MAKING MODERN LIVING POSSIBLE

Design Guide

VLT® Micro Drive

VLT®
THE REAL DRIVE

Contents

1 How to Read this Design Guide

VLT® Micro Drive FC 51
FC 51 Series
Software version: 2.6X

This guide can be used with all VLT® Micro Drive FC 51 frequency converters with software version 2.6X.
The actual software version number can be read from *15-43 Software Version*.

1.1.1 Copyright, Limitation of Liability and Revision Rights

1.1.2 Available Literature

NOTE

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

If more information is needed, the literature below can be downloaded from:
http: //www.danfoss.com/BusinessAreas/DrivesSolutions/Documentations

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Title	Literature no.
VLT Micro Drive FC 51 Design Guide	MG.02.K1.YY
VLT Micro Drive FC 51 Quick Guide	MG.02.BX.YY
VLT Micro Drive FC 51 Programming Guide	MG.02.CX.YY
FC 51 LCP Mounting Instruction	MI.02.AX.YY
FC 51 De-coupling Plate Mounting Instruction	MI.02.BX.YY
FC 51 Remote Mounting Kit Mounting Instruction	MI.02.CX.YY
FC 51 DIN Rail Kit Mounting Instruction	MI.02.DX.YY
FC 51 IP21 Kit Mounting Instruction	MI.02.EX.YY
FC 51 Nema1 Kit Mounting Instruction	MI.02.FX.YY

X = Revision Number, Y = Language code

1.1.3 Symbols

Symbols used in this guide.

NOTE

Indicates something to be noted by the reader.

⚠CAUTION

Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury or equipment damage.

⚠WARNING

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

*	Indicates default setting

1.1.4 Abbreviations

Alternating current	AC
American wire gauge	AWG
Ampere/AMP	A
Automatic Motor Tuning	AMT
Current limit	I_{LIM}
Degrees Celsius	°C
Direct current	DC
Electro Magnetic Compatibility	EMC
Electronic Thermal Relay	ETR
Frequency Converter	FC
Gram	g
Hertz	Hz
Kilohertz	kHz
Local Control Panel	LCP
Meter	m
Millihenry Inductance	mH
Milliampere	mA
Millisecond	ms
Minute	min
Motion Control Tool	MCT
Nanofarad	nF
Newton Meters	Nm
Nominal motor current	$I_{M,N}$
Nominal motor frequency	$f_{M,N}$
Nominal motor power	$P_{M,N}$
Nominal motor voltage	$U_{M,N}$
Protective Extra Low Voltage	PELV
Printed Circuit Board	PCB
Rated Inverter Output Current	I_{INV}
Revolutions Per Minute	RPM
Regenerative terminals	Regen
Second	sec.
Synchronous Motor Speed	n_s
Torque limit	T_{LIM}
Volts	V
The maximum output current	$I_{VLT,MAX}$
The rated output current supplied by the frequency converter	$I_{VLT,N}$

1.1.5 Definitions

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.

Input

Control command You can start and stop the connected motor by means of 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, Coasting stop, Reset and Coasting stop, Quick-stop, DC braking, Stop and the [Off] key.
	Group 2	Start, Pulse start, Reversing, Start reversing, Jog and Freeze output

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).

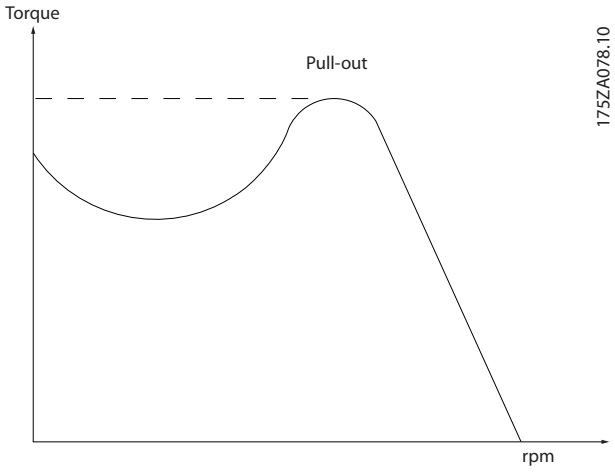
$n_{M,N}$
The rated motor speed (nameplate data).

$P_{M,N}$
The rated motor power (nameplate data).

U_M
The instantaneous motor voltage.

$U_{M,N}$
The rated motor voltage (nameplate data).

Break-away torque



η_{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 this group.

Stop command
See Control commands.

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 eight preset references via the digital terminals.

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

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

Miscellaneous

Analog Inputs
The analog inputs are used for controlling various functions of the frequency converter.
There are two types of analog inputs:
Current input, 0-20mA and 4-20mA
Voltage input, 0-10V DC.

Analog Outputs
The analog outputs can supply a signal of 0-20mA, 4-20mA, 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 braking power increases the intermediate circuit voltage and a brake chopper ensures that the power is transmitted to the brake resistor.

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

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

Relay Outputs
The frequency converter features two 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.

Initialising
If initialising is carried out (*14-22 Operation Mode*), the programmable parameters of the frequency converter return to their default settings.
Initialising; *14-22 Operation Mode* will not initialise 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 (LCP) makes up a complete interface for control and programming of the frequency converter. The control panel is detachable and can be installed up to 3m from the frfrequency converter, i.e. in a front panel by means of the installation kit option.

lsb
Least significant bit.

MCM
Short for Mille Circular Mil, an American measuring unit for cable cross-section. 1 MCM ≡ 0.5067mm^2.

msb
Most significant bit.

On-line/Off-line Parameters
Changes to on-line parameters are activated immediately after the data value is changed. Changes to off-line parameters are not activated until you enter [OK] on the LCP.

PI Controller
The PI controller maintains the desired speed, pressure, temperature, etc. by adjusting the output frequency to match the varying load.

RCD
Residual Current Device.

Set-up
You can save parameter settings in 2 Set-ups. Change between the 2 parameter Set-ups and edit one 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 placed where the temperature is to be monitored (frequency converter or motor).

STW
Status Word

FC Standard Bus
Includes RS 485 bus with FC protocol. See *8-30 Protocol*.

Trip
A state entered in fault situations, e.g. if the frequency converter is subject to an over-temperature or when the frequency converter is protecting the motor, process or mechanism. Restart is prevented until the cause of the

fault has disappeared and the trip state is canceled by activating reset or, in some cases, by being programmed to reset automatically. Trip may not be used for personal safety.

Trip Locked
A state entered in fault situations when the frequency converter is protecting itself and requiring physical intervention, e.g. if the frequency converter is subject to a short circuit on the output. A locked trip can only be 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, in some cases, by being programmed to reset automatically. Trip locked may not be used for personal safety.

VT Characteristics
Variable torque characteristics used for pumps and fans.

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

1.1.6 Power Factor

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

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

The power factor for 3-phase control:

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

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

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

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

2 Safety and Conformity

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2.1 Safety

2.1.1 Safety Note

⚠WARNING

DANGEROUS VOLTAGE

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

Safety Regulations

1. The frequency converter must be disconnected from mains if repair work is to be carried out. Check that the mains supply has been disconnected and that the necessary time has passed before removing motor and mains plugs.
2. The [STOP/RESET] key on the LCP of the frequency converter does not disconnect the equipment from mains and is thus not to be used as a safety switch.
3. Correct protective earthing of the equipment must be established, the user must be protected against supply voltage, and the motor must be protected against overload in accordance with applicable national and local regulations.
4. The earth leakage currents are higher than 3.5mA.
5. Protection against motor overload is set by *1-90 Motor Thermal Protection*. If this function is desired, set *1-90 Motor Thermal Protection* to data value [ETR trip] (default value) or data value [ETR warning]. Note: The function is initialized at 1.16 x rated motor current and rated motor frequency. For the North American market: The ETR functions provide class 20 motor overload protection in accordance with NEC.
6. Do not remove the plugs for the motor and mains supply while the frequency converter is connected to mains. Check that the mains supply has been disconnected and that the necessary time has passed before removing motor and mains plugs.
7. Check that all voltage inputs have been disconnected and that the necessary time has passed before commencing repair work.

Installation at high altitudes

⚠CAUTION

At altitudes above 2km, please contact Danfoss regarding PELV.

⚠WARNING

UNINTENDED START

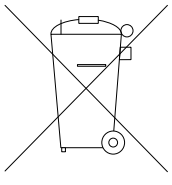
1. **The motor can be brought to a stop by means of digital commands, bus commands, references or a local stop, while the frequency converter is connected to mains. If personal safety considerations make it necessary to ensure that no unintended start occurs, these stop functions are not sufficient.**
2. **While parameters are being changed, the motor may start. Consequently, the stop key [STOP/RESET] must always be activated; following which data can be modified.**
3. **A motor that has been stopped may start if faults occur in the electronics of the frequency converter, or if a temporary overload or a fault in the supply mains or the motor connection ceases.**

⚠WARNING

DISCHARGE TIME

Touching the electrical parts may be fatal - even after the equipment has been disconnected from mains.
Also make sure that other voltage inputs have been disconnected, load sharing (linkage of DC intermediate circuit), as well as the motor connection for kinetic back up.
The frequency converter DC link capacitors remain charged after power has been disconnected. To avoid an electrical shock hazard, disconnect the frequency converter from the mains before carrying out maintenance. Before touching any potentially live parts of the frequency converter, wait at least 4 minutes for M1, M2 and M3 sizes. Wait at least 15 minutes for all M4 and M5 sizes.

2.1.2 Disposal Instruction



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

2.2 CE Labeling

2.2.1 CE conformity and labeling

What is CE Conformity and Labeling?

The purpose of CE labeling 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 three 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, we provide information on safety aspects relating to the frequency converter. We do this by means of 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 - 1000V AC and the 75 - 1500V DC voltage ranges. Danfoss CE-labels in accordance with the directive and issues a declaration of conformity upon request.

The EMC directive (89/336/EEC)

EMC is short for electromagnetic compatibility. The presence of electromagnetic compatibility means that the mutual interference between different components/ appliances does not affect the way the appliances work. The EMC directive came into effect January 1, 1996. Danfoss CE-labels in accordance with the directive and issues a declaration of conformity upon request. To carry out EMC-correct installation, see the instructions in this Design Guide. In addition, we specify which standards our products comply with. We offer 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. It must be noted that the responsibility for the final EMC properties of the appliance, system or installation rests with the installer.

2.2.2 What is Covered

The EU "*Guidelines on the Application of Council Directive 89/336/EEC*" outline three typical situations of using a frequency converter. See below for EMC coverage and CE labeling.

1. 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. He installs the frequency converter himself for use with a hobby machine, a kitchen appliance, etc. For such applications, the frequency converter must be CE labeled in accordance with the EMC directive.
2. The frequency converter is sold for installation in a plant. The plant is built up by professionals of the trade. It could be a production plant or a heating/ventilation plant designed and installed by professionals of the trade. Neither the frequency converter nor the finished plant has to be CE 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.
3. The frequency converter is sold as part of a complete system. The system is being marketed as complete and could e.g. be an air-conditioning system. The complete system must be CE labeled in accordance with the EMC directive. The manufacturer can ensure CE labeling under the EMC directive either by using CE labeled components or by testing the EMC of the system. If he chooses to use only CE labeled components, he does not have to test the entire system.

2.2.3 Danfoss Frequency Converter and CE Labeling

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

However, CE labeling may cover many different specifications. Thus, you have to check what a given CE label specifically covers.

The covered specifications can be very 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, we guarantee compliance with the low-voltage directive. Danfoss issues a declaration of conformity that confirms our CE labeling in accordance with the low-voltage directive.

The CE label also applies to the EMC directive provided that the instructions for EMC-correct installation and

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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 you obtain the best EMC result.

2.2.4 Compliance with EMC Directive 89/336/EEC

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. It must be noted 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. The standards and test levels stated for Power Drive systems are complied with, provided that the EMC-correct instructions for installation are followed, see the section *EMC Immunity*.

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

2.3 Aggressive Environments

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

⚠CAUTION

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

Liquids can be carried through the air and condense in the frequency converter and may cause corrosion of components and metal parts. Steam, oil, and salt water may cause corrosion of components and metal parts. In such environments, use equipment with enclosure rating IP54. 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 very 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 will cause chemical processes on the frequency converter components.

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

NOTE

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

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

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

2.4 Vibration and Shock

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

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

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

2.5 Advantages

2.5.1 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 *2.5.3 Example of Energy Savings*.

2.5.2 The Clear Advantage - Energy Savings

The very 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.

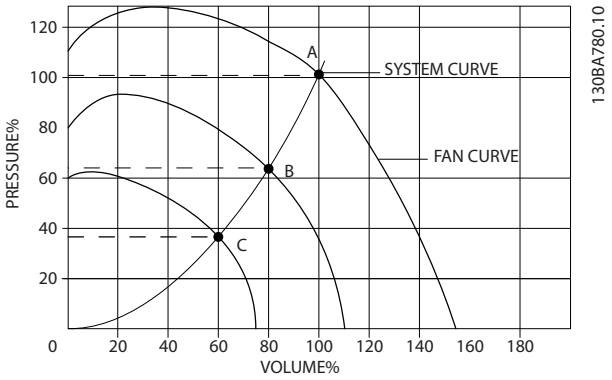

Illustration 2.1 The graph is showing fan curves (A, B and C) for reduced fan volumes.

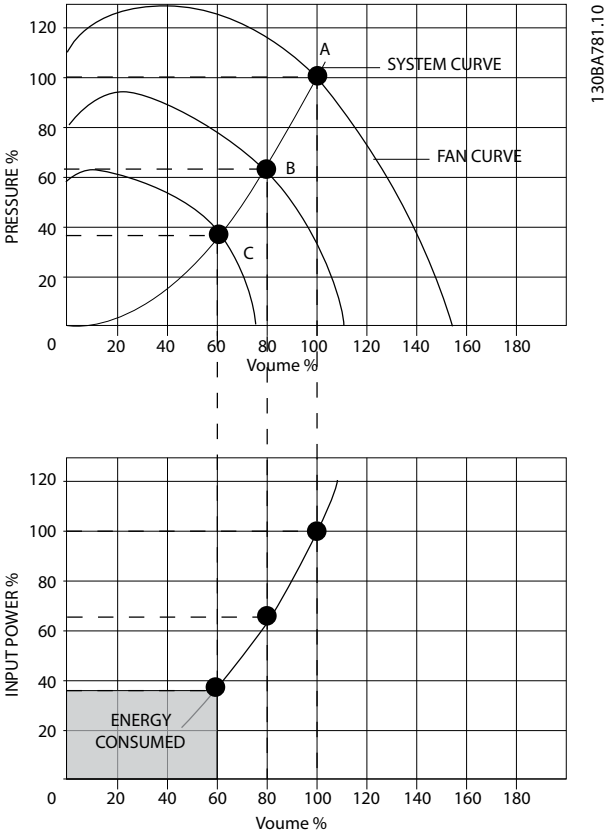

Illustration 2.2 When using a frequency converter to reduce fan capacity to 60% - more than 50% energy savings may be obtained in typical applications.

2.5.3 Example of Energy Savings

As shown in *Illustration 2.3*, the flow is controlled by changing the RPM. By reducing the speed only 20% from the rated speed, the flow is also reduced by 20%. This is because the flow is directly proportional to the RPM. The consumption of electricity, however, is reduced by 50%.
If the system in question only needs to be able to supply a flow that corresponds to 100% a few days in a year, while the average is below 80% of the rated flow for the remainder of the year, the amount of energy saved is even more than 50%.

The laws of proportionality	
Illustration 2.3 describes the dependence of flow, pressure and power consumption on RPM.	
Q = Flow	P = Power
Q_1 = Rated flow	P_1 = Rated power
Q_2 = Reduced flow	P_2 = Reduced power
H = Pressure	n = Speed regulation
H_1 = Rated pressure	n_1 = Rated speed
H_2 = Reduced pressure	n_2 = Reduced speed

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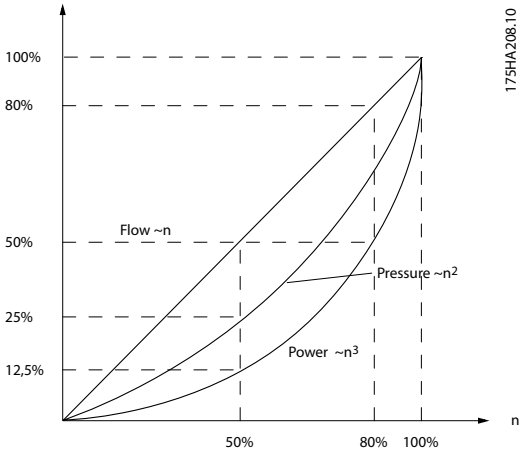


Illustration 2.3 Laws of Proportionally

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

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

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

2.5.4 Comparison of Energy Savings

The Danfoss frequency converter solution offers major savings compared with traditional energy saving solutions. This is because the frequency converter is able to control fan speed according to thermal load on the system and the fact that the frequency converter has a built-in facility that enables the frequency converter to function as a Building Management System, BMS.

Illustration 2.5 shows typical energy savings obtainable with 3 well-known solutions when fan volume is reduced to i.e. 60%.
As the graph shows, more than 50% energy savings can be achieved in typical applications.

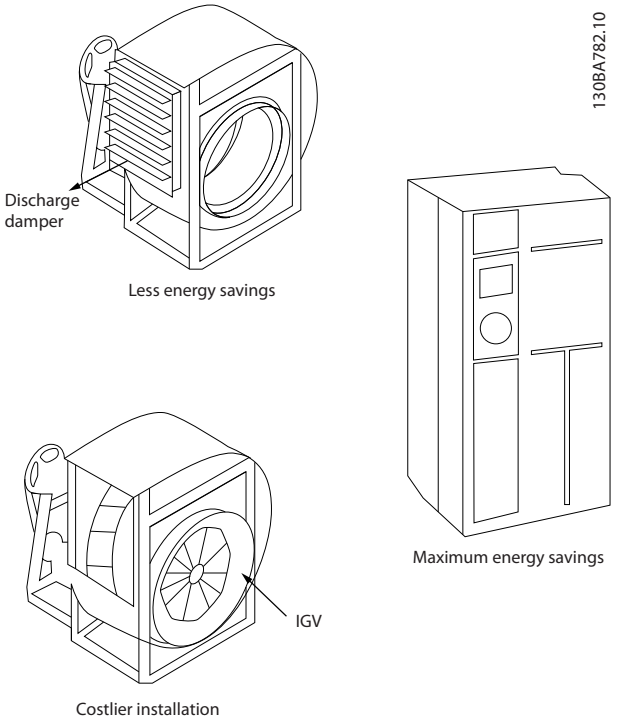


Illustration 2.4 The Three Common Energy Saving Systems

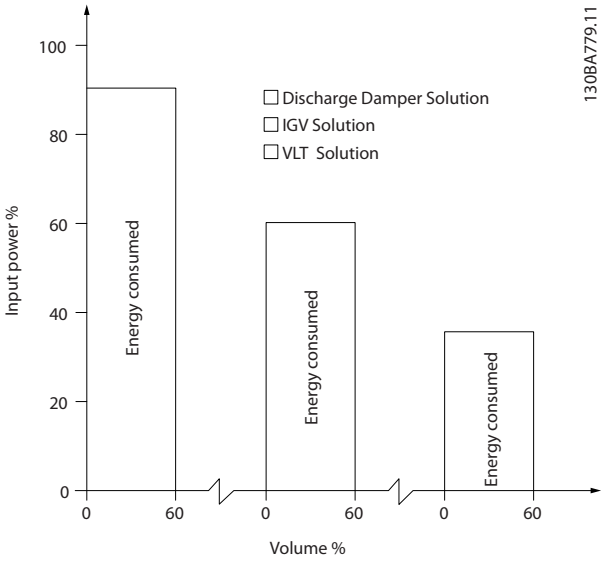


Illustration 2.5 Energy Savings

Discharge dampers reduce power consumption somewhat. Inlet Guide Vans 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.

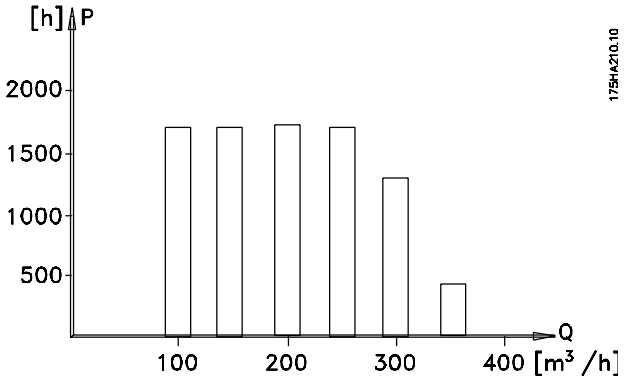
2.5.5 Example with Varying Flow over 1 Year

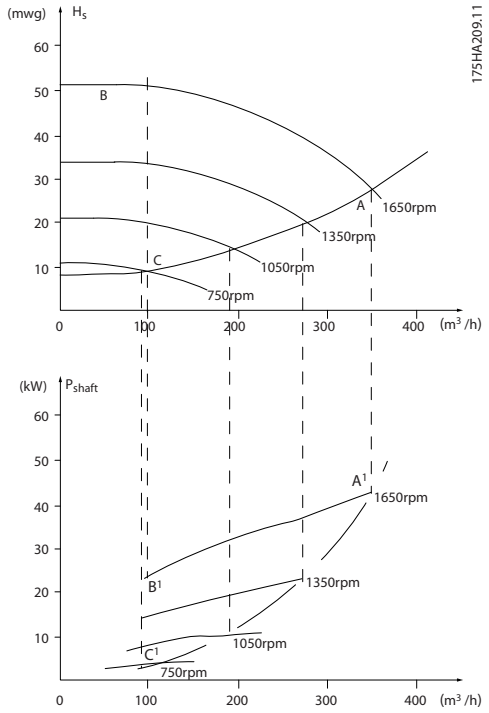
The example below is calculated on the basis of pump characteristics obtained from a pump datasheet.
The result obtained shows energy savings in excess of 50% at the given flow distribution over a year. The pay back period depends on the price per kWh and price of frequency converter. In this example it is less than a year when compared with valves and constant speed.

Energy savings

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

Flow distribution over 1 year





m³/h	Distribution		Valve regulation		Frequency converter control	
	%	Hours	Power	Consumption	Power	Consumption
			A_1 - B_1	kWh	A_1 - C_1	kWh
350	5	438	42.5	18,615	42.5	18,615
300	15	1314	38.5	50,589	29.0	38,106
250	20	1752	35.0	61,320	18.5	32,412
200	20	1752	31.5	55,188	11.5	20,148
150	20	1752	28.0	49,056	6.5	11,388
100	20	1752	23.0	40,296	3.5	6,132
Σ	100	8760		275,064		26,801

2.5.6 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, thereby 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.

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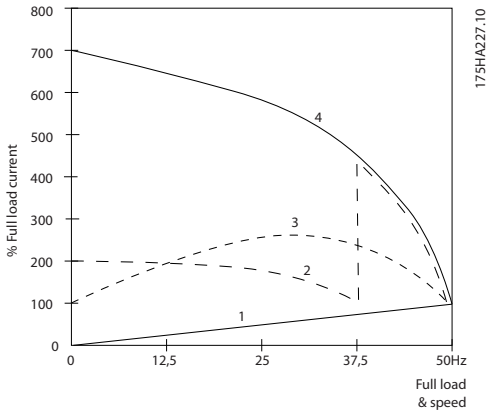
2.5.7 Star/Delta Starter or Soft-starter not Required

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 the illustration below, a frequency converter does not consume more than rated current.



1. VLT® Micro Drive FC 51
2. Star/delta starter
3. Soft-starter
4. Start directly on mains

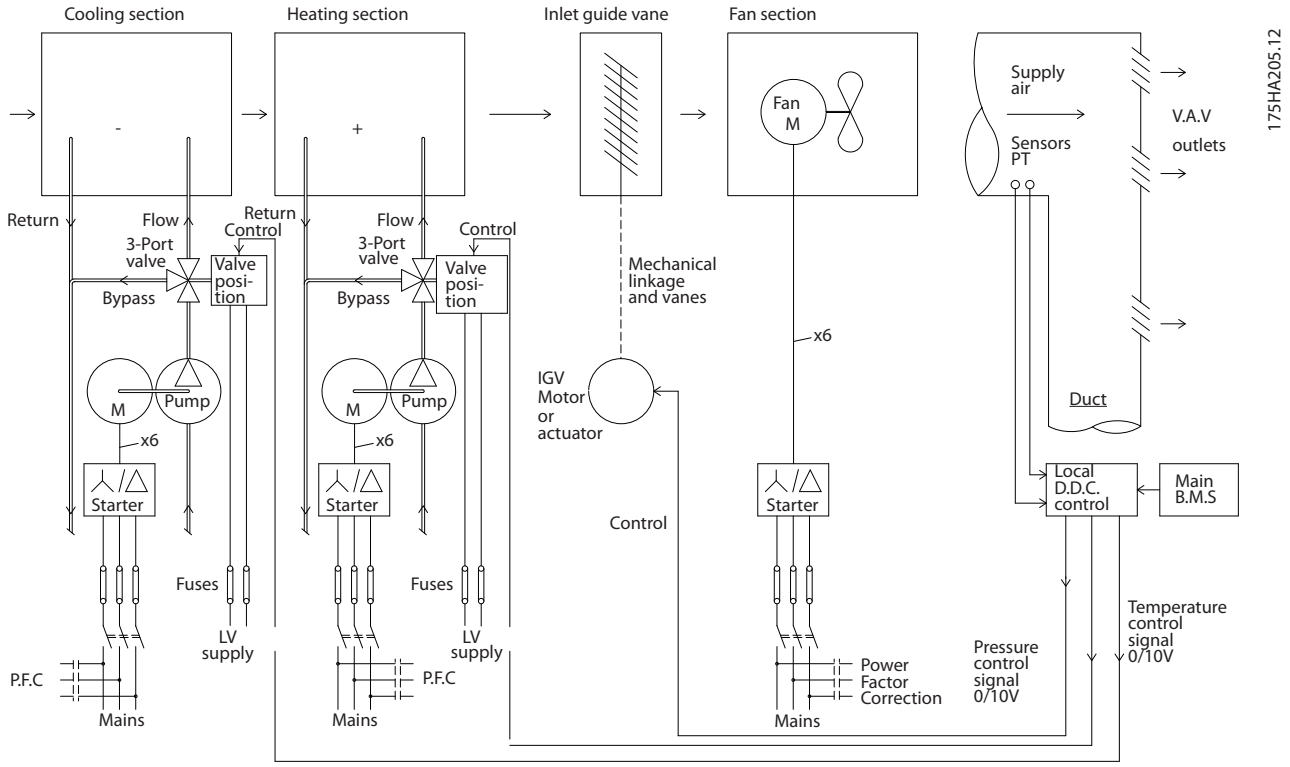
2.5.8 Using a Frequency Converter Saves Money

The example on the following page shows that a lot of equipment is not required when a frequency converter is used. It is possible to calculate the cost of installing the two different systems. In the example on the following page, the two systems can be established at roughly the same price.

2.5.9 Without a Frequency Converter

D.D.C.	=	Direct Digital Control	E.M.S.	=	Energy Management system
V.A.V.	=	Variable Air Volume			
Sensor P	=	Pressure	Sensor T	=	Temperature

Table 2.1 Fan System made in the Traditional Way



2.5.10 With a Frequency Converter

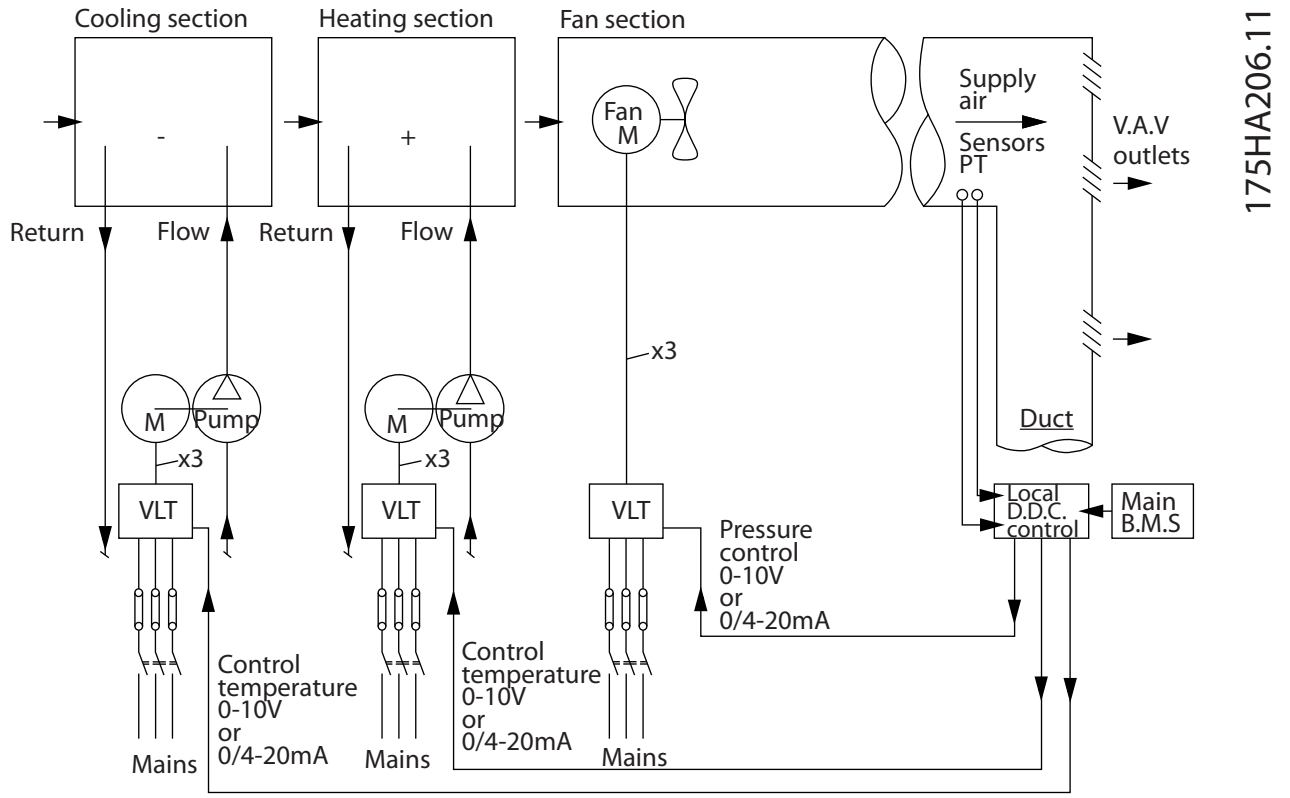


Illustration 2.6 Fan System Controlled by Frequency Converters

3 Introduction to VLT Micro Drive

3

3.1 Control Structures

In *1-00 Configuration Mode* it can be selected if open or closed loop is to be used.

3.1.1 Control Structure Open Loop

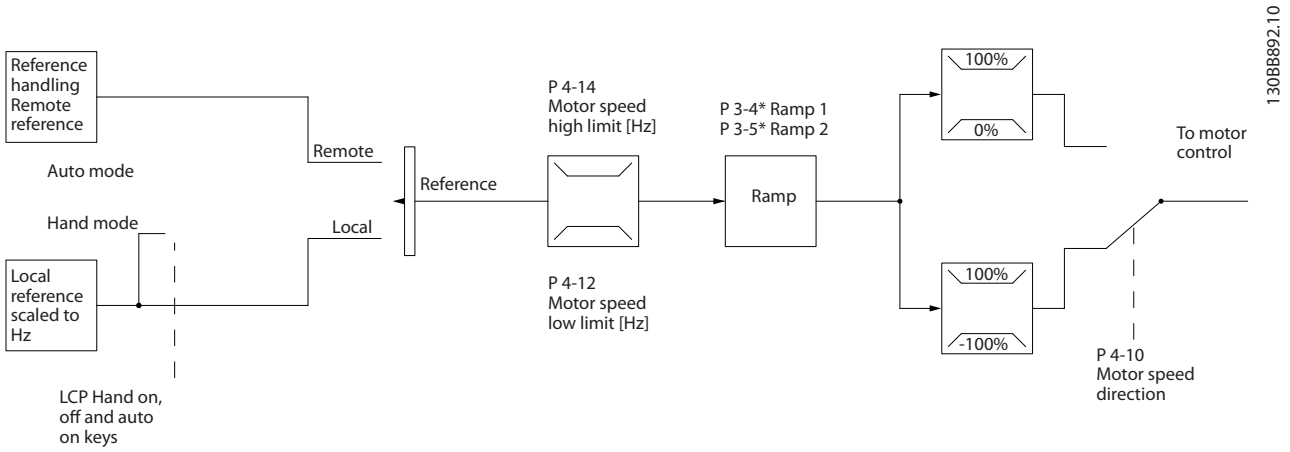


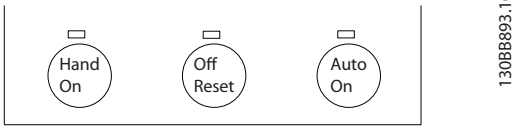
Illustration 3.1 Open Loop Structure

In the configuration shown in *Illustration 3.1*, *1-00 Configuration Mode* is set to Open loop [0]. 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 serial bus. If allowed in *0-40 [Hand on] Key on LCP*, *0-44 [Off / Reset] Key on LCP*, and *0-42 [Auto on] Key on LCP*, it is possible to start and stop the frequency converter by LCP using 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 (as default) the Local reference set by using the LCP potentiometer (LCP12) or arrow keys up [▲] and down [▼] (LCP11). The potentiometer can be disabled by parameter P6-80. If potentiometer is disabled, arrow keys can be used for adjusting reference.

After pressing the [Auto On] key, the frequency converter goes into Auto mode and follows (as default) the Remote reference. In this mode, it is possible to control the frequency converter via the digital inputs and RS485. See more about starting, stopping, changing ramps and parameter set-ups etc. in parameter group 5-1* (digital inputs) or parameter group 8-5* (serial communication).



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

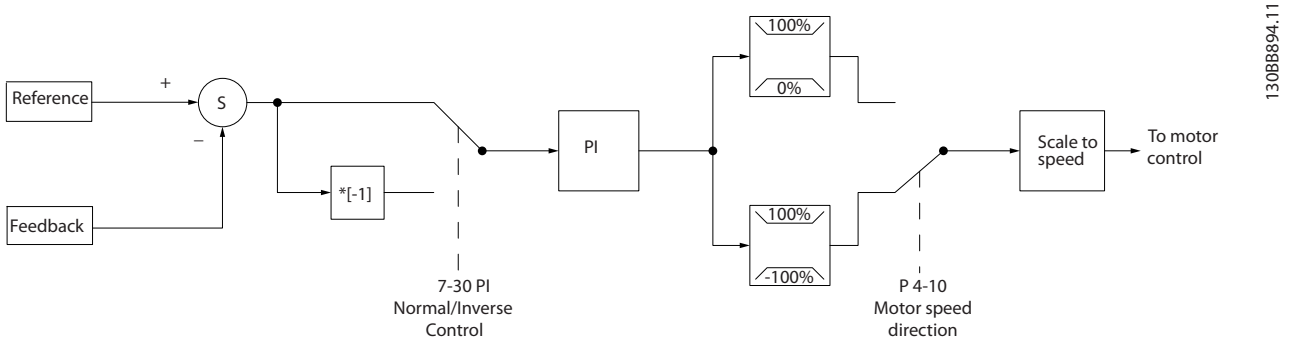
Local Reference will be restored at power-down.

3.1.3 Control Structure Closed Loop

The internal controller allows the frequency converter to become an integral 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 set-point reference value and determines the error, if any, between these two signals. It then adjusts the speed of the motor to correct this error.

3

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 desired static pressure value is supplied to the frequency converter as the set-point reference. A static pressure sensor measures the actual static pressure in the pipe and supplies this to the frequency converter as a feedback signal. If the feedback signal is greater than the set-point reference, the frequency converter will slow down to reduce the pressure. In a similar way, if the pipe pressure is lower than the set-point reference, the frequency converter will automatically speed up to increase the pressure provided by the pump.



While the default values for the frequency converter's Closed Loop controller will often provide satisfactory performance, the control of the system can often be optimized by adjusting some of the Closed Loop controller's parameters.

3.1.4 Reference Handling

Details for Open Loop and Closed Loop operation.

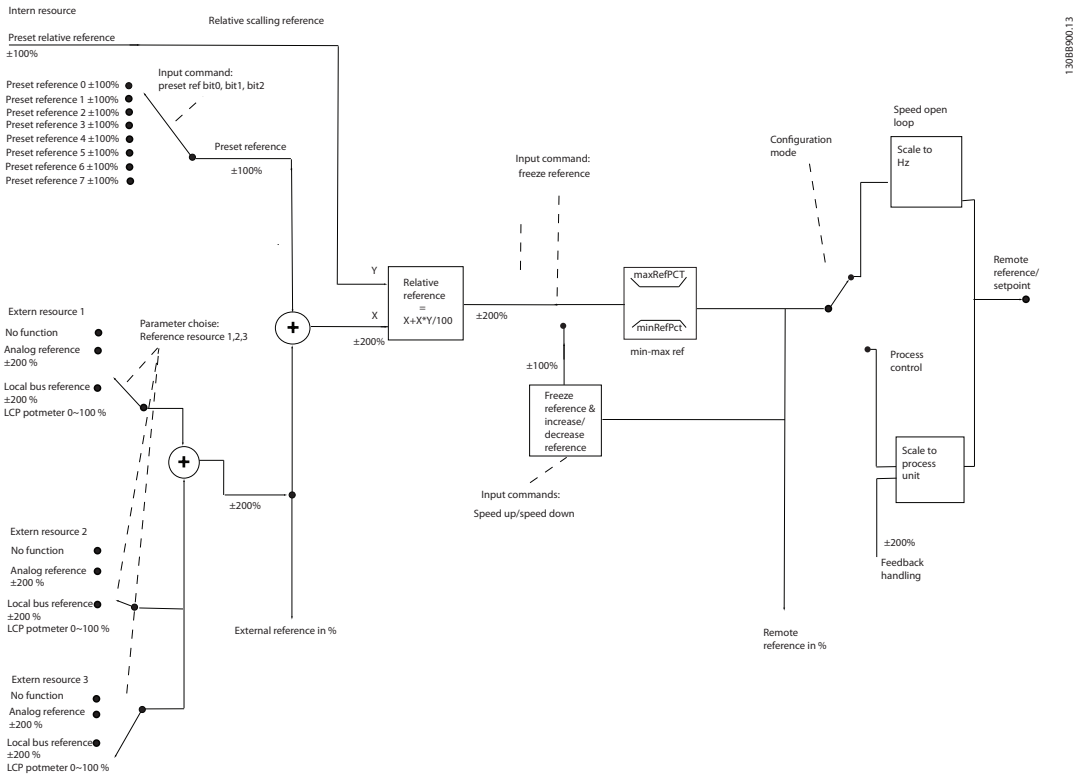


Illustration 3.2 Block Diagram Showing Remote Reference

The Remote Reference is comprised 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 one of the 3 Reference Source parameters (*3-15 Reference 1 Source*, *3-16 Reference 2 Source* and *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 two can be selected to be the active reference. Finally, this reference can by be scaled using *3-14 Preset Relative Reference*.

The scaled reference is calculated as follows:

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

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

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

3.2 General Aspects of EMC

3.2.1 General Aspects of EMC Emissions

Electrical interference is usually conducted at frequencies in the range 150kHz to 30MHz. Airborne interference from the frequency converter system in the range 30MHz to 1GHz is generated from the inverter, motor cable, and the motor.
As shown in *Illustration 3.3*, capacitive currents in the motor cable coupled with a high dU/dt from the motor voltage generate leakage currents.
The use of a screened motor cable increases the leakage current (see *Illustration 3.3*) because screened cables have higher capacitance to earth than unscreened cables. If the leakage current is not filtered, it will cause greater interference on the mains in the radio frequency range below approximately 5MHz. Since the leakage current (I_1) is carried back to the unit through the screen (I_3), there will in principle only be a small electro-magnetic field (I_4) from the screened motor cable according to the below figure.

The screen reduces the radiated interference but increases the low-frequency interference on the mains. The motor cable screen must be connected to the frequency converter enclosure as well as on the motor enclosure. This is best done by using integrated screen clamps so as to avoid twisted screen ends (pigtails). These increase the screen impedance at higher frequencies, which reduces the screen effect and increases the leakage current (I_4).
If a screened cable is used for fieldbus, relay, control cable, signal interface and brake, the screen must be mounted on the enclosure at both ends. In some situations, however, it will be necessary to break the screen to avoid current loops.

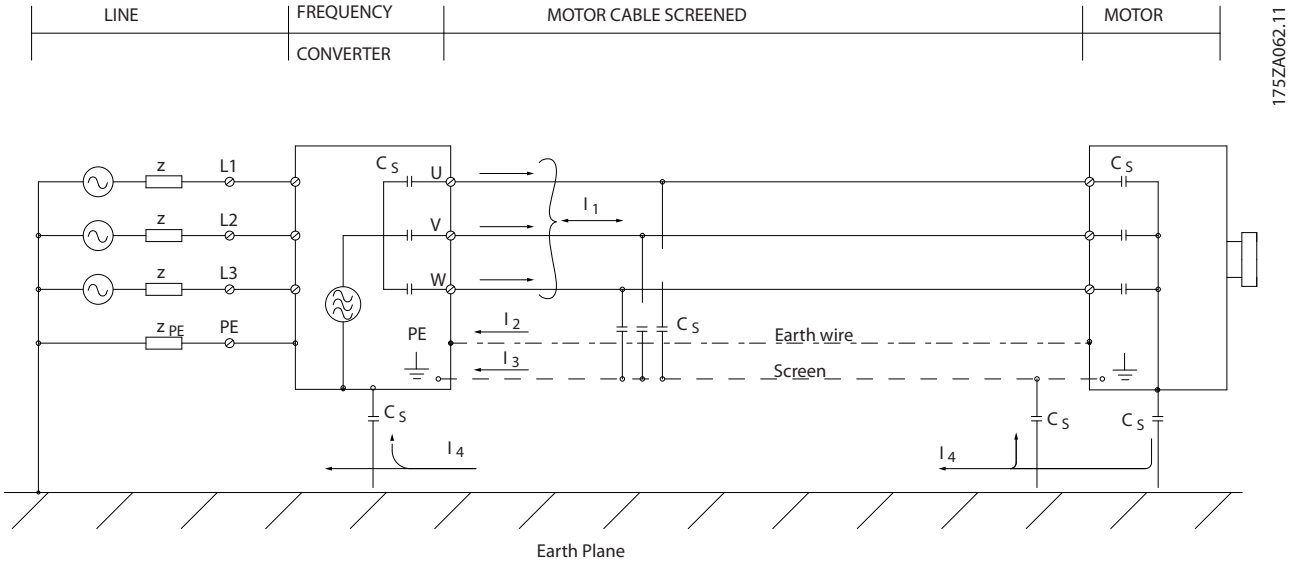


Illustration 3.3 Situation that Generates Leakage Currents

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

When unscreened cables are used, some emission requirements are not complied with, although the immunity requirements are observed.

In order to reduce the interference level from the entire system (unit + installation), make motor and brake cables as short as possible. Avoid placing cables with a sensitive signal level alongside motor and brake cables. Radio interference higher than 50MHz (airborne) is especially generated by the control electronics. Please see for more information on EMC.

3

3.2.2 Emission Requirements

According to the EMC product standard for adjustable speed frequency converters EN/IEC 61800-3:2004 the EMC requirements depend on the intended use of the frequency converter. Four categories are defined in the EMC product standard. The definitions of the 4 categories together with the requirements for mains supply voltage conducted emissions are given in *Table 3.1*.

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

Table 3.1 Emission Requirements

When the generic emission standards are used the frequency converters are required to comply with the following limits

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

3.2.3 EMC Test Results (Emission)

Drive type	Conducted emission. Maximum shielded cable length						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
≤ 2.2kW. Single phase, 230V	25m	-	-	15m	-	5m	Yes	-	No	Yes
≤ 7.5kW. Up to 500VAC, three phase	25m	-	-	15m	-	-	Yes	-	No	Yes
11kW to 22kW. Up to 500VAC, three phase	25m	-	-	15m	-	-	Yes	-	No	Yes

Table 3.2 EMC Test Result

3.2.4 Harmonics Emission Requirements

Equipment connected to the public supply network

⚠WARNING

Cannot comply, only with power option

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

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

3.3 Galvanic Isolation (PELV)

3.3.1 PELV - Protective Extra Low Voltage

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

All control terminals and relay terminals 01-03/04-06 comply with PELV (Protective Extra Low Voltage) (Does not apply to grounded Delta leg above 440V).

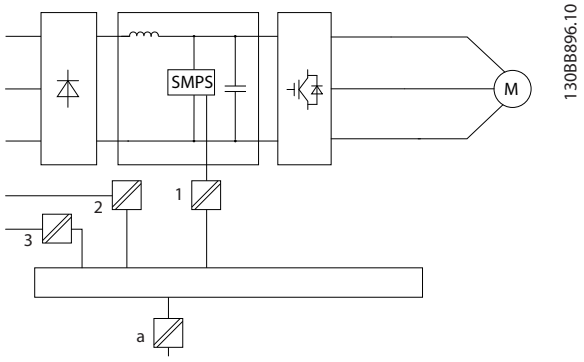
Galvanic (ensured) isolation is obtained by fulfilling requirements for higher isolation and by providing the relevant creapage/clearance distances. These requirements are described in the EN 61800-5-1 standard.

The components that make up the electrical isolation, as described below, also comply with the requirements for higher isolation and the relevant test as described in EN 61800-5-1.
The PELV galvanic isolation can be shown in 5 locations (see *illustration*):

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

0.18-22kW

1. Power supply (SMPS)
2. Optocouplers, communication between AOC and MOC
3. Custom relays



The functional galvanic isolation (a on drawing) is for the RS485 standard bus interface.

⚠CAUTION

Installation at high altitude:
At altitudes above 2km, please contact Danfoss regarding PELV.

3.4 Earth 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), as well as the motor connection for kinetic back-up.
Before touching any electrical parts, wait at least the amount of time indicated in the *Safety Precautions* section. Shorter time is allowed only if indicated on the nameplate for the specific unit.

3

NOTE

Leakage Current

The earth leakage current from the frequency converter exceeds 3.5 mA. To ensure that the earth cable has a good mechanical connection to the earth connection, the cable cross section must be at least 10 mm^2 or 2 rated earth wires terminated separately.

Residual Current Device

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, another protective measure shall be applied, 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* MN90G202.

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

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

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

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

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

Mains Drop-out
During a mains drop-out, the frequency converter keeps running until the intermediate circuit voltage drops below the minimum stop level, which is 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 inverter to coast.

3.5.1 Motor Thermal Protection

To protect the application from serious damages offers several dedicated features
Torque Limit: The Torque limit feature the motor is protected for being overloaded independent of the speed. Torque limit is controlled in *4-16 Torque Limit Motor Mode* and or *4-17 Torque Limit Generator Mode* and the time before the torque limit warning shall trip is controlled in *14-25 Trip Delay at Torque Limit*.
Current Limit: The current limit is controlled in *4-18 Current Limit* and the time before the current limit warning shall trip is controlled in *14-24 Trip Delay at Current Limit*.
Min Speed Limit: (*4-11 Motor Speed Low Limit [RPM]* or *4-12 Motor Speed Low Limit [Hz]*) limit the operating speed range to for instance between 30 and 50/60Hz. Max Speed Limit: (*4-13 Motor Speed High Limit [RPM]* or *4-19 Max Output Frequency*) limit the max output speed the frequency converter can provide
ETR (Electronic Thermal relay): The frequency converter ETR function measures actual current, speed and time to calculate motor temperature and protect the motor from being overheated (Warning or trip). An external thermistor input is also available. ETR is an electronic feature that simulates a bimetal relay based on internal measurements. The characteristic is shown in *Illustration 3.4*:

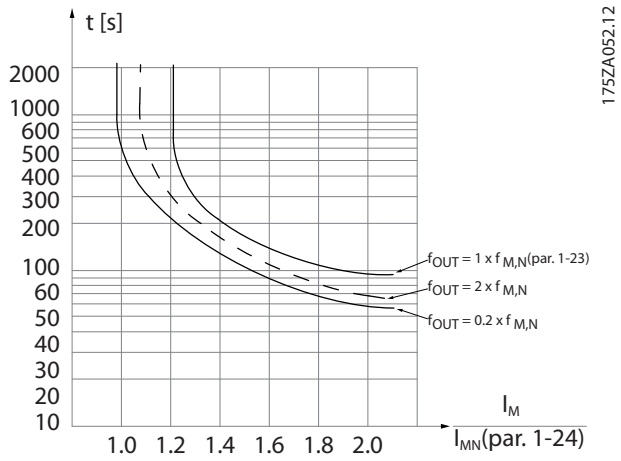


Illustration 3.4 ETR: The X-axis shows the ratio between I_{motor} and I_{motor} nominal. The Y- axis shows the time in seconds before the ETR cut of and trips the drive. The curves show the characteristic nominal speed, at twice the nominal speed and at 0,2 x the nominal speed.
At lower speed the ETR cuts of at lower heat due to less cooling of the motor. In that way the motor are protected from being over heated 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 read out parameter in *16-18 Motor Thermal* in the *FC 51 Micro Drive Programming Guide, MG02CXYY*.

4 VLT Micro Drive Selection

4.1 Options and Accessories

4.1.1 Local Control Panel (LCP)

4

For detailed information on programming, please see *Programming Guide MG02CXYY*, .

The frequency converter can also be programmed from a PC via RS485 com-port by installing the MCT 10 Set-up Software. This software can either be ordered using code number 130B1000 or downloaded from the Danfoss Web site: *www.danfoss.com/BusinessAreas/DrivesSolutions/softwaredownload*

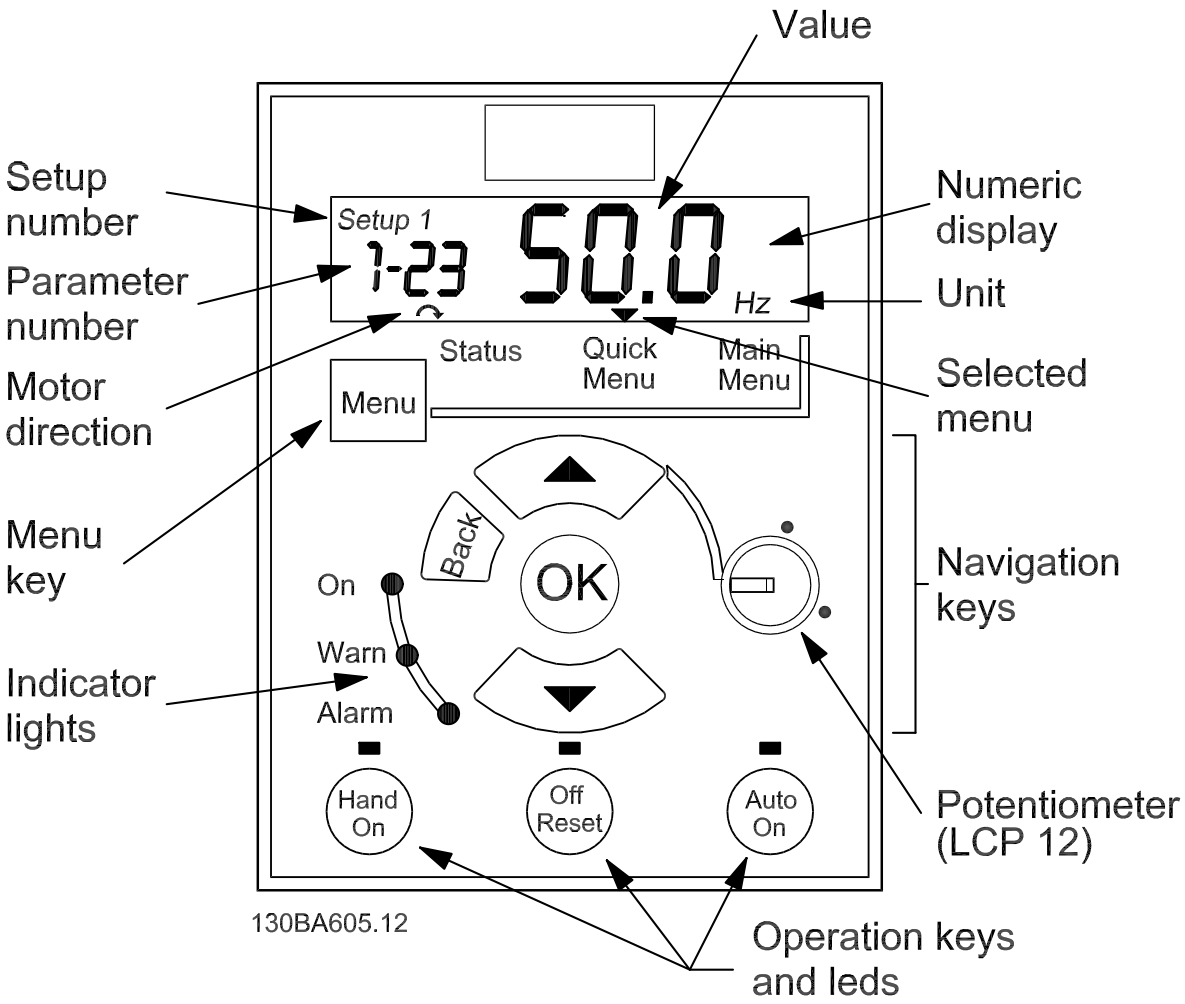


Illustration 4.1 Description of LCP Buttons and Display

Use the [MENU] key to select one of the following menus:

Status:
For readouts only.

Quick Menu:
For access to Quick Menus 1 and 2, respectively.

Main Menu:
For access to all parameters.

Navigation Keys:
[Back]: For moving to the previous step or layer in the navigation structure.
Arrows [▲] [▼]: For maneuvering between parameter groups, parameters and within parameters.
[OK]: For selecting a parameter and for accepting changes to parameter settings.

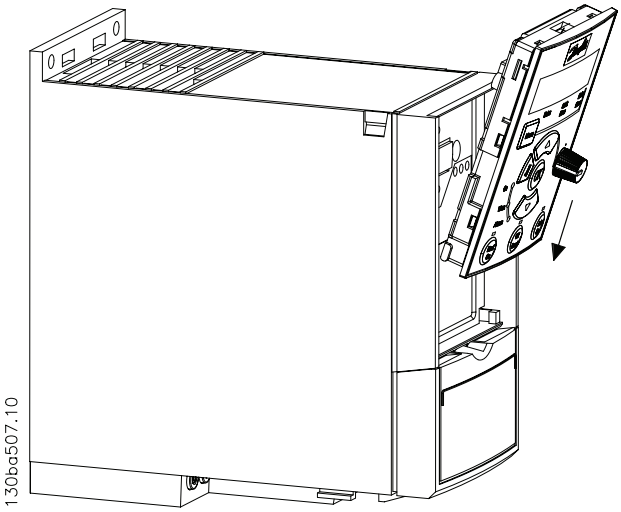
Operation Keys:
A yellow light above the operation keys indicates the active key.
[Hand on]: Starts the motor and enables control of the frequency converter via the LCP.
[Off/Reset]: Stops the motor (off). If in alarm mode the alarm will be reset.
[Auto on]: The frequency converter is controlled either via control terminals or serial communication.
[Potentiometer] (LCP12): The potentiometer works in two 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.

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

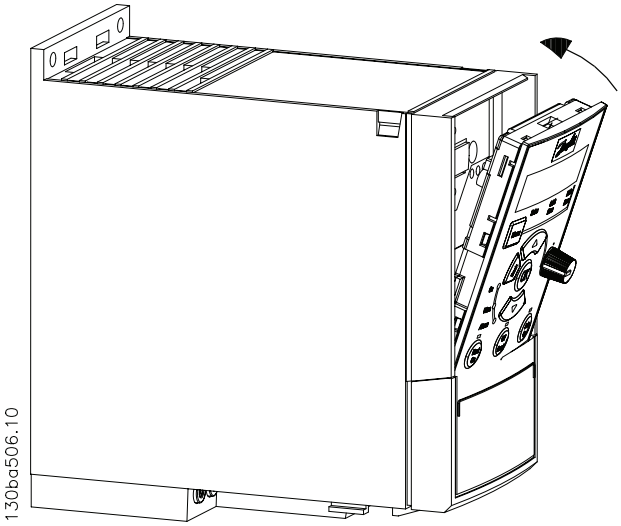
Technical data	
Enclosure:	IP55 front
Max. cable length between and unit:	3m
Communication std:	RS485
Ordering no.	132B0201

4.1.2 FC 51 LCP Mounting Instruction

Step 1
Place the bottom of the LCP in the frequency converter.



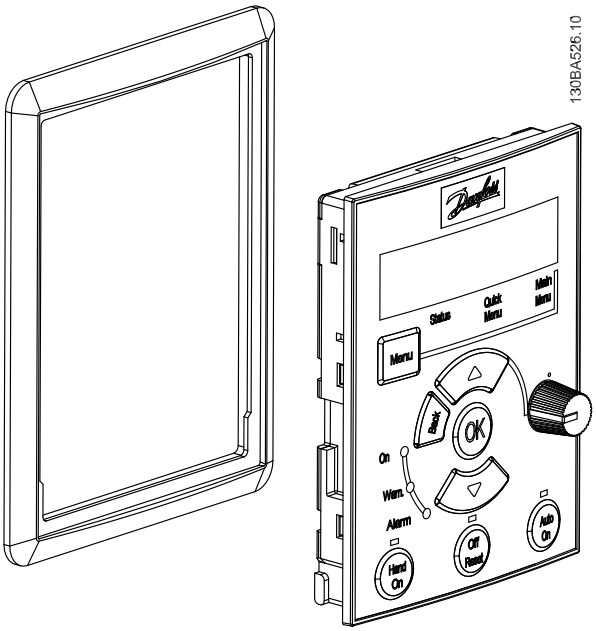
Step 2
Push the top of the LCP into the frequency converter.



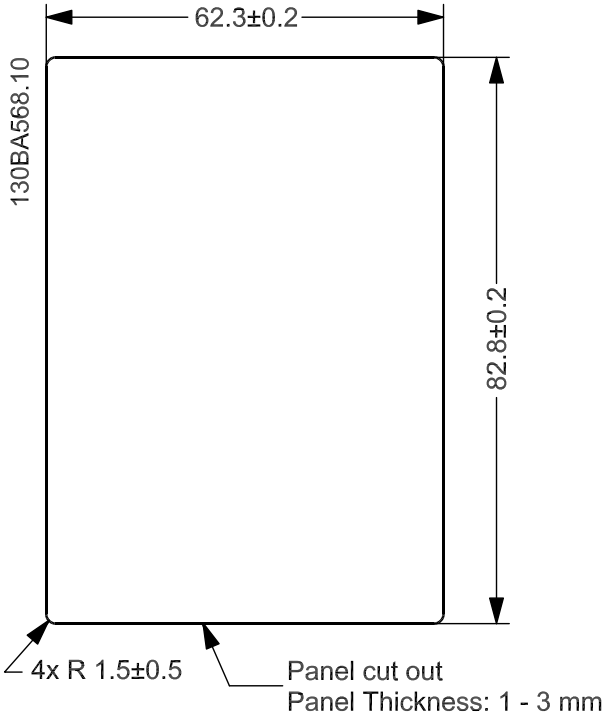
4

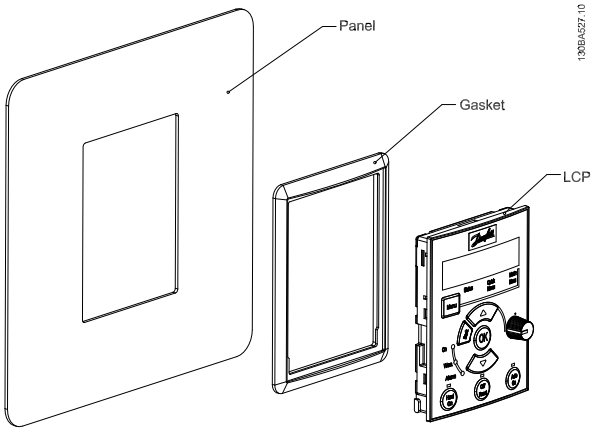
4.1.3 FC 51 Remote Mounting Kit Mounting Instruction

Step 1
Fit gasket on LCP in the frequency converter.



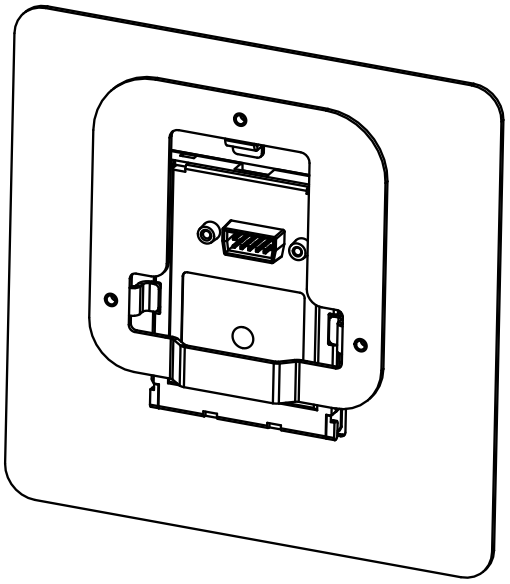
Step 2
Place LCP on panel - see dimensions of hole on drawing.

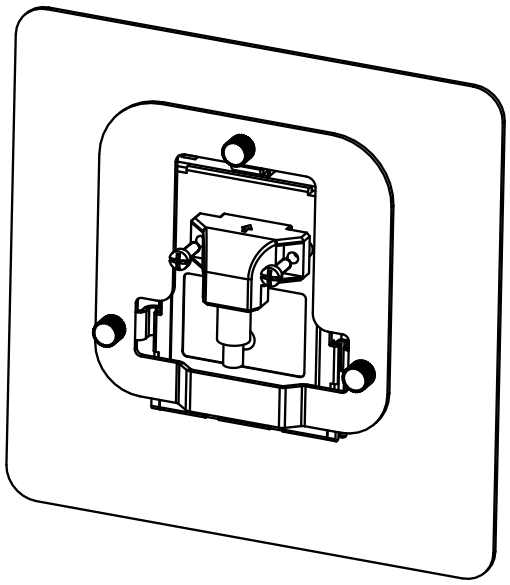




Step 3
Place bracket on back of the LCP, then slide down. Tighten screws and connect cable to LCP.

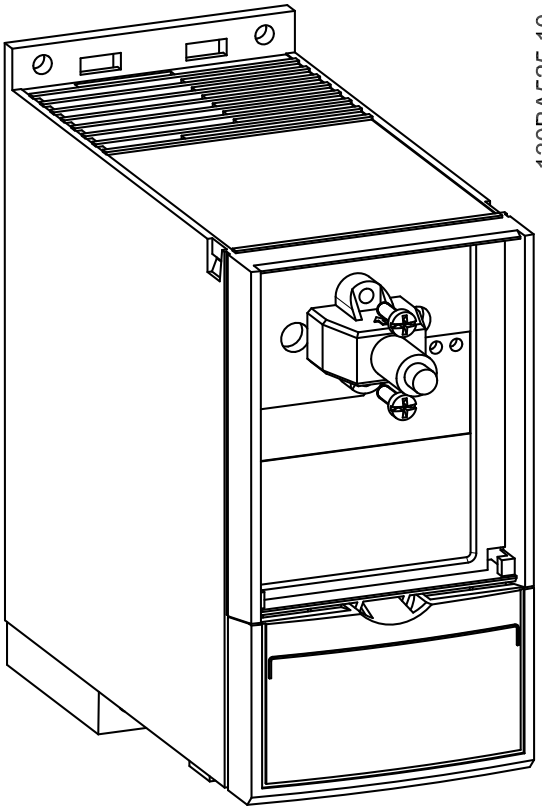
NOTE! Use the provided thread cutting screws to fasten connector to LCP. Tightening torque: 1.3Nm.





Step 4
Connect cable to frequency converter.

NOTE! Use the provided thread cutting screws to fasten connector to the frequency converter. Tightening torque: 1.3Nm.



4.1.4 IP21/TYPE 1 Enclosure Kit

Frame	IP class	Power			Height (mm) A	Width (mm) B	Depth (mm) C	Ordering no.
		1x200-240V	3x200-240V	3x380-480V				
M1	IP21	0.18-0.75kW	0.25-0.75kW	0.37-0.75kW	219.3	73	155.9	132B0108
M2	IP21	1.5kW	1.25kW	1.5-2.2kW	245.6	78	175.4	132B0109
M3	IP21	2.2kW	2.2-3.7kW	3.0-7.5kW	297.5	95	201.4	132B0110
M4	IP21	-	-	11-15kW	-	-	-	-
M5	IP21	-	-	18.5-22kW	-	-	-	-

4

4.1.5 Type 1 (NEMA)

Frame	IP class	Power			Height (mm) A	Width (mm) B	Depth (mm) C	Ordering no.
		1x200-240V	3x200-240V	3x380-480V				
M1	IP20	0.18-0.75kW	0.25-0.75kW	0.37-0.75kW	194.3	70.0	155.9	132B0103
M2	IP20	1.5kW	1.25kW	1.5-2.2kW	220.6	75.0	175.4	132B0104
M3	IP20	2.2kW	2.2-3.7kW	3.0-7.5kW	282.5	90.0	201.3	132B0105
M4	IP20	-	-	11-15kW	345.6	125.0	248.5	132B0120
M5	IP20	-	-	18.5-22kW	385.5	165.0	248.2	132B0121

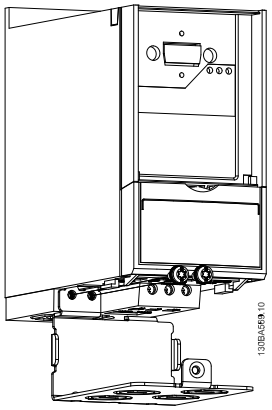
4.1.6 De-Coupling

Frame	IP class	Power			Height (mm) A	Width (mm) B	Depth (mm) C	Ordering no.
		1x200-240V	3x200-240V	3x380-480V				
M1	IP20	0.18-0.75kW	0.25-0.75kW	0.37-0.75kW	204.2	70.0	155.9	132B0106
M2	IP20	1.5kW	1.25kW	1.5-2.2kW	230.0	75.0	175.4	132B0106
M3	IP20	2.2kW	2.2-3.7kW	3.0-7.5kW	218.5	90.0	201.3	132B0107
M4	IP20	-	-	11-15kW	347.5	125.0	248.5	132B0122
M5	IP20	-	-	18.5-22kW	387.5	165.0	248.2	132B0122

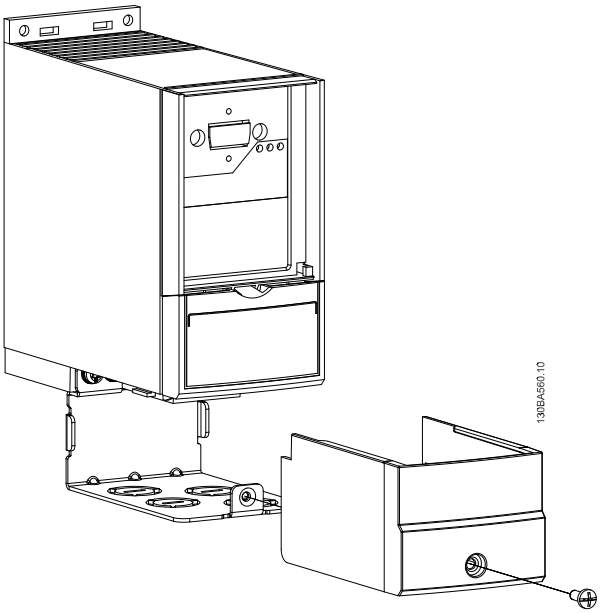
4.1.7 FC 51 Type 1 Kit Mounting Instruction for M1, M2 and M3

Step 1
Mount metal plate on frequency converter and tighten the screws. Tightening torque: 2 Nm.

Conduit sizes	
M1	4 x ½"
M2	5 x ½ "
M3	2 x ½"
	3 x 3/4"



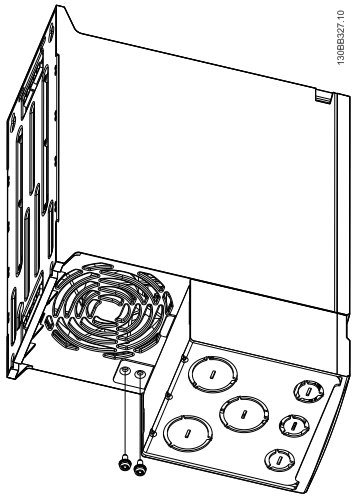
Step 2
Fit bottom cover on frequency converter and tighten screw.



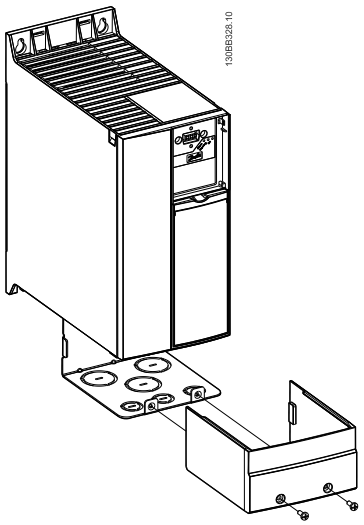
4.1.8 FC 51 Type 1 Kit Mounting Instruction for M4 and M5

Step 1
Mount metal plate on frequency converter and tighten the screws. Tightening torque: 2 Nm.

Conduit sizes:	
M4	3 x ½"
M5	3 x 1"

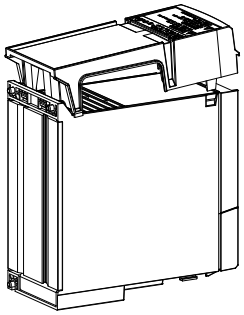


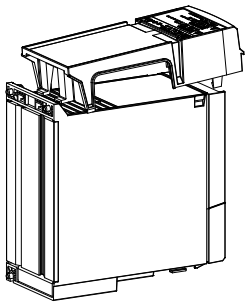
Step 2
Fit bottom cover on frequency converter and tighten screw.



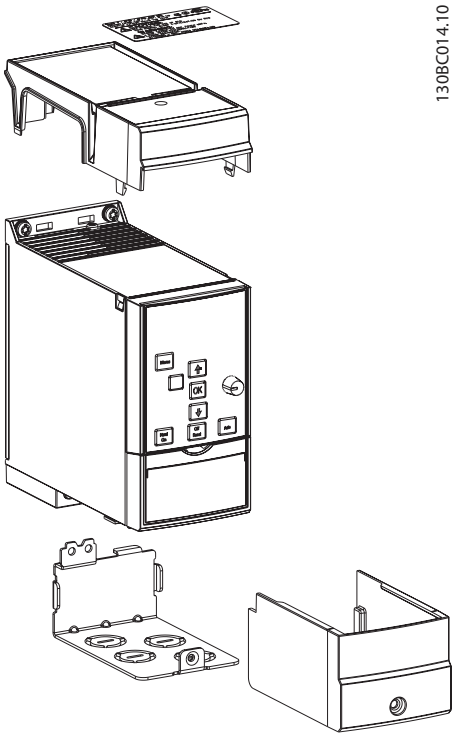
4.1.9 FC 51 IP21 Kit Mounting Instruction

Step 1
Fit top cover on frequency converter.

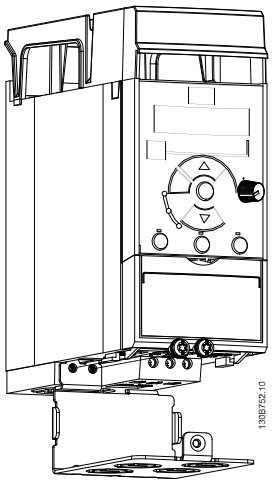




Step 2
Remove knockouts on metal plate and fit rubber grommets.

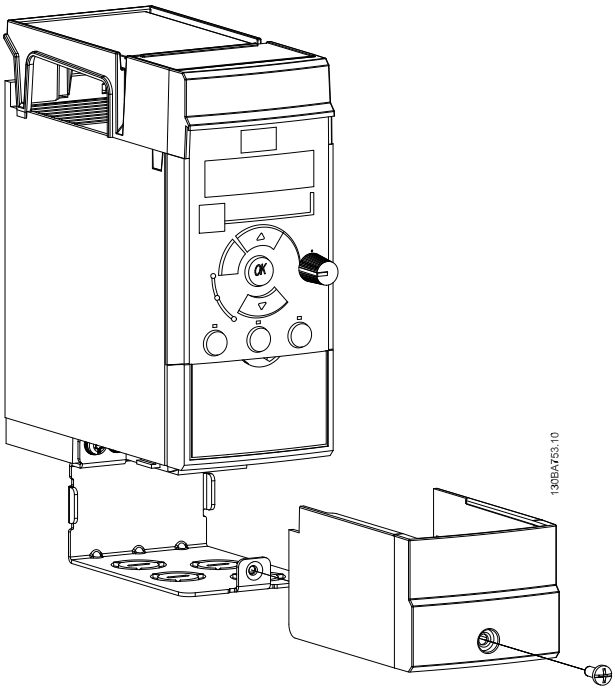


Step 3
Mount metal plate on frequency converter and tighten screws. Tightening torque: 2Nm.



Step 4
Fit bottom cover on frequency converter and tighten screw.

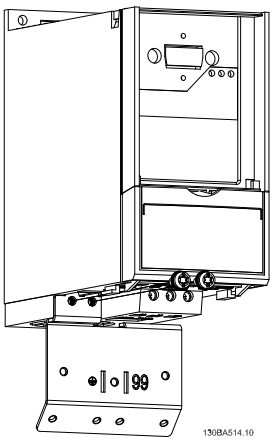
NOTE! IP21 is only achieved with LCP11 or LCP12 mounted.



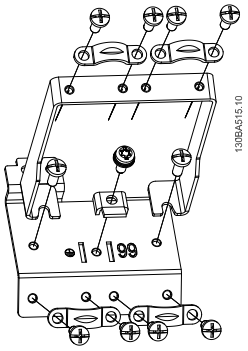
4

4.1.10 FC 51 De-coupling Plate Mounting Instruction for M1 and M2

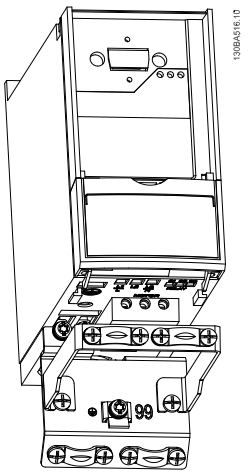
Step 1
Mount metal plate on frequency converter and fasten with two screws. Tightening torque: 2 Nm.



Step 2
Mount bracket on de-coupling plate.

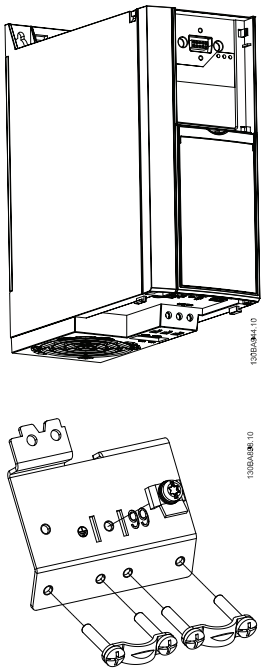


Step 3
VLT Micro frequency converter FC 51 mounted with de-coupling plate.

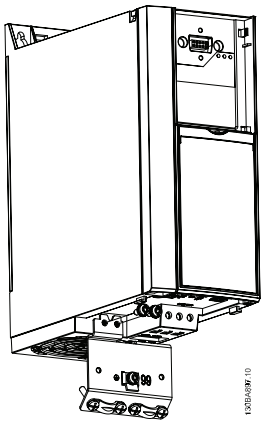


4.1.11 FC 51 De-coupling Plate Mounting Instruction for M3

Step 1
Mount de-coupling plate on frequency converter and fasten with two screws. Tightening torque: 2 Nm.

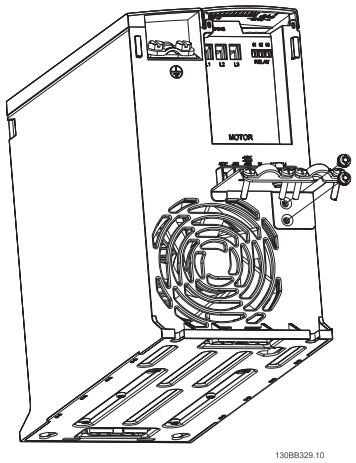


Step 2
VLT Micro frequency converter FC 51 mounted with de-coupling plate.

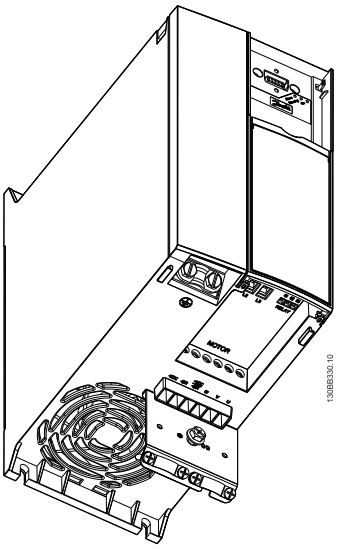


4.1.12 FC 51 De-coupling Plate Mounting Instruction for M4 and M5

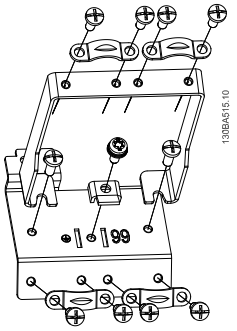
Step 1
Mount metal plate on frequency converter and fasten with two screws. Tightening torque: 2 Nm.



Step 2
VLT Micro frequency converter FC 51 mounted with de-coupling plate.

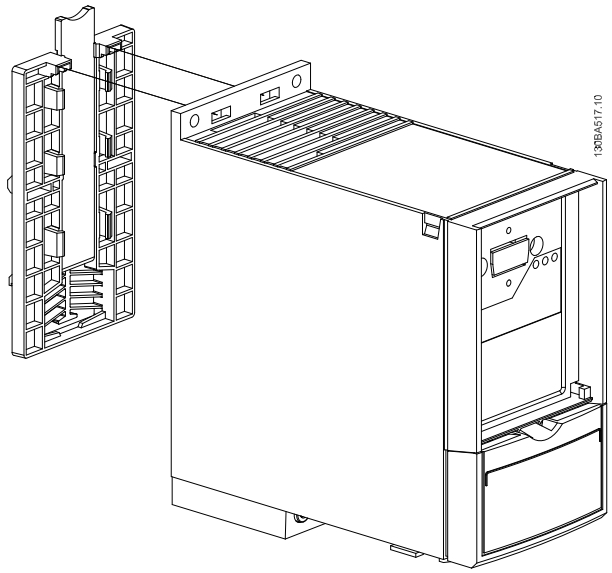


Step 3
Mount bracket on de-coupling plate.

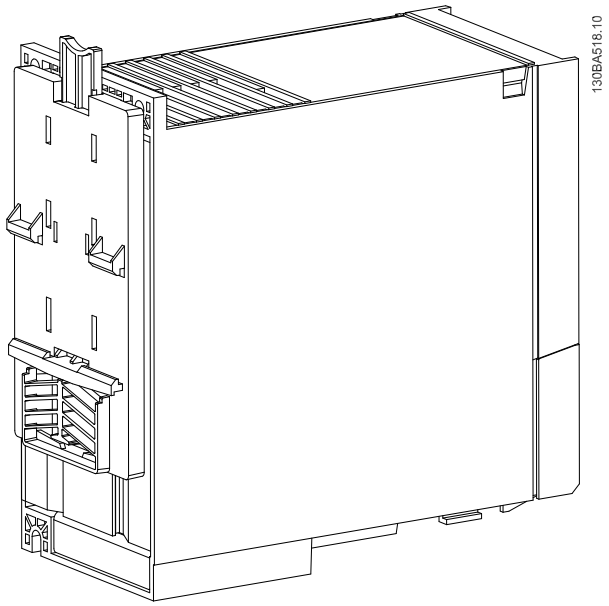


4.1.13 FC 51 DIN Rail Kit Mounting Instruction

Step 1
Mount plastic part on frequency converter.



Step 2
Fit frequency converter on DIN rail (Din Rail kit is only for M1 and M2).



4.2 Special Condition

4.2.1 Purpose of Derating

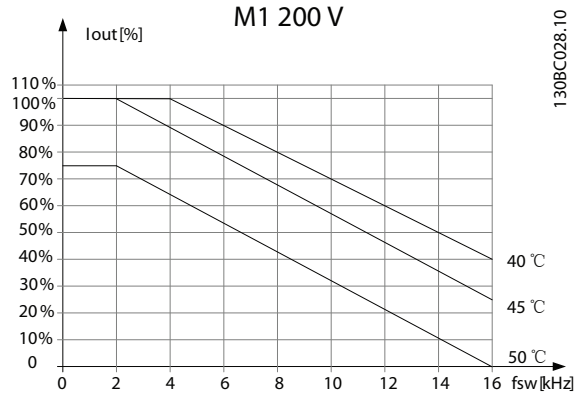
Purpose of Derating must be taken into account when using the frequency converter at low air pressure (heights), at low speeds, with long motor cables, cables with a large cross section or at high ambient temperature. The required action is described in this section.

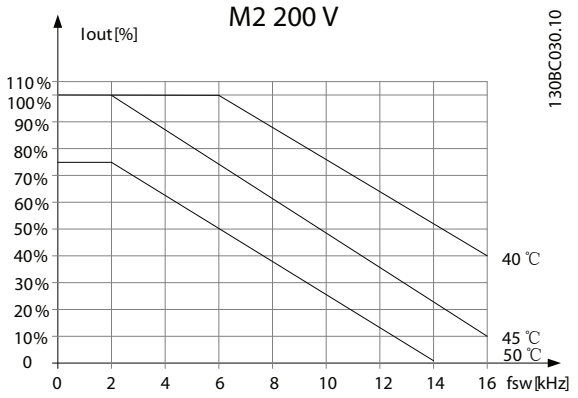
4

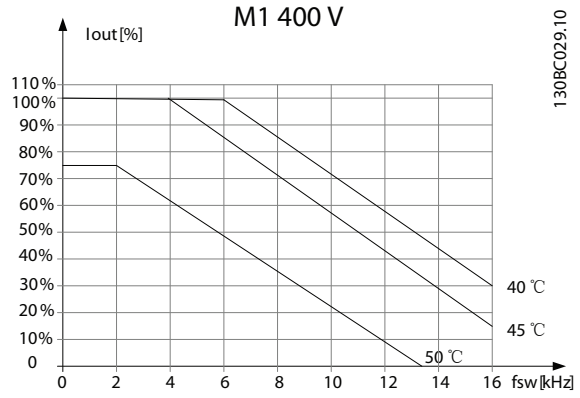
4.2.2 Derating for Ambient Temperature

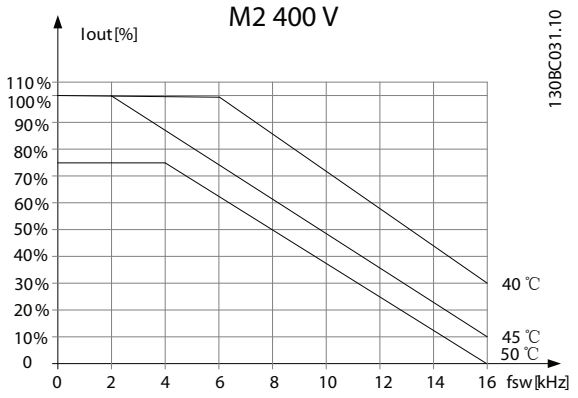
Derating for Ambient Temperature and IGBT Switching.

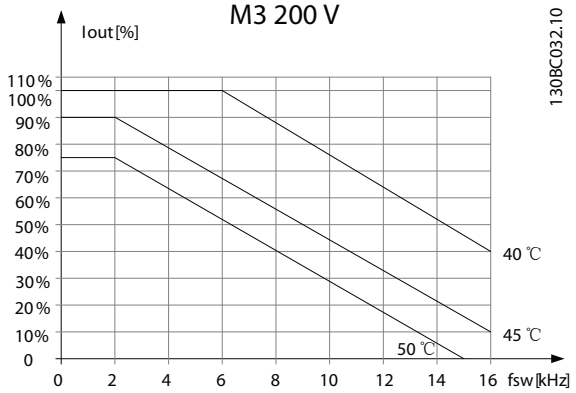
The ambient temperature measured over 24 hours should be at least 5° C lower than the max. ambient temperature. If the frequency converter is operated at high ambient temperature, the continuous output current should be decreased. The frequency converter has been designed for operation at max. 50° C ambient temperature with one motor size smaller than nominal. Continuous operation at full load at 50° C ambient temperature will reduce the lifetime of the frequency converter.

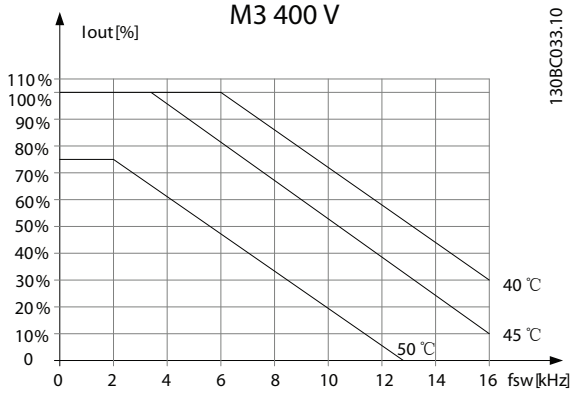


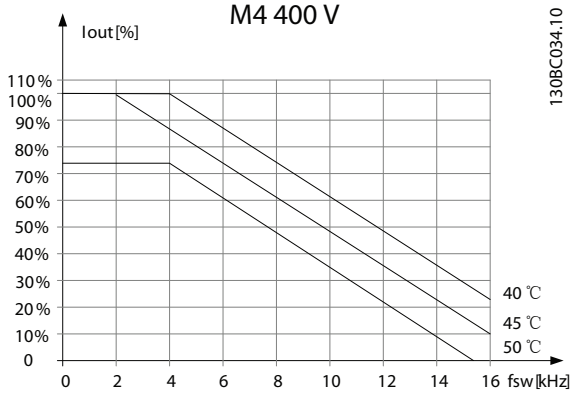


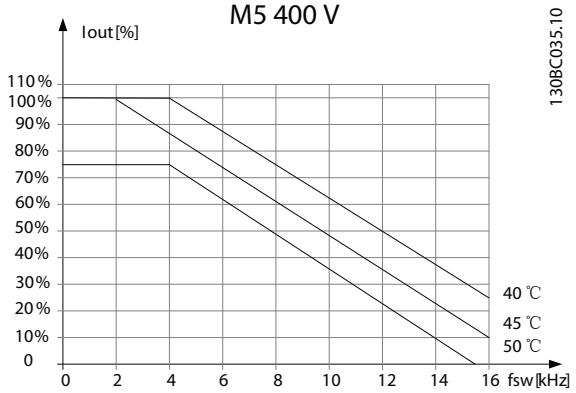












4.2.3 Derating for Low Air Pressure

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

For altitudes above 2000 m, please contact Danfoss regarding PELV.

Below 1000 m altitude no de-rating is necessary but above 1000 m the ambient temperature or the maximum output current should be decreased.
Decrease the output by 1% per 100 m altitude above 1000 m or reduce the max. ambient temperature by 1 degree per 200 m.

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 intermediate circuit and low motor speeds. As a response to a critical level, the frequency converter can adjust the switching frequency and / or change the switching pattern in order to ensure the performance of the frequency converter. The capability to automatically reduce the output current 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 over-heat at low speeds due to less cooling air from the motor integral fan.

Therefore, if the motor is to be run continuously at an RPM value lower than half of the rated value, the motor must be supplied with additional air-cooling (or a motor designed for this type of operation may be used).

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

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.

5

Frequency converters can be ordered as standard or with internal options by using a type code string, i.e.

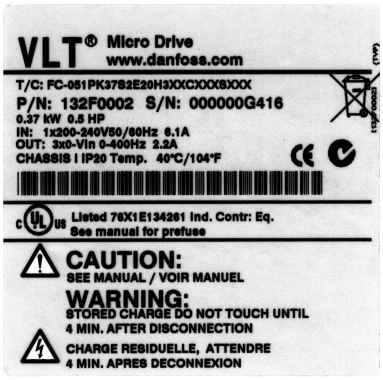
FC051PXXXXXXXXHXXXXXXXSXXX

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

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

5.2.1 FC Identification

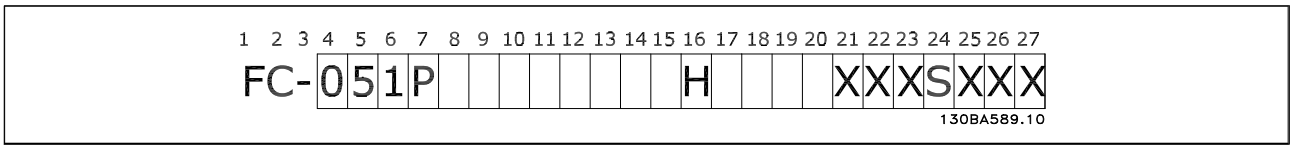
Below is an example of the frequency converter nameplate sticker. This sticker is located on the top of each frequency converter and shows the ratings, serial number, warnings catalog number, and other relevant data for each unit. See for details, how to read the Type code string.



130BA505

Illustration 5.1 This example shows the identification sticker.

5.3.1 Type Code



Description	Pos	Possible choice
Product group	1-3	Adjustable Frequency Converters
Series and product type	4-6	Micro Drive
Power size	7-10	0.18-22 kW
Mains voltage	11-12	S2: Single phase 200 - 240 V AC T 2: Three phase 200 - 240 V AC T 4: Three phase 380 - 480 V AC
Enclosure	13-15	IP20/Chassis
RFI filter	16-17	HX: No RFI filter H1: RFI filter class A1/B H3:RFI filter A1/B (reduced cable length*)
Brake	18	B: Brake chopper included (from 1.5 kW 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 5.1 Type code description

5

5.4.1 Ordering Numbers

	200-240 V			380-480 V	
Power [kW]	Current [I-nom.]	1 ph.	3 ph.	Current [I-nom.]	3 ph.
0.18	1.2	132F 0001			
0.25	1.5		132F 0008		
0.37	2.2	132F 0002	132F 0009	1.2	132F 0017
0.75	4.2	132F 0003	132F0010	2.2	132F 0018
1.5	6.8	132F 0005	132F0012	3.7	132F 0020
2.2	9.6	132F 0007	132F0014	5.3	132F 0022
3.0				7.2	132F 0024
3.7	15.2		132F 0016		
4.0	Micro drives from 1.5 kW and up have built in brake chopper			9.0	132F 0026
5.5				12.0	132F 0028
7.5				15.5	132F 0030
11.0				23.0	132F 0058
15.0				31.0	132F 0059
18.5				37.0	132F 0060
22.0				43.0	132F 0061

5

5.5.1 Options for VLT Micro Drive

Ordering No	Description
132B0100	VLT Control Panel LCP 11 w/o potentiometer
132B0101	VLT Control Panel LCP 12 w/o 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 frame
132B0104	Type 1 kit for M2 frame
132B0105	Type 1 kit for M3 frame
132B0106	De-coupling plate kit for M1 and M2 frames
132B0107	De-coupling plate kit for M3 frame
132B0108	IP21 for M1 frame
132B0109	IP21 for M2 frame
132B0110	IP21 for M3 frame
132B0111	DIN rail mounting kit for M1 and M2 frame
132B0120	Type 1 kit for M4 frame
132B0121	Type 1 kit for M5 frame
132B0122	De-coupling plate kit for M4 and M5 frames
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
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

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 FC 51
- Quick Guide

Optional: LCP and/or de-coupling plate.

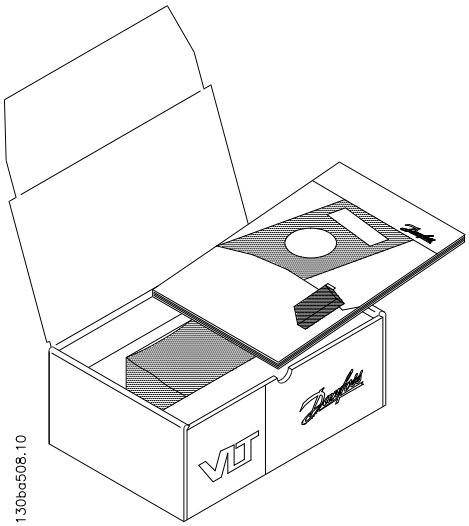


Illustration 6.1 Content of box

6.2 Side-by-Side Installation

The frequency converter can be mounted side-by-side for IP 20 rating units and requires 100 mm clearance above and below for cooling. Regarding surroundings in general, please see *7 Programming*.

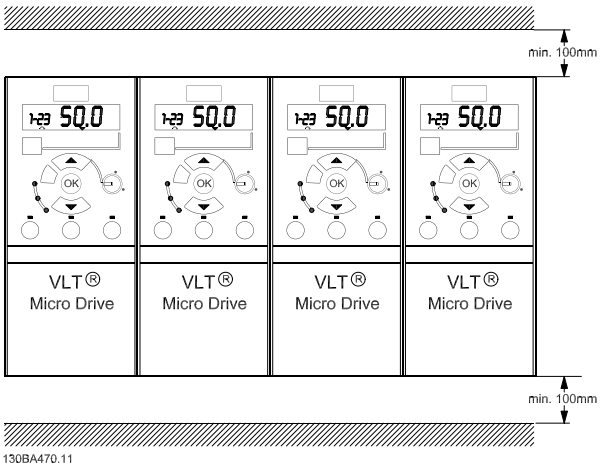


Illustration 6.2 Side-by-side installation

6.3 Before Commencing Repair Work

1. Disconnect 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.
3. Disconnect DC bus terminals and brake terminals (if present).
4. Remove motor cable.

6.4 Mechanical Dimensions

A template for drilling can be found on the flap of the packaging.

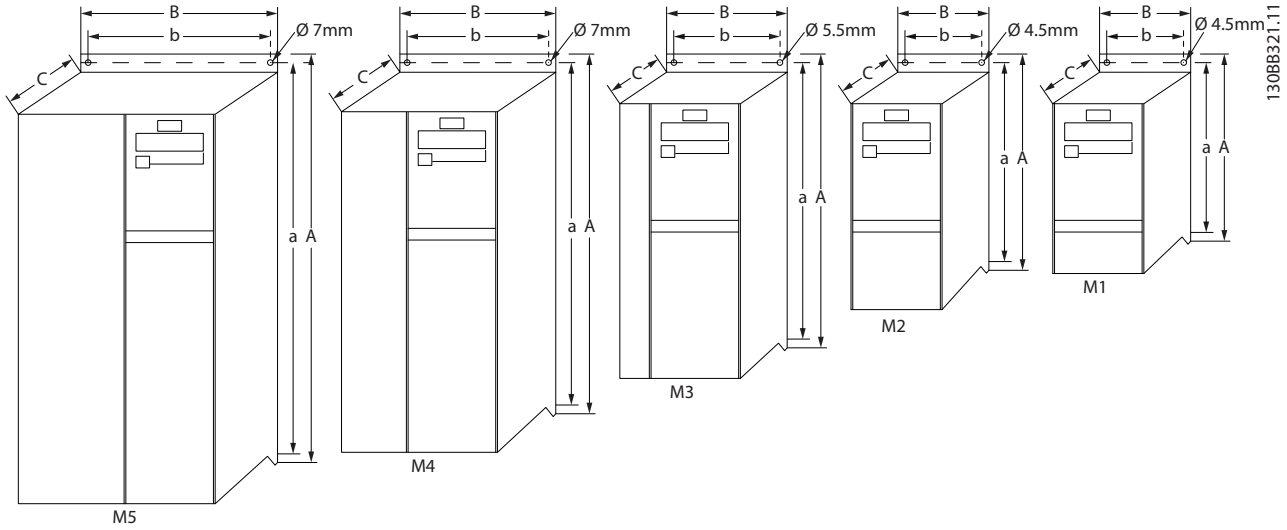


Illustration 6.3 Mechanical Dimensions

	Power (kW)			Height (mm)			Width (mm)		Depth [1] (mm)	Max. Weight
Frame	1 X 200-240 V	3 X 200 -240 V	3 X 380-480 V	A	A (incl. 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, please add 7.6 mm.										

Table 6.1 Mechanical Dimensions

6.5 Electrical Installation in General

NOTE

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

	Power (kW)			Torque (Nm)					
Frame	1 x 200-240 V	3 x 200-240 V	3 x 380-480 V	Line	Motor	DC connection/Brake	Control Terminals	Earth	Relay
M1	0.18 - 0.75	0.25 - 0.75	0.37 - 0.75	1.4	0.7	Spade[1)]	0.15	3	0.5
M2	1.5	1.5	1.5 - 2.2	1.4	0.7	Spade[1)]	0.15	3	0.5
M3	2.2	2.2 - 3.7	3.0 - 7.5	1.4	0.7	Spade[1)]	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 Faston plugs)									

Table 6.2 Tightening of Terminals

6

6.6 Fuses

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

Short circuit protection:
Danfoss recommends using the fuses mentioned in the following tables to protect service personnel or other equipment in case of an internal failure in the unit or short-circuit on DC-link. The frequency converter provides full short circuit protection in case of a short-circuit on the motor or brake output.

Overcurrent protection:
Provide overload protection to avoid overheating of the cables in the installation. Overcurrent protection must always be carried out according to national regulations. Fuses must be designed for protection in a circuit capable of supplying a maximum of 100,000A_{rms} (symmetrical), 480V maximum.

Non UL compliance:
If UL/cUL is not to be complied with, Danfoss recommends using the fuses mentioned in the below table, which will ensure compliance with EN50178/IEC61800-5-1:
In case of malfunction, not following the fuse recommendation may result in damage to the frequency converter and the installation.

FC 51	Max. Fuses UL						Max. fuses non UL
	Bussmann	Bussmann	Bussmann	Littel fuse	Ferraz-Shawmut	Ferraz-Shawmut	
1 X 200-240 V							
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
3 x 200-240 V							
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
3 x 380-480 V							
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	A6K405R	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 6.3 Fuses

6.7 Mains Connection

Step 1: First mount earth cable.

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

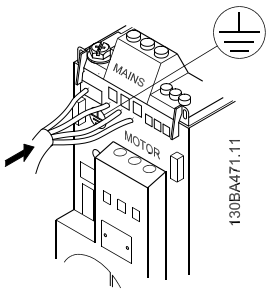


Illustration 6.4 Mounting of earth cable and mains wires

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

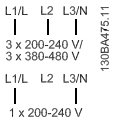


Illustration 6.5 Three-phase and single-phase wire connections

6.8 Motor Connection

6.8.1 How to Connect the Motor

See *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 motor cable as short as possible to reduce the noise level and leakage currents.

For further details on mounting of the decoupling plate, please see instruction MI.02.BX.YY.

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

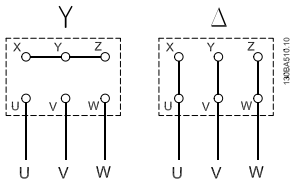


Illustration 6.6 Star and delta connections.

Step 1: First, mount the earth cable.

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

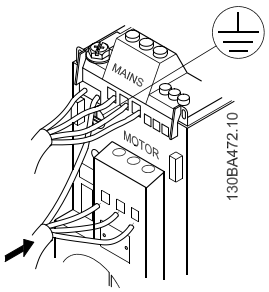


Illustration 6.7 Mounting of earth cable and motor wires.

For EMC correct installation, use optional de-coupling plate, see chapter *5.2 Options for VLT Micro Drive*.

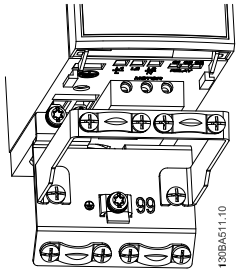


Illustration 6.8 Frequency converter with de-coupling plate

6.8.2 Motor Cables

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

- Use a screened/armoured 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 screen to both the de-coupling plate of the frequency converter and to the metal cabinet of the motor.
- Make the screen connections with the largest possible surface area (cable clamp). This is done by using the supplied installation devices in the frequency converter.
- Avoid mounting with twisted screen ends (pigtails), which will spoil high frequency screening effects.
- If it is necessary to split the screen to install a motor isolator or motor relay, the screen must be continued with the lowest possible HF impedance.

6.8.3 Electrical Installation of Motor Cables

Screening of cables
Avoid installation with twisted screen ends (pigtails). They spoil the screening effect at higher frequencies.
If it is necessary to break the screen to install a motor isolator or motor contactor, the screen must be continued at the lowest possible HF impedance.

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.

6

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 *14-01 Switching Frequency*.

Aluminium conductors
Aluminium conductors are not recommended. Terminals can accept aluminium conductors but the conductor surface has to be clean and the oxidation must be removed and sealed by neutral acid free Vaseline grease before the conductor is connected.
Furthermore, the terminal screw must be retightened after two days due to the softness of the aluminium. It is crucial to keep the connection a gas tight joint, otherwise the aluminium surface will oxidize again.

6

6.8.4 EMC-Correct Electrical Installation

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

- Use only screened/armoured motor cables and screened/armoured control cables.
- Connect the screen to earth at both ends.
- Avoid installation with twisted screen ends (pigtails), since this ruins the screening effect at high frequencies. Use the cable clamps provide-dinstead.
- 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 starwashers and galvanically conductive installation plates.
- Do not use unscreened/unarmoured motor cables in the installation cabinets.

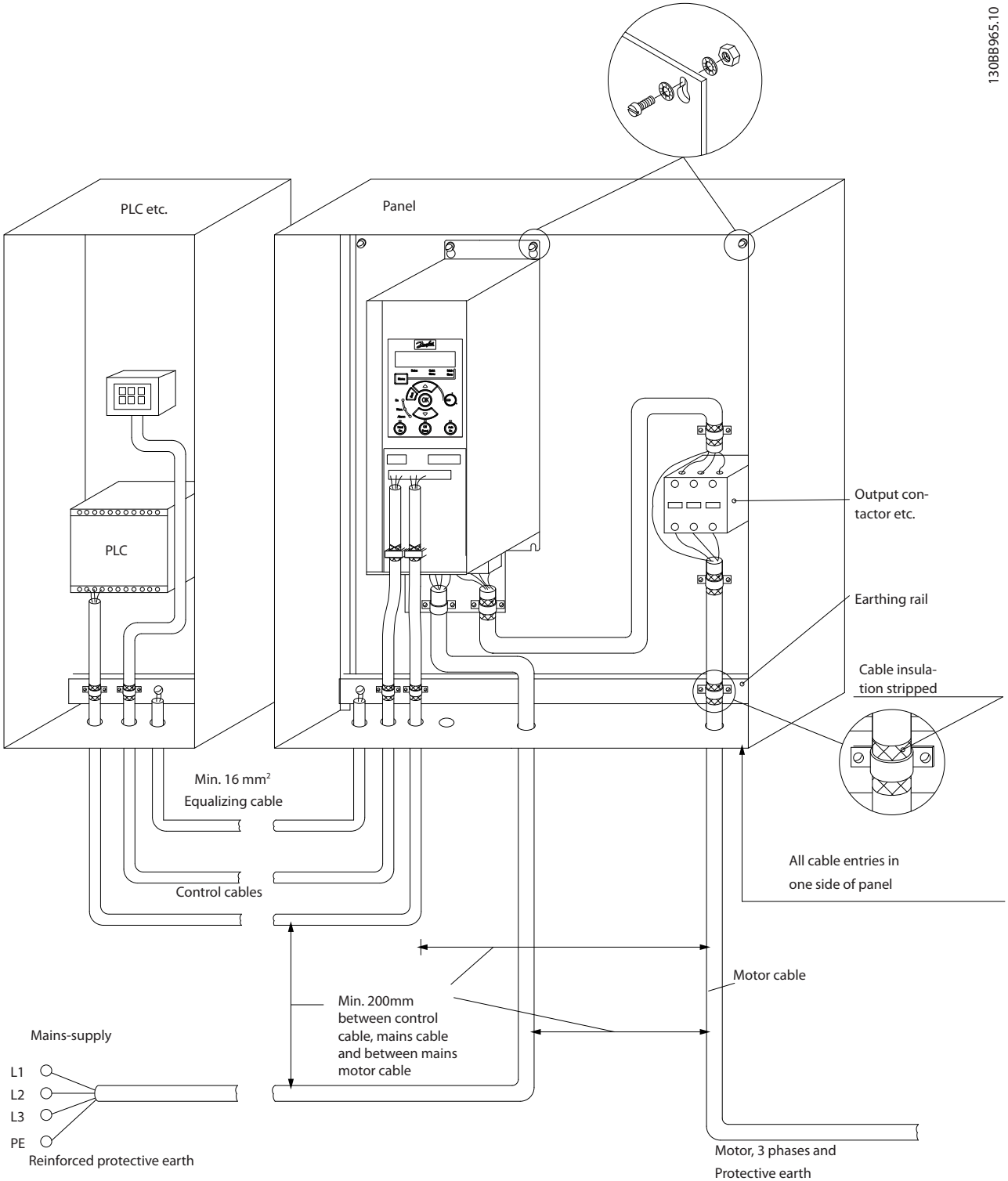


Illustration 6.9 EMC-correct Electrical Installation

For North America use metal conduits instead of shielded cables.

6.9.1 Use of EMC-Correct Cables

Danfoss recommends braided screened/armoured cables to optimise EMC immunity of the control cables and the EMC emission from the motor cables.

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

6

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 on the basis of the following factors:

- The conductibility of the screen material.
- The contact resistance between the individual screen conductors.
- The screen coverage, i.e. the physical area of the cable covered by the screen - often stated as a percentage value.
- Screen type, i.e. braided or twisted pattern.

a. Aluminium-clad with copper wire.

b. Twisted copper wire or armoured steel wire cable.

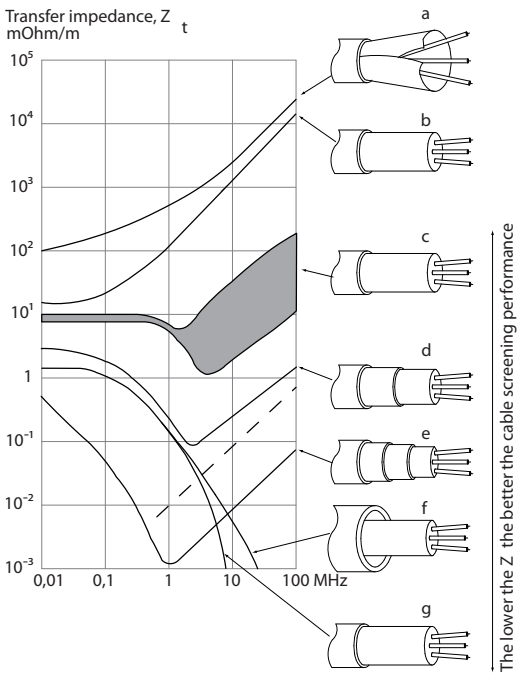
c. Single-layer braided copper wire with varying percentage screen coverage.
This is the typical Danfoss reference cable.

d. Double-layer braided copper wire.

e. Twin layer of braided copper wire with a magnetic, screened/armoured intermediate layer.

f. Cable that runs in copper tube or steel tube.

g. Lead cable with 1.1mm wall thickness.



6

6.10.1 Earthing of Screened/Armoured Control Cables

Generally speaking, control cables must be braided screened/armoured and the screen must be connected by means of a cable clamp at both ends to the metal cabinet of the unit.

The drawing below indicates how correct earthing is carried out and what to do if in doubt.

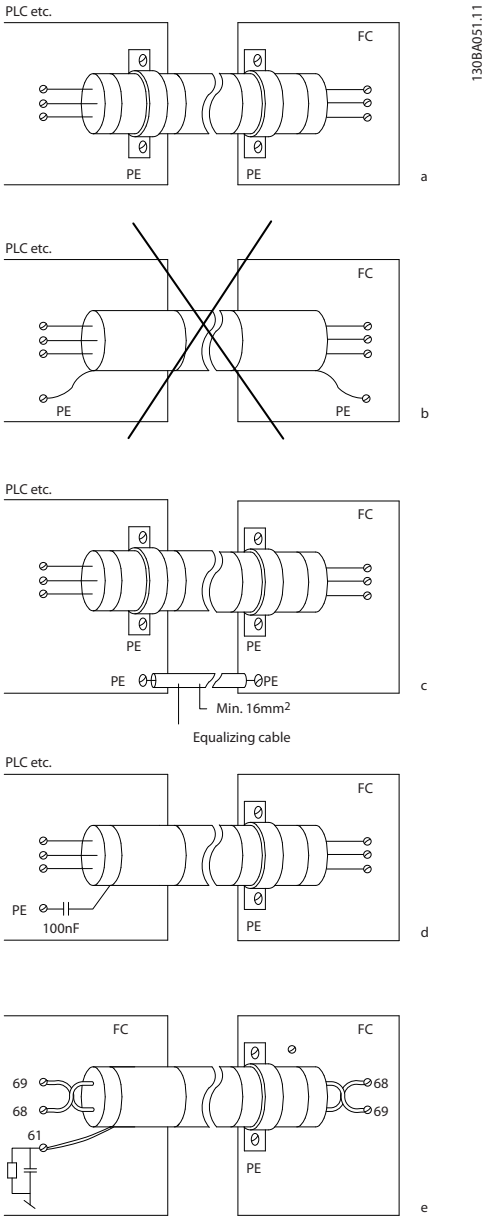
a. **Correct earthing**
Control cables and cables for serial communication must be fitted with cable clamps at both ends to ensure the best possible electrical contact.

b. **Wrong earthing**
Do not use twisted cable ends (pigtails). They increase the screen impedance at high frequencies.

c. **Protection with respect to earth potential between PLC and frequency converter**
If the earth potential between the frequency converter and the PLC (etc.) is different, electric noise may occur that will disturb the entire system. Solve this problem by fitting an equalising cable, next to the control cable. Minimum cable cross-section: 16 mm ^{2}.

d. **For 50/60 Hz earth loops**
If very long control cables are used, 50/60 Hz earth loops may occur. Solve this problem by connecting one end of the screen to earth via a 100nF capacitor (keeping leads short).

e. **Cables for serial communication**
Eliminate low-frequency noise currents between two frequency converters by connecting one end of the screen to terminal 61. This terminal is connected to earth via an internal RC link. Use twisted-pair cables to reduce the differential mode interference between the conductors.



6.11 Residual Current Device

Use RCD relays, multiple protective earthing or earthing as extra protection, provided that local safety regulations are complied with.
If an earth fault appears, a DC content may develop in the faulty current.
If RCD relays are used, local regulations must be observed. Relays must be suitable for protection of 3-phase equipment with a bridge rectifier and for a brief discharge on power-up see section *3.4 Earth Leakage Current* for further information.

6.12 Electrical Overview

6.12.1 Power Circuit - Overview

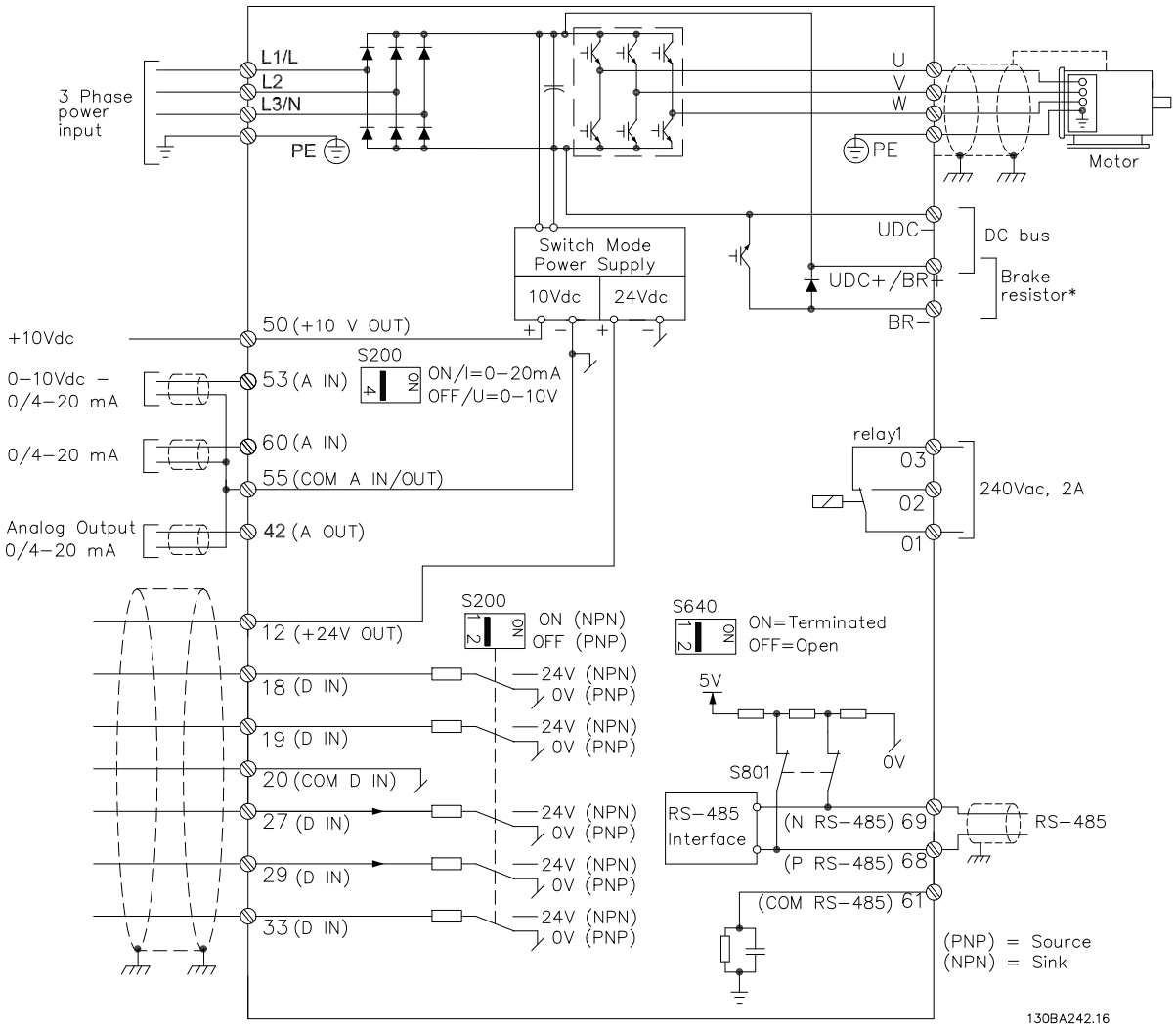


Illustration 6.10 Diagram Showing all Electrical Terminals

* Brake (BR+ and BR-) are not applicable for frame M1.

Brake resistors are available from Danfoss.
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.

6.13 Electrical Installation and Control Cables

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

Table 6.4 Terminal Connections

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

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

NOTE

The common of digital / analog inputs and outputs should be connected to separate common terminals 20, 39, and 55. This will avoid ground current interference among groups. For example, it avoids switching on digital inputs disturbing analog inputs.

NOTE

Control cables must be screened/armoured.

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.

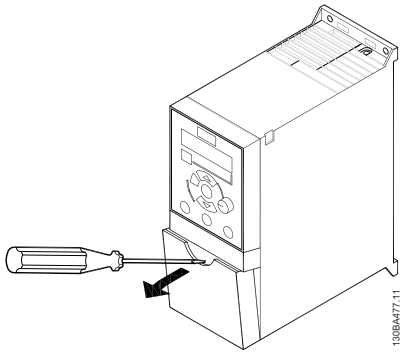


Illustration 6.11 Removing terminal cover

NOTE

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

6.14.2 Connecting to Control Terminals

Illustration 6.12 shows all control terminals of the frequency converter. Applying Start (term. 18) and an analog reference (term. 53 or 60) make the frequency converter run.

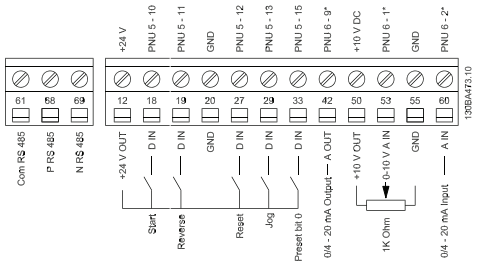


Illustration 6.12 Overview of control terminals in PNP-configuration and factory setting.

6.15 Switches

NOTE

Do not operate switches with power on the frequency converter.

Bus termination:
Switch *BUS TER* pos. ON terminates the RS485 port, terminals 68, 69. See *Illustration 6.10*.

Default setting = Off.

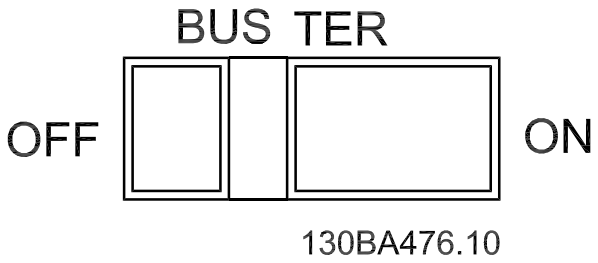


Illustration 6.13 S640 Bus termination

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	

Table 6.5 Settings for S200 Switches 1-4

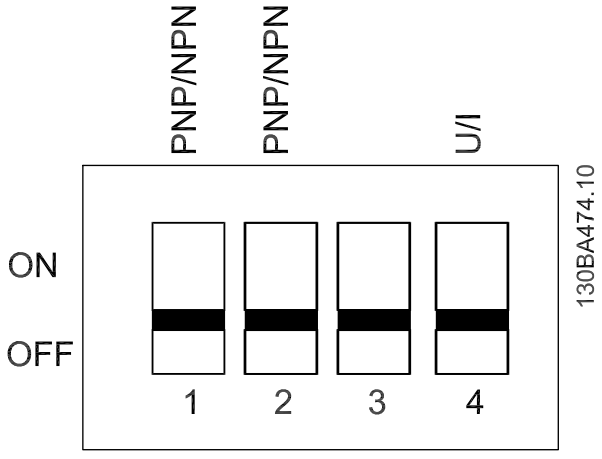


Illustration 6.14 S200 Switches 1-4.

NOTE

Parameter 6-19 must be set 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.

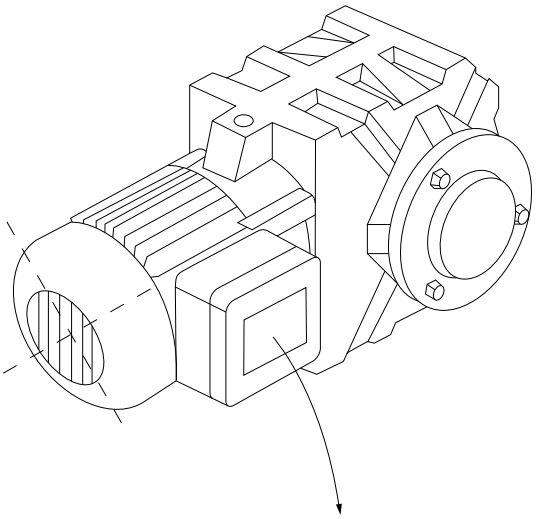
Step 1. Locate the motor name plate

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

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

To access this list first press the [QUICK MENU] key then select “Q2 Quick Setup”.

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



130BT307.10

BAUER D-7 3734 ESLINGEN				
3~ MOTOR NR. 1827421 2003				
S/E005A9				
	1,5	KW		
n_2 31,5	/min.	400	Y	V
n_1 1400	/min.		50	Hz
COS θ 0,80			3,6	A
1,7L				
B	IP 65	H1/1A		

Step 3. Activate the Automatic Motor Tuning (AMT)

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

1. Connect terminal 27 to terminal 12 or set *5-12 Terminal 27 Digital Input* to 'No function' (*5-12 Terminal 27 Digital Input* [0])
2. Activate the AMT *1-29 Automatic Motor Adaptation (AMA)*.
3. Choose 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 the [OK] key. The display shows “Press [Hand on] to start”.
5. Press the [Hand on] key. A progress bar indicates if the AMT is in progress.

Stop the AMT during operation

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

Successful AMT

1. The display shows “Press [OK] to finish AMT”.
2. Press the [OK] key 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.
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 will assist you in troubleshooting. If you contact Danfoss Service, make sure to mention number and alarm description.

Unsuccessful AMT is often caused by incorrectly registered motor name plate 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 desired limits for speed and ramp time.

Minimum Reference	*3-02 Minimum Reference*
Maximum Reference	*3-03 Maximum Reference*

Motor Speed Low Limit	*4-11 Motor Speed Low Limit [RPM]* or *4-12 Motor Speed Low Limit [Hz]*
Motor Speed High Limit	*4-13 Motor Speed High Limit [RPM]* or *4-14 Motor Speed High Limit [Hz]*

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

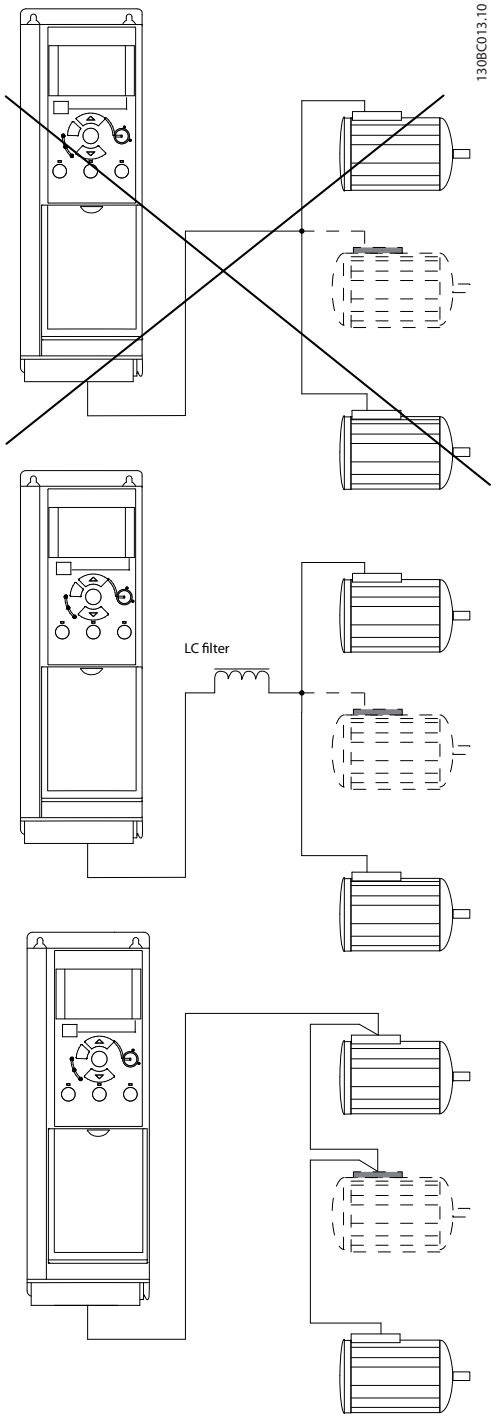
6.17 Parallel Connection of Motors

The frequency converter can control several parallel-connected motors. The total current consumption of the motors must not exceed the rated output current I_{INV} for the frequency converter.

When motors are connected in parallel, *7.4.2 1-29 Automatic Motor Tuning (AMT)* cannot be used.

Problems may arise at start and at low RPM values if motor sizes are widely different because small motors' relatively high ohmic resistance in the stator calls for a higher voltage at start and at low RPM values.

The electronic thermal relay (ETR) of the frequency converter cannot be used as motor protection for the individual motor of systems with parallel-connected motors. Provide further motor protection by e.g. thermistors in each motor or individual thermal relays. (Circuit breakers are not suitable as protection).



6.18 Motor Installation

6.18.1 Motor Insulation

For motor cable lengths ≤ the maximum cable length listed in *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 it recommended to use a dU/dt or sine wave filter.

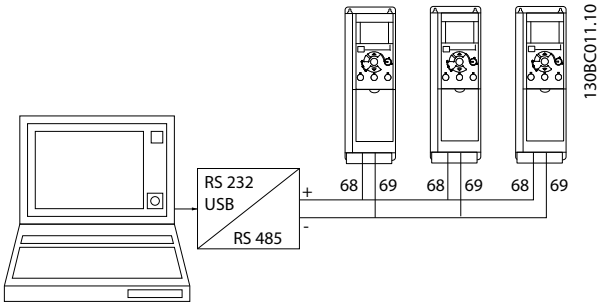
Nominal Mains Voltage	Motor Insulation
$U_N \leq 420$ V	Standard U_{LL} = 1300 V
420V < $U_N \leq$ 500 V	Reinforced U_{LL} = 1600 V
500V < $U_N \leq$ 600 V	Reinforced U_{LL} = 1800 V
600V < $U_N \leq$ 690 V	Reinforced U_{LL} = 2000 V

6.19 Installation of Misc. Connections

6.19.1 RS485 Bus Connection

One or more frequency converters can be connected to a control (or master) using the RS485 standardized 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 one frequency converter is connected to a master, use parallel connections.



In order to avoid potential equalizing currents in the screen, earth the cable screen via terminal 61, which is connected to the frame via an RC-link.

Bus termination
The RS485 bus must be terminated by a resistor network at both ends. For this purpose, set switch S801 on the control card for "ON".
For more information, see the paragraph *Switches S201, S202, and S801*.

Communication protocol must be set to *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 will be useful for:

- Planning a communication network off-line. MCT 10 Set-up Software contains a complete frequency converter database
- Commissioning frequency converters on line
- Saving settings for all frequency converters
- Replacing a frequency converter in a network
- Expanding an existing network
- Future developed drives will be supported

Save Drive Settings:
1. Connect a PC to the unit via USB com port
2. Open PC-based Configuration Tool MCT 10 Set-up Software
3. Choose “Read from drive”
4. Choose “Save as”

All parameters are now stored in the PC.

Load Drive Settings:
1. Connect a PC to the unit via USB com port
2. Open PC-based Configuration Tool MCT 10 Set-up Software
3. Choose “Open”– stored files will be shown
4. Open the appropriate file
5. Choose “Write to drive”

All parameter settings are now transferred to the frequency converter.

A separate manual for PC-based Configuration Tool MCT 10 Set-up Software is available.

The PC-based Configuration Tool MCT 10 Set-up Software modules
The following modules are included in the software package:

	**MCT 10 Set-up Software** Setting parameters Copy to and from frequency converters Documentation and print out of parameter settings incl. diagrams
	Ext. User Interface Preventive Maintenance Schedule Clock settings Timed Action Programming Smart Logic Controller Set-up

Ordering number:
Please order the CD containing the PC-based Configuration Tool MCT 10 Set-up Software using code number 130B1000.

MCT 10 Set-up Software can also be downloaded from the Danfoss Internet: *http://www.danfoss.com/BusinessAreas/DrivesSolutions/Softwaredownload/DDPC+Software+Program.htm*.

6.20 Safety

6.20.1 High Voltage Test

Carry out a high voltage test by short-circuiting terminals U, V, W, L_1, L_2 and L_3. Energize maximum 2.15 kV DC for 380-500V frequency converters and 2.525 kV DC for 525-690V frequency converters for one second between this short-circuit and the chassis.

⚠WARNING

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

6.20.2 Safety Earth Connection

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

⚠WARNING

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

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 com-port by installing the MCT-10 Set-up Software.

This software can either be ordered using code number 130B1000 or downloaded from the Danfoss Web site: www.danfoss.com, Business Area: Motion Controls.

Please refer to manual MG10RXYY.

7.1.2 Programming with the LCP 11 or LCP 12

The LCP is divided into four functional groups:

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

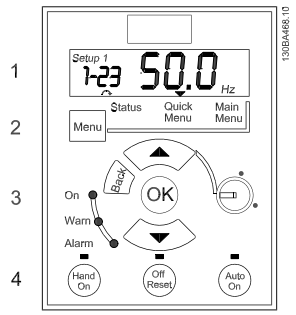


Illustration 7.1 LCP 12 with Potentiometer

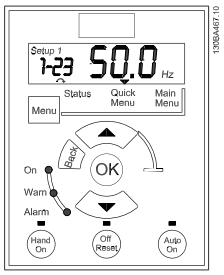


Illustration 7.2 LCP 11 without Potentiometer

The display:
Different information can be read from the display.

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, both numbers are shown in the display (Setup 12). The number flashing, indicates the edit set-up.

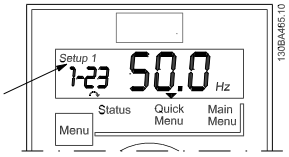


Illustration 7.3 Indicating Set-up

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

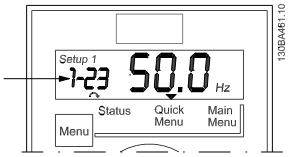


Illustration 7.4 Indicating Selected Parameter No.

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.

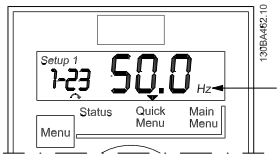


Illustration 7.6 Indicating Unit of Selected Parameter.

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

Use the [MENU] key to select one 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 the Quick Menus.

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

Indicator lights:

- Green LED: The frequency converter is on.
- Yellow LED: Indicates a warning. Please see section *Troubleshooting*
- Flashing red LED: Indicates an alarm. Please see section *Troubleshooting*

Navigation Keys:
[Back]: For moving to the previous step or layer in the navigation structure.
Arrows [▲] [▼]: 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 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 that case the motor will be reset.
[Auto on]: The frequency converter is controlled either via control terminals or serial communication.
[Potentiometer] (LCP12): The potentiometer works in two 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 the [Menu] key to toggle between Status, Quick Menu and Main Menu.

Arrows [▲] and [▼] toggles between the choices in each menu.

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

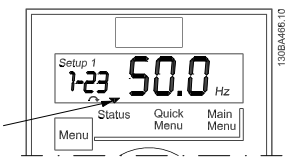


Illustration 7.8 Indicating Status Mode

7.3 Quick Menu

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

1. To enter the Quick Menu, press [Menu] key until indicator in display is placed above *Quick Menu*.
2. Use [▲] [▼] to select either QM1 or QM2, then press [OK].
3. Use [▲] [▼] to browse through the parameters in the Quick Menu.
4. Press [OK] to select a parameter.
5. Use [▲] [▼] 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

Below are descriptions of all parameters found in the Quick Menu.

* = Factory setting.

1-20 Motor Power [kW]/[HP] ($P_{m.n}$)

Option:		Function:
		Enter motor power from nameplate data. Two sizes down, one 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	
[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	

NOTE

Changing this parameter affects parameter 1-22 to 1-25, 1-30, 1-33 and 1-35.

1-22 Motor Voltage ($U_{m.n}$)

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

1-23 Motor Frequency ($f_{m.n}$)

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

1-24 Motor Current (I m,n)

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

1-25 Motor Nominal Speed (n m,n)

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. **NOTE** **This parameter cannot be changed while motor runs.** 1. Stop the frequency converter - make sure motor is at standstill 2. Choose [2] Enable AMT 3. Apply start signal - Via LCP: Press [Hand On] - Or in Remote On mode: Apply start signal on terminal 18
[0] *	Off	AMT function is disabled.
[2]	Enable AMT	AMT function starts running. **NOTE** **To gain optimum tuning of frequency converter, run AMT on a cold motor.**

3-02 Minimum Reference

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

3-03 Maximum Reference

Range:		Function:
		Maximum Reference is adjustable in the range Minimum Reference - 4999.
50.00*	[-4999 - 4999]	Enter value for Maximum Reference. The sum of all internal and external references are clamped (limited) to the maximum reference value, *3-03 Maximum Reference*.

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 *1-23 Motor Frequency*.

3-41 Ramp1 Ramp-up Time

Range:		Function:
		Choose a ramp-up time ensuring that torque limit is not exceeded, see *4-16 Torque Limit in Motor Mode*.

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 *1-23 Motor Frequency* to 0 Hz. Choose a ramp down time that does not cause over-voltage in inverter due to regenerative operation of motor. Furthermore, regenerative torque must not exceed limit set in *4-17 Torque Limit in Generator Mode*.

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, please see *VLT Micro Drive Programming Guide*, MG02CXYY.

1-00 Configuration Mode

Range:		Function:
	[]	Choose [3] Process Closed Loop

3-02 Min. Reference

Range:		Function:
	[-4999 - 4999]	Sets limits for set-point and feedback.

3-03 Max. Reference

Range:		Function:
	[-4999 - 4999]	Sets limits for set-point and feedback.

3-10 Preset Reference

Range:		Function:
	[-100.00 - 100.00]	Preset [0] works as set-point.

4-12 Motor Speed Low Limit

Range:		Function:
	[0.0 - 400 Hz]	Lowest possible output frequency.

4-14 Motor Speed High Limit

Range:		Function:
	[0.0 - 400.00 Hz]	Highest possible output frequency.

NOTE

Default 65 Hz should normally be reduced to 50 - 55 Hz.

6-22 Terminal 60 Low Current

Range:		Function:
	[0.00 - 19.99 mA]	Normally set to 0 or 4 mA.

6-23 Terminal 60 High Current

Range:	Function:
[0.01 - 20.00 mA]	Normally (default) set to 20 mA.

6-24 Terminal 60 Low Feedback Value

Range:	Function:
[-4999 - 4999]	Value corresponding to *7.4.3 QM2 - 6-22 - Terminal 60 Low Current* setting.

6-25 Terminal 60 High Feedback Value

Range:	Function:
[-4999 - 4999]	Value corresponding to *7.4.3 QM2 - 6-23 Terminal 60 High Current* setting.

6-26 Terminal 60 Filter Time Constant

Range:	Function:
[0.01 - 10.00 s]	Filter for suppressing electrical noise.

7-20 Process CL Feedback Resource

Range:	Function:
[]	Choose [2] analog input 60.

7-30 Process PI Normal/Inverse

Range:	Function:
[]	Most PI controllers are “Normal”.

7-31 Process PI Anti Windup

Range:	Function:
[]	Leave *Enabled* normally.

7-32 Process PI Start Speed

Range:	Function:
[0.0 - 200.0 Hz]	Choose expected normal running speed.

7-33 Process PI Proportional Gain

Range:	Function:
[0.00 - 10.00]	Enter the P-factor.

7-34 Process PI Integral Time

Range:	Function:
[0.10 - 9999.00 s]	Enter the I-factor.

7-38 Process Feed Forward Factor

Range:	Function:
[0 - 400%]	Only applicable with changing set-points.

7.5 Main Menu

7.5.1 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 *0-60 Main Menu Password*. For the majority of VLT® Micro Drive FC 51 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 in display is placed 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.

[BACK] is used to go one level back.

7

7.6 Quick Transfer of Parameter Settings between Multiple Frequency Converters

Once the set-up of a frequency converter is complete, Danfoss recommends that you store the data in the LCP or on a PC via MCT 10 Set-up Software tool.

Data storage in LCP.

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

⚠WARNING

Stop the motor before performing this operation.

You can now connect the LCP to another frequency converter and copy the parameter settings to this frequency converter as well.

Data transfer from LCP to frequency converter:

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

NOTE

Stop the motor before performing this operation.

7.7 Read-out and Programming of Indexed Parameters

Use *7.4.3 QM2 - 3-10 - Preset Reference* as an example. Choose the parameter, press [OK], and use the up/down navigation keys to scroll through the indexed values. To change the parameter value, select the indexed value and press [OK]. Change the value by using the up/down keys. Press [OK] to accept the new setting. Press [CANCEL] to abort. Press [Back] to leave the parameter.

7.8 Initialise the Frequency Converter to Default Settings in two Ways

7.8.1 Initialise the Frequency Converter to Default Settings in two Ways

Recommended initialisation (via *14-22 Operation Mode*)

1. Select *14-22 Operation Mode*.
2. Press [OK].
3. Select *Initialisation* 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. *Except the following parameters.*

   8-30 Protocol

   8-31 Address

   8-32 Baud Rate

   8-33 Parity / Stop Bits

   8-35 Minimum Response Delay

   8-36 Maximum Response Delay

   15-00 Operating Hours to *15-05 Over Volt's*

   15-03 Power Up's

   15-04 Over Temp's

   15-05 Over Volt's

   15-30 Alarm Log: Error Code

   15-4* Drive identification parameters

Two finger initialization:

1. Power off the frequency converter.
2. Press [OK] and [MENU].
3. Power up the frequency converter while still pressing the keys above for 10 sec.
4. The frequency converter is now reset, except the following parameters:

   15-00 Operating Hours

   15-03 Power Up's

   15-04 Over Temp's

   15-05 Over Volt's

   15-4* Drive identification parameters

Initialisation of parameters is confirmed by AL80 in the display after the power cycle.

8 RS485 Installation and Set-up

RS485 is a two-wire bus interface compatible with multi-drop network topology, i.e. nodes can be connected as a bus, or via drop cables from a common trunk line. A total of 32 nodes can be connected to one network segment. Repeaters divide network segments. Please note that each repeater functions as a node within the segment in which it is installed. Each node connected within a given network must have a unique node address, across all segments. Terminate each segment at both ends, using either the termination switch (S801) of the frequency converters or a biased termination resistor network. Always use screened twisted pair (STP) cable for bus cabling, and always follow good common installation practice.
Low-impedance earth connection of the screen at every node is important, including at high frequencies. Thus, connect a large surface of the screen to earth, for example with a cable clamp or a conductive cable gland. It may be necessary to apply potential-equalizing cables to maintain the same earth 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 screened motor cable.

Cable: Screened twisted pair (STP)
Impedance: 120Ω
Cable length: Max. 1200 m (including drop lines)
Max. 500 m station-to-station

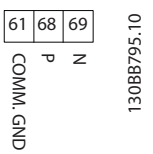
8.1.1 Network Connection

Connect the frequency converter to the RS485 network as follows (see also diagram):

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

NOTE

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



8.1.2 Frequency Converter Hardware Set-up

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

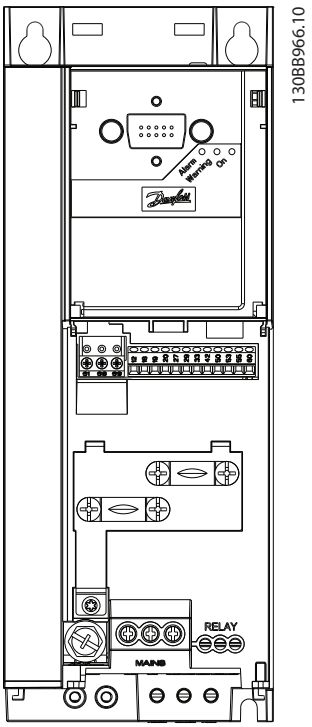


Illustration 8.1 Terminator Switch Factory Setting

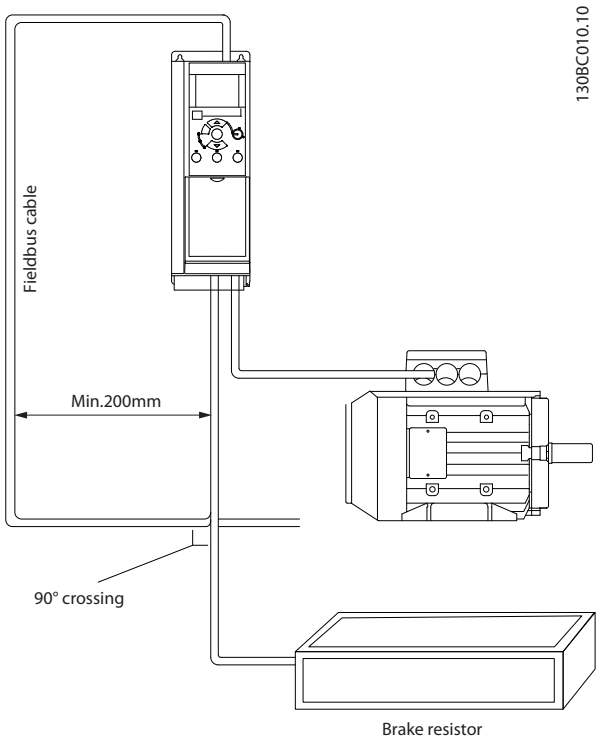
The factory setting for the dip switch is OFF.

8

8.1.3 EMC Precautions

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

Relevant national and local regulations, for example regarding protective earth connection, must be observed. The RS485 communication cable must be kept away from motor and brake resistor cables to avoid coupling of high frequency noise from one cable to another. Normally a distance of 200mm (8 inches) is sufficient, but keeping the greatest possible distance between the cables is generally recommended, especially where cables run in parallel over long distances. When crossing is unavoidable, the RS485 cable must cross motor and brake resistor cables at an angle of 90 degrees.



8.1.4 Frequency Converter Parameter Settings for Modbus Communication

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

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

8.2 FC Protocol Overview

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

8.2.1 FC with Modbus RTU

The FC protocol provides access to the Control Word and Bus Reference of the frequency converter.

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

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

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

8.3 Network Configuration

8.3.1 Frequency Converter Set-up

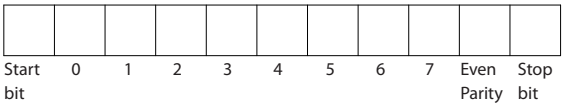
Set the following parameters to enable the FC protocol for the frequency converter.

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

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 1s in the 8 data bits and the parity bit in total. A stop bit completes a character, thus consisting of 11 bits in all.



8.4.2 Telegram Structure

Each telegram has the following structure:

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

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

A data control byte (BCC) completes the telegram.

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.

The length of telegrams with 4 data bytes is	LGE = 4 + 1 + 1 = 6 bytes
The length of telegrams with 12 data bytes is	LGE = 12 + 1 + 1 = 14 bytes
The length of telegrams containing texts is	10[1)]+n bytes

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

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

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)

8

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

8.4.6 The Data Field

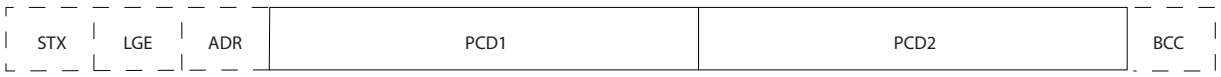
The structure of data blocks depends on the type of telegram. There are three telegram types, and the type applies for both control telegrams (master=>slave) and response telegrams (slave=>master).

The 3 types of telegram are:

Process block (PCD)

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)



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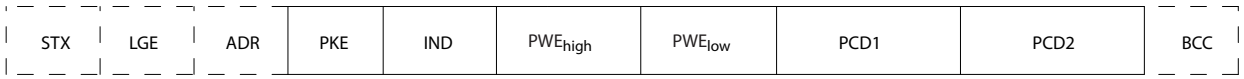
Parameter block

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.



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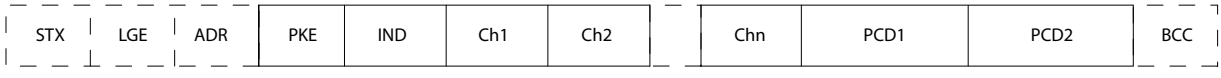
Text block

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



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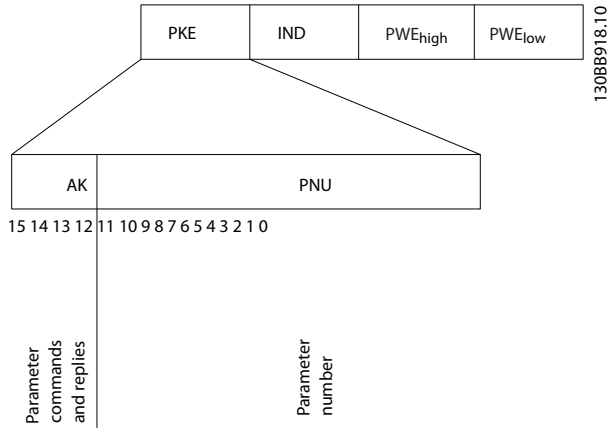
8.4.7 The PKE Field

The PKE field contains two subfields: Parameter command and response (AK) and Parameter number (PNU):



Bits no. 12-15 transfer parameter commands from master to slave and return processed slave responses to the master.

Parameter commands master ⇒ slave				
Bit no.				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

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

If the command cannot be performed, the slave sends this response:
0111 Command cannot be performed
- and issues the following fault report in the parameter value:

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

8.4.8 Parameter Number (PNU)

Bits no. 0-11 transfer parameter numbers. The function of the relevant parameter is defined in the parameter description in the Programming Guide.

8.4.9 Index (IND)

The index is used together with the parameter number to read/write-access parameters with an index, e.g. *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, e.g. *0-01 Language*, select the data value by entering the value in the PWE block.

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Serial communication is only capable of reading parameters containing data type 9 (text string).

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

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

8.4.11 Data Types Supported by the Frequency Converter

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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

8.4.12 Conversion

The various attributes of each parameter are displayed in the section Factory Settings. Parameter values are transferred as whole numbers only. Conversion factors are therefore used to transfer decimals.

4-12 Motor Speed Low Limit [Hz] has a conversion factor of 0.1.
To preset the minimum frequency to 10Hz, 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	0.1
2	100
1	10
0	1
-1	0.1
-2	0.01
-3	0.001
-4	0.0001
-5	0.00001

8.4.13 Process Words (PCD)

The block of process words is divided into two 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

8.5 Examples

8.5.1 Writing a Parameter Value

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

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

IND = 0000 Hex

PWEHIGH = 0000 Hex

PWELOW = 03E8 Hex

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

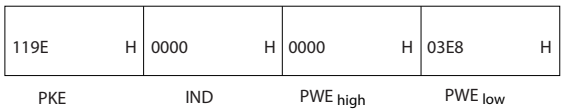
The telegram looks like this:

E19E H	0000 H	0000 H	03E8 H
PKE	IND	PWE_{high}	PWE_{low}

130BA092.10

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

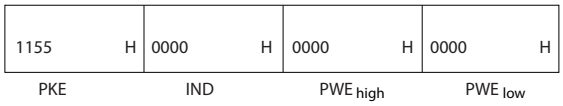
The response from the slave to the master is:



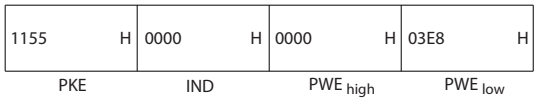
8.5.2 Reading a Parameter Value

Read the value in *3-41 Ramp 1 Ramp up Time*

PKE = 1155 Hex - Read parameter value in *3-41 Ramp 1 Ramp up Time*
IND = 0000 Hex
PWEHIGH = 0000 Hex
PWELOW = 0000 Hex



If the value in *3-41 Ramp 1 Ramp up Time* is 10 s, the response from the slave to the master is:



3E8 Hex corresponds to 1000 decimal. The conversion index for *3-41 Ramp 1 Ramp up Time* is -2, i.e. 0.01.
3-41 Ramp 1 Ramp up Time is of the type *Unsigned 32*.

8.6 Modbus RTU Overview

8.6.1 Assumptions

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

8.6.2 What the User Should Already Know

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

8.6.3 Modbus RTU Overview

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

How each controller learns its device address

Recognizes a message addressed to it

Determines which actions to take

Extracts any data or other information contained in the message

If a reply is required, the controller constructs the reply message and sends it.
Controllers communicate using a master-slave technique in which only one device (the master) can initiate transactions (called queries). The other devices (slaves) respond by supplying the requested data to the master, or by taking the action requested in the query.
The master can address individual slaves, or can initiate a broadcast message to all slaves. Slaves return a message (called a response) to queries that are addressed to them individually. No responses are returned to broadcast queries from the master. The Modbus RTU protocol establishes the format for the master's query by placing into it the device (or broadcast) address, a function code defining the requested action, any data to be sent, and an error-checking field. The slave's response message is also constructed using Modbus protocol. It contains fields confirming the action taken, any data to be returned, and an error-checking field. If an error occurs in receipt of the message, or if the slave is unable to perform the requested action, the slave will construct an error message, and send it in response, or a time-out 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
- 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 a variety of preset speeds

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- Run in reverse
- Change the active set-up
- Control the frequency converter's built-in relay

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

8.7 Network Configuration

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

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

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8.8 Modbus RTU Message Framing Structure

8.8.1 Frequency Converter with Modbus RTU

The controllers are set up to communicate on the Modbus network using RTU (Remote Terminal Unit) mode, with each byte in a message containing 2 4-bit hexadecimal characters. The format for each byte is shown in *Table 8.1*.

Start bit	Data byte								Stop/ parity	Stop

Coding System	8-bit binary, hexadecimal 0-9, A-F. 2 hexadecimal characters contained in each 8-bit field of the message
Bits Per Byte	1 start bit 8 data bits, least significant bit sent first 1 bit for even/odd parity; no bit for no parity 1 stop bit if parity is used; 2 bits if no parity
Error Check Field	Cyclical Redundancy Check (CRC)

8.8.2 Modbus RTU Message Structure

The transmitting device places a Modbus RTU message into a frame with a known beginning and ending point. This allows receiving devices to begin at the start of the message, read the address portion, determine which device is addressed (or all devices, if the message is broadcast), and to recognise when the message is completed. Partial messages are detected and errors set as a result. Characters for transmission must be in hexadecimal 00 to FF format in each field. The frequency converter continuously monitors the network bus, also during 'silent' intervals. When the first field (the address field) is received, each frequency converter or device decodes it to determine which device is being addressed. Modbus RTU messages addressed to zero are broadcast messages. No response is permitted for broadcast messages. A typical message frame is shown in *Table 8.1*.

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 8.1 Typical Modbus RTU Message Structure

8.8.3 Start/Stop Field

Messages start with a silent period of at least 3.5 character intervals. This is implemented as a multiple of character intervals at the selected network baud rate (shown as Start T1-T2-T3-T4). The first field to be transmitted is the device address. Following the last transmitted character, a similar period of at least 3.5 character intervals marks the end of the message. A new message can begin after this period. The entire message frame must be transmitted as a continuous stream. If a silent period of more than 1.5 character intervals occurs before completion of the frame, the receiving device flushes the incomplete message and assumes that the next byte will be the address field of a new message. Similarly, if a new message begins prior to 3.5 character intervals after a previous message, the receiving device will consider it a continuation of the previous message. This will cause a time-out (no response from the slave), since the value in the final CRC field will not be valid for the combined messages.

8.8.4 Address Field

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

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 slave. When a

message is sent from a master to a slave device, the function code field tells the slave what kind of action to perform. When the slave responds to the master, it uses the function code field to indicate either a normal (error-free) response, or that some kind of error occurred (called an exception response). For a normal response, the slave simply echoes the original function code. For an exception response, the slave returns a code that is equivalent to the original function code with its most significant bit set to logic 1. In addition, the slave places a unique code into the data field of the response message. This tells the master what kind of error occurred, or the reason for the exception. Please also refer to the sections *8.8.10 Function Codes Supported by Modbus RTU* and *8.8.11 Modbus Exception Codes*.

8.8.6 Data Field

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

8.8.7 CRC Check Field

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

8.8.8 Coil Register Addressing

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

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

Coil Number	Description		Signal Direction
1-16	Frequency converter control word (see *Table 8.2*)		Master to slave
17-32	Frequency converter speed or set-point reference Range 0x0 – 0xFFFF (-200% ... ~200%)		Master to slave
33-48	Frequency converter status word (see *Table 8.2*)		Slave to master
49-64	Open loop mode: Frequency converter output frequency Closed loop mode: Frequency converter feedback signal		Slave to master
65	Parameter write control (master to slave)		Master to slave
	0 =	Parameter changes are written to the RAM of the frequency converter	
	1 =	Parameter changes are written to the RAM and EEPROM of the frequency converter.	
66-65536	Reserved		

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 freq.	No freeze freq.
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 8.2 Frequency Converter Control Word (FC Profile)

Coil	0	1
33	Control not ready	Control ready
34	Frequency converter not ready	Frequency converter ready
35	Coasting stop	Safety closed
36	No alarm	Alarm
37	Not used	Not used
38	Not used	Not used
39	Not used	Not used
40	No warning	Warning
41	Not at reference	At reference
42	Hand mode	Auto mode
43	Out of freq. 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

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Table 8.3 Frequency Converter status word (FC profile)

Bus adress	Bus register[1]	PLC Register	Content	Access	Description
0	1	40001	Reserved		Reserved for Legacy Drives VLT 5000 and VLT 2800
1	2	40002	Reserved		Reserved for Legacy Drives VLT 5000 and VLT 2800
2	3	40003	Reserved		Reserved for Legacy Drives VLT 5000 and VLT 2800
3	4	40004	Free		
4	5	40005	Free		
5	6	40006	Modbus conf	Read/Write	TCP only. Reserved for Modbus TCP (p12-28 and 12-29 - store in Eeprom etc.)
6	7	40007	Last error code	Read only	Error code recieved from parameter database, refer to WHAT 38295for details
7	8	40008	Last error register	Read only	Address of register with which last error occurred, refer to WHAT 38296 for details
8	9	40009	Index pointer	Read/Write	Sub index of parameter to be accessed. Refer to WHAT 38297 for details
9	10	40010	FC par. 0-01	Dependent on parameter access	Parameter 0-01 (Modbus Register = 10 parameter number 20 bytes space reserved pr parameter in Modbus Map
19	20	40020	FC par. 0-02	Dependent on parameter access	Parameter 0-02 20 bytes space reserved pr parameter in Modbus Map
29	30	40030	FC par. xx-xx	Dependent on parameter access	Parameter 0-03 20 bytes space reserved pr parameter in Modbus Map

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

* Used to specify the index number to be used when accessing an indexed parameter.

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 message.

8.8.10 Function Codes Supported by Modbus RTU

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

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

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

8.8.11 Modbus Exception Codes

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

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

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.

8.9.2 Storage of Data

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

8.9.3 IND

The array index is set in Holding Register 9 and used when accessing array parameters.

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. Please refer to the *7.4 Quick Menu Parameters*.

8.9.6 Parameter Values

Standard Data Types
Standard data types are int16, int32, uint8, uint16 and uint32. They are stored as 4x registers (40001 – 4FFFF). The parameters are read using function 03HEX "Read Holding Registers." Parameters are written using the function 6HEX "Preset Single Register" for 1 register (16 bits), and the function 10HEX "Preset Multiple Registers" for 2 registers (32 bits). Readable sizes range from 1 register (16 bits) up to 10 registers (20 characters).

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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 03HEX "Read Holding Registers" and written using function 10HEX "Preset Multiple Registers." Readable sizes range from 1 register (2 characters) up to 10 registers (20 characters).

8.10 Examples

The following examples illustrate various Modbus RTU commands. If an error occurs, please refer to *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 message specifies the starting coil and quantity of coils to be read. Coil addresses start at zero, i.e. 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
No. of Points HI	00
No. of Points LO	10 (16 decimals)
Error Check (CRC)	-

Response
The coil status in the response message is packed as one 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 eight, the remaining bits in the final data byte will be padded with zeros (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)	-

NOTE

Coils and registers are addressed explicit with an off-set of -1 in Modbus.
I.e. 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 message specifies the coil 65 (parameter write control) to be forced. Coil addresses start at zero, i.e. coil 65 is addressed as 64. Force Data = 00 00HEX (OFF) or FF 00HEX (ON).

Field Name	Example (HEX)
Slave Address	01 (frequency converter address)
Function	05 (write single coil)
Coil Address HI	00
Coil Address LO	40 (64 decimal) Coil 65
Force Data HI	FF
Force Data LO	00 (FF 00 = ON)
Error Check (CRC)	-

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)	-

8.10.3 Force/Write Multiple Coils (0F HEX)

This function forces each coil in a sequence of coils to either ON or OFF. When broadcast the function forces the same coil references in all attached slaves.

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

NOTE

Coil addresses start at zero, i.e. 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 10-9)	00 (ref. = 2000hex)
Error Check (CRC)	-

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)	-

8.10.4 Read Holding Registers (03 HEX)

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

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

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

Field Name	Example (HEX)
Slave Address	01
Function	03 (read holding registers)
Starting Address HI	0B (Register address 3029)
Starting Address LO	05 (Register address 3029)
No. of Points HI	00
No. of Points LO	02 - (*3-03 Maximum Reference* is 32 bits long, i.e. 2 registers)
Error Check (CRC)	-

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

Example: Hex 000088B8 = 35.000 = 15Hz.

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)	-

8.10.5 Preset Single Register (06 HEX)

Description
This function presets a value into a single holding register.

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

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

Field Name	Example (HEX)
Slave Address	01
Function	06
Register Address HI	03 (Register address 999)
Register Address LO	E7 (Register address 999)
Preset Data HI	00
Preset Data LO	01
Error Check (CRC)	-

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)	-

8.10.6 Preset Multiple Registers (10 HEX)

Description
This function presets values into a sequence of holding registers.

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

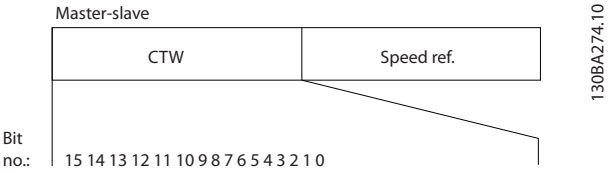
Field Name	Example (HEX)
Slave Address	01
Function	10
Starting Address HI	04
Starting Address LO	19
No. of Registers HI	00
No. of registers LO	02
Byte Count	04
Write Data HI (Register 4: 1049)	00
Write Data LO (Register 4: 1049)	00
Write Data HI (Register 4: 1050)	02
Write Data LO (Register 4: 1050)	E2
Error Check (CRC)	-

Response
The normal response returns the 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
No. of Registers HI	00
No. of registers LO	02
Error Check (CRC)	-

8.11 Danfoss FC Control Profile

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



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

Explanation of the Control Bits

Bits 00/01
Bits 00 and 01 are used to choose between the four reference values, which are pre-programmed in *3-10 Preset Reference* according to the *Table 8.4*:

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

NOTE

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

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

Bit 03, Coasting
Bit 03 = '0': The frequency converter immediately "lets go" of the motor, (the output transistors are "shut off") and it coasts to a standstill. Bit 03 = '1': The frequency converter starts the motor if the other starting conditions are met.

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

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

Bit 05, Hold output frequency
Bit 05 = '0': The present output frequency (in Hz) freezes. Change the frozen output frequency only by means of the digital inputs (*5-10 Terminal 18 Digital Input* to *5-13 Terminal 29 Digital Input*) programmed to *Speed up* and *Slow down*.

NOTE

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

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

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

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

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

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

Bit 09, Selection of ramp 1/2
Bit 09 = "0": Ramp 1 is active (*3-41 Ramp 1 Ramp up Time* to *3-42 Ramp 1 Ramp Down Time*). Bit 09 = "1": Ramp 2 (*3-51 Ramp 2 Ramp up Time* to *3-52 Ramp 2 Ramp down Time*) is active.

Bit 10, Data not valid/Data valid
Tell the frequency converter whether to use or ignore the control word. Bit 10 = '0': The control word is ignored. Bit 10 = '1': The control word is used. This function is relevant because the telegram always contains the control word, regardless of the telegram type. Thus, you can turn off the control word if you do not want to use it when updating or reading parameters.

Bit 11, Relay 01
Bit 11 = "0": Relay not activated. Bit 11 = "1": Relay 01 activated provided that *Control word bit 11* is chosen in *5-40 Function Relay*.

Bit 12, Relay 02
Bit 12 = "0": Relay 02 is not activated. Bit 12 = "1": Relay 02 is activated provided that *Control word bit 12* is chosen in *5-40 Function Relay*.

Bit 13, Selection of set-up
Use bits 13 to choose from the 2 menu set-ups according to the shown table.

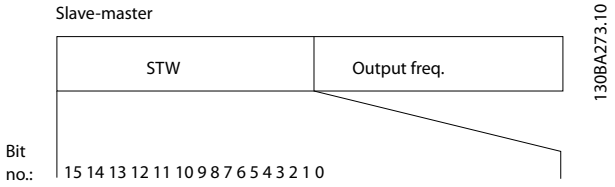
Set-up	Bit 13
1	0
2	1

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

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

Bit 15 Reverse
Bit 15 = '0': No reversing. Bit 15 = '1': Reversing. In the default setting, reversing is set to digital in *8-54 Reversing Select*. Bit 15 causes reversing only when Ser. communication, Logic or Logic and is selected.

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



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

Explanation of the Status Bits
Bit 00, Control not ready/ready
Bit 00 = '0': The frequency converter trips. Bit 00 = '1': The frequency converter controls are ready but the power component does not necessarily receive any power supply (in case of external 24V supply to controls).

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

Bit 02, Coasting stop
Bit 02 = '0': The frequency converter releases the motor. Bit 02 = '1': The frequency converter starts the motor with a start command.

Bit 03, No error/trip
Bit 03 = '0' : The frequency converter is not in fault mode. Bit 03 = '1': The frequency converter trips. To re-establish operation, enter [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 is running but the present speed is different from the preset speed reference. It might e.g. be the case when the speed ramps up/down during start/stop. Bit 08 = '1': The motor speed matches the preset speed reference.

Bit 09, Local operation/bus control
Bit 09 = '0': [STOP/RESET] is activate on the control unit or *Local control* in *F-02 Operation Method* is selected. You cannot control the frequency converter via serial communication. Bit 09 = '1' It is possible to control the frequency converter via the fieldbus / serial communication.

Bit 10, Out of frequency limit
Bit 10 = '0': The output frequency has reached the value in *4-12 Motor Speed Low Limit [Hz]* or *4-14 Motor Speed High Limit [Hz]*. Bit 10 = "1": The output frequency is within the defined limits.

Bit 11, No operation/in operation
Bit 11 = '0': The motor is not running. Bit 11 = '1': The frequency converter has a start signal or the output frequency is greater than 0Hz.

Bit 12, Drive OK/stopped, autostart:
Bit 12 = '0': There is no temporary over temperature on the inverter. Bit 12 = '1': The inverter stops because of over temperature but the unit does not trip and will resume operation once the over temperature stops.

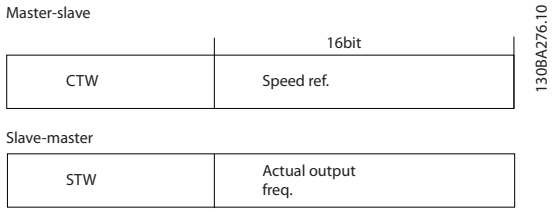
Bit 13, Voltage OK/limit exceeded
Bit 13 = '0': There are no voltage warnings. Bit 13 = '1': The DC voltage in the frequency converter's intermediate circuit is too low or too high.

Bit 14, Torque OK/limit exceeded
Bit 14 = '0': The motor current is lower than the torque limit selected in *4-18 Current Limit*. Bit 14 = '1': The torque limit in *4-18 Current Limit* is exceeded.

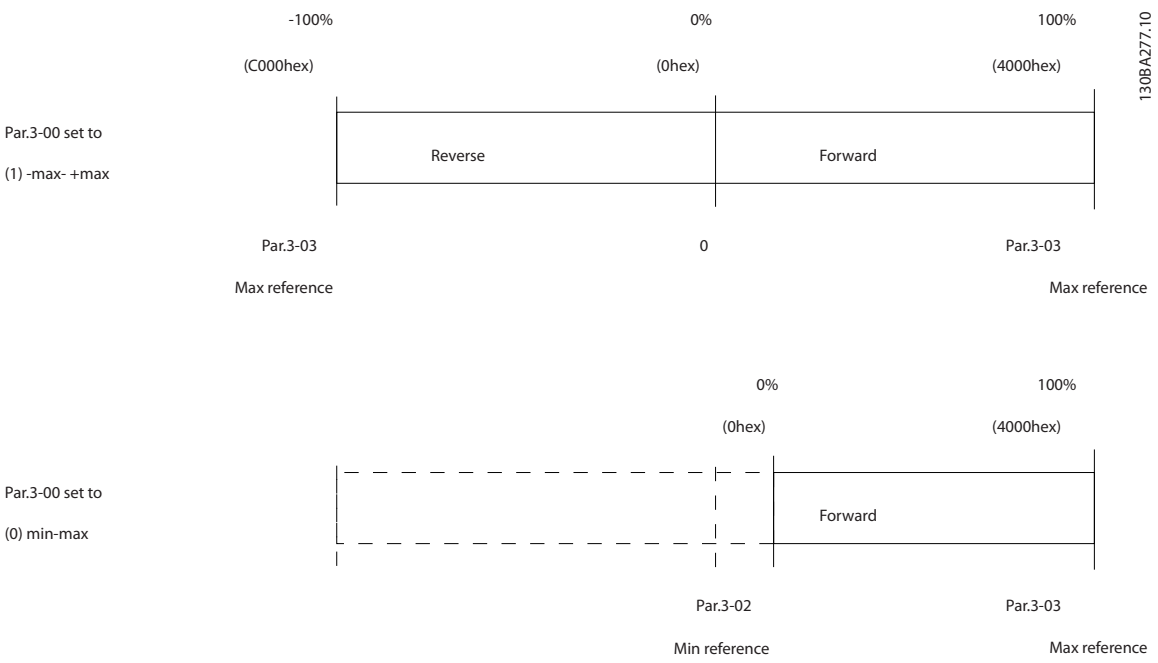
Bit 15, Timer OK/limit exceeded
Bit 15 = '0': The timers for motor thermal protection and thermal protection are not exceeded 100%. Bit 15 = '1': One of the timers exceeds 100%.

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; in integers (0-32767) the value 16384 (4000 Hex) corresponds to 100%. Negative figures are formatted by means of 2's complement. The Actual Output frequency (MAV) is scaled in the same way as the bus reference.



The reference and MAV are scaled as follows:



8

9 Specifications

9.1 Specifications

9.1.1 Mains Supply 1 x 200 - 240 V AC

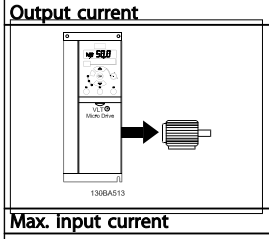
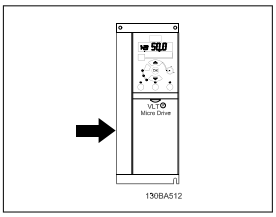
Normal overload 150% for 1 minute						
Frequency converter Typical Shaft Output [kW]		**PK18 0.18**	**PK37 0.37**	**PK75 0.75**	**P1K5 1.5**	**P2K2 2.2**
Typical Shaft Output [HP]		0.25	0.5	1	2	3
IP 20		Frame M1	Frame M1	Frame M1	Frame M2	Frame M3
Output current						
	Continuous (3 x 200-240 V) [A]	1.2	2.2	4.2	6.8	9.6
	Intermittent (3 x 200-240 V) [A]	1.8	3.3	6.3	10.2	14.4
	Max. cable size:					
	(mains, motor) [mm^2 /AWG]	4/10				
Max. input current						
	Continuous (1 x 200-240 V) [A]	3.3	6.1	11.6	18.7	26.4
	Intermittent (1 x 200-240 V) [A]	4.5	8.3	15.6	26.4	37.0
	Max. mains fuses [A]	See Section *Fuses*				
	Environment					
	Estimated power loss [W], Best case/ Typical[1)]	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[1)]	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 1 x 200 - 240 V AC

1. *At rated load conditions.*

9.1.2 Mains Supply 3 x 200 - 240 V AC

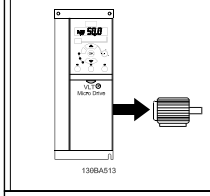
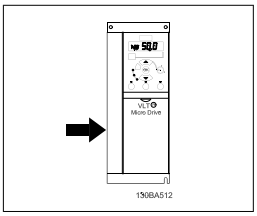
Normal overload 150% for 1 minute							
Frequency converter Typical Shaft Output [kW]		**PK25 0.25**	**PK37 0.37**	**PK75 0.75**	**P1K5 1.5**	**P2K2 2.2**	**P3K7 3.7**
Typical Shaft Output [HP]		0.33	0.5	1	2	3	5
IP 20		Frame M1	Frame M1	Frame M1	Frame M2	Frame M3	Frame M3
Output current							
	Continuous (3 x 200-240 V) [A]	1.5	2.2	4.2	6.8	9.6	15.2
	Intermittent (3 x 200-240 V) [A]	2.3	3.3	6.3	10.2	14.4	22.8
	Max. cable size:						
	(mains, motor) [mm^2 /AWG]	4/10					
Max. input current							
	Continuous (3 x 200-240 V) [A]	2.4	3.5	6.7	10.9	15.4	24.3
	Intermittent (3 x 200-240 V) [A]	3.2	4.6	8.3	14.4	23.4	35.3
	Max.mains fuses [A]	See Section *Fuses*					
	Environment						
	Estimated power loss [W], Best case/ Typical[1)]	14.0/ 20.0	19.0/ 24.0	31.5/ 39.5	51.0/ 57.0	72.0/ 77.1	115.0/ 122.8
	Weight enclosure IP20 [kg]	1.1	1.1	1.1	1.6	3.0	3.0
	Efficiency [%], Best case/Typical[1)]	96.4/ 94.9	96.7/ 95.8	97.1/ 96.3	97.4/ 97.2	97.2/ 97.4	97.3/ 97.4

Table 9.2 Mains Supply 3 x 200 - 240 V AC

1. *At rated load conditions.*

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9.1.3 Mains Supply 3 x 380 - 480 V AC

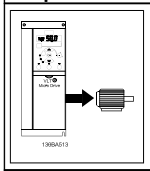
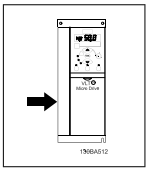
Normal overload 150 % for 1 minute							
Frequency converter Typical Shaft Output [kW]		**PK37 0.37**	**PK75 0.75**	**P1K5 1.5**	**P2K2 2.2**	**P3K0 3.0**	**P4K0 4.0**
Typical Shaft Output [HP]		0.5	1	2	3	4	5
IP 20		Frame M1	Frame M1	Frame M2	Frame M2	Frame M3	Frame M3
Output current							
	Continuous (3 x 380-440 V) [A]	1.2	2.2	3.7	5.3	7.2	9.0
	Intermittent (3 x 380-440 V) [A]	1.8	3.3	5.6	8.0	10.8	13.7
	Continuous (3 x 440-480 V) [A]	1.1	2.1	3.4	4.8	6.3	8.2
	Intermittent (3 x 440-480 V) [A]	1.7	3.2	5.1	7.2	9.5	12.3
	Max. cable size:						
	(mains, motor) [mm^2/ AWG]	4/10					
Max. input current							
	Continuous (3 x 380-440 V) [A]	1.9	3.5	5.9	8.5	11.5	14.4
	Intermittent (3 x 380-440 V) [A]	2.6	4.7	8.7	12.6	16.8	20.2
	Continuous (3 x 440-480 V) [A]	1.7	3.0	5.1	7.3	9.9	12.4
	Intermittent (3 x 440-480 V) [A]	2.3	4.0	7.5	10.8	14.4	17.5
	Max. mains fuses [A]	See Section *Fuses*					
	Environment						
	Estimated power loss [W], Best case/ Typical[1)]	18.5/ 25.5	28.5/ 43.5	41.5/ 56.5	57.5/ 81.5	75.0/ 101.6	98.5/ 133.5
	Weight enclosure IP20 [kg]	1.1	1.1	1.6	1.6	3.0	3.0
	Efficiency [%], Best case/Typical[1)]	96.8/ 95.5	97.4/ 96.0	98.0/ 97.2	97.9/ 97.1	98.0/ 97.2	98.0/ 97.3

Table 9.3 Mains Supply 3 x 380 - 480 V AC

1. At rated load conditions.

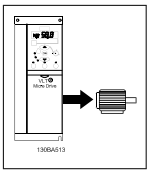
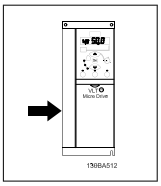
Normal overload 150 % for 1 minute							
Frequency converter Typical Shaft Output [kW]		**P5K5 5.5**	**P7K5 7.5**	**P11K 11**	**P15K 15**	**P18K 18.5**	**P22K 22**
Typical Shaft Output [HP]		7.5	10	15	20	25	30
IP 20		Frame M3	Frame M3	Frame M4	Frame M4	Frame M5	Frame M5
Output current							
	Continuous (3 x 380-440 V) [A]	12.0	15.5	23.0	31.0	37.0	42.0
	Intermittent (3 x 380-440 V) [A]	18.0	23.5	34.5	46.5	55.5	63.0
	Continuous (3 x 440-480 V) [A]	11.0	14.0	21.0	27.0	34.0	40.0
	Intermittent (3 x 440-480 V) [A]	16.5	21.3	31.5	40.5	51.0	60.0
	Max. cable size:						
	(mains, motor) [mm^2/ AWG]	4/10		16/6			
Max. input current							
	Continuous (3 x 380-440 V) [A]	19.2	24.8	33.0	42.0	34.7	41.2
	Intermittent (3 x 380-440 V) [A]	27.4	36.3	47.5	60.0	49.0	57.6
	Continuous (3 x 440-480 V) [A]	16.6	21.4	29.0	36.0	31.5	37.5
	Intermittent (3 x 440-480 V) [A]	23.6	30.1	41.0	52.0	44.0	53.0
	Max. mains fuses [A]	See Section *Fuses*					
	Environment						
	Estimated power loss [W], Best case/ Typical[1)]	131.0/ 166.8	175.0/ 217.5	290.0/ 342.0	387.0/ 454.0	395.0/ 428.0	467.0/ 520.0
	Weight enclosure IP20 [kg]	3.0	3.0				
	Efficiency [%], Best case/Typical[1)]	98.0/ 97.5	98.0/ 97.5	97.8/ 97.4	97.7/ 97.4	98.1/ 98.0	98.1/ 97.9

Table 9.4 Mains Supply 3 x 380 - 480 V AC

1. At rated load conditions.

Protection and features

- Electronic thermal motor protection against overload.
- Temperature monitoring of the heatsink ensures that the frequency converter trips in case of overtemperature.
- The frequency converter is protected against short-circuits between motor terminals U, V, W.
- If a motor phase is missing, the frequency converter trips and issues an alarm.
- If a mains phase is missing, the frequency converter trips or issues a warning (depending on the load).
- Monitoring of the intermediate circuit voltage ensures that the frequency converter trips if the intermediate circuit voltage is too low or too high.
- The frequency converter is protected against earth 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
Max. 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/min.
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 100.000 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+), 0-400 Hz (u/f)
Switching on output	Unlimited
Ramp times	0.05 - 3600 sec.
Cable lengths and cross sections	
Max. motor cable length, screened/armoured (EMC correct installation)	15 m
Max. motor cable length, unscreened/unarmoured	50 m
Max. cross section to motor, mains*	
Connection to load sharing/brake (M1, M2, M3)	6.3 mm insulated Faston Plugs
Max. cross section to load sharing/brake (M4, M5)	16 mm^2/6 AWG
Maximum cross section to control terminals, rigid wire	1.5 mm^2/16 AWG (2 x 0.75 mm^2)
Maximum cross section to control terminals, flexible cable	1 mm^2/18 AWG
Maximum cross section to control terminals, cable with enclosed core	0.5 mm^2/20 AWG
Minimum cross section to control terminals	0.25 mm^2

** See tables for mains supply 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_i	approx. 4 k
Max. pulse frequency at terminal 33	5000 Hz
Min. pulse frequency at terminal 33	20 Hz

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	approx. 10 kΩ
Max. voltage	20 V
Current level	0/4 to 20 mA (scaleable)
Input resistance, R_i	approx. 200 Ω
Max. current	30 mA

Analog output	
Number of programmable analog outputs	1
Terminal number	42
Current range at analog output	0/4 - 20 mA
Max. load to common at analog output	500 Ω
Max. voltage at analog output	17 V
Accuracy on analog output	Max. error: 0.8 % of full scale
Scan interval	4 msec
Resolution on analog output	8 bit

Control card, RS-485 serial communication	
Terminal number	68 (P,TX+, RX+), 69 (N,TX-, RX-)
Terminal number 61	Common for terminals 68 and 69

Control card, 24 V DC output	
Terminal number	12
Max. load (M1 and M2)	160 mA
Max. load (M3)	30 mA
Max. load (M4 and M5)	200 mA

Relay output	
Programmable relay output	1
Relay 01 Terminal number	01-03 (break), 01-02(make)
Max. terminal load (AC-1)[1)] on 01-02 (NO) (Resistive load)	250 V AC, 2 A
Max. terminal load (AC-15)[1)] on 01-02 (NO) (Inductive load @ cosφ 0.4)	250 V AC, 0.2 A
Max. terminal load (DC-1)[1)] on 01-02 (NO) (Resistive load)	30 V DC, 2 A
Max. terminal load (DC-13)[1)] on 01-02 (NO) (Inductive load)	24 V DC, 0.1A
Max. terminal load (AC-1)[1)] on 01-03 (NC) (Resistive load)	250 V AC, 2 A
Max. terminal load (AC-15)[1)] on 01-03 (NC) (Inductive load @ cosφ 0.4)	250 V AC, 0.2A
Max. terminal load (DC-1)[1)] on 01-03 (NC) (Resistive load)	30 V DC, 2 A
Min. 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 ±0.5 V
Max. load	25 mA

NOTE

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

Surroundings	
Enclosure	IP 20
Enclosure kit available	IP 21, TYPE 1
Vibration test	1.0 g
Max. 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	Max. 40 °C
Derating for high ambient temperature, see 4.2.2 Derating for Ambient Temperature	
Minimum ambient temperature during full-scale operation	0 °C
Minimum ambient temperature at reduced performance	- 10 °C
Temperature during storage/transport	-25 - +65/70 °C
Maximum altitude above sea level without derating	1000 m
Maximum altitude above sea level with derating	3000 m
Derating for high altitude, see section on special conditions	
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
See 4.2 Special Condition	

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