	Parameter 4-11 Motor Speed Low Limit [RPM] or Parameter 4-12 Motor Speed Low Limit [Hz]
Motor speed high limit	Parameter 4-13 Motor Speed High Limit [RPM] or Parameter 4-14 Motor Speed High Limit [Hz]

Table 6.6 Speed Limit Parameters

Ramp-up time 1 [s]	Parameter 3-41 Ramp 1 Ramp Up Time
Ramp-down time 1 [s]	Parameter 3-42 Ramp 1 Ramp Down Time

Table 6.7 Ramp Time Parameters

## 6.17 Parallel Connection of Motors

The frequency converter can control several motors connected in parallel. When using a parallel motor connection, consider the following points:

- When motors are connected in parallel, *parameter 1-29 Automatic Motor Tuning (AMT)* cannot be used.
- Run applications with motors connected in parallel in U/F mode (volts per hertz).
- The usage of VVC<sup>+</sup> mode is limited to certain applications when the motors connected in parallel are of the same type and size.
- Total current consumption of motors must not exceed the rated output current  $I_{INV}$  of the frequency converter.
- Significant difference in motor sizes may cause problems at start and at low RPM. The relatively high ohmic resistance in the stator of a small motor demands higher voltage at start and at low RPM.
- Do not use the electronic thermal relay (ETR) of the frequency converter as motor protection. To provide extra motor protection, include thermistors in each motor winding or individual thermal relays.

During the installation of a parallel motor application, consider the following points:

- Connection A/B is only possible when the total motor cable is shorter than 50 m (164 ft).
- In connection C/D the total motor cable length specified in general specifications is valid as long as the parallel cables are less than 10 m (32.8 ft).

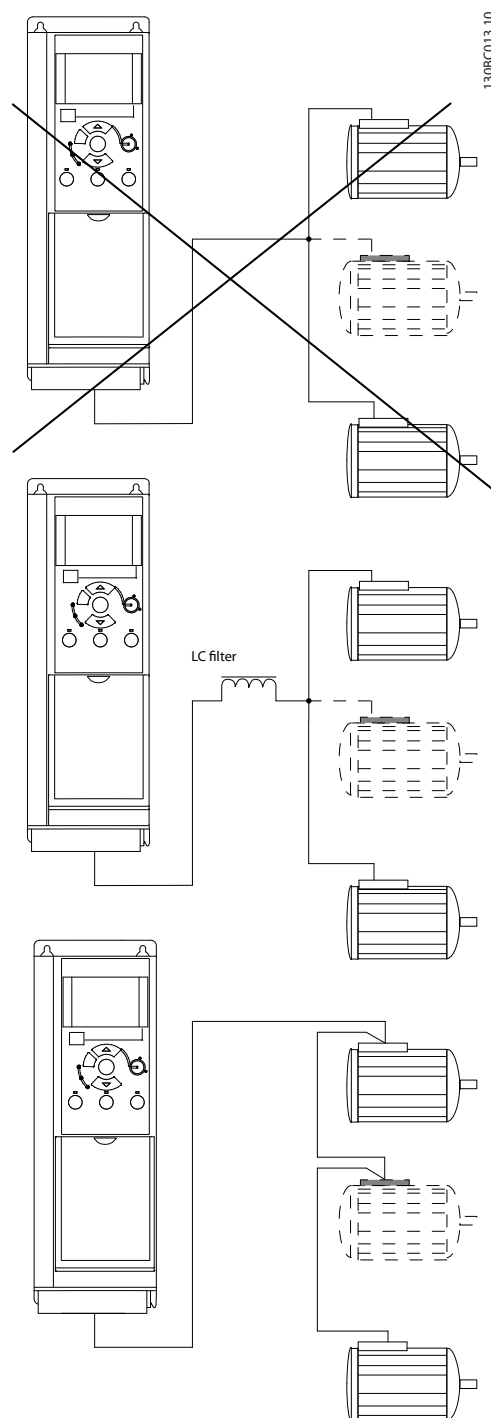


Illustration 6.18 Parallel Connection of Motors

## 6.18 Motor Installation

### 6.18.1 Motor Insulation

For motor cable lengths  $\leq$  the maximum cable length listed in *chapter 9.1 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, use a dU/dt or sine-wave filter.

Nominal Mains Voltage	Motor Insulation
$U_N \leq 420$ V	Standard $U_{LL}=1300$ V
$420$ V $< U_N \leq 500$ V	Reinforced $U_{LL}=1600$ V
$500$ V $< U_N \leq 600$ V	Reinforced $U_{LL}=1800$ V
$600$ V $< U_N \leq 690$ V	Reinforced $U_{LL}=2000$ V

Table 6.8 Motor Insulation Ratings

## 6.19 Installation of Misc. Connections

### 6.19.1 RS485 Bus Connection

1 or more frequency converters can be connected to a control (or master) using the RS485 interface. Terminal 68 is connected to the P signal (TX+, RX+), while terminal 69 is connected to the N signal (TX-, RX-).

If more than 1 frequency converter is connected to a master, use parallel connections.

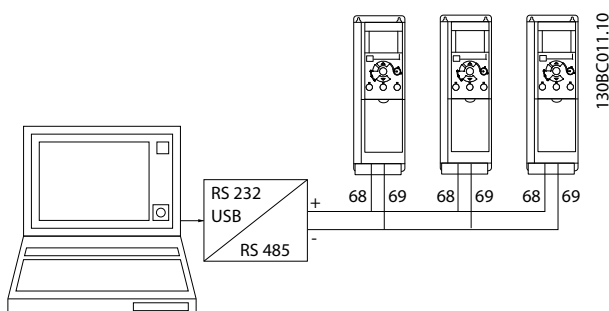


Illustration 6.19 RS485 Bus Connection

To avoid potential equalizing currents in the shield, ground the cable shield via terminal 61, which is connected to the enclosure via an RC-link.

#### Bus termination

Terminate the RS485 bus with resistors at both ends. For this purpose, set switch S801 on the control card for ON.

Set the communication protocol to *parameter 8-30 Protocol*.

### 6.19.2 How to Connect a PC to the Frequency Converter

To control or program the frequency converter from a PC, install the PC-based configuration tool MCT 10 Set-up Software.

#### MCT 10 Set-up Software

MCT 10 Set-up Software has been designed as an easy-to-use interactive tool for setting parameters in our frequency converters.

The PC-based configuration tool MCT 10 Set-up Software is useful for:

- Planning a communication network off-line. MCT 10 Set-up Software contains a complete frequency converter database.
- Commissioning frequency converters online.
- Saving settings for all frequency converters.
- Replacing a frequency converter in a network.
- Expanding an existing network.

#### Save frequency converter settings

1. Connect a PC to the unit via USB port.
2. Open the MCT 10 Set-up Software.
3. Select *Read from drive*.
4. Select *Save as*.

All parameters are now stored in the PC.

#### Save frequency converter settings

1. Connect a PC to the unit via USB port.
2. Open the MCT 10 Set-up Software.
3. Select *Open*, the software shows the stored files.
4. Open the appropriate file.
5. Select *Write to drive*.

All parameter settings are now transferred to the frequency converter.

A separate manual for the MCT 10 Set-up Software is available.

### The MCT 10 Set-up Software modules

The following modules are included in the software package:


	<b>MCT 10 Set-up Software</b> Setting parameters. Copy to and from frequency converters. Documentation and print out of parameter settings including diagrams.
	<b>External user interface</b> Preventive maintenance schedule. Clock settings. Timed action programming. Smart logic controller set-up.

Table 6.9 MCT 10 Set-up Software

### Ordering number

Order the CD containing the MCT 10 Set-up Software using code number 130B1000.

## 6.20.2 Safety Ground Connection

The frequency converter has a high leakage current and must be grounded appropriately for safety reasons according to EN 50178.

### **WARNING**

#### LEAKAGE CURRENT HAZARD

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

- Ensure the correct grounding of the equipment by a certified electrical installer.

6

## 6.20 Safety

### 6.20.1 High-voltage Test

Carry out a high-voltage test by short-circuiting terminals U, V, W, L<sub>1</sub>, L<sub>2</sub>, and L<sub>3</sub>. Energize maximum 2.15 kV DC for 380–500 V frequency converters and 2.525 kV DC for 525–690 V frequency converters for 1 s between this short circuit and the chassis.

### **WARNING**

#### LEAKAGE CURRENT HAZARD

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

- Ensure the correct grounding of the equipment by a certified electrical installer.

## 7 Programming

### 7.1 How to Programme

#### 7.1.1 Programming with MCT 10 Set-up Software

The frequency converter can be programmed from a PC via RS485 port using the MCT 10 Set-up Software.

Refer to *VLT® Motion Control Tools MCT 10 Set-up Software Operating Instructions*.

#### 7.1.2 Programming with the LCP 11 or LCP 12

The LCP is divided into 4 functional groups:

1. Numeric display.
2. Menu key.
3. Navigation keys.
4. Operation keys and indicator lights.

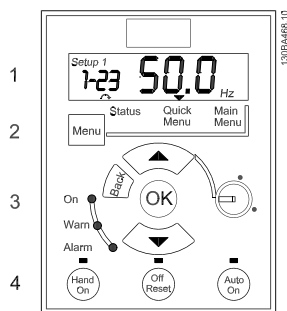


Illustration 7.1 LCP 12 with Potentiometer

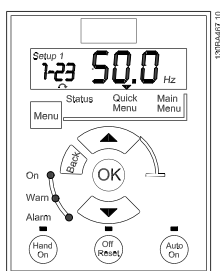


Illustration 7.2 LCP 11 without Potentiometer

#### The display

The display shows different information.

**Set-up number** shows the active set-up and the edit set-up. If the same set-up acts as both active and edit set-up, only that set-up number is shown (factory setting). When active and edit set-up differ, the display shows both numbers (set-up 12). The flashing number indicates the edit set-up.



Illustration 7.3 Indicating Set-up

The small digits to the left are the selected parameter number.

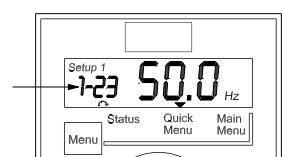


Illustration 7.4 Indicating Selected Parameter Number

The large digits in the middle of the display show the value of the selected parameter.



Illustration 7.5 Indicating Value of Selected Parameter

The right side of the display shows the unit of the selected parameter. This can be either Hz, A, V, kW, hp, %, s, or RPM.



Illustration 7.6 Indicating Unit of Selected Parameter

Motor direction is shown to the bottom left of the display, indicated by a small arrow pointing either clockwise or counterclockwise.



Illustration 7.7 Indicating Motor Direction

Press [Menu] to select 1 of the following menus

#### Status Menu

The status menu is either in readout mode or hand-on mode. In readout mode, the value of the currently selected readout parameter is shown in the display.

In hand-on mode, the local LCP reference is displayed.

#### Quick Menu

Displays Quick Menu parameters and their settings. Parameters in the Quick Menu can be accessed and edited from here. Most applications can be run by setting the parameters in Quick Menu.

#### Main Menu

Displays Main Menu parameters and their settings. All parameters can be accessed and edited here.

#### Indicator lights

- Green indicator light: The frequency converter is on.
- Yellow indicator light: Indicates a warning. See chapter *Troubleshooting* in the *VLT® Micro Drive FC 51 Programming Guide*.
- Flashing red LED: Indicates an alarm. See chapter *Troubleshooting* in *VLT® Micro Drive FC 51 Programming Guide*.

#### Navigation keys

[Back]: For moving to the previous step or layer in the navigation structure.

[▲] [▼]: For maneuvering between parameter groups, parameters, and within parameters.

[OK]: For selecting a parameter and for accepting changes to parameter settings.

Pressing [OK] for more than 1 s enters the adjust mode. In the adjust mode, it is possible to make fast adjustment by pressing [▲] [▼] combined with [OK].

Press [▲] [▼] to change value. Press [OK] to shift between digits quickly.

To exit the adjust mode, press [OK] more than 1 s again with changes saving or press [Back] without changes saving.

#### Operation keys

A yellow indicator light above the operation keys indicates the active key.

**[Hand On]:** Starts the motor and enables control of the frequency converter via the LCP.

**[Off/Reset]:** The motor stops except in alarm mode. In alarm mode, the motor is reset.

**[Auto On]:** The frequency converter is controlled either via control terminals or serial communication.

**[Potentiometer] (LCP 12):** The potentiometer works in 2 ways depending on the mode in which the frequency converter is running.

In auto mode, the potentiometer acts as an extra programmable analog input.

In hand-on mode, the potentiometer controls local reference.

## 7.2 Status Menu

After power-up, the Status Menu is active. Press [Menu] to toggle between Status, Quick Menu, and Main Menu.

[▲] and [▼] toggle between the options in each menu.

The display indicates the status mode with a small arrow above Status.

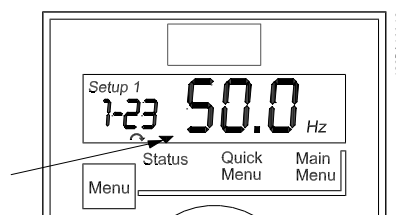


Illustration 7.8 Indicating Status Mode



## 7.3 Quick Menu

The Quick Menu gives easy access to the most frequently used parameters.

1. To enter Quick Menu, press [Menu] key until indicator in display is placed above Quick Menu.
2. Press [▲] [▼] to select either QM1 or QM2, then press [OK].
3. Press [▲] [▼] to browse through the parameters in the Quick Menu.
4. Press [OK] to select a parameter.
5. Press [▲] [▼] to change the value of a parameter setting.
6. Press [OK] to accept the change.
7. To exit, press either [Back] twice to enter Status, or press [Menu] once to enter Main Menu.

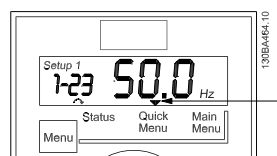


Illustration 7.9 Indicating Quick Menu Mode

## 7.4 Quick Menu Parameters

### 7.4.1 Quick Menu Parameters - Basic Settings QM1

This section describes the parameters in Quick Menu.

\*=Factory setting.

#### 1-20 Motor Power [kW]/[hp] (P<sub>m.n</sub>)

Option:	Function:
	Enter motor power from nameplate data. Two sizes down, 1 size up from nominal VLT rating.
[1]	0.09 kW/0.12 hp
[2]	0.12 kW/0.16 hp
[3]	0.18kW/0.25 hp
[4]	0.25 kW/0.33 hp
[5]	0.37kW/0.50 hp
[6]	0.55 kW/0.75 hp
[7]	0.75 kW/1.00 hp
[8]	1.10 kW/1.50 hp
[9]	1.50 kW/2.00 hp
[10]	2.20 kW/3.00 hp
[11]	3.00 kW/4.00 hp
[12]	3.70 kW/5.00 hp
[13]	4.00 kW/5.40 hp

#### 1-20 Motor Power [kW]/[hp] (P<sub>m.n</sub>)

Option:	Function:
[14]	5.50 kW/7.50 hp
[15]	7.50 kW/10.0 hp
[16]	11.00 kW/15.00 hp
[17]	15.00 kW/20.00 hp
[18]	18.50 kW/25.00 hp
[19]	22.00 kW/29.50 hp
[20]	30.00 kW/40.00 hp

### NOTICE

Changing this parameter affects parameters 1-22 Motor Voltage to 1-25 Motor Nominal Speed, 1-30 Stator Resistance (Rs), 1-33 Stator Leakage Reactance (X1), and 1-35 Main Reactance (Xh).

#### 1-22 Motor Voltage (U<sub>m.n</sub>)

Range:	Function:
230/400 V	[50–999 V] Enter motor voltage from nameplate data.

#### 1-23 Motor Frequency (f<sub>m.n</sub>)

Range:	Function:
50 Hz*	[20–400 Hz] Enter motor frequency from nameplate data.

#### 1-24 Motor Current (I<sub>m.n</sub>)

Range:	Function:
M-type dependent*	[0.01–100.00 A] Enter motor current from nameplate data.

#### 1-25 Motor Nominal Speed (n<sub>m.n</sub>)

Range:	Function:
M-type Dependent*	[100–9999 RPM] Enter motor nominal speed from nameplate data.

#### 1-29 Automatic Motor Tuning (AMT)

Option:	Function:
	Use AMT to optimize motor performance. When parameter 1-01 Motor Control Principle is set to [0] U/f, AMT does not work.
	<b>NOTICE</b> This parameter cannot be changed while the motor is running.
	<ol style="list-style-type: none"> <li>1. Stop the frequency converter - make sure that the motor is at standstill.</li> <li>2. Select [2] Enable AMT.</li> <li>3. Apply start signal: <ul style="list-style-type: none"> <li>- Via LCP: Press [Hand On].</li> <li>- Or in remote on mode: Apply start signal on terminal 18.</li> </ul> </li> </ol>
[0] *	Off AMT function is disabled.

### 1-29 Automatic Motor Tuning (AMT)

#### Option: Function:

[2]	Enable AMT	AMT function starts running. <b>NOTICE</b> To gain optimum tuning of the frequency converter, run AMT on a cold motor.
[3]	Complete AMT with Rotating motor	<b>NOTICE</b> The motor rotates when this option is active. With this option selected, the frequency converter optimizes the following parameters: 1-35 Main Reactance (X2), 1-30 Stator Resistance (Rs), and 1-33 Stator Leakage Reactance (X1).

### 3-02 Minimum Reference

#### Range: Function:

0.00*	[-4999-4999]	Enter the value for minimum reference. The sum of all internal and external references are clamped (limited) to the minimum reference value, <i>parameter 3-02 Minimum Reference</i> .
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### 3-03 Maximum Reference

#### Range: Function:

		The range of this parameter is <i>parameter 3-02 Minimum Reference</i> -4999.
60.000 Hz or 50.000 Hz depending on the setting in par. 0-03.*	[-4999-4999]	Enter the value for maximum reference. The sum of all internal and external references are clamped (limited) to the maximum reference value, <i>parameter 3-03 Maximum Reference</i> .

### 3-41 Ramp1 Ramp-up Time

#### Range: Function:

Size related*	[0.05-3600.00 s]	Enter ramp-up time from 0 Hz to rated motor frequency ( $f_{M,N}$ ) set in <i>parameter 1-23 Motor Frequency</i> . Select a ramp-up time ensuring that torque limit is not exceeded, see <i>parameter 4-16 Torque Limit in Motor Mode</i> .
---------------	------------------	---

### 3-42 Ramp1 Ramp-down Time

#### Range: Function:

Size related*	[0.05-3600.00 s]	Enter ramp-down time from rated motor frequency ( $f_{M,N}$ ) in <i>parameter 1-23 Motor Frequency</i> to 0 Hz. Select a ramp-down time that does not cause overvoltage in the inverter due to regenerative operation of motor. Furthermore, regenerative torque must not exceed limit set in <i>parameter 4-17 Torque Limit in Generator Mode</i> .
---------------	------------------	--

7

## 7.4.2 Quick Menu Parameters - PI Basic Settings QM2

The following is a brief description of the parameters for the PI basic settings. For a more detailed description, see *VL7<sup>®</sup> Micro Drive FC 51 Programming Guide*.

### 1-00 Configuration Mode

Option:	Function:
	Use this parameter for selecting the application control principle to be used when a remote reference is active. <b>NOTICE</b> Changing this parameter resets <i>parameter 3-00 Reference Range</i> , <i>parameter 3-02 Minimum Reference</i> and <i>parameter 3-03 Maximum Reference</i> to their default values. <b>NOTICE</b> This parameter cannot be adjusted while motor is running.
[0] *	Speed Open Loop For normal speed control (references).
[3]	Process Enables process closed-loop control. See parameter group 7-3* <i>Process PI Control</i> for further information on PI controller.

### 3-02 Minimum Reference

Range:	Function:
0.00* [-4999-4999]	Enter the value for minimum reference. The sum of all internal and external references are clamped (limited) to the minimum reference value, <i>parameter 3-02 Minimum Reference</i> .

### 3-03 Maximum Reference

Range:	Function:
	The range of this parameter is <i>parameter 3-02 Minimum Reference</i> -4999.
60.000 Hz or 50.000 Hz depending on the setting in par. 0-03.*	[-4999-4999] Enter the value for maximum reference. The sum of all internal and external references are clamped (limited) to the maximum reference value, <i>parameter 3-03 Maximum Reference</i> .

### 3-10 Preset Reference

**Option:** **Function:**

		Each parameter set-up contains 8 preset references which are selectable via 3 digital inputs or fieldbus.																																				
		<table><tr><th>[18] Bit2</th><th>[17] Bit1</th><th>[16] Bit0</th><th>[16] Bit0</th></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>0</td><td>1</td><td>1</td></tr><tr><td>0</td><td>1</td><td>0</td><td>2</td></tr><tr><td>0</td><td>1</td><td>1</td><td>3</td></tr><tr><td>1</td><td>0</td><td>0</td><td>4</td></tr><tr><td>1</td><td>0</td><td>1</td><td>5</td></tr><tr><td>1</td><td>1</td><td>0</td><td>6</td></tr><tr><td>1</td><td>1</td><td>1</td><td>7</td></tr></table>	[18] Bit2	[17] Bit1	[16] Bit0	[16] Bit0	0	0	0	0	0	0	1	1	0	1	0	2	0	1	1	3	1	0	0	4	1	0	1	5	1	1	0	6	1	1	1	7
[18] Bit2	[17] Bit1	[16] Bit0	[16] Bit0																																			
0	0	0	0																																			
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1	0	0	4																																			
1	0	1	5																																			
1	1	0	6																																			
1	1	1	7																																			
		<b>Table 7.1 Parameter Group 5-1* Digital Inputs Option [16], [17], and [18]</b>																																				
[0.00] *	-100.00– 100.00%	<p>Enter the different preset references using array programming.</p> <p>Normally, 100%=value set in <i>parameter 3-03 Maximum Reference</i>.</p> <p>However, there are exceptions if <i>parameter 3-00 Reference Range</i> is set to [0] Min - Max.</p> <p>Example 1:</p> <p><i>Parameter 3-02 Minimum Reference</i> is set to 20, and <i>parameter 3-03 Maximum Reference</i> is set to 50. In this case 0%=0, and 100%=50.</p> <p>Example 2:</p> <p><i>Parameter 3-02 Minimum Reference</i> is set to -70 and <i>parameter 3-03 Maximum Reference</i> is set to 50. In this case 0%=0, and 100%=70.</p>																																				

### 4-12 Motor Speed Low Limit

**Range:** **Function:**

0.0 Hz*	[0.0-400.0 Hz]	Set the minimum motor speed limit corresponding to the minimum output frequency of the motor shaft. <b>NOTICE</b> As the minimum output frequency is an absolute value, and the frequency converter cannot deviate from it.
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### 4-14 Motor Speed High Limit

**Range:** **Function:**

65.0 Hz*	[0.0-400.0 Hz]	Set the maximum motor speed corresponding to the maximum output frequency of the motor shaft. <b>NOTICE</b> The maximum output frequency is an absolute value, and the frequency converter cannot deviate from it.
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#### 6-22 Terminal 60 Low Current

Range: Function:

		<b>NOTICE</b> Set the value to a minimum of 2 mA to activate the live zero timeout function in <i>parameter 6-01 Live Zero Timeout Time</i> .  This reference signal should correspond to minimum reference value set in <i>parameter 6-24 Terminal 60 Low Ref./Feedb. Value</i> .
0.14 mA*	[0.00–20.00 mA]	Enter the low current value.

#### 6-23 Terminal 60 High Current

Range: Function:

		This reference signal should correspond to the high current value set in <i>parameter 6-25 Terminal 60 High Ref./Feedb. Value</i> .
20.00 mA*	[0.00–20.00 mA]	Enter high current value.

#### 6-24 Terminal 60 Low Ref./Feedb. Value

Range: Function:

		The scaling value corresponding to the low current set in <i>parameter 6-22 Terminal 60 Low Current</i> .
0.000*	[-4999–4999]	Enter analog input scaling value.

#### 6-25 Terminal 60 High Ref./Feedb. Value

Range: Function:

		The scaling value corresponding to the high current set in <i>parameter 6-23 Terminal 60 High Current</i> .
60.000 Hz or 50.000 Hz depending on the setting in par. 0-03.*	[-4999–4999]	Enter analog input scaling value.

#### 6-26 Terminal 60 Filter Time Constant

Range: Function:

		A first-order digital low-pass filter time constant for suppressing electrical noise in terminal 60. A high time constant value improves dampening, but also increases time delay through the filter.  <b>NOTICE</b> This parameter cannot be changed while the motor is running.
0.01 s*	[0.01–10.00 s]	Enter the time constant.

#### 7-20 Process CL Feedback Resources

Option: Function:

		Select input to function as feedback signal.
[0] *	No Function	
[1]	Analog Input 53	
[2]	Analog Input 60	
[8]	Pulse Input 33	
[11]	Local Bus	

#### 7-30 Process PI Normal/Inverse Control

Option: Function:

[0] *	Normal	Feedback larger than setpoint results in a speed reduction. Feedback less than setpoint results in a speed increase.
[1]	Inverse	Feedback larger than setpoint results in a speed increase. Feedback less than setpoint results in a speed reduction.

#### 7-31 Process PI Anti Windup

Option: Function:

[0]	Disable	Regulation of a given error continues even when the output frequency cannot be increased/decreased.
[1] *	Enable	PI controller ceases from regulating a given error when the output frequency cannot be increased/decreased.

#### 7-32 Process PI Start Speed

Range: Function:

0.0 Hz*	[0.0–200.0 Hz]	Until the set motor speed has been reached, the frequency converter operates in open-loop mode.
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#### 7-33 Process PI Proportional Gain

Option: Function:

[0.01] *	0.00–10.00	Enter the value for the proportional gain, that is, the multiplication factor of the error between the setpoint and the feedback signal.  <b>NOTICE</b> 0.00=Off.
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#### 7-34 Process PI Integral Time

Range: Function:

9999.00 s*	[0.10–9999.00 s]	The integrator provides an increasing gain at a constant error between the setpoint and the feedback signal. The integral time is the time needed by the integrator to reach the same gain as the proportional gain.
------------	------------------	--

### 7-38 Process Feed Forward Factor

Range:	Function:
0%* [0–400%]	<p>The FF factor sends a part of the reference signal around the PI controller which then only affects part of the control signal.</p> <p>Activate the FF factor to obtain less overshoot and high dynamics when changing the setpoint.</p> <p>This parameter is always active when <i>parameter 1-00 Configuration Mode</i> is set to [3] <i>Process</i>.</p>

## 7.5 Main Menu

[Main Menu] is used for programming all parameters. The Main Menu parameters can be accessed immediately unless a password has been created via *parameter 0-60 Main Menu Password*. For most VLT® Micro Drive applications it is not necessary to access the Main Menu parameters, but instead the Quick Menu provides the simplest and quickest access to the typical required parameters.

The Main Menu accesses all parameters.

1. Press [Menu] key until indicator light in the display is located above Main Menu.
2. Use [▲] [▼] to browse through the parameter groups.
3. Press [OK] to select a parameter group.
4. Use [▲] [▼] to browse through the parameters in the specific group.
5. Press [OK] to select the parameter.
6. Use [▲] [▼] to set/change the parameter value.

Press [Back] to go back 1 level.

## 7.6 Quick Transfer of Parameter Settings between Multiple Frequency Converters

When the set-up of a frequency converter is completed, it is recommended to store the data in the LCP or on a PC via MCT 10 Set-up Software.

### Data transfer from the frequency converter to the LCP

1. Go to *parameter 0-50 LCP Copy*.
2. Press [OK].
3. Select [1] *All to LCP*.
4. Press [OK].

Connect the LCP to another frequency converter and copy the parameter settings to this frequency converter as well.

### Data transfer from the LCP to the frequency converter

1. Go to *parameter 0-50 LCP Copy*.
2. Press [OK].
3. Select [2] *All from LCP*.
4. Press [OK].

## 7.7 Readout and Programming of Indexed Parameters

Use chapter 7.4.2 *Quick Menu Parameters - PI Basic Settings QM2* as an example.

- Press [OK] to select a parameter and use [▲]/[▼] for selecting the indexed values.
- To change a parameter value, select the value and press [OK].
- Change the value using [▲]/[▼].
- Press [OK] to accept the new setting.
- Pressing [OK] for more than 1 s activates the adjust mode. In the adjust mode, it is possible to make fast adjustment by pressing [▲]/[▼] together with [OK].
- Press [▲]/[▼] to change the value. Press [OK] to shift between digits. To exit the adjust mode, press [OK] for more than 1 s again to exit and save changes, or press [Back] to exit without saving changes.

## 7.8 Initialize the Frequency Converter to Default Settings in two Ways

Recommended initialization (via *parameter 14-22 Operation Mode*)

1. Select *parameter 14-22 Operation Mode*.
2. Press [OK].
3. Select *initialization* and Press [OK].
4. Cut off the mains supply and wait until the display turns off.
5. Reconnect the mains supply, the frequency converter is now reset.

The following parameters are not reset during the initialization:

- *Parameter 8-30 Protocol*
- *Parameter 8-31 Address*
- *Parameter 8-32 Baud Rate*
- *Parameter 8-33 Parity / Stop Bits*
- *Parameter 8-35 Minimum Response Delay*
- *Parameter 8-36 Maximum Response Delay*
- *Parameter 15-00 Operating hours to parameter 15-05 Over Volt's*
- *Parameter 15-03 Power Up's*
- *Parameter 15-04 Over Temp's*
- *Parameter 15-05 Over Volt's*
- *Parameter 15-30 Alarm Log: Error Code*
- *Parameter group 15-4\* Drive Identification parameters*

**Initialization using [OK] and [Menu] keys:**

1. Power off the frequency converter.
2. Press [OK] and [Menu].
3. Power up the frequency converter while still pressing the keys for 10 s.
4. The frequency converter is now reset, except for the following parameters:
  - *Parameter 15-00 Operating hours*
  - *Parameter 15-03 Power Up's*
  - *Parameter 15-04 Over Temp's*
  - *Parameter 15-05 Over Volt's*
  - *Parameter group 15-4\* Drive identification parameters*

The LCP display shows *alarm 80, Drive initialised to default value* after the power cycle.

## 8 RS485 Installation and Set-up

### 8.1 RS485 Installation and Set-up

#### 8.1.1 Overview

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

#### **NOTICE**

Each repeater functions as a node within the segment in which it is installed. Each node connected within a given network must have a unique node address across all segments.

Terminate each segment at both ends, using either the termination switch (S801) of the frequency converters or a biased termination resistor network. Always use shielded twisted pair (STP) cable for bus cabling, and always follow good common installation practice.

Low-impedance ground connection of the shield at every node is important, including at high frequencies. Thus, connect a large surface of the shield to ground, for example with a cable clamp or a conductive cable gland. It may be necessary to apply potential equalizing cables to maintain the same ground potential throughout the network, particularly in installations with long cables. To prevent impedance mismatch, always use the same type of cable throughout the entire network. When connecting a motor to the frequency converter, always use shielded motor cable.

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

Table 8.1 Cable Specifications

#### 8.1.2 Network Connection

Connect the frequency converter to the RS485 network as follows (see also *Illustration 8.1*):

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

#### **NOTICE**

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

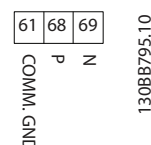


Illustration 8.1 Network Connection

#### 8.1.3 Frequency Converter Hardware Set-up

To terminate the RS485 bus, use the terminator DIP switch on the main control board of the frequency converter.

8

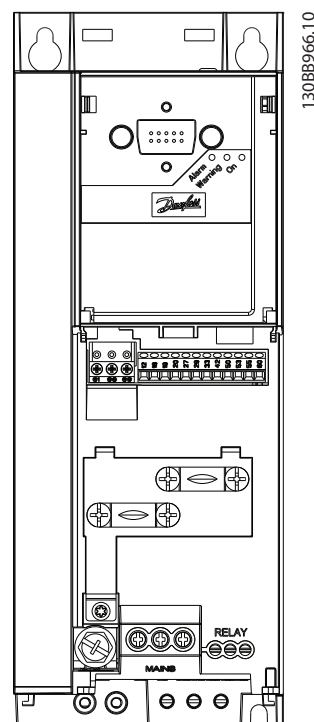


Illustration 8.2 Terminator Switch Factory Setting

The factory setting for the DIP switch is OFF.



## 8.1.4 EMC Precautions

The following EMC precautions are recommended to achieve interference-free operation of the RS485 network.

Observe relevant national and local regulations, for example regarding protective ground connection. To avoid coupling of high frequency noise from 1 cable to another, keep the RS485 communication cable away from motor and brake resistor cables. Keep the greatest possible distance between the cables, especially where cables run in parallel over long distances. The minimum distance is 200 mm (8 inches). When crossing is unavoidable, the RS485 cable must cross motor cable and brake resistor cables at an angle of 90°.

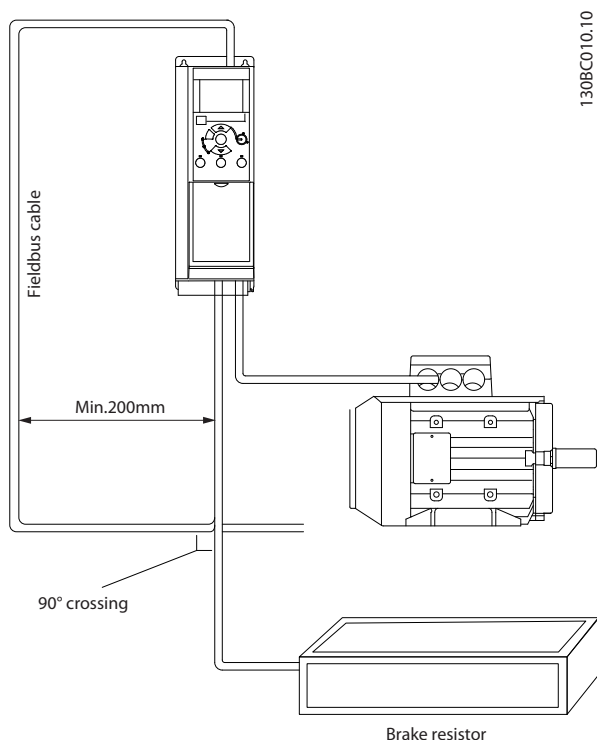


Illustration 8.3 EMC Precautions for RS485

## 8.1.5 Frequency Converter Parameter Settings for Modbus Communication

The following parameters apply to the RS485 interface (FC-port):

Parameter	Function
Parameter 8-30 Protocol	Select the application protocol to run on the RS485 interface.
Parameter 8-31 Address	Set the node address. <b>NOTICE</b> The address range depends on the protocol selected in parameter 8-30 Protocol.
Parameter 8-32 Baud Rate	Set the baud rate. <b>NOTICE</b> The baud rate depends on the protocol selected in parameter 8-30 Protocol.
Parameter 8-33 Parity / Stop Bits	Set the parity and number of stop bits. <b>NOTICE</b> The selection depends on the protocol selected in parameter 8-30 Protocol.
Parameter 8-35 Minimum Response Delay	Specify a minimum delay time between receiving a request and transmitting a response. This function is for overcoming modem turnaround delays.
Parameter 8-36 Maximum Response Delay	Specify a maximum delay time between transmitting a request and receiving a response.

Table 8.2 Parameters Related to RS485 Interface

## 8.2 FC Protocol Overview

### 8.2.1 Overview

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

1 master and a maximum of 126 slaves can be connected to the bus. The master selects the individual slaves via an address character in the telegram. A slave itself can never transmit without first being requested to do so, and direct message transfer between the individual slaves is not possible. Communications occur in the half-duplex mode. The master function cannot be transferred to another node (single-master system).

The physical layer is RS485, thus utilizing the RS485 port built into the frequency converter.



The FC protocol supports different telegram formats:

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

### 8.2.2 FC with Modbus RTU

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

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

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

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

## 8.3 Network Configuration

To enable the FC protocol for the frequency converter, set the following parameters.

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

Table 8.3 Parameters to Enable the Protocol

## 8.4 FC Protocol Message Framing Structure

### 8.4.1 Content of a Character (byte)

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



Illustration 8.4 Content of a Character

### 8.4.2 Telegram Structure

Each telegram has the following structure:

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

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

A data control byte (BCC) completes the telegram.



Illustration 8.5 Telegram Structure

### 8.4.3 Telegram Length (LGE)

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

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

**Table 8.4 Length of Telegrams**

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

- Bit 0–6 = 0 broadcast.

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

### 8.4.5 Data Control Byte (BCC)

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

### 8.4.4 Frequency Converter Address (ADR)

#### Address format 1–126

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

### 8.4.6 The Data Field

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

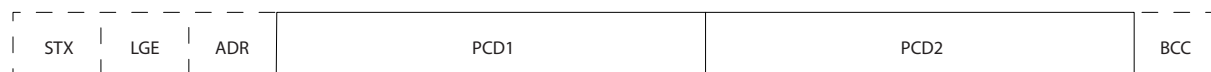
The 3 types of telegram are:

- Process block (PCD).
- Parameter block.
- Text block.

#### Process block (PCD)

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

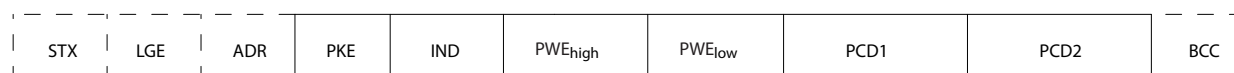
- Control word and reference value (from master to slave).
- Status word and present output frequency (from slave to master).



**Illustration 8.6 Process Block**

#### Parameter block

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



**Illustration 8.7 Parameter Block**

### Text block

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

STX	LGE	ADR	PKE	IND	Ch1	Ch2	Chn	PCD1	PCD2	BCC
-----	-----	-----	-----	-----	-----	-----	-----	------	------	-----

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Illustration 8.8 Text Block

## 8.4.7 The PKE Field

The PKE field contains 2 subfields:

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

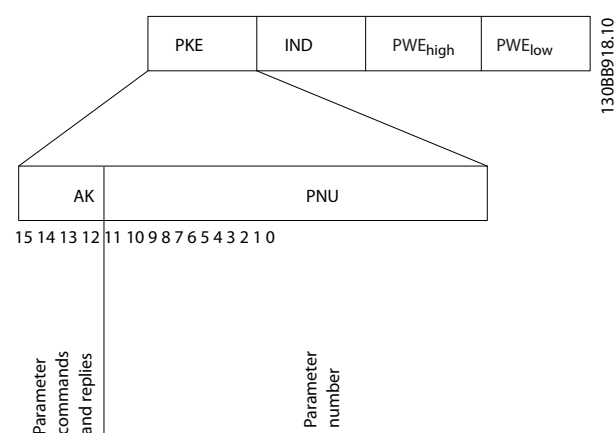


Illustration 8.9 PKE Field

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

Parameter commands master⇒slave				
Bit number				Parameter command
15	14	13	12	
0	0	0	0	No command.
0	0	0	1	Read parameter value.
0	0	1	0	Write parameter value in RAM (word).
0	0	1	1	Write parameter value in RAM (double word).
1	1	0	1	Write parameter value in RAM and EEPROM (double word).
1	1	1	0	Write parameter value in RAM and EEPROM (word).
1	1	1	1	Read text.

Table 8.5 Parameter Commands

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

Table 8.6 Response

If the command cannot be performed, the slave sends this response *0111 Command cannot be performed* and issues the following fault report in Table 8.7.

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

Table 8.7 Slave Report

### 8.4.8 Parameter Number (PNU)

Bits 0–11 transfer parameter numbers. The function of the relevant parameter is defined in the parameter description in the *VLT® Micro Drive FC 51 Programming Guide*.

### 8.4.9 Index (IND)

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

Only the low byte is used as an index.

### 8.4.10 Parameter Value (PWE)

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

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

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

For example, read the unit size and mains voltage range in *parameter 15-40 FC Type*. When a text string is transferred (read), the length of the telegram is variable, and the texts are of different lengths. The telegram length is defined in the 2<sup>nd</sup> byte of the telegram (LGE). When using text transfer, the index character indicates whether it is a read or a write command.

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

### 8.4.11 Data Types Supported by the Frequency Converter

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

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

Table 8.8 Data Types

### 8.4.12 Conversion

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

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

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

Table 8.9 Conversion

### 8.4.13 Process Words (PCD)

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

PCD 1	PCD 2
Control telegram (master→slave) control word	Reference value
Control telegram (slave→master) status word	Present output frequency

Table 8.10 Process Words (PCD)

## 8.5 Examples

### 8.5.1 Writing a Parameter Value

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

Write the data in EEPROM.

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

- IND = 0000 hex.
- PWE<sub>HIGH</sub> = 0000 hex.
- PWE<sub>LOW</sub> = 03E8 hex.

Data value 1000, corresponding to 100 Hz, see *chapter 8.4.12 Conversion*.

The telegram looks like *Illustration 8.10*.

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

Illustration 8.10 Telegram

130BA092.10

### NOTICE

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

The response from the slave to the master is shown in *Illustration 8.11*.

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

Illustration 8.11 Response from Master

130BA093.10

### 8.5.2 Reading a Parameter Value

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

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

- IND = 0000 hex.
- PWE<sub>HIGH</sub> = 0000 hex.
- PWE<sub>LOW</sub> = 0000 hex.

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

Illustration 8.12 Telegram

130BA094.10

If the value in *parameter 3-41 Ramp 1 Ramp Up Time* is 10 s, the response from the slave to the master is shown in *Illustration 8.13*.

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

Illustration 8.13 Response

130BA267.10

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

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

## 8.6 Modbus RTU Overview

### 8.6.1 Prerequisite Knowledge

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

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

### 8.6.2 What the User Should Already Know

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

### 8.6.3 Overview

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

During communications over a Modbus RTU network, the protocol:

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

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

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

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

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

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

## 8.6.4 Frequency Converter with Modbus RTU

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

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

- Start.
- Various stops:
  - Coast stop.
  - Quick stop.
  - DC brake stop.
  - Normal (ramp) stop.
- Reset after a fault trip.

- Run at various preset speeds.
- Run in reverse.
- Change the active set-up.
- Control built-in relay of the frequency converter.

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

## 8.7 Network Configuration

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

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

Table 8.11 Network Configuration

## 8.8 Modbus RTU Message Framing Structure

### 8.8.1 Introduction

The controllers are set up to communicate on the Modbus network using RTU (remote terminal unit) mode, with each byte in a telegram containing 2 4-bit hexadecimal characters. The format for each byte is shown in Table 8.12.

Start bit	Data byte								Stop/parity	Stop

Table 8.12 Format for Each Byte

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

Table 8.13 Byte Details

## 8.8.2 Modbus RTU Telegram Structure

The transmitting device places a Modbus RTU telegram into a frame with a known beginning and ending point. This allows receiving devices to begin at the start of the telegram, read the address portion, determine which device is addressed (or all devices, if the telegram is broadcast), and to recognize when the telegram is completed. Partial telegrams are detected and errors set as a result. Characters for transmission must be in hexadecimal 00–FF format in each field. The frequency converter continuously monitors the network bus, also during silent intervals. When the first field (the address field) is received, each frequency converter or device decodes it to determine which device is being addressed. Modbus RTU telegrams addressed to 0 are broadcast telegrams. No response is permitted for broadcast telegrams. A typical telegram frame is shown in *Table 8.14*.

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

Table 8.14 Typical Modbus RTU Telegram Structure

## 8.8.3 Start/Stop Field

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

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

## 8.8.4 Address Field

The address field of a telegram frame contains 8 bits. Valid slave device addresses are in the range of 0–247 decimal. The individual slave devices are assigned addresses in the range of 1–247. (0 is reserved for broadcast mode, which all slaves recognize.) A master addresses a slave by placing the slave address in the address field of the telegram.

When the slave sends its response, it places its own address in this address field to let the master know which slave is responding.

## 8.8.5 Function Field

The function field of a message frame contains 8 bits. Valid codes are in the range of 1–FF. Function fields are used to send messages between master and follower. When a message is sent from a master to a follower device, the function code field tells the follower what kind of action to perform. When the follower responds to the master, it uses the function code field to indicate either a normal (error-free) response, or that some kind of error occurred (called an exception response). For a normal response, the follower simply echoes the original function code. For an exception response, the follower returns a code that is equivalent to the original function code with its most significant bit set to logic 1. In addition, the follower places a unique code into the data field of the response message. This tells the master what kind of error occurred, or the reason for the exception. Also refer to *chapter 8.8.10 Function Codes Supported by Modbus RTU* and *chapter 8.8.11 Modbus Exception Codes*.

## 8.8.6 Data Field

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

The information can include items such as:

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

## 8.8.7 CRC Check Field

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



## 8.8.8 Coil Register Addressing

In Modbus, all data is organized in coils and holding registers. Coils hold a single bit, whereas holding registers hold a 2 byte word (that is 16 bits). All data addresses in Modbus telegrams are referenced to 0. The first occurrence of a data item is addressed as item number 0. For example: The coil known as coil 1 in a programmable controller is addressed as coil 0000 in the data address field of a Modbus telegram. Coil 127 decimal is addressed as coil 007Ehex (126 decimal).

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

Coil number	Description	Signal direction
1–16	Frequency converter control word (see Table 8.16).	Master to slave
17–32	Frequency converter speed or setpoint reference range 0x0–0xFFFF (-200% ... ~200%).	Master to slave
33–48	Frequency converter status word (see Table 8.17).	Slave to master
49–64	Open-loop mode: Frequency converter output frequency. Closed-loop mode: Frequency converter feedback signal.	Slave to master
65	Parameter write control (master to slave). 0 = Parameter changes are written to the RAM of the frequency converter. 1 = Parameter changes are written to the RAM and EEPROM of the frequency converter.	Master to slave
66–65536	Reserved.	–

Table 8.15 Coil Register

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

Table 8.16 Frequency Converter Control Word (FC Profile)

Coil	0	1
33	Control not ready	Control ready
34	Frequency converter not ready	Frequency converter ready
35	Coast stop	Safety closed
36	No alarm	Alarm
37	Not used	Not used
38	Not used	Not used
39	Not used	Not used
40	No warning	Warning
41	Not at reference	At reference
42	Hand mode	Auto mode
43	Out of frequency range	In frequency range
44	Stopped	Running
45	Not used	Not used
46	No voltage warning	Voltage warning
47	Not in current limit	Current limit
48	No thermal warning	Thermal warning

Table 8.17 Frequency Converter Status Word (FC Profile)



Bus address	Bus register <sup>1)</sup>	PLC register	Content	Access	Description
0	1	40001	Reserved	–	Reserved for legacy frequency converters VLT® 5000 and VLT® 2800.
1	2	40002	Reserved	–	Reserved for legacy frequency converters VLT® 5000 and VLT® 2800.
2	3	40003	Reserved	–	Reserved for legacy frequency converters VLT® 5000 and VLT® 2800.
3	4	40004	Free	–	–
4	5	40005	Free	–	–
5	6	40006	Modbus configuration	Read/Write	TCP only. Reserved for Modbus TCP (parameter 12-28 Store Data Values and parameter 12-29 Store Always - stored in, for example, EEPROM).
6	7	40007	Last fault code	Read only	Fault code received from parameter database, refer to WHAT 38295 for details.
7	8	40008	Last error register	Read only	Address of register with which last error occurred, refer to WHAT 38296 for details.
8	9	40009	Index pointer	Read/Write	Sub index of parameter to be accessed. Refer to WHAT 38297 for details.
9	10	40010	Parameter 0-01 Language	Dependent on parameter access	Parameter 0-01 Language (Modbus register = 10 parameter number) 20 bytes space reserved for parameter in Modbus map.
19	20	40020	Parameter 0-02 Motor Speed Unit	Dependent on parameter access	Parameter 0-02 Motor Speed Unit 20 bytes space reserved for parameter in Modbus map.
29	30	40030	Parameter 0-03 Regional Settings	Dependent on parameter access	Parameter 0-03 Regional Settings 20 bytes space reserved for parameter in Modbus map.

**Table 8.18 Address/Registers**

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

### 8.8.9 How to Control the Frequency Converter

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

### 8.8.10 Function Codes Supported by Modbus RTU

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

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

**Table 8.19 Function Codes**

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

Table 8.20 Function Codes

### 8.8.11 Modbus Exception Codes

For a full explanation of the structure of an exception code response, refer to *chapter 8.8.5 Function Field*.

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

Code	Name	Meaning
4	Slave device failure	An unrecoverable error occurred while the server (or slave) was attempting to perform the requested action.

Table 8.21 Modbus Exception Codes

## 8.9 How to Access Parameters

### 8.9.1 Parameter Handling

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

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

For information on the parameters, size, and conversion index, see *chapter 7 Programming*.

### 8.9.2 Storage of Data

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

### 8.9.3 IND (Index)

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

### 8.9.4 Text Blocks

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

## 8.9.5 Conversion Factor

The different attributes for each parameter can be seen in the section on factory settings. Since a parameter value can only be transferred as a whole number, a conversion factor must be used to transfer decimals. Refer to the *chapter 7.4 Quick Menu Parameters*.

## 8.9.6 Parameter Values

### Standard data types

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

### Non-standard data types

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

## 8.10 Examples

The following examples show various Modbus RTU commands. If an error occurs, refer to *chapter 8.8.11 Modbus Exception Codes*.

### 8.10.1 Read Coil Status (01 hex)

#### Description

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

#### Query

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

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

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

Table 8.22 Query

#### Response

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

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

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

Table 8.23 Response

### NOTICE

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

For example, coil 33 is addressed as coil 32.

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

#### Description

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

#### Query

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

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

Table 8.24 Query

#### Response

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

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

Table 8.25 Response

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

#### Description

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

#### Query

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

#### NOTICE

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

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

Table 8.26 Query

www.famcocorp.com  
E-mail: info@famcocorp.com  
@famco\_group

Tel: ۰۲۱-۴۸۰۰۰۰۰۴۹

Fax: ۰۲۱-۴۴۹۹۴۶۴۲

#### Response

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

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

Table 8.27 Response

### 8.10.4 Read Holding Registers (03 hex)

#### Description

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

#### Query

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

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

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

Table 8.28 Query

#### Response

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

Example: hex 000088B8=35.000=35 Hz.

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

Table 8.29 Response

### 8.10.5 Preset Single Register (06 hex)

#### Description

This function presets a value into a single holding register.

#### Query

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

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

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

Table 8.30 Query

#### Response

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

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

Table 8.31 Response

### 8.10.6 Preset Multiple Registers (10 hex)

#### Description

This function presets values into a sequence of holding registers.

#### Query

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

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

Table 8.32 Query

#### Response

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

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

Table 8.33 Response

## 8.11 FC Drive Control Profile

### 8.11.1 Control Word According to FC Profile

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

Modbus Holding Register numbers for Input data – CTW and REF – and Output data – STW and MAV – are defined in *Table 8.34*:

50000 input data	Frequency converter control word register (CTW)
50010 input data	Bus reference register (REF)
50200 output data	Frequency converter status word register (STW)
50210 output data	Frequency converter main value register (MAV)

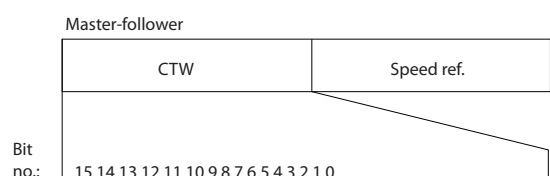
**Table 8.34 Modbus Holding Register Numbers for Input and Output Data**

8

In *VLT® Micro Drive FC 51* after software version 2.32, the input/output data is also available in a lower holding register area:

02810 input data	Frequency converter control word register (CTW)
02811 input data	Bus reference register (REF)
02910 output data	Frequency converter status word register (STW)
02911 output data	Frequency converter main value register (MAV)

**Table 8.35 Lower Register Numbers for Input and Output Data**



**Illustration 8.14 Control Word**

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

**Table 8.36 Definition of Control Bits**

#### Explanation of the control bits

##### Bits 00/01

Bits 00 and 01 are used to select between the 4 reference values, which are pre-programmed in *parameter 3-10 Preset Reference* according to the *Table 8.37*.

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

**Table 8.37 Control Bits**

#### NOTICE

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

##### Bit 02, DC brake

Bit 02=0 leads to DC brake and stop. Set braking current and duration in *parameter 2-01 DC Brake Current* and *parameter 2-02 DC Braking Time*.  
Bit 02=1 leads to ramping.

##### Bit 03, Coasting

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

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

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

#### Bit 04, Quick stop

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

#### Bit 05, Hold output frequency

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

### NOTICE

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

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

#### Bit 06, Ramp stop/start

Bit 06=0: Causes a stop and makes the motor speed ramp down to stop via the selected ramp down parameter.  
Bit 06=1: Allows the frequency converter to start the motor if the other starting conditions are met.

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

#### Bit 07, Reset

Bit 07=0: No reset.  
Bit 07=1: Resets a trip. Reset is activated on the signal's leading edge, that is, when changing from logic 0 to logic 1.

#### Bit 08, Jog

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

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

Bit 09=0: Ramp 1 is active (*parameter 3-41 Ramp 1 Ramp Up Time* to *parameter 3-42 Ramp 1 Ramp Down Time*).  
Bit 09=1: Ramp 2 (*parameter 3-51 Ramp 2 Ramp Up Time* to *parameter 3-52 Ramp 2 Ramp Down Time*) is active.

#### Bit 10, Data not valid/Data valid

Tell the frequency converter whether to use or ignore the control word.  
Bit 10=0: The control word is ignored.  
Bit 10=1: The control word is used.  
This function is relevant because the telegram always contains the control word, regardless of the telegram type. Turn off the control word if not wanting to use it when updating or reading parameters.

#### Bit 11, Relay 01

Bit 11=0: Relay not activated.  
Bit 11=1: Relay 01 activated if [36] *Control word bit 11* is selected in *parameter 5-40 Function Relay*.

#### Bit 12, Relay 02

Bit 12=0: Relay 02 is not activated.  
Bit 12=1: Relay 02 is activated if [37] *Control word bit 12* is selected in *parameter 5-40 Function Relay*.

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

Use bit 13 to select from the 2 menu set-ups according to *Table 8.38*.

Set-up	Bit 13
1	0
2	1

Table 8.38 Set-up Selection

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

Make a selection in *parameter 8-55 Set-up Select* to define how bit 13 communicates with the corresponding function on the digital inputs.

#### Bit 15 Reverse

Bit 15=0: No reversing.  
Bit 15=1: Reversing. In the default setting, reversing is set to digital in *parameter 8-54 Reversing Select*. Bit 15 causes reversing only when 1 of the following options is selected: [1] *Bus*, [2] *Logic AND*, [3] *Logic OR*.

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

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

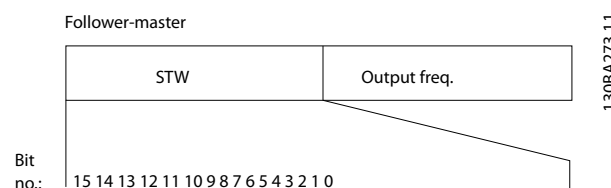


Illustration 8.15 Status Word



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

Table 8.39 Status Word According to FC Profile

#### Explanation of the status bits

##### Bit 00, Control not ready/ready

Bit 00=0: The frequency converter trips.

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

##### Bit 01, Frequency converter ready

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

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

##### Bit 02, Coast stop

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

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

##### Bit 03, No error/trip

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

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

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

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

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

##### Bit 05, Not used

Bit 05 is not used in the status word.

##### Bit 06, No error/triplock

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

Bit 06=1: The frequency converter is tripped and locked.

##### Bit 07, No warning/warning

Bit 07=0: There are no warnings.

Bit 07=1: A warning has occurred.

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

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

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

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

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

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

##### Bit 10, Out of frequency limit

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

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

##### Bit 11, No operation/in operation

Bit 11=0: The motor is not running.

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

##### Bit 12, Frequency converter OK/stopped, auto start

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

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

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

Bit 13=0: There are no voltage warnings.

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

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

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

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

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

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

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



### 8.11.3 Bus Speed Reference Value

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

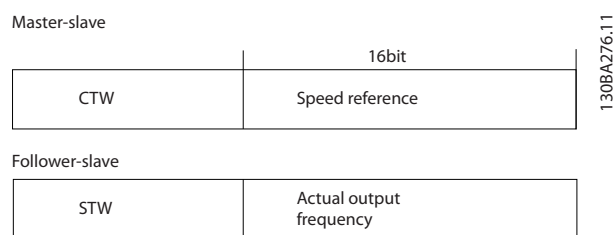


Illustration 8.16 Actual Output Frequency (MAV)

The reference and MAV are scaled as follows:

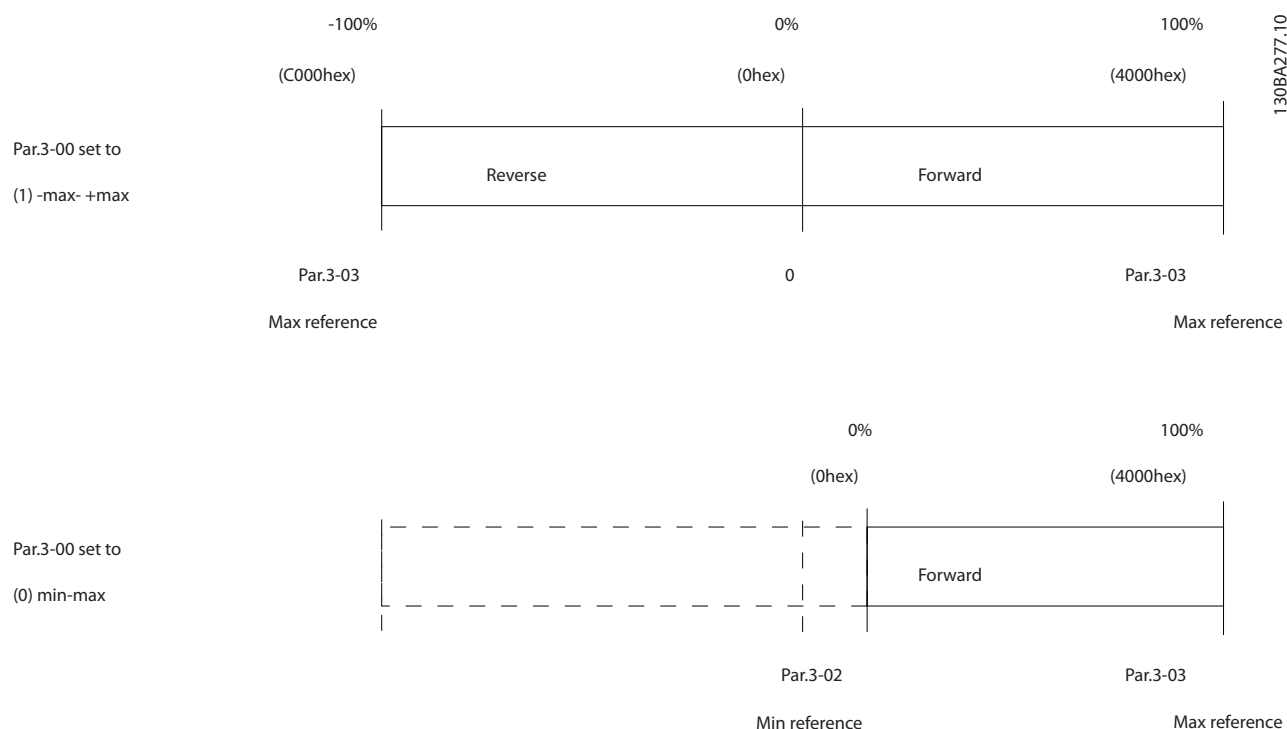


Illustration 8.17 Reference and MAV

## 9 Specifications

### 9.1.1 Mains Supply 1x200–240 V AC

Normal overload 150% for 1 minute					
Frequency converter	PK18	PK37	PK75	P1K5	P2K2
Typical shaft output [kW]	0.18	0.37	0.75	1.5	2.2
Typical shaft output [hp]	0.25	0.5	1	2	3
Enclosure protection rating IP20	M1	M1	M1	M2	M3
Output current					
Continuous (1x200–240 V AC) [A]	1.2	2.2	4.2	6.8	9.6
Intermittent (1x200–240 V AC) [A]	1.8	3.3	6.3	10.2	14.4
Maximum cable size:					
(Mains, motor) [mm <sup>2</sup> /AWG]	4/10				
Maximum input current					
Continuous (1x200–240 V) [A]	3.3	6.1	11.6	18.7	26.4
Intermittent (1x200–240 V) [A]	4.5	8.3	15.6	26.4	37.0
Maximum mains fuses [A]	See chapter 6.6.1 Fuses				
Environment					
Estimated power loss [W], Best case/typical <sup>1)</sup>	12.5/ 15.5	20.0/ 25.0	36.5/ 44.0	61.0/ 67.0	81.0/ 85.1
Weight enclosure IP20 [kg]	1.1	1.1	1.1	1.6	3.0
Efficiency [%], Best case/typical <sup>2)</sup>	95.6/ 94.5	96.5/ 95.6	96.6/ 96.0	97.0/ 96.7	96.9/ 97.1

**Table 9.1 Mains Supply 1x200–240 V AC**

1) Applies for dimensioning of frequency converter cooling. If the switching frequency is higher than the default setting, the power losses may increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50598-2, refer to [danfoss.com/vltenergyefficiency](http://danfoss.com/vltenergyefficiency).

2) Efficiency measured at nominal current. For energy efficiency class, see chapter 9.1.4 Surroundings. For part load losses, see [danfoss.com/vltenergyefficiency](http://danfoss.com/vltenergyefficiency).

## 9.1.2 Mains Supply 3x200–240 V AC

Normal overload 150% for 1 minute						
Frequency converter	PK25	PK37	PK75	P1K5	P2K2	P3K7
Typical shaft output [kW]	0.25	0.37	0.75	1.5	2.2	3.7
Typical shaft output [hp]	0.33	0.5	1	2	3	5
Enclosure protection rating IP20	M1	M1	M1	M2	M3	M3
Output current						
Continuous (3x200–240 V) [A]	1.5	2.2	4.2	6.8	9.6	15.2
Intermittent (3x200–240 V) [A]	2.3	3.3	6.3	10.2	14.4	22.8
Maximum cable size:						
(Mains, motor) [mm²/AWG]	4/10					
Maximum input current						
Continuous (3x200–240 V) [A]	2.4	3.5	6.7	10.9	15.4	24.3
Intermittent (3x200–240 V) [A]	3.2	4.6	8.3	14.4	23.4	35.3
Maximum mains fuses [A]	See chapter 6.6.1 Fuses					
Environment						
Estimated power loss [W]	14.0/	19.0/	31.5/	51.0/	72.0/	115.0/
Best case/typical <sup>1)</sup>	20.0	24.0	39.5	57.0	77.1	122.8
Weight enclosure IP20 [kg]	1.1	1.1	1.1	1.6	3.0	3.0
Efficiency [%]	96.4/	96.7/	97.1/	97.4/	97.2/	97.3/
Best case/typical <sup>2)</sup>	94.9	95.8	96.3	97.2	97.4	97.4

**Table 9.2 Mains Supply 3x200–240 V AC**

1) Applies for dimensioning of frequency converter cooling. If the switching frequency is higher than the default setting, the power losses may increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50598-2, refer to [danfoss.com/vltenergyefficiency](http://danfoss.com/vltenergyefficiency).

2) Efficiency measured at nominal current. For energy efficiency class, see chapter 9.1.4 Surroundings. For part load losses, see [danfoss.com/vltenergyefficiency](http://danfoss.com/vltenergyefficiency).

### 9.1.3 Mains Supply 3x380–480 V AC

Normal overload 150% for 1 minute						
Frequency converter	PK37	PK75	P1K5	P2K2	P3K0	P4K0
Typical shaft output [kW]	0.37	0.75	1.5	2.2	3.0	4.0
Typical shaft output [hp]	0.5	1	2	3	4	5.5
Enclosure protection rating IP20	M1	M1	M2	M2	M3	M3
Output current						
Continuous (3x380–440 V) [A]	1.2	2.2	3.7	5.3	7.2	9.0
Intermittent (3x380–440 V) [A]	1.8	3.3	5.6	8.0	10.8	13.7
Continuous (3x440–480 V) [A]	1.1	2.1	3.4	4.8	6.3	8.2
Intermittent (3x440–480 V) [A]	1.7	3.2	5.1	7.2	9.5	12.3
Maximum cable size:						
(Mains, motor) [mm²/AWG]	4/10					
Maximum input current						
Continuous (3x380–440 V) [A]	1.9	3.5	5.9	8.5	11.5	14.4
Intermittent (3x380–440 V) [A]	2.6	4.7	8.7	12.6	16.8	20.2
Continuous (3x440–480 V) [A]	1.7	3.0	5.1	7.3	9.9	12.4
Intermittent (3x440–480 V) [A]	2.3	4.0	7.5	10.8	14.4	17.5
Maximum mains fuses [A]	See chapter 6.6.1 Fuses					
Environment						
Estimated power loss [W]	18.5/	28.5/	41.5/	57.5/	75.0/	98.5/
Best case/typical <sup>1)</sup>	25.5	43.5	56.5	81.5	101.6	133.5
Weight enclosure IP20 [kg]	1.1	1.1	1.6	1.6	3.0	3.0
Efficiency [%]	96.8/	97.4/	98.0/	97.9/	98.0/	98.0/
Best case/typical <sup>2)</sup>	95.5	96.0	97.2	97.1	97.2	97.3

Table 9.3 Mains Supply 3x380–480 V AC

Normal overload 150% for 1 minute						
Frequency converter	P5K5	P7K5	P11K	P15K	P18K	P22K
Typical shaft output [kW]	5.5	7.5	11	15	18.5	22
Typical shaft output [hp]	7.5	10	15	20	25	30
Enclosure protection rating IP20	M3	M3	M4	M4	M5	M5
Output current						
Continuous (3x380–440 V) [A]	12.0	15.5	23.0	31.0	37.0	43.0
Intermittent (3x380–440 V) [A]	18.0	23.5	34.5	46.5	55.5	64.5
Continuous (3x440–480 V) [A]	11.0	14.0	21.0	27.0	34.0	40.0
Intermittent (3x440–480 V) [A]	16.5	21.3	31.5	40.5	51.0	60.0
Maximum cable size:						
(Mains, motor) [mm²/AWG]	4/10		16/6			
Maximum input current						
Continuous (3x380–440 V) [A]	19.2	24.8	33.0	42.0	34.7	41.2
Intermittent (3x380–440 V) [A]	27.4	36.3	47.5	60.0	49.0	57.6
Continuous (3x440–480 V) [A]	16.6	21.4	29.0	36.0	31.5	37.5
Intermittent (3x440–480 V) [A]	23.6	30.1	41.0	52.0	44.0	53.0
Maximum mains fuses [A]	See chapter 6.6.1 Fuses					
Environment						
Estimated power loss [W]	131.0/	175.0/	290.0/	387.0/	395.0/	467.0/
Best case/typical <sup>1)</sup>	166.8	217.5	342.0	454.0	428.0	520.0
Weight enclosure IP20 [kg]	3.0	3.0				
Efficiency [%]	98.0/	98.0/	97.8/	97.7/	98.1/	98.1/
Best case/typical <sup>2)</sup>	97.5	97.5	97.4	97.4	98.0	97.9

**Table 9.4 Mains Supply 3x380–480 V AC**

1) Applies for dimensioning of frequency converter cooling. If the switching frequency is higher than the default setting, the power losses may increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50598-2, refer to [danfoss.com/vltenergyefficiency](http://danfoss.com/vltenergyefficiency).

2) Efficiency measured at nominal current. For energy efficiency class, see chapter 9.1.4 Surroundings. For part load losses, see [danfoss.com/vltenergyefficiency](http://danfoss.com/vltenergyefficiency).

Specifications

VLT® Micro Drive FC 51

Protection and Features

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

Mains supply (L1/L, L2, L3/N)

Supply voltage	200–240 V ±10%
Supply voltage	380–480 V ±10%
Supply frequency	50/60 Hz
Maximum imbalance temporary between mains phases	3.0% of rated supply voltage
True power factor	≥0.4 nominal at rated load
Displacement power factor (cosφ) near unity	(>0.98)
Switching on input supply L1/L, L2, L3/N (power-ups)	Maximum 2 times/minute
Environment according to EN60664-1	Overvoltage category III/pollution degree 2

*The unit is suitable for use on a circuit capable of delivering not more than 100000 RMS symmetrical Amperes, 240/480 V maximum.*

Motor output (U, V, W)

Output voltage	0–100% of supply voltage
Output frequency	0–200 Hz (VVC <sup>+</sup> ), 0–400 Hz (u/f)
Switching on output	Unlimited
Ramp times	0.05–3600 s

Cable length and cross-section

Maximum motor cable length, shielded/armored (EMC-correct installation)	15 m (49 ft)
Maximum motor cable length, unshielded/unarmored	50 m (164 ft)
Maximum cross-section to motor, mains <sup>1)</sup>	
Connection to load sharing/brake (M1, M2, M3)	6.3 mm insulated Faston plugs
Maximum cross-section to load sharing/brake (M4, M5)	16 mm <sup>2</sup> /6 AWG
Maximum cross-section to control terminals, rigid wire	1.5 mm <sup>2</sup> /16 AWG (2x0.75 mm <sup>2</sup> )
Maximum cross-section to control terminals, flexible cable	1 mm <sup>2</sup> /18 AWG
Maximum cross-section to control terminals, cable with enclosed core	0.5 mm <sup>2</sup> /20 AWG
Minimum cross-section to control terminals	0.25 mm <sup>2</sup> (24 AWG)

*1) See chapter 9 Specifications for more information.*

Digital inputs (pulse/encoder inputs)

Programmable digital inputs (pulse/encoder)	5 (1)
Terminal number	18, 19, 27, 29, 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	>19 V DC
Voltage level, logic 1 NPN	<14 V DC
Maximum voltage on input	28 V DC
Input resistance, R <sub>i</sub>	Approximately 4000 Ω
Maximum pulse frequency at terminal 33	5000 Hz
Minimum pulse frequency at terminal 33	20 Hz

Specifications

Design Guide

Analog inputs

Number of analog inputs	2
Terminal number	53, 60
Voltage mode (terminal 53)	Switch S200=OFF(U)
Current mode (terminal 53 and 60)	Switch S200=ON(I)
Voltage level	0–10 V
Input resistance, $R_i$	Approximately 10000 $\Omega$
Maximum voltage	20 V
Current level	0/4 to 20 mA (scaleable)
Input resistance, $R_i$	Approximately 200 $\Omega$
Maximum current	30 mA

Analog output

Number of programmable analog outputs	1
Terminal number	42
Current range at analog output	0/4–20 mA
Maximum load to common at analog output	500 $\Omega$
Maximum voltage at analog output	17 V
Accuracy on analog output	Maximum error: 0.8% of full scale
Scan interval	4 ms
Resolution on analog output	8 bit
Scan interval	4 ms

Control card, RS485 serial communication

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

Control card, 24 V DC output

Terminal number	12
Maximum load (M1 and M2)	100 mA
Maximum load (M3)	50 mA
Maximum load (M4 and M5)	80 mA

Relay output

Programmable relay output	1
Relay 01 terminal number	01-03 (break), 01-02 (make)
Maximum terminal load (AC-1) <sup>1)</sup> on 01-02 (NO) (Resistive load)	250 V AC, 2 A
Maximum terminal load (AC-15) <sup>1)</sup> on 01-02 (NO) (Inductive load @ $\cos\phi$ 0.4)	250 V AC, 0.2 A
Maximum terminal load (DC-1) <sup>1)</sup> on 01-02 (NO) (Resistive load)	30 V DC, 2 A
Maximum terminal load (DC-13) <sup>1)</sup> on 01-02 (NO) (Inductive load)	24 V DC, 0.1 A
Maximum terminal load (AC-1) <sup>1)</sup> on 01-03 (NC) (Resistive load)	250 V AC, 2 A
Maximum terminal load (AC-15) <sup>1)</sup> on 01-03 (NC) (Inductive load @ $\cos\phi$ 0.4)	250 V AC, 0.2 A
Maximum terminal load (DC-1) <sup>1)</sup> on 01-03 (NC) (Resistive load)	30 V DC, 2 A
Minimum terminal load on 01-03 (NC), 01-02 (NO)	24 V DC 10 mA, 24 V AC 20 mA
Environment according to EN 60664-1	Overvoltage category III/pollution degree 2

1) IEC 60947 part 4 and 5

Control card, 10 V DC output

Terminal number	50
Output voltage	10.5 V $\pm$ 0.5 V
Maximum load	25 mA

**NOTICE**

All inputs, outputs, circuits, DC supplies, and relay contacts are galvanically isolated from the supply voltage (PELV) and other high voltage terminals.

Specifications

VLT® Micro Drive FC 51

Surroundings

Enclosure protection rating	IP20
Enclosure kit available	IP21, TYPE 1
Vibration test	1.0 g
Maximum relative humidity	5%–95 % (IEC 60721-3-3; Class 3K3 (non-condensing) during operation
Aggressive environment (IEC 60721-3-3), coated	class 3C3
Test method according to IEC 60068-2-43 H2S (10 days)	
Ambient temperature <sup>1)</sup>	Maximum 40 °C (104 °F)
Minimum ambient temperature during full-scale operation	0 °C (32 °F)
Minimum ambient temperature at reduced performance	-10 °C (14 °F)
Temperature during storage/transport	-25 to +65/70 °C
Maximum altitude above sea level without derating <sup>1)</sup>	1000 m (3280 ft)
Maximum altitude above sea level with derating <sup>1)</sup>	3000 m (9842 ft)
Safety standards	EN/IEC 61800-5-1, UL 508C
EMC standards, Emission	EN 61800-3, EN 61000-6-3/4, EN 55011, IEC 61800-3
EMC standards, Immunity	EN 61800-3, EN 61000-6-1/2, EN 61000-4-2, EN 61000-4-3, EN 61000-4-4, EN 61000-4-5, EN 61000-4-6
Energy efficiency class	IE2

1) Refer to chapter 4.2 Special Conditions for:

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

2) Determined according to EN 50598-2 at:

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



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