Contents

1. How to Read this Design Guide

1.1.1. Copyright, Limitation of Liability and Revision Rights

1.1.2. Available Literature for VLT AQUA Drive

- VLT® AQUA Drive Operating Instructions MG.20.Mx.yy provide the neccessary information for getting the drive up and running.
- VLT® AQUA Drive Design Guide MG.20.Nx.yy entails all technical information about the drive and customer design and applications.
- VLT® AQUA Drive Programming Guide MN.20.Ox.yy provides information on how to programme and includes complete parameter descriptions.
- VLT® AQUA Drive FC 200 Profibus MG.33.Cx.yy
- VLT® AQUA Drive FC 200 DeviceNet MG.33.Dx.yy
- VLT® AQUA Drive FC 200 Cascade Controller MI.38.Cx.yy
- Application Note MN20B102: Master/Follower Operation Application
- Application Note MN20A102: Submersible Pump Application
- Instruction MI.38.Bx.yy: Installation Instruction for Mounting Brackets Enclosure type A5, B1, B2, C1 and C2 IP21, IP55 or IP66
- Instruction MI.90.Lx.yy: Analog I/O Option MCB109
- Instruction MI.33.Hx.yy: Panel through mount kit

x = Revision number
yy = Language code

technical literature is also available online at
www.danfoss.com/BusinessAreas/DrivesSolutions/Documentations/Technical+Documentation.htm.

1.1.3. Approvals

1.1.4. Symbols

Symbols used in this guide.

NB!
Indicates something to be noted by the reader.

Indicates a general warning.

Indicates a high-voltage warning.

*	Indicates default setting

1.1.5. Abbreviations

Alternating current	AC
American wire gauge	AWG
Ampere/AMP	A
Automatic Motor Adaptation	AMA
Current limit	I_{LIM}
Degrees Celsius	°C
Direct current	DC
Drive Dependent	D-TYPE
Electro Magnetic Compatibility	EMC
Electronic Thermal Relay	ETR
Drive	FC
Gram	g
Hertz	Hz
Kilohertz	kHz
Local Control Panel	
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	$U_{M,N}$
Parameter	par.
Protective Extra Low Voltage	PELV
Printed Circuit Board	PCB
Rated Inverter Output Current	I_{INV}
Revolutions Per Minute	RPM
Regenerative terminals	Regen
Second	s
Synchronous Motor Speed	n_s
Torque limit	T_{LIM}
Volts	V

1.1.6. Definitions

Drive:

$I_{VLT,MAX}$

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 two groups. Functions in group 1 have higher priority than functions in group 2.	Grou p 1 Grou p 2	Reset, Coasting stop, Reset and Coasting stop, Quick-stop, DC braking, Stop and the "Off" key. 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).

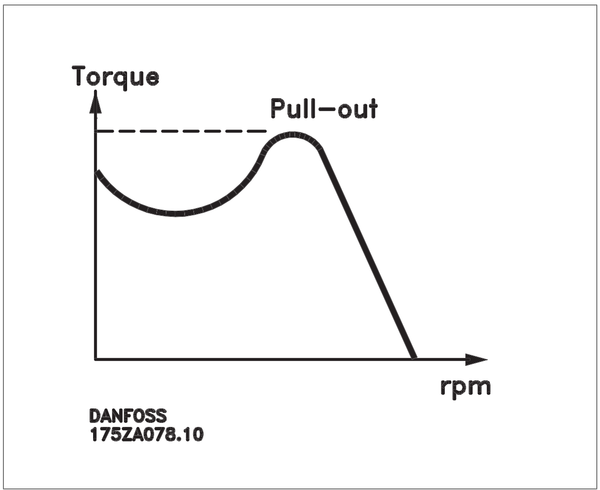
$n_{M,N}$
The rated motor speed (nameplate data).

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

$T_{M,N}$
The rated torque (motor).

U_M
The instantaneous motor voltage.

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



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.

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

Ref_{MAX}

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

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 par. 3-02.

Miscellaneous:

Analog Inputs

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

Analog Outputs

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

Automatic Motor Adaptation, AMA

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

Brake Resistor

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

CT Characteristics

Constant torque characteristics used for positive displacement pumps and blowers.

Digital Inputs

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

Digital Outputs

The drive features two Solid State outputs that can supply a 24 V DC (max. 40 mA) signal.

DSP

Digital Signal Processor.

1

Relay Outputs:
The frequency converter drive 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.

GLCP:
Graphical Local Control Panel (LCP102)

Initialising
If initialising is carried out (par. 14-22), the programmable parameters of the frequency converter return to their default settings.

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 3 metres from the frequency converter, i.e. in a front panel by means of the installation kit option.
The Local Control Panel is available in two versions:

- Numerical LCP101 (NLCP)
- Graphical LCP102 (GLCP)

lsb
Least significant bit.

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

msb
Most significant bit.

NLCP
Numerical Local Control Panel LCP101

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.

PID Controller
The PID 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 four Set-ups. Change between the four parameter Set-ups and edit one Set-up, while another Set-up is active.

SFAVM
Switching pattern called S tator F lux oriented A synchronous V ector M odulation (par. 14-00).

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).

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

Trip Locked
A state entered in fault situations when the frequency converter is protecting itself and requiring physical intervention, e.g. if the frequency converter is subject to a short circuit on the output. A locked trip can only be cancelled by cutting off mains, removing the cause of the fault, and reconnecting the frequency converter. Restart is prevented until the trip state is cancelled by activating reset or, in some cases, by being programmed to reset automatically. Trip 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.

60° AVM
Switching pattern called 60°Asynchronous Vector Modulation (par. 14-00).

1.1.7. 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.
The frequency converters' built-in DC coils produce a high power factor, which minimises the imposed load on the mains supply.

2

2. Introduction to VLT AQUA Drive

2.1. Safety

2.1.1. Safety note

The voltage of the frequency converter is dangerous whenever connected to mains. Incorrect installation of the motor, frequency converter or fieldbus may cause damage to the equipment, serious personal injury or death. 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 control panel 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 3.5 mA.
5. Protection against motor overload is set by par. 1-90 *Motor Thermal Protection*. If this function is desired, set par. 1-90 to data value [ETR trip] (default value) or data value [ETR warning]. Note: The function is initialised 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. Please note that the frequency converter has more voltage inputs than L1, L2 and L3, when load sharing (linking of DC intermediate circuit) and external 24 V DC have been installed. Check that all voltage inputs have been disconnected and that the necessary time has passed before commencing repair work.

Installation at High Altitudes

By altitudes above 2 km, please contact Danfoss Drives regarding PELV.

Warning against 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:
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, such as external 24 V DC, load sharing (linkage of DC intermediate circuit), as well as the motor connection for kinetic back up.

Refer to *VLT® AQUA Drive Operating Instructions MG.20.MX.YY* for further safety guidelines.

2.1.2. Caution

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. Wait at least as follows before doing service on the frequency converter:

Voltage	Min. Waiting Time			
	4 min.	15 min.	**20 min.**	**30 min.**
200 - 240 V	0.25 - 3.7 kW	5.5 - 45 kW		
380 - 480 V	0.37 - 7.5 kW	11 - 90 kW	110 - 250 kW	315 - 450 kW
525-600 V	0.75 kW - 7.5 kW		110 - 250 kW	315 - 560 kW
525-690 V			45 - 400 kW	450 - 630 kW

Be aware that there may be high voltage on the DC link even when the LEDs are turned off.

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. Software Version

2.2.1. Software Version and Approvals

VLT AQUA Drive

Software version: 1.24

This manual can be used with all VLT AQUA Drive frequency converters with software version 1.24.
The software version number can be found in parameter 15-43.

2.3. CE labelling

2.3.1. CE Conformity and Labelling

What is CE Conformity and Labelling?
The purpose of CE labelling is to avoid technical trade obstacles within EFTA and the EU. The EU has introduced the CE label as a simple way of showing whether a product complies with the relevant EU directives. The CE label says nothing about the specifications or quality of the product. Frequency converters are regulated by 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 labelled in accordance with the low-voltage directive of January 1, 1997. The directive applies to all electrical equipment and appliances used in the 50 - 1000 V AC and the 75 - 1500 V DC voltage ranges. 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. 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.

2.3.2. 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 labelling.

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 labelled in accordance with the EMC directive.
2. The frequency converter is sold for installation in a plant. The plant is built up by professionals of the trade. It could be a production plant or a heating/ventilation plant designed and installed by professionals of the trade. Neither the frequency converter nor the finished plant has to be CE labelled under the EMC directive. However, the unit must comply with the basic EMC requirements of the directive. This is ensured by using components, appliances, and systems that are CE labelled under the EMC directive.
3. The frequency converter is sold as part of a complete system. The system is being marketed as complete and could e.g. be an air-conditioning system. The complete system must be CE labelled in accordance with the EMC directive. The manufacturer can ensure CE labelling under the EMC directive either by using CE labelled components or by testing the EMC of the system. If he chooses to use only CE labelled components, he does not have to test the entire system.

2.3.3. Frequency Converter and CE Labelling

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

However, CE labelling may cover many different specifications. 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.

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

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

The Design Guide offers detailed instructions for installation to ensure EMC-correct installation. Furthermore, specifies which our different products comply with.

gladly provides other types of assistance that can help you obtain the best EMC result.

2.3.4. 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, 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*.

2.4. Air humidity

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

2.5. Aggressive Environments

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

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 IP 54/55. As an extra protection, coated printet circuit boards can be orded as an option.

Airborne Particles such as dust may cause mechanical, electrical, or thermal failure in the frequency converter. A typical indicator of excessive levels of airborne particles is dust particles around the frequency converter fan. In very dusty environments, use equipment with enclosure rating IP 54/55 or a cabinet for IP 00/IP 20/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.

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

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

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

2.6. 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

2.7. Advantages

2.7.1. 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 the text *The Laws of Proportionality*.

2.7.2. 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.

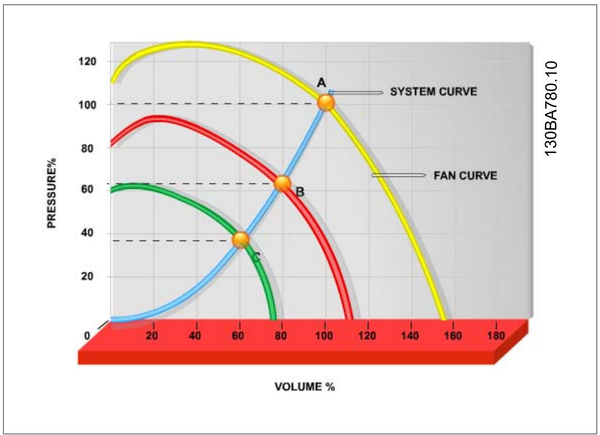


Illustration 2.1: The graph is showing fan curves (A, B and C) for reduced fan volumes.

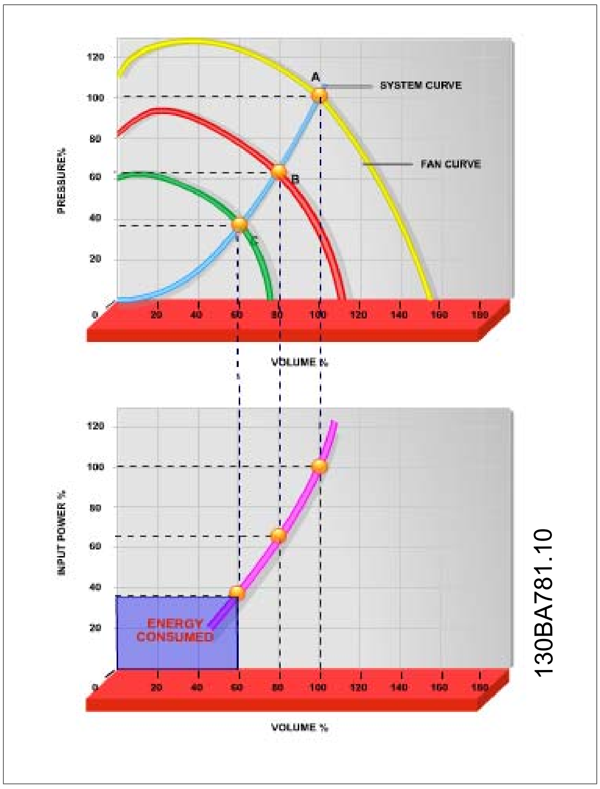


Illustration 2.2: When using a frequency converter to reduce fan capacity to 60% - more than 50% energy savings may be obtained in typical applications.

2.7.3. Example of energy savings

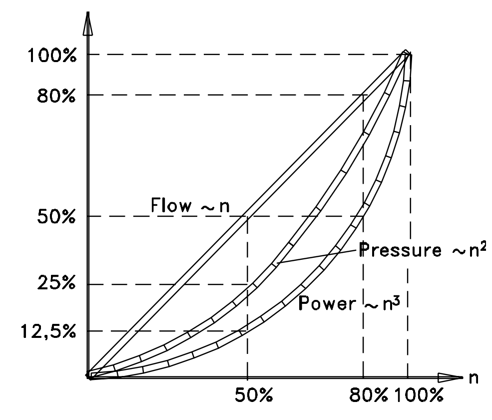
As can be seen from the figure (the laws of proportionality), the flow is controlled by changing the rpm. By reducing the speed only 20% from the rated speed, the flow is also reduced by 20%. This is because the flow is directly proportional to the rpm. The consumption of electricity, however, is reduced 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

The figure below 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



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

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

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

2.7.4. Example with varying flow over 1 year

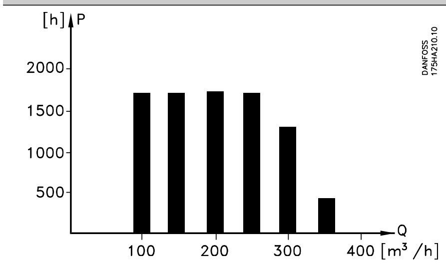
The example below is calculated on the basis of pump characteristics obtained from a pump datasheet.

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.

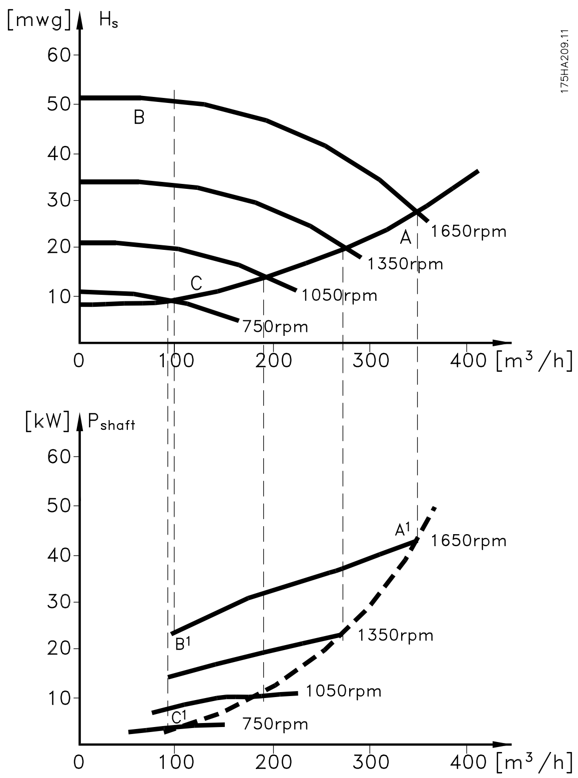
Energy savings

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

Flow distribution over 1 year



2



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

2.7.5. 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 PID control.

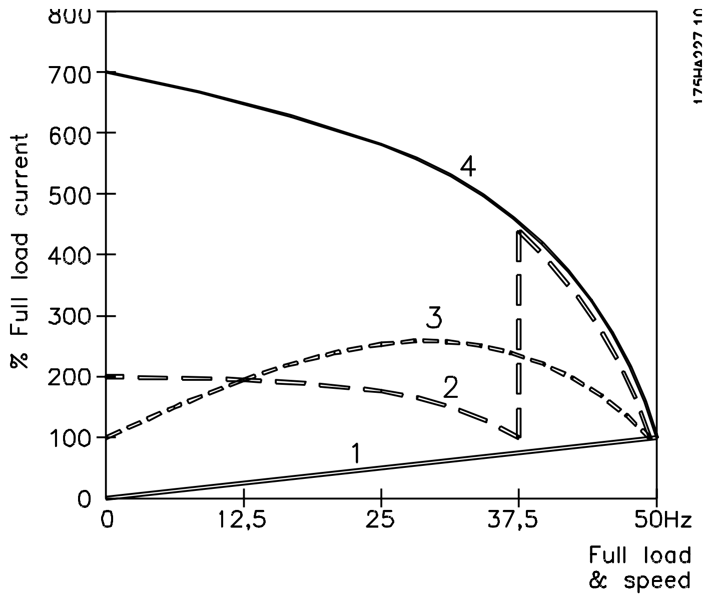
2.7.6. Cos φ compensation

Generally speaking, a frequency converter with a cos φ of 1 provides power factor correction for the cos φ of the motor, which means that there is no need to make allowance for the cos φ of the motor when sizing the power factor correction unit.

2.7.7. 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 figure below, a frequency converter does not consume more than rated current.



1 = VLT AQUA Drive	
2 = Star/delta starter	
3 = Soft-starter	
4 = Start directly on mains	

2

2.8. VLT AQUA Controls

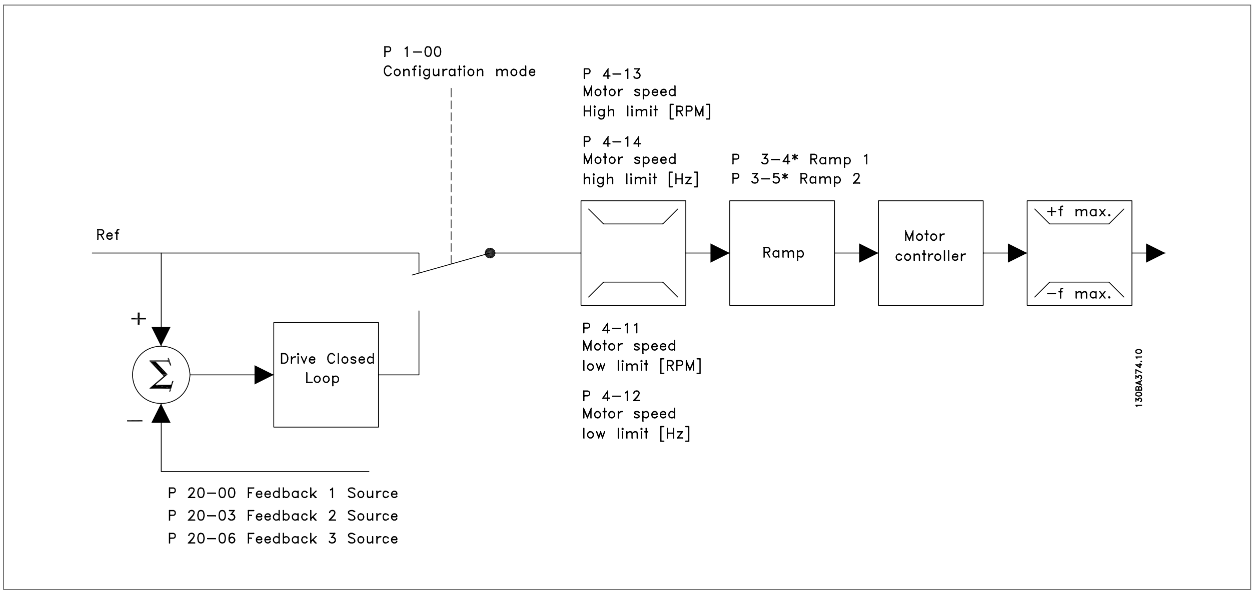
2.8.1. Control Principle

A frequency converter rectifies AC voltage from mains into DC voltage, after which this DC voltage is converted into a AC current with a variable amplitude and frequency.

The motor is supplied with variable voltage / current and frequency, which enables infinitely variable speed control of three-phased, standard AC motors.

2.8.2. Control Structure

Control structure in open loop and closed loop configurations:



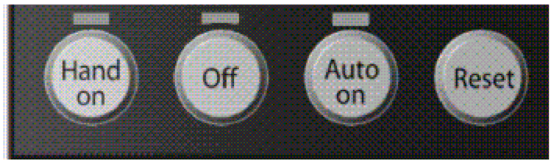
In the configuration shown in the illustration above, par. 1-00 is set to *Open loop* [0]. The resulting reference from the reference handling system is received and fed through the ramp limitation and speed limitation before being sent to the motor control. The output of the motor control is then limited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

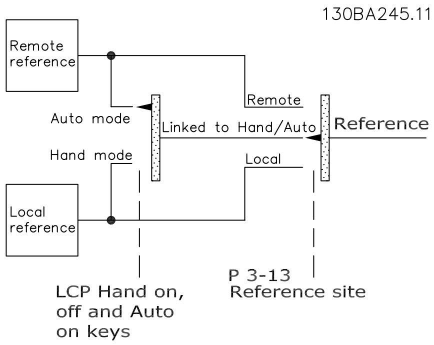
Select *Closed loop* [3] in par. 1-00 to use the PID controller for closed loop control of e.g. flow, level or pressure in the controlled application. The PID parameters are located in par. group 20-**.

2.8.3. 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 and digital inputs and serial bus.
If allowed in par. 0-40 [Hand *on] Key on LCP*, par. 0-41 [Off] *Key on LCP*, par. 0-42 [Auto *on] Key on LCP*, and par. 0-43 [Reset] *Key on LCP*, it is possible to start and stop the frequency converter via the using the [Hand ON] and [Off] keys. Alarms can be reset via the [RESET] key. After pressing the [Hand On] key, the frequency converter goes into Hand Mode and follows (as default) the Local reference set by using the arrow keys.

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





Active Reference and Configuration Mode

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

In par. 3-13 Reference *Site* the local reference can be permanently selected by selecting *Local* [2].
To permanently select the remote reference select *Remote* [1]. By selecting *Linked to Hand/Auto* [0] (default) the reference site will depend on which mode is active. (Hand Mode or Auto Mode).

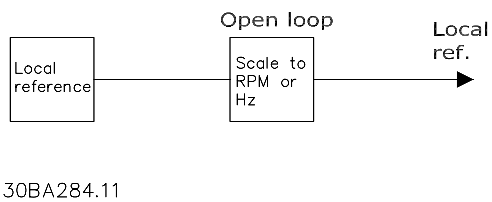
Hand Off Auto Keys	**Reference Site par. 3-13 Reference *Site***	**Active Reference**
Hand	Linked to Hand / Auto	Local
Hand -> Off	Linked to Hand / Auto	Local
Auto	Linked to Hand / Auto	Remote
Auto -> Off	Linked to Hand / Auto	Remote
All keys	Local	Local
All keys	Remote	Remote

The table shows under which conditions either the Local reference or the Remote reference is active. One of them is always active, but both can not be active at the same time.

NB!
Local Ref. will be restored at power-down.

par. 1-00 Configuration *Mode* determines what kind of application control principle (i.e. Open Loop or Closed loop) is used when the Remote reference is active (see table above for the conditions).

Reference Handling - Local Reference



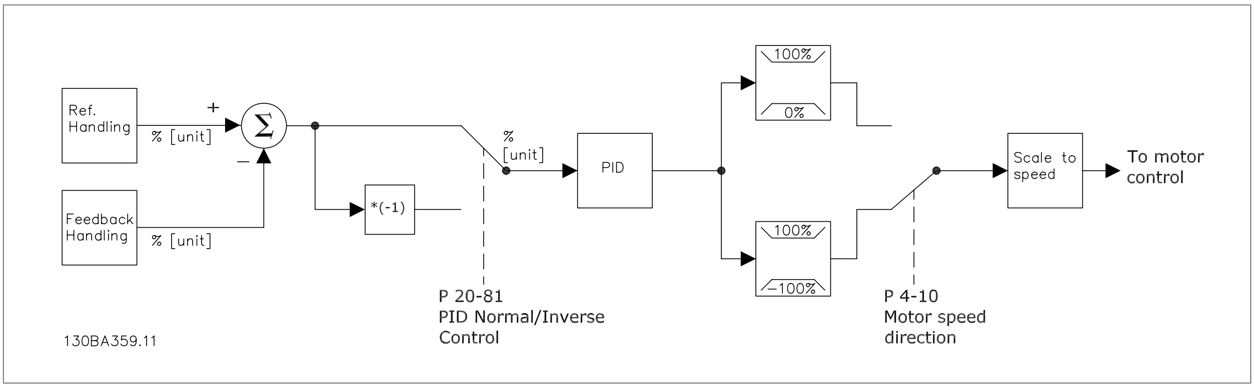
2

2.9. PID

2.9.1. Closed Loop (PID) Controller

The drive's Closed Loop Controller allows the drive to become an integral part of the controlled system. The drive receives a feedback signal from a sensor in the system. It then compares this feedback to a setpoint reference value and determines the error, if any, between these two signals. It then adjusts the speed of the motor to correct this error.

For example, consider a pump application where the speed of a pump is to be controlled so that the static pressure in a pipe is constant. The desired static pressure value is supplied to the drive as the setpoint reference. A static pressure sensor measures the actual static pressure in the pipe and supplies this to the drive as a feedback signal. If the feedback signal is greater than the setpoint reference, the drive will slow down to reduce the pressure. In a similar way, if the pipe pressure is lower than the setpoint reference, the drive will automatically speed up to increase the pressure provided by the pump.



NB!
While the default values for the drive'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. It is also possible to autotune the PI constants.

The figure is a block diagram of the drive's Closed Loop Controller. The details of the Reference Handling block and Feedback Handling block are described in their respective sections below.

The following parameters are relevant for a simple PID control application:

Parameter		Description of function
Feedback 1 Source	par. 20-00	Select the source for Feedback 1. This is most commonly an analog input, but other sources are also available. Use the scaling of this input to provide the appropriate values for this signal. By default, Analog Input 54 is the default source for Feedback 1.
Reference/Feedback Unit	par 20-12	Select the unit for the setpoint reference and feedback for the drive's Closed Loop Controller. Note: Because a conversion can be applied to the feedback signal before it is used by the Closed Loop Controller, the Reference/Feedback Unit (par. 20-12) may not be the same as the Feedback Source Unit (par. 20-02, 20-05 and 20-08).
PID Normal/Inverse Control	par. 20-81	Select *Normal* [0] if the motor's speed should decrease when the feedback is greater than the setpoint reference. Select *Inverse* [1] if the motor's speed should increase when the feedback is greater than the setpoint reference.
PID Proportional Gain	par. 20-93	This parameter adjusts the output of the drive's closed loop controlled based on the error between the feedback and the setpoint reference. Quick controller response is obtained when this value is large. However, if too large of a value is used, the drive's output frequency may become unstable.
PID Integral Time	par. 20-94	The integrator adds over time (integrates) the error between the feedback and the setpoint reference. This is required to ensure that the error approaches zero. Quick controller response is obtained when this value is small. However, if too small of a value is used, the drive's output frequency may become unstable. A setting of 10000 s disables the integrator.

This table summarizes the parameters that are needed to set up the drive's Closed Loop Controller when a single feedback signal with no conversion is compared to a single setpoint. This is the most common type of Closed Loop Controller.

2.9.2. Closed Loop Control Relevant Parameters

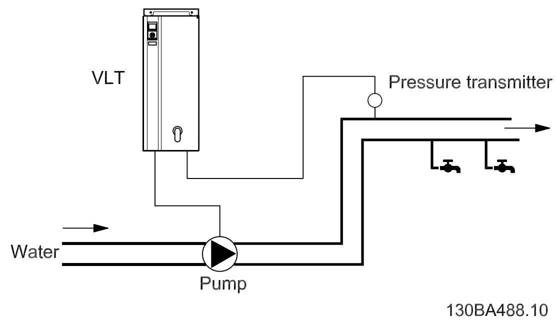
The drive's Closed Loop Controller is capable of handling more complex applications, such as situations where a conversion function is applied to the feedback signal or situations where multiple feedback signals and/or setpoint references are used. The below table summarizes the additional parameters that may be useful in such applications.

2

Parameter	Par. No.	Description of function
Feedback 2 Source Feedback 3 Source	20-03 20-06	Select the source, if any, for Feedback 2 or 3. This is most commonly a drive analog input, but other sources are also available. Par. 20-20 determines how multiple feedback signals will be processed by the drive's Closed Loop Controller. By default, these are set to *No function* [0].
Feedback 1 Conversion Feedback 2 Conversion Feedback 3 Conversion	20-01 20-04 20-07	These are used to convert the feedback signal from one type to another, for example from pressure to flow. $Flow = \sqrt{Pressure}$
Reference Feedback	20-12	For setting the unit used for setpoint reference and feedback.
Feedback Function	20-20	When multiple feedbacks or setpoints are used, this determines how they will be processed by the drive's Closed Loop Controller.
Setpoint 1 Setpoint 2 Setpoint 3 Setpoint Adjustment Factor	20-21 20-22 20-23 20-29	These setpoints can be used to provide a setpoint reference to the drive's Closed Loop Controller. Par. 20-20 determines how multiple setpoint references will be processed. Any other references that are activated in par. group 3-1* will add to these values. Par. 20-29 can be used to reduce the setpoint at low flow benefiting from a reduced pipe resistance at reduced flow.
PID Start Speed [RPM] PID Start Speed [Hz]	20-82 20-83	The parameter that is visible will depend on the setting of par. 0-02, Motor Speed Unit. In some applications, after a start command it is important to quickly ramp the motor up to some pre-determined speed before activating the drive's Closed Loop Controller. This parameter defines that starting speed.
On Reference Bandwidth	20-84	This determines how close the feedback must be to the setpoint reference for the drive to indicate that the feedback is equal to the setpoint.
PID Anti Windup	20-91	*On* [1] effectively disables the Closed Loop Controller's integral function when it is not possible to adjust the output frequency of the drive to correct the error. This allows the controller to respond more quickly once it can again control the system. *Off* [0] disables this function, making the integral function stay active continuously.
PID Differentiation Time	20-95	This controls the output of the drive's Closed Loop Controller based on the rate of change of feedback. While this can provide fast controller response, such response is seldom needed in Water systems. The default value for this parameter is Off, or 0.00 s.
PID Diff. Gain Limit	20-96	Because the differentiator responds to the rate of change of the feedback, a rapid change can cause a large, undesired change in the output of the controller. This is used to limit the maximum effect of the differentiator. This is not active when par. 20-95 is set to Off.
Flow Compensation Square-linear Curve Approximation Work Point Calculation Speed at No-Flow [RPM] Speed at No-Flow [Hz] Speed at Design Point [RPM] Speed at Design Point [Hz] Pressure at No-Flow Speed Pressure at Rated Speed Flow at Design Point Flow at Rated Speed	22-80 22-81 22-82 22-83 22-84 22-85 22-86 22-87 22-88 22-89 22-90	It is sometimes the case that it is not possible for a pressure transducer to be placed at a remote point in the system and it can only be located close to the fan/pump outlet. Flow compensation operates by adjusting the setpoint according to the output frequency, which is almost proportional to flow, thus compensating for higher losses at higher flow rates. These parameters are used for setting up flow compensation.
Lowpass Filter Time : Analog Input 53 Analog Input 54 Digital (pulse) input 29 Digital (pulse) input 33	6-16 6-26 5-54 5-59	This is used to filter out high frequency noise from the feedback signal. The value entered here is the time constant for the low pass filter. The cut-off frequency in Hz can be calculated as follows: $F_{cut-off} = \frac{1}{2\pi T_{lowpass}}$ Variations in the feedback signal whose frequency is below $F_{cut-off}$ will be used by the drive's Closed Loop Controller, while variations at a higher frequency are considered to be noise and will be attenuated. Large values of Lowpass Filter Time will provide more filtering, but may cause the controller to not respond to actual variations in the feedback signal.

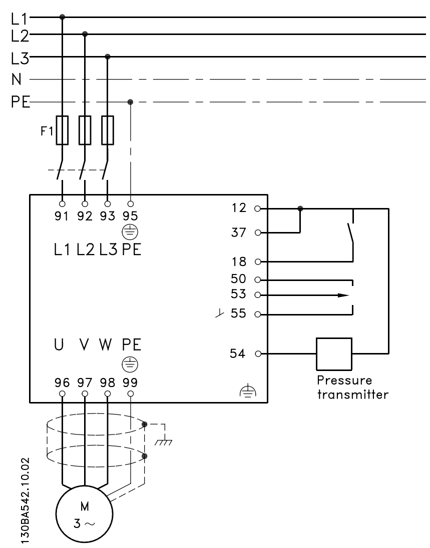
2.9.3. Example of Closed Loop PID Control

The following is an example of a Closed Loop Control for a booster pump application:



In a water distribution system, the pressure is to be maintained at a constant value. The desired pressure (setpoint) is set between 0 and 10 Bar using a 0-10 volt potentiometer or can be set by a parameter. The pressure sensor has a range of 0 to 10 Bar and uses a two-wire transmitter to provide a 4-20 mA signal. The output frequency range of the drive is 10 to 50 Hz.

1. Start/Stop via switch connected between terminals 12 (+24 V) and 18.
2. Pressure reference via a potentiometer (0-10 Bar, 0-10 V) connected to terminals 50 (+10 V), 53 (input) and 55 (common).
3. Pressure feedback via transmitter (0-10 Bar, 4-20 mA) connected to terminal 54. Switch S202 behind the Local Control Panel set to ON (current input).



2.9.4. Programming Order

Function	Par. no.	Setting
1) Make sure the motor runs properly. Do the following:		
Set the drive to control the motor based on drive output frequency.	0-02	*Hz* [1]
Set the motor parameters using nameplate data.	1-2*	As specified by motor name plate
Run Automatic Motor Adaptation.	1-29	*Enable complete AMA* [1] and then run the AMA function.
2) Check that the motor is running in the right direction.		
Press the "Hand On" LCP key and the ^ key to make the motor turn slowly. Check that the motor runs in the correct direction.		If the motor runs in the wrong direction, remove power temporarily and reverse two of the motor phases.
3) Make sure the frequency converter limits are set to safe values		
Check that the ramp settings are within capabilities of the drive and allowed application operating specifications.	3-41 3-42	60 sec. 60 sec. Depends on motor/load size! Also active in Hand mode.
Prohibit the motor from reversing (if necessary)	4-10	*Clockwise* [0]
Set acceptable limits for the motor speed.	4-12 4-14 4-19	10 Hz, *Motor min speed* 50 Hz, *Motor max speed* 50 Hz, *Drive max output frequency*
Switch from open loop to closed loop.	1-00	*Closed Loop* [3]
4) Configure the feedback to the PID controller.		
Set up Analog Input 54 as a feedback input.	20-00	*Analog input 54* [2] (default)
Select the appropriate reference/feedback unit.	20-12	*Bar* [71]
5) Configure the setpoint reference for the PID controller.		
Set acceptable limits for the setpoint reference.	3-02 3-03	0 Bar 10 Bar
Set up Analog Input 53 as Reference 1 Source.	3-15	*Analog input 53* [1] (default)
6) Scale the analog inputs used for setpoint reference and feedback.		
Scale Analog Input 53 for the pressure range of the potentiometer (0 - 10 Bar, 0 - 10 V).	6-10 6-11 6-14 6-15	0 V 10 V (default) 0 Bar 10 Bar
Scale Analog Input 54 for pressure sensor (0 - 10 Bar, 4 - 20 mA)	6-22 6-23 6-24 6-25	4 mA 20 mA (default) 0 Bar 10 Bar
7) Tune the PID controller parameters.		
Adjust the drive's Closed Loop Controller, if needed.	20-93 20-94	See Optimization of the PID Controller, below.
8) Finished!		
Save the parameter setting to the LCP for safe keeping	0-50	*All to LCP* [1]

2.9.5. Tuning the Drive Closed Loop Controller

Once the drive's Closed Loop Controller has been set up, the performance of the controller should be tested. In many cases, its performance may be acceptable using the default values of PID Proportional Gain (par. 20-93) and PID Integral Time (par. 20-94). However, in some cases it may be helpful to optimize these parameter values to provide faster system response while still controlling speed overshoot.

2.9.6. Manual PID Adjustment

1. Start the motor
2. Set par. 20-93 (PID Proportional Gain) to 0.3 and increase it until the feedback signal begins to oscillate. If necessary, start and stop the drive or make step changes in the setpoint reference to attempt to cause oscillation. Next reduce the PID Proportional Gain until the feedback signal stabilizes. Then reduce the proportional gain by 40-60%.
3. Set par. 20-94 (PID Integral Time) to 20 sec. and reduce it until the feedback signal begins to oscillate. If necessary, start and stop the drive or make step changes in the setpoint reference to attempt to cause oscillation. Next, increase the PID Integral Time until the feedback signal stabilizes. Then increase of the Integral Time by 15-50%.
4. Par. 20-95 (PID Differentiation Time) should only be used for very fast-acting systems. The typical value is 25% of the PID Integral Time (par. 20-94). The differentiator should only be used when the setting of the proportional gain and the integral time has been fully optimized. Make sure that oscillations of the feedback signal are sufficiently dampened by the lowpass filter for the feedback signal (par 6 16, 6 26, 5 54 or 5 59, as required).

2.9.7. Ziegler Nichols Tuning Method

In general, the above procedure is sufficient for Water applications. However, other, more sophisticated procedures can also be used. The Ziegler Nichols tuning method is a technique which was developed in the 1940s, but is still commonly used today. It generally provides acceptable control performance using a simple experiment and parameter calculation.

NB!
This method must not be used on applications that could be damaged by oscillations created by marginally stable control settings.

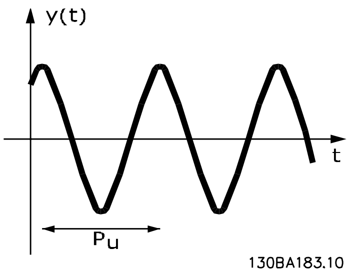


Illustration 2.3: **Figure 1: Marginally stable system**

1. Select proportional control only. That is, PID Integral Time (par. 20-94) is set to Off (10000 s) and PID Differentiation Time (par. 20 95) is also set to Off (0 s, in this case).
2. Increase the value of the PID Proportional Gain (par 20-93) until the point of instability is reached, as indicated by sustained oscillations of the feedback signal. The PID Proportional Gain that causes sustained oscillations is called the critical gain, K_u.
3. Measure the period of oscillation, P_u.
   NOTE: P_u should be measured when the amplitude of oscillation is relatively small. The output must not saturate (i.e., the maximum or minimum feedback signal must not be reached during the test).
4. Use the table below to calculate the necessary PID control parameters.

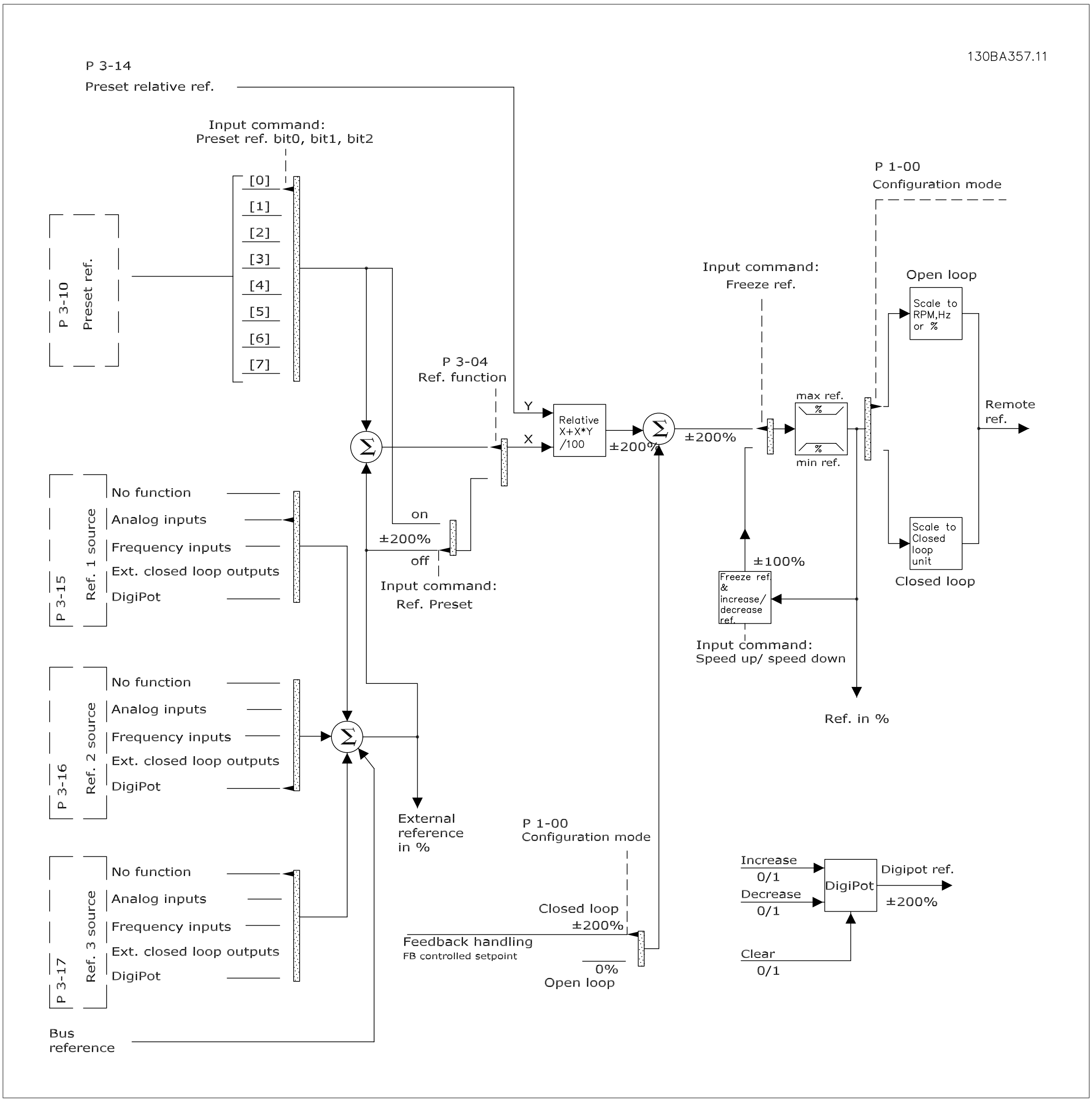
Type of Control	Proportional Gain	Integral Time	Differentiation Time
PI-control	0.45 * K_u	0.833 * P_u	-
PID tight control	0.6 * K_u	0.5 * P_u	0.125 * P_u
PID some overshoot	0.33 * K_u	0.5 * P_u	0.33 * P_u

Ziegler Nichols tuning for regulator, based on a stability boundary.

Experience has shown that the control setting according to Ziegler Nichols rule provides a good closed loop response for many systems. If necessary, the operator can do the final tuning of the control iteratively to modify the response of the control loop.

2.9.8. Reference Handling

A block diagram of how the drive produces the Remote Reference is shown below.



The Remote Reference is comprised of:

- Preset references.
- External references (analog inputs, pulse frequency inputs, digital potentiometer inputs and serial communication bus references).
- The Preset relative reference.
- Feedback controlled setpoint.

Up to 8 preset references can be programmed in the drive. 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 (par. 3-15 Reference *1 Source*, par. 3-16 Reference *2 Source* and par. 3-17 Reference *3 Source*). Digipot is a digital potentiometer. This is also commonly called a Speed Up/Speed Down Control or a Floating Point Control. To set it up, one digital input is programmed to increase the reference while another digital input is programmed to decrease the reference. A third digital input can be used to reset the Digipot reference. 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 par. 3-14 Preset *Relative Reference*.

The scaled reference is calculated as follows:

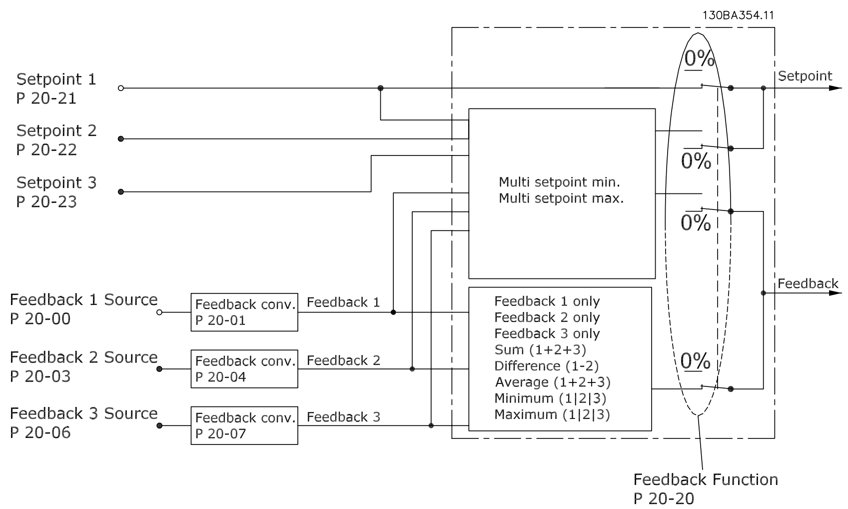
$$Reference = X + X \times \left(\frac{Y}{100}\right)$$

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

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

2.9.9. Feedback Handling

A block diagram of how the drive processes the feedback signal is shown below.



Feedback handling can be configured to work with applications requiring advanced control, such as multiple setpoints and multiple feedbacks. Three types of control are common.

Single Zone, Single Setpoint
Single Zone Single Setpoint is a basic configuration. Setpoint 1 is added to any other reference (if any, see Reference Handling) and the feedback signal is selected using par. 20-20.

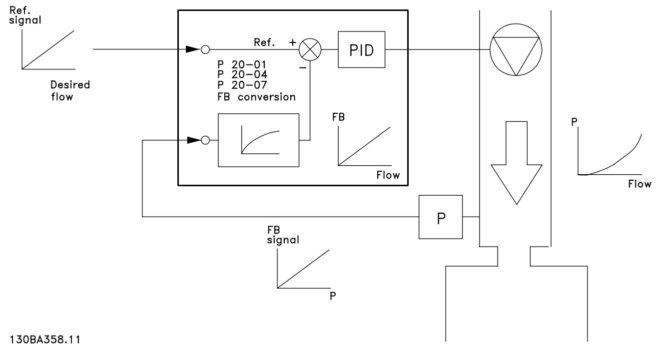
Multi Zone, Single Setpoint
Multi Zone Single Setpoint uses two or three feedback sensors but only one setpoint. The feedbacks can be added, subtracted (only feedback 1 and 2) or averaged. In addition, the maximum or minimum value may be used. Setpoint 1 is used exclusively in this configuration.

If *Multi Setpoint Min* [13] is selected, the setpoint/feedback pair with the largest difference controls the speed of the drive. *Multi Setpoint Maximum* [14] attempts to keep all zones at or below their respective setpoints, while *Multi Setpoint Min* [13] attempts to keep all zones at or above their respective setpoints.

Example:
A two zone two setpoint application Zone 1 setpoint is 15 bar and the feedback is 5.5 bar. Zone 2 setpoint is 4.4 bar and the feedback is 4.6 bar. If *Multi Setpoint Max* [14] is selected, Zone 1's setpoint and feedback are sent to the PID controller, since this has the smaller difference (feedback is higher than setpoint, resulting in a negative difference). If *Multi Setpoint Min* [13] is selected, Zone 2's setpoint and feedback is sent to the PID controller, since this has the larger difference (feedback is lower than setpoint, resulting in a positive difference).

2.9.10. Feedback Conversion

In some applications it may be useful to convert the feedback signal. One example of this is using a pressure signal to provide flow feedback. Since the square root of pressure is proportional to flow, the square root of the pressure signal yields a value proportional to the flow. This is shown below.

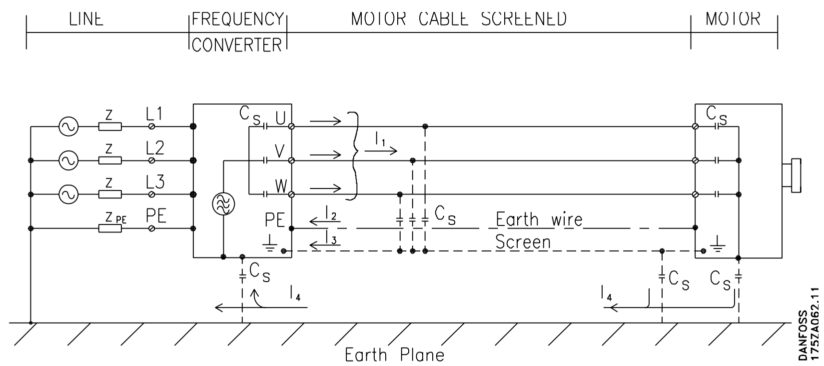


2.10. General aspects of EMC

2.10.1. General Aspects of EMC Emissions

Electrical interference is usually conducted at frequences in the range 150 kHz to 30 MHz. Airborne interference from the drive system in the range 30 MHz to 1 GHz is generated from the inverter, motor cable, and the motor.
As shown in the illustration below, capacitive currents in the motor cable coupled with a high dV/dt from the motor voltage generate leakage currents.
The use of a screened motor cable increases the leakage current (see illustration below) 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 approx. 5 MHz. Since the leakage current (I_1) is carried back to the unit through the screen (I_3), there will in principle only be a small electro-magnetic field (I_4) from the screened motor cable according to the below figure.

The screen reduces the radiated interference but increases the low-frequency interference on the mains. 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.



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.

NB!
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 50 MHz (airborne) is especially generated by the control electronics.

2.10.2. Emission Requirements

According to the EMC product standard for adjustable speed frequency converters EN/IEC61800-3:2004 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 four categories together with the requirements for mains line conducted emissions are given in the table below:

Category	Definition	Conducted emission requirement according to the limits given in EN55011
C1	frequency converters installed in the first environment (home and office) with a supply voltage less than 1000 V.	Class B
C2	frequency converters installed in the first environment (home and office) with a supply voltage less than 1000 V which are neither plug-in nor movable and are intended to be installed and commissioned by a professional.	Class A Group 1
C3	frequency converters installed in the second environment (industrial) with a supply voltage lower than 1000 V.	Class A Group 2
C4	frequency converters installed in the second environment with a supply voltage above 1000 V and rated current above 400 A or intended for use in complex systems.	No limit line. An EMC plan should be made.

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 EN55011
First environment (home and office)	EN/IEC61000-6-3 Emission standard for residential, commercial and light industrial environments.	Class B
Second environment (industrial environment)	EN/IEC61000-6-4 Emission standard for industrial environments.	Class A Group 1

2.10.3. EMC Test Results (Emission)

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

RFI filter type	**Conducted emission.** Maximum shielded cable length.			**Radiated emission**	
	Industrial environment		Housing, trades and light industries	Industrial environment	Housing, trades and light industries
Setup	EN 55011 Class A2	EN 55011 Class A1	EN 55011 Class B	EN 55011 Class A1	EN 55011 Class B
H1	meter	meter	meter		
0.25-45 kW 200-240 V	150	150	50	Yes	No
0.25-90 kW 380-480 V	150	150	50	Yes	No
H2					
0.25-3.7 kW 200-240 V	5	No	No	No	No
5.5-45 kW 200-240 V	25	No	No	No	No
0.25-7.5 kW 380-480 V	5	No	No	No	No
11-90 kW 380-480 V	25	No	No	No	No
110-450 kW 380-480 V	50	No	No	No	No
75-500 kW 525-600 V	150	No	No	No	No
H3					
0.25-45 kW 200-240 V	75	50	10	Yes	No
0.37-90 kW 380-480 V	75	50	10	Yes	No
H4					
110-450 kW 380-480 V	150	150	No	Yes	No
75-315 kW 525-600 V	150	30	No	No	No
Hx					
0.25-90 kW 525-600 V	-	-	-	-	-

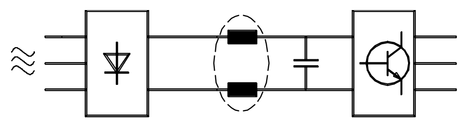
Table 2.1: EMC Test Results (Emission)

2.10.4. General Aspects of Harmonics Emission

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

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

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



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

NB!

To ensure low harmonic currents, the frequency converter is equipped with intermediate circuit coils as standard. This normally reduces the input current I_{RMS} by 40%.

2

The voltage distortion on the mains supply depends on the size of the harmonic currents multiplied by the mains impedance for the frequency in question. The total voltage distortion THD is calculated on the basis of the individual voltage harmonics using this formula:

$$THD\,\% = \sqrt{U_5^2 + U_7^2 + \ldots + U_N^2}$$ (U_N% of U)

2.10.5. Harmonics Emission Requirements

Equipment connected to the public supply network:

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

2.10.6. Harmonics Test Results (Emission)

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

Table 2.2: Harmonic currents compared to the RMS input current

Power sizes up to PK75 in T2 and T4 complies with IEC/EN 61000-3-2 Class A. Power sizes from P1K1 and up to P18K in T2 and up to P75K in T4 complies with IEC/EN 61000-3-12. Table 4, R_{sce} >= 120, THD <= 48% provided that the short-circuit power of the supply S_{sc} is greater than or equal to:

$$S_{SC} = \sqrt{3} \times R_{SCE} \times U_{line} \times I_{equ} = \sqrt{3} \times 120 \times 400 \times I_{equ}$$

at the interface point between the user's supply and the public system.

It is the responsibility of the installer or user of the equipment to ensure, by consultation with the distribution network operator if necessary, that the equipment is connected only to a supply with a short-circuit power S_{sc} greater than or equal to specified above.
Other power sizes can be connected to the public supply network by consultation with the distribution network operator.

2.11. Immunity Requirements

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

In order to document immunity against electrical interference from electrical phenomena, the following immunity tests have been made on a system consisting of a frequency converter (with options if relevant), a screened control cable and a control box with potentiometer, motor cable and motor.
The tests were performed in accordance with the following basic standards:

- **EN 61000-4-2 (IEC 61000-4-2):** Electrostatic discharges (ESD): Simulation of electrostatic discharges from human beings.

- **EN 61000-4-3 (IEC 61000-4-3):** Incoming electromagnetic field radiation, amplitude modulated simulation of the effects of radar and radio communication equipment as well as mobile communications equipment.
- **EN 61000-4-4 (IEC 61000-4-4):** Burst transients: Simulation of interference brought about by switching a contactor, relay or similar devices.
- **EN 61000-4-5 (IEC 61000-4-5):** Surge transients: Simulation of transients brought about e.g. by lightning that strikes near installations.
- **EN 61000-4-6 (IEC 61000-4-6):** RF Common mode: Simulation of the effect from radio-transmission equipment joined by connection cables.

See following EMC immunity form.

Voltage range: 200-240 V, 380-480 V

Basic standard	Burst IEC 61000-4-4	Surge IEC 61000-4-5	ESD IEC 61000-4-2	Radiated electromagnetic field IEC 61000-4-3	RF common mode voltage IEC 61000-4-6
Acceptance criterion	B	B	B	A	A
Line	4 kV CM	2 kV/2 Ω DM 4 kV/12 Ω CM	—	—	10 V_{RMS}
Motor	4 kV CM	4 kV/2 Ω1)	—	—	10 V_{RMS}
Brake	4 kV CM	4 kV/2 Ω1)	—	—	10 V_{RMS}
Load sharing	4 kV CM	4 kV/2 Ω1)	—	—	10 V_{RMS}
Control wires	2 kV CM	2 kV/2 Ω1)	—	—	10 V_{RMS}
Standard bus	2 kV CM	2 kV/2 Ω1)	—	—	10 V_{RMS}
Relay wires	2 kV CM	2 kV/2 Ω1)	—	—	10 V_{RMS}
Application and Fieldbus options	2 kV CM	2 kV/2 Ω1)	—	—	10 V_{RMS}
cable	2 kV CM	2 kV/2 Ω1)	—	—	10 V_{RMS}
External 24 V DC	2 kV CM	0.5 kV/2 Ω DM 1 kV/12 Ω CM	—	—	10 V_{RMS}
Enclosure	—	—	8 kV AD 6 kV CD	10 V/m	—

AD: Air Discharge
CD: Contact Discharge
CM: Common mode
DM: Differential mode

1. Injection on cable shield.

Table 2.3: Immunity

2.12. Galvanic isolation (PELV)

2.12.1. 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 525-600 V units and at grounded Delta leg above 300 V).

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

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

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

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

2

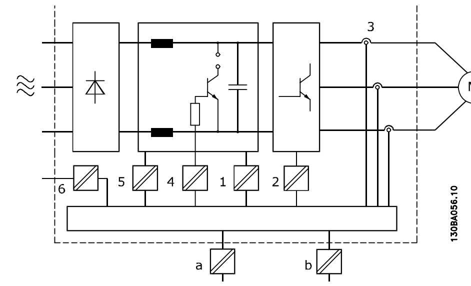


Illustration 2.4: Galvanic isolation

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

Installation at high altitude
380 - 500 V, frame size A, B and C: At altitudes above 2 km, please contact regarding PELV.
380 - 500 V, frame size D, E and F: At altitudes above 3 km, please contact regarding PELV.
525 - 690 V: At altitudes above 2 km, please contact regarding PELV.

2.13. Earth leakage current

2.13.1. Earth Leakage Current

Warning:
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, 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: Please consult the section *Safety>Caution*.
Shorter time than stated in the table is allowed only if indicated on the nameplate for the specific unit.

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 (terminal 95), 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 d.c. current in the protective conductor. Where a residual current device (RCD) is used for extra protection, only an RCD of Type B (time delayed) shall be used on the supply side of this product. See also RCD Application Note MN.90.Gx.yy.
Protective earthing of the frequency converter and the use of RCD's must always follow national and local regulations.

2.14. Control with brake function

2.14.1. Selection of Brake Resistor

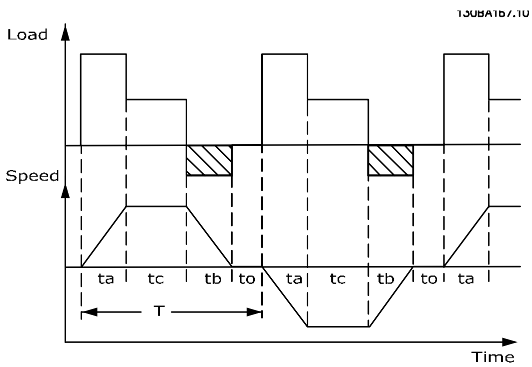
In certain applications, for instance centrifuges, it is desirable to bring the motor to a stop more rapidly than can be achieved through controlling via ramp down or by free-wheeling. In such applications, dynamic braking with a braking resistor may be utilized. Using a braking resistor ensures that the energy is absorbed in the resistor and not in the frequency converter.

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

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

Duty Cycle = t_b/T

T = cycle time in seconds
t_b is the braking time in seconds (as part of the total cycle time)



Danfoss offers brake resistors with duty cycle of 5%, 10% and 40% suitable for use with the FC202 AQUA drive series. If a 10% duty cycle resistor is applied, this is able of absorbing braking power upto 10% of the cycle time with the remaining 90% being used to dissipate heat from the resistor.

For further selection advice, please contact Danfoss.

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

2.14.2. Control with Brake Function

The brake is to limit the voltage in the intermediate circuit when the motor acts as a generator. This occurs, for example, when the load drives the motor and the power accumulates on the DC link. The brake is built up as a chopper circuit with the connection of an external brake resistor.

Placing the brake resistor externally offers the following advantages:
- The brake resistor can be selected on the basis of the application in question.
- The brake energy can be dissipated outside the control panel, i.e. where the energy can be utilized.
- The electronics of the frequency converter will not be overheated if the brake resistor is overloaded.

The brake is protected against short-circuiting of the brake resistor, and the brake transistor is monitored to ensure that short-circuiting of the transistor is detected. A relay/digital output can be used for protecting the brake resistor against overloading in connection with a fault in the frequency converter. In addition, the brake makes it possible to read out the momentary power and the mean power for the latest 120 seconds. The brake can also monitor the power energizing and make sure it does not exceed a limit selected in par. 2-12 Brake *Power Limit (kW)*. In par. 2-13 Brake *Power Monitoring*, select the function to carry out when the power transmitted to the brake resistor exceeds the limit set in par. 2-12 Brake *Power Limit (kW)*.

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

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

2.15. Mechanical brake control

2.15.1. Brake Resistor Cabling

EMC (twisted cables/shielding)
To reduce the electrical noise from the wires between the brake resistor and the frequency converter, the wires must be twisted.

For enhanced EMC performance a metal screen can be used.

2.16. 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 drive 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. You cannot damage the frequency converter in any way by switching on the output. However, fault messages may appear.

Motor-generated Overvoltage
The voltage in the intermediate circuit is increased when the motor acts as a generator.

This occurs in following cases:

1. The load drives the motor, 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. In-correct slip compensation setting may cause higher DC link voltage.

The control unit may attempt to correct the ramp if possible (par. 2-17 *Over-voltage Control*.
The inverter turns off to protect the transistors and the intermediate circuit capacitors when a certain voltage level is reached.
See par. 2-10 and par. 2-17 to select the method used for controlling the intermediate circuit voltage level.

High Temperature
High ambient temperature may overheat the frequency converter.

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.

Static Overload in VVC^plus mode

When the frequency converter is overloaded (the torque limit in par. 4-16/4-17 is reached), the controls reduces the output frequency to reduce the load. If the overload is excessive, a current may occur that makes the frequency converter cut out after approx. 5-10 s.

Operation within the torque limit is limited in time (0-60 s) in par. 14-25.

2.16.1. Motor Thermal Protection

This is the way is protecting the motor from being overheated. It is an electronic feature that simulates a bimetal relay based on internal measurements. The characteristic is shown in the following figure:

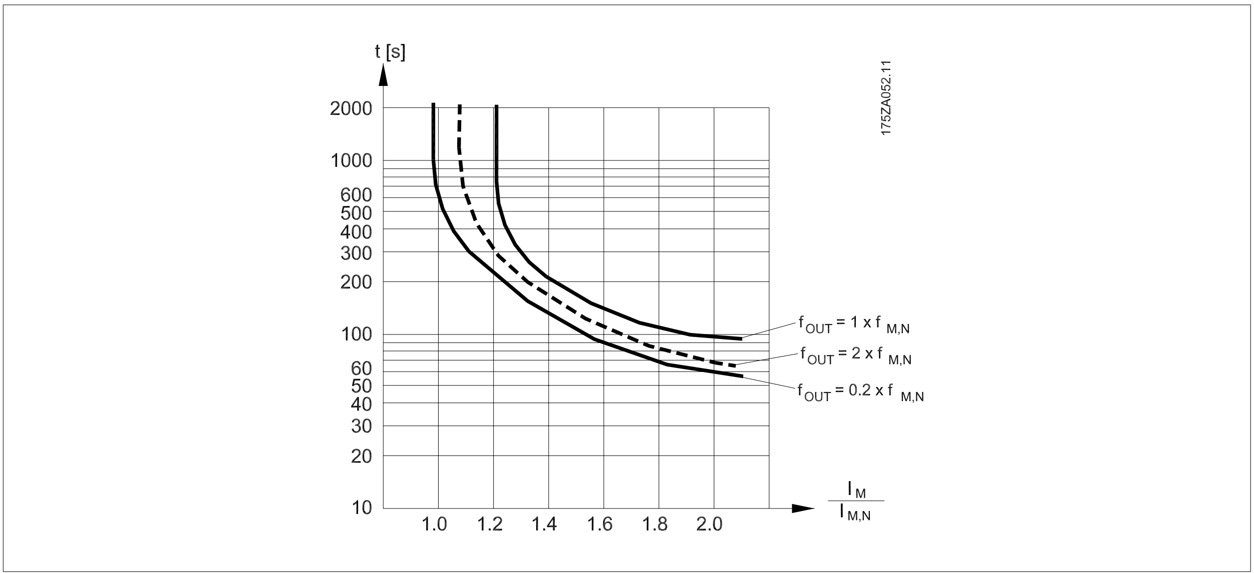


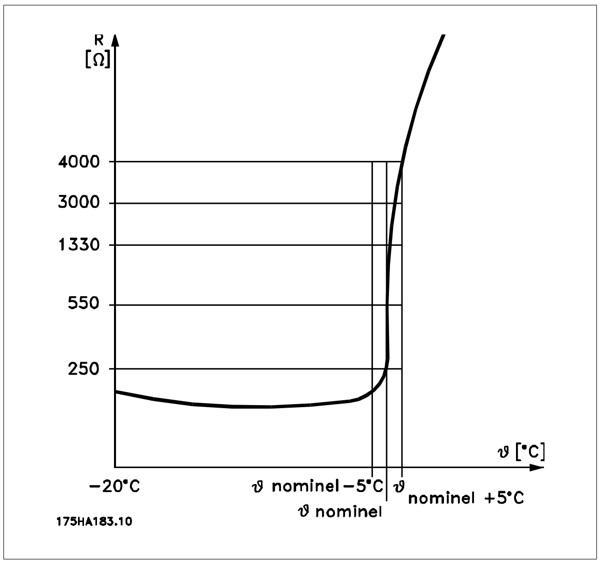
Illustration 2.5: The X-axis is showing the ratio between I_{motor} and I_{motor} nominal. The Y- axis is showing the time in seconds before the ETR cuts off and trips the drive. The curves are showing the characteristic nominal speed at twice the nominal speed and at 0,2x the nominal speed.

It is clear that 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 par. 16-18 Motor *Thermal* in the frequency converter.

The thermistor cut-out value is > 3 kΩ.

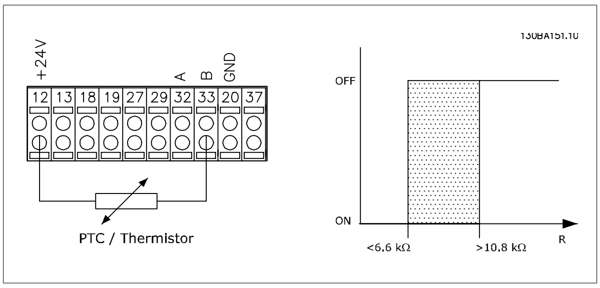
Integrate a thermistor (PTC sensor) in the motor for winding protection.

Motor protection can be implemented using a range of techniques: PTC sensor in motor windings; mechanical thermal switch (Klixon type); or Electronic Thermal Relay (ETR).

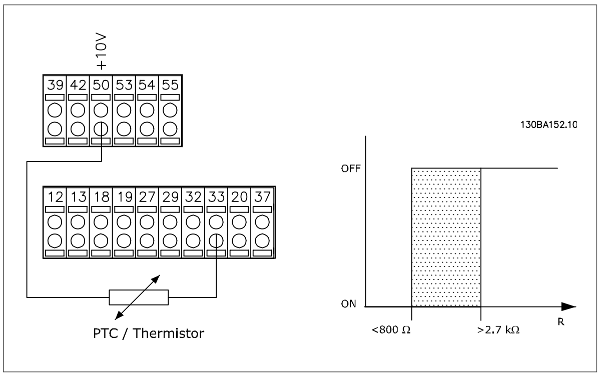


2

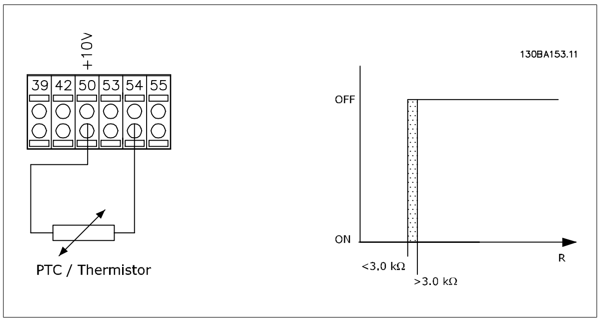
Using a digital input and 24 V as power supply:
Example: The frequency converter trips when the motor temperature is too high.
Parameter set-up:
Set par. 1-90 Motor *Thermal Protection* to *Thermistor Trip* [2]
Set par. 1-93 Thermistor *Source* to *Digital Input 33* [6]



Using a digital input and 10 V as power supply:
Example: The frequency converter trips when the motor temperature is too high.
Parameter set-up:
Set par. 1-90 Motor *Thermal Protection* to *Thermistor Trip* [2]
Set par. 1-93 Thermistor *Source* to *Digital Input 33* [6]



Using an analog input and 10 V as power supply:
Example: The frequency converter trips when the motor temperature is too high.
Parameter set-up:
Set par. 1-90 Motor *Thermal Protection* to *Thermistor Trip* [2]
Set par. 1-93 Thermistor *Source* to *Analog Input 54* [2]
Do not select a reference source.



Input Digital/analog	Supply Voltage Volt	Threshold Cut-out Values
Digital	24 V	< 6.6 kΩ - > 10.8 kΩ
Digital	10 V	< 800Ω - > 2.7 kΩ
Analog	10 V	< 3.0 kΩ - > 3.0 kΩ

NB!
Check that the chosen supply voltage follows the specification of the used thermistor element.

Summary
With the Torque limit feature the motor is protected for being overloaded independent of the speed. With the ETR the motor is protected for being over heated and there is no need for any further motor protection. That means when the motor is heated up the ETR timer controls for how long time the motor can be running at the high temperature before it is stopped in order to prevent over heating. If the motor is overloaded without reaching the temperature where the ETR shuts of the motor, the torque limit is protecting the motor and application for being overloaded.

NB!
ETR is activated in par.   and is controlled in par. 4-16 Torque *Limit Motor Mode*. The time before the torque limit warning trips the frequency converter is set in par. 14-25 Trip *Delay at Torque Limit*.

2.16.2. Safe Stop Operation (optional)

The FC 202 can perform the Safety Function "Uncontrolled Stopping by removal of power" (as defined by draft IEC 61800-5-2) or Stop Category 0 (as defined in EN 60204-1).
It is designed and approved suitable for the requirements of Safety Category 3 in EN 954-1. This functionality is called Safe Stop.
Prior to integration and use of FC 202 Safe Stop in an installation, a thorough risk analysis on the installation must be carried out in order to determine whether the FC 202 Safe Stop functionality and safety category are appropriate and sufficient.
The Safe Stop function is activated by removing the voltage at Terminal 37 of the Safe Inverter. By connecting the Safe Inverter to external safety devices providing a safe relay, an installation for a safe Stop Category 1 can be obtained. The Safe Stop function of FC 202 can be used for asynchronous and synchronous motors.

Safe Stop activation (i.e. removal of 24 V DC voltage supply to terminal 37) does not provide electrical safety.

NB!
The Safe Stop function of FC 202 can be used for asynchronous and synchronous motors. It may happen that two faults occur in the frequency converter's power semiconductor. When using synchronous motors this may cause a residual rotation. The rotation can be calculated to Angle=360/(Number of Poles). The application using synchronous motors must take this into consideration and ensure that this is not a safety critical issue. This situation is not relevant for asynchronous motors.

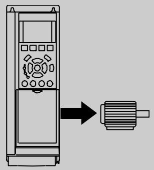
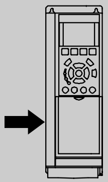
NB!
In order to use the Safe Stop functionality in conformance with the requirements of EN-954-1 Category 3, a number of conditions must be fulfilled by the installation of Safe Stop. Please see section *Safe Stop Installation* for further information.

NB!
The frequency converter does not provide a safety-related protection against unintended or malicious voltage supply to terminal 37 and subsequent reset. Provide this protection via the interrupt device, at the application level, or organisational level.
For more information - see section *Safe Stop Installation*.

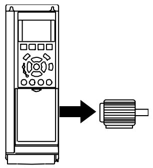
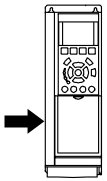
3. VLT AQUA Selection

3.1. General Specifications

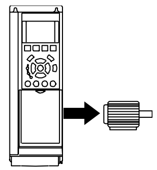
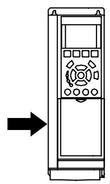
3.1.1. Mains Supply 1 x 200 - 240 VAC

Mains Supply 1 x 200 - 240 VAC - Normal overload 110% for 1 minute					
Frequency converter Typical Shaft Output [kW]		P5K 5	P7K 5	P15K	P22K
Typical Shaft Output [HP] at 240 V		7.5	10	20	30
IP 21 / NEMA 1		B1	B2	C1	C2
IP 55 / NEMA 12		B1	B2	C1	C2
IP 66		B1	B2	C1	C2
Output current					
	Continuous (1 x 200-240 V) [A]	24.2	30.8	59.4	88
	Intermittent (1 x 200-240 V) [A]	26.6	33.4	65.3	96.8
	Continuous kVA (208 V AC) [kVA]	5.00	6.40	12.27	18.30
	Max. cable size: (mains, motor, brake) [[mm^2/ AWG] [2]	10/7	35/2	50/1/0	95/4/0
Max. input current					
	Continuous (1 x 200-240 V) [A]	46	59	111	172
	Intermittent (1 x 200-240 V) [A]	50.6	64.9	122.1	189.2
	Max. pre-fuses[1][A]	80	100	150	200
	Environment				
	Estimated power loss at rated max. load [W] [4]	110	150	300	440
	Weight enclosure IP 21 [kg]	23	27	45	65
	Weight enclosure IP 55 [kg]	23	27	45	65
	Weight enclosure IP 66 [kg]	23	27	45	65
	Efficiency [3]	0.98	0.98	0.98	0.98

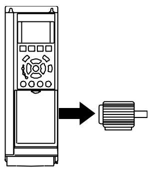
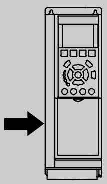
3.1.2. Mains Supply 3 x 200 - 240 VAC

Normal overload 110% for 1 minute										
IP 20 / NEMA Chassis		A2	A2	A2	A2	A2	A2	A2	A3	A3
IP 21 / NEMA 1		A2	A2	A2	A2	A2	A2	A2	A3	A3
IP 55 / NEMA 12		A5	A5	A5	A5	A5	A5	A5	A5	A5
IP 66		A5	A5	A5	A5	A5	A5	A5	A5	A5
Mains supply 200 - 240 VAC										
Frequency converter		PK25	PK37	PK55	PK75	P1K1	P1K5	P2K2	P3K0	P3K7
Typical Shaft Output [kW]		0.25	0.37	0.55	0.75	1.1	1.5	2.2	3	3.7
Typical Shaft Output [HP] at 208 V		0.25	0.37	0.55	0.75	1.5	2.0	2.9	4.0	4.9
Output current										
	Continuous (3 x 200-240 V) [A]	1.8	2.4	3.5	4.6	6.6	7.5	10.6	12.5	16.7
	Intermittent (3 x 200-240 V) [A]	1.98	2.64	3.85	5.06	7.26	8.3	11.7	13.8	18.4
	Continuous kVA (208 V AC) [kVA]	0.65	0.86	1.26	1.66	2.38	2.70	3.82	4.50	6.00
	Max. cable size: (mains, motor, brake) [mm² /AWG] 2)	0.2 - 4 mm² / 4 - 10 AWG								
Max. input current										
	Continuous (3 x 200-240 V) [A]	1.6	2.2	3.2	4.1	5.9	6.8	9.5	11.3	15.0
	Intermittent (3 x 200-240 V) [A]	1.7	2.42	3.52	4.51	6.5	7.5	10.5	12.4	16.5
	Max. pre-fuses1) [A]	10	10	10	10	20	20	20	32	32
	Environment									
	Estimated power loss at rated max. load [W] 4)	21	29	42	54	63	82	116	155	185
	Weight enclosure IP20 [kg]	4.9	4.9	4.9	4.9	4.9	4.9	4.9	6.6	6.6
	Weight enclosure IP21 [kg]	5.5	5.5	5.5	5.5	5.5	5.5	5.5	7.5	7.5
	Weight enclosure IP55 [kg]	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5
	Weight enclosure IP 66 [kg]	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5
	Efficiency 3)	0.94	0.94	0.95	0.95	0.96	0.96	0.96	0.96	0.96

3

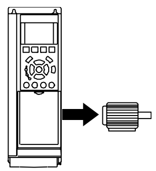
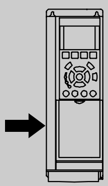
Mains supply 3 x 200 - 240 VAC - Normal overload 110% for 1 minute										
IP 20 / NEMA Chassis (B3+4 and C3+4 may be converted to IP21 using a conversion kit (Please contact Danfoss)		B3	B3	B3	B4	B4	C3	C3	C4	C4
IP 21 / NEMA 1		B1	B1	B1	B2	C1	C1	C1	C2	C2
IP 55 / NEMA 12		B1	B1	B1	B2	C1	C1	C1	C2	C2
IP 66		B1	B1	B1	B2	C1	C1	C1	C2	C2
Frequency converter		P5K5	P7K5	P11K	P15K	P18K	P22K	P30K	P37K	P45K
Typical Shaft Output [kW]		5.5	7.5	11	15	18.5	22	30	37	45
Typical Shaft Output [HP] at 208 V		7.5	10	15	20	25	30	40	50	60
Output current										
	Continuous (3 x 200-240 V) [A]	24.2	30.8	46.2	59.4	74.8	88.0	115	143	170
	Intermittent (3 x 200-240 V) [A]	26.6	33.9	50.8	65.3	82.3	96.8	127	157	187
	Continuous kVA (208 V AC) [kVA]	8.7	11.1	16.6	21.4	26.9	31.7	41.4	51.5	61.2
	Max. cable size:									
	(mains, motor, brake) [mm^2 /AWG] [2]		10/7		35/2		50/1/0		95/4/0	120/250 MCM
Max. input current										
	Continuous (3 x 200-240 V) [A]	22.0	28.0	42.0	54.0	68.0	80.0	104.0	130.0	154.0
	Intermittent (3 x 200-240 V) [A]	24.2	30.8	46.2	59.4	74.8	88.0	114.0	143.0	169.0
	Max. pre-fuses[1] [A]	63	63	63	80	125	125	160	200	250
	Environment:									
	Estimated power loss at rated max. load [W] [4]	269	310	447	602	737	845	1140	1353	1636
	Weight enclosure IP20 [kg]	12	12	12	23.5	23.5	35	35	50	50
	Weight enclosure IP21 [kg]	23	23	23	27	45	45	65	65	65
	Weight enclosure IP55 [kg]	23	23	23	27	45	45	65	65	65
	Weight enclosure IP 66 [kg]	23	23	23	27	45	45	65	65	65
	Efficiency [3]	0.96	0.96	0.96	0.96	0.96	0.97	0.97	0.97	0.97

3.1.3. Mains Supply 1 x 380 - 480 VAC

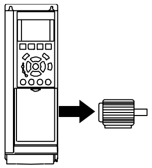
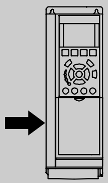
Mains Supply 1x 380 VAC - Normal overload 110% for 1 minute					
Frequency converter Typical Shaft Output [kW]		P7K5 7.5	P11K	P22K	P37K
Typical Shaft Output [HP] at 460 V		10	15	30	50
IP 21 / NEMA 1		B1	B2	C1	C2
IP 55 / NEMA 12		B1	B2	C1	C2
IP 66		B1	B2	C1	C2
Output current					
	Continuous (1 x 380-440 V) [A]	16	24	44	73
	Intermittent (1 x 380-440 V) [A]	17.6	26.4	48.4	80.3
	Continuous (1 x 441-480 V) [A]	14.5	21	40	65
	Intermittent (1 x 441-480 V) [A]	15.4	23.1	44	71.5
	Continuous kVA (400 V AC) [kVA]	11.0	16.6	30.5	50.6
	Continuous kVA (460 V AC) [kVA]	11.6	16.7	31.9	51.8
	Max. cable size: (mains, motor, brake) [[mm^2/ AWG] [2)]	10/7	35/2	50/1/0	120/4/0
Max. input current					
	Continuous (1 x 380-440 V) [A]	33	48	94	151
	Intermittent (1 x 380-440 V) [A]	36	53	103	166
	Continuous (1 x 441-480 V) [A]	30	41	85	135
	Intermittent (1 x 441-480 V) [A]	33	46	93	148
	Max. pre-fuses[1)][A]	63	80	160	250
	Environment				
	Estimated power loss at rated max. load [W] [4)]	300	440	880	1480
	Weight enclosure IP 21 [kg]	23	27	45	65
	Weight enclosure IP 55 [kg]	23	27	45	65
	Weight enclosure IP 66 [kg]	23	27	45	65
	Efficiency [3)]	0.96	0.96	0.96	0.96

3.1.4. Mains Supply 3 x 380 - 480 VAC

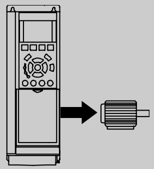
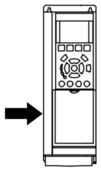
Mains Supply 3 x 380 - 480 VAC - Normal overload 110% for 1 minute

	PK37	PK55	PK75	P1K1	P1K5	P2K2	P3K0	P4K0	P5K5	P7K5
Frequency converter	PK37	PK55	PK75	P1K1	P1K5	P2K2	P3K0	P4K0	P5K5	P7K5
Typical Shaft Output [kW]	0.37	0.55	0.75	1.1	1.5	2.2	3	4	5.5	7.5
Typical Shaft Output [HP] at 460 V	0.5	0.75	1.0	1.5	2.0	2.9	4.0	5.3	7.5	10
IP 20 / NEMA Chassis	A2	A2	A2	A2	A2	A2	A2	A2	A3	A3
IP 21 / NEMA 1										
IP 55 / NEMA 12	A5	A5	A5	A5	A5	A5	A5	A5	A5	A5
IP 66	A5	A5	A5	A5	A5	A5	A5	A5	AA	A5
Output current 										
Continuous (3 x 380-440 V) [A]	1.3	1.8	2.4	3	4.1	5.6	7.2	10	13	16
Intermittent (3 x 380-440 V) [A]	1.43	1.98	2.64	3.3	4.5	6.2	7.9	11	14.3	17.6
Continuous (3 x 441-480 V) [A]	1.2	1.6	2.1	2.7	3.4	4.8	6.3	8.2	11	14.5
Intermittent (3 x 441-480 V) [A]	1.32	1.76	2.31	3.0	3.7	5.3	6.9	9.0	12.1	15.4
Continuous kVA (400 V AC) [kVA]	0.9	1.3	1.7	2.1	2.8	3.9	5.0	6.9	9.0	11.0
Continuous kVA (460 V AC) [kVA]	0.9	1.3	1.7	2.4	2.7	3.8	5.0	6.5	8.8	11.6
Max. cable size: (mains, motor, brake) [[mm²/ AWG] 2)]	4/10									
Max. input current 										
Continuous (3 x 380-440 V) [A]	1.2	1.6	2.2	2.7	3.7	5.0	6.5	9.0	11.7	14.4
Intermittent (3 x 380-440 V) [A]	1.32	1.76	2.42	3.0	4.1	5.5	7.2	9.9	12.9	15.8
Continuous (3 x 441-480 V) [A]	1.0	1.4	1.9	2.7	3.1	4.3	5.7	7.4	9.9	13.0
Intermittent (3 x 441-480 V) [A]	1.1	1.54	2.09	3.0	3.4	4.7	6.3	8.1	10.9	14.3
Max. pre-fuses 1) [A]	10	10	10	10	10	20	20	20	30	30
Environment										
Estimated power loss at rated max. load [W] 4)	35	42	46	58	62	88	116	124	187	255
Weight enclosure IP20 [kg]	4.7	4.7	4.8	4.8	4.9	4.9	4.9	4.9	6.6	6.6
Weight enclosure IP 21 [kg]										
Weight enclosure IP 55 [kg]	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	14.2	14.2
Weight enclosure IP 66 [kg]	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	14.2	14.2
Efficiency 3)	0.93	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.97

Mains Supply 3 x 380 - 480 VAC - Normal overload 110% for 1 minute

		P11K	P15K	P18K	P22K	P30K	P37K	P45K	P55K	P75K	P90K
Frequency converter Typical Shaft Output [kW]		11	15	18.5	22	30	37	45	55	75	90
Typical Shaft Output [HP] at 460 V		15	20	25	30	40	50	60	75	100	125
IP 20 / NEMA Chassis (B3+4 and C3+4 may be converted to IP21 using a conversion kit (Please contact Danfoss)		B3	B3	B3	B4	B4	B4	C3	C3	C4	C4
IP 21 / NEMA 1		B1	B1	B1	B2	B2	C1	C1	C1	C2	C2
IP 55 / NEMA 12		B1	B1	B1	B2	B2	C1	C1	C1	C2	-
IP 66		B1	B1	B1	B2	B2	C1	C1	C1	C2	-
Output current											
	Continuous (3 x 380-440 V) [A]	24	32	37.5	44	61	73	90	106	147	177
	Intermittent (3 x 380-440 V) [A]	26.4	35.2	41.3	48.4	67.1	80.3	99	117	162	195
	Continuous (3 x 441-480 V) [A]	21	27	34	40	52	65	80	105	130	160
	Intermittent (3 x 441-480 V) [A]	23.1	29.7	37.4	44	61.6	71.5	88	116	143	176
	Continuous kVA (400 V AC) [kVA]	16.6	22.2	26	30.5	42.3	50.6	62.4	73.4	102	123
	Continuous kVA (460 V AC) [kVA]	16.7	21.5	27.1	31.9	41.4	51.8	63.7	83.7	104	128
	Max. cable size: (mains, motor, brake) [[mm²/ AWG] 2)]		10/7		35/2			50/1/0		120/4/0	120/4/0
Max. input current											
	Continuous (3 x 380-440 V) [A]	22	29	34	40	55	66	82	96	133	161
	Intermittent (3 x 380-440 V) [A]	24.2	31.9	37.4	44	60.5	72.6	90.2	106	146	177
	Continuous (3 x 441-480 V) [A]	19	25	31	36	47	59	73	95	118	145
	Intermittent (3 x 441-480 V) [A]	20.9	27.5	34.1	39.6	51.7	64.9	80.3	105	130	160
	Max. pre-fuses 1) [A]	63	63	63	63	80	100	125	160	250	250
	Environment										
	Estimated power loss at rated max. load [W] 4)	278	392	465	525	698	739	843	1083	1384	1474
	Weight enclosure IP20 [kg]	12	12	12	23.5	23.5	23.5	35	35	50	50
	Weight enclosure IP 21 [kg]	23	23	23	27	27	45	45	45	65	65
	Weight enclosure IP 55 [kg]	23	23	23	27	27	45	45	45	65	65
	Weight enclosure IP 66 [kg]	23	23	23	27	27	45	45	45	65	65
	Efficiency 3)	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.99

3

Normal overload 110% for 1 minute										
Frequency converter		P110	P132	P160	P200	P250	P315	P355	P400	P450
Typical Shaft Output [kW]		110	132	160	200	250	315	355	400	450
Typical Shaft Output [HP] at 460V		150	200	250	300	350	450	500	550	600
IP 00		D3	D3	D4	D4	D4	E2	E2	E2	E2
IP 21 / Nema 1		D1	D1	D2	D2	D2	E1	E1	E1	E1
IP 54 / Nema 12		D1	D1	D2	D2	D2	E1	E1	E1	E1
Output current										
	Continuous (3 x 380-400 V) [A]	212	260	315	395	480	600	658	745	800
	Intermittent (3 x 380-400 V) [A]	233	286	347	435	528	660	724	820	880
	Continuous (3 x 401-480V) [A]	190	240	302	361	443	540	590	678	730
	Intermittent (3 x 401-480V) [A]	209	264	332	397	487	594	649	746	803
	Continuous kVA (400 VAC) [kVA]	147	180	218	274	333	416	456	516	554
	Continuous kVA (460 VAC) [kVA]	151	191	241	288	353	430	470	540	582
	Max. cable size:									
	(mains, motor, brake) [mm²/ AWG] 2)	2x70 2x2/0		2x185 2x350 mcm			4x240 4x500 mcm			
Max. input current										
	Continuous (3 x 380-400 V) [A]	204	251	304	381	463	590	647	733	787
	Continuous (3 x 401-480V) [A]	183	231	291	348	427	531	580	667	718
	Max. pre-fuses1)[A]	300	350	400	500	600	700	900	900	900
	Environment									
	Estimated power loss at rated max. load [W] 4)	3234	3782	4213	5119	5893	7630	7701	8879	9428
	Weight enclosure IP00 [kg]	81.9	90.5	111.8	122.9	137.7	221.4	234.1	236.4	277.3
	Weight enclosure IP 21 [kg]	95.5	104.1	125.4	136.3	151.3	263.2	270.0	272.3	313.2
	Weight enclosure IP 54 [kg]	95.5	104.1	125.4	136.3	151.3	263.2	270.0	272.3	313.2
	Efficiency 3)	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98

1) For type of fuse see section *Fuses*
2) American Wire Gauge
3) Measured using 5 m screened motor cables at rated load and rated frequency
4) The typical power loss is at normal load conditions and expected to be within +/- 15% (tolerance relates to variety in voltage and cable conditions).
Values are based on a typical motor efficiency (eff2/eff3 border line). Lower efficiency motors will also add to the power loss in the frequency converter and vice versa.
If the switching frequency is raised from nominal the power losses may rise significantly.
and typical control card power consumptions are included. Further options and customer load may add up to 30W to the losses. (Though typically only 4W extra for a fully loaded control card, or options for slot A or slot B, each).
Although measurements are made with state of the art equipment, some measurement inaccuracy must be allowed for (+/- 5%).

3.1.5. Mains Supply 3 x 525 - 600 VAC

Normal overload 110% for 1 minute																			
Size:	PK75	P1K1	P1K5	P2K2	P3K0	P3K7	P4K0	P5K5	P7K5	P11K	P15K	P18K	P22K	P30K	P37K	P45K	P55K	P75K	P90K
Typical Shaft Output [kW]	0.75	1.1	1.5	2.2	3	3.7	4	5.5	7.5	11	15	18.5	22	30	37	45	55	75	90
IP 20 / NEMA Chassis	A2	A2	A2	A2	A2	A2	A2	A3	A3	B3	B3	B3	B4	B4	B4	C3	C3	C4	C4
IP 21 / NEMA 1	A2	A2	A2	A2	A2	A2	A2	A3	A3	B1	B1	B1	B2	B2	B2	C1	C1	C2	C2
IP 55 / NEMA 12	A5	A5	A5	A5	A5	A5	A5	A5	A5	B1	B1	B1	B2	B2	B2	C1	C1	C2	C2
IP 66	A5	A5	A5	A5	A5	A5	A5	A5	A5	B1	B1	B1	B2	B2	B2	C1	C1	C2	C2
Output current																			
Continuous (3 x 525-550 V) [A]	1.8	2.6	2.9	4.1	5.2	-	6.4	9.5	11.5	19	23	28	36	43	54	65	87	105	137
Intermittent (3 x 525-550 V) [A]		2.9	3.2	4.5	5.7	-	7.0	10.5	12.7	21	25	31	40	47	59	72	96	116	151
Continuous (3 x 525-600 V) [A]	1.7	2.4	2.7	3.9	4.9	-	6.1	9.0	11.0	18	22	27	34	41	52	62	83	100	131
Intermittent (3 x 525-600 V) [A]		2.6	3.0	4.3	5.4	-	6.7	9.9	12.1	20	24	30	37	45	57	68	91	110	144
Continuous kVA (525 V AC) [kVA]	1.7	2.5	2.8	3.9	5.0	-	6.1	9.0	11.0	18.1	21.9	26.7	34.3	41	51.4	61.9	82.9	100	130.5
Continuous kVA (575 V AC) [kVA]	1.7	2.4	2.7	3.9	4.9	-	6.1	9.0	11.0	17.9	21.9	26.9	33.9	40.8	51.8	61.7	82.7	99.6	130.5
Max. cable size (mains, motor, brake) [AWG] 2) [mm²]						-		24 - 10 AWG 0.2 - 4			6 16			2 35		1 50		3/0 95 5)	
Max. input current																			
Continuous (3 x 525-600 V) [A]	1.7	2.4	2.7	4.1	5.2	-	5.8	8.6	10.4	17.2	20.9	25.4	32.7	39	49	59	78.9	95.3	124.3
Intermittent (3 x 525-600 V) [A]		2.7	3.0	4.5	5.7	-	6.4	9.5	11.5	19	23	28	36	43	54	65	87	105	137
Max. pre-fuses1) [A]	10	10	10	20	20	-	20	32	32										
Environment:																			
Estimated power loss at rated max. load [W] 4)	35	50	65	92	122	-	145	195	261	225	285	329							
Enclosure IP 20:																			
Weight enclosure IP20 [kg]	6.5	6.5	6.5	6.5	6.5	-	6.5	6.6	6.6	12	12	12	23.5	23.5	23.5	35	35	50	50
Efficiency 4)	0.97	0.97	0.97	0.97	0.97	-	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98

Table 3.1: 5) Motor and mains cable: 300MCM/150mm²

3.1.6. Mains Supply 3 x 525 - 690 VAC

Normal overload 110% for 1 minute																				
Frequency converter	P45K	P55K	P75K	P90K	P110	P132	P160	P200	P250	P315	P400	P450	P500	P560	P630	P710	P800	P900	P1M0	P1M2
Typical Shaft Output [kW]	45	55	75	90	110	132	160	200	250	315	400	450	500	560	630	710	800	900	1000	1200
Typical Shaft Output [HP] at 575 V	50	60	75	100	125	150	200	250	300	350	400	450	500	600	650	750	950	1050	1150	1350
IP 00	D3	D3	D3	D3	D3	D3	D3	D4	D4	D4	D4	E2	E2	E2	E2	-	-	-	-	-
IP 21 / Nema 1	D1	D1	D1	D1	D1	D1	D1	D2	D2	D2	D2	E1	E1	E1	E1	F1/F3 6)	F1/F3 6)	F1/F3 6)	F2/F4 6)	F2/F4 6)
IP 54 / Nema 12	D1	D1	D1	D1	D1	D1	D1	D2	D2	D2	D2	E1	E1	E1	E1	F1/F3 6)	F1/F3 6)	F1/F3 6)	F1/F3 6)	F1/F3 6)
Output current																				
Continuous (3 x 550 V) [A]	56	76	90	113	137	162	201	253	303	360	418	470	523	596	630	763	889	988	1108	1317
Intermittent (3 x 550 V) [A]	62	84	99	124	151	178	221	278	333	396	460	517	575	656	693	839	978	1087	1219	1449
Continuous (3 x 690V) [A]	54	73	86	108	131	155	192	242	290	344	400	450	500	570	630	730	850	945	1060	1260
Intermittent (3 x 690 V) [A]	59	80	95	119	144	171	211	266	319	378	440	495	550	627	693	803	935	1040	1166	1386
Continuous kVA (550 VAC) [kVA]	53	72	86	108	131	154	191	241	289	343	398	448	498	568	600	727	847	941	1056	1255
Continuous kVA (575 VAC) [kVA]	54	73	86	108	130	154	191	241	289	343	398	448	498	568	627	727	847	941	1056	1255
Continuous kVA (690 VACr) [kVA]	65	87	103	129	157	185	229	289	347	411	478	538	598	681	753	872	1016	1129	1267	1506
Max. cable size:																				
(Mains) [mm²/ AWG] 2)	2x70 2x2/0							2x185 2x350 mcm				4x240 4x500 mcm				8x240 8x500 mcm			8x240 8x500 mcm	
(Motor) [mm²/ AWG] 2)	2x70 2x2/0							2x185 2x350 mcm				4x240 4x500 mcm				8x150 8x300 mcm			12x150 12x300 mcm	
(Brake) [mm²/ AWG] 2)	2x70 2x2/0							2x185 2x350 mcm				2x185 2x350 mcm				4x185 4x350 mcm			6x185 6x350 mcm	
Max. input current																				
Continuous (3 x 525 V) [A]	60	77	89	110	130	158	198	299	245	299	355	453	504	574	607	743	866	962	1079	1282
Continuous (3 x 575 V) [A]	58	74	85	106	124	151	189	286	234	286	339	434	482	549	607	711	828	920	1032	1227
Continuous (3 x 690 V) [A]	58	77	87	109	128	155	197	296	240	296	352	434	482	549	607	711	828	920	1032	1227
Max. mains pre-fuses 1) [A]	125	160	200	200	250	315	350	350	400	500	550	700	700	900	900	2000	2000	2000	2000	2000
Environment:																				
Estimated power loss at rated max. load [W] 4)	1458	1717	1913	2262	2662	3114	3612	4292	5156	5821	6149	6449	7249	8727	9673					
Weight enclosure IP00 [kg]	82	82	82	82	82	82	91	112	123	138	151	221	221	236	277	-	-	-	-	-
Weight enclosure IP 21 [kg] 6)	96	96	96	96	96	96	104	125	136	151	165	263	263	272	313	1004	1004	1004	1246	1246
Weight enclosure IP 54 [kg] 6)	96	96	96	96	96	96	104	125	136	151	165	263	263	272	313	1004	1004	1004	1246	1246
Efficiency 3)	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98

1) For type of fuse see section *Fuses*
2) American Wire Gauge
3) Measured using 5 m screened motor cables at rated load and rated frequency
4) The typical power loss is at normal load conditions and expected to be within +/- 15% (tolerance relates to variety in voltage and cable conditions).
Values are based on a typical motor efficiency (eff2/eff3 border line). Lower efficiency motors will also add to the power loss in the frequency converter and vice versa.
If the switching frequency is raised from nominal the power losses may rise significantly.
and typical control card power consumptions are included. Further options and customer load may add up to 30W to the losses. (Though typically only 4W extra for a fully loaded control card, or options for slot A or slot B, each).
Although measurements are made with state of the art equipment, some measurement inaccuracy must be allowed for (+/- 5%).
6) Adding the F-enclosure option cabinet (resulting in the F3 and F4 enclosure sizes) adds 295 kgto the estimated weight.

3

Protection and Features:

- Electronic thermal motor protection against overload.
- Temperature monitoring of the heatsink ensures that the frequency converter trips if the temperature reaches 95 °C ± 5°C. An overload temperature cannot be reset until the temperature of the heatsink is below 70 °C ± 5°C (Guideline - these temperatures may vary for different power sizes, enclosures etc.). VLT AQUA Drive has an auto derating function to avoid it's heatsink reaching 95 deg C.
- The frequency converter is protected against short-circuits on motor terminals U, V, W.
- If a mains phase is missing, the frequency converter trips or issues a warning (depending on the load).
- Monitoring of the intermediate circuit voltage ensures that the frequency converter trips if the intermediate circuit voltage is too low or too high.
- The frequency converter is protected against earth faults on motor terminals U, V, W.

Mains supply (L1, L2, L3):	
Supply voltage	200-240 V ±10%
Supply voltage	380-480 V ±10%
Supply voltage	525-600 V ±10%
Supply frequency	50/60 Hz
Max. imbalance temporary between mains phases	3.0 % of rated supply voltage
True Power Factor (λ)	≥ 0.9 nominal at rated load
Displacement Power Factor (cosφ) near unity	(> 0.98)
Switching on input supply L1, L2, L3 (power-ups) ≤ enclosure type A	maximum 2 times/min.
Switching on input supply L1, L2, L3 (power-ups) ≥ enclosure type B, C	maximum 1 time/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 - 1000 Hz
Switching on output	Unlimited
Ramp times	1 - 3600 sec.

Torque characteristics:	
Starting torque (Constant torque)	maximum 110% for 1 min.*
Starting torque	maximum 135% up to 0.5 sec.*
Overload torque (Constant torque)	maximum 110% for 1 min.*

**Percentage relates to VLT AQUA Drive's nominal torque.*

Cable lengths and cross sections:	
Max. motor cable length, screened/armoured	VLT AQUA Drive: 150 m
Max. motor cable length, unscreened/unarmoured	VLT AQUA Drive: 300 m
Max. cross section to motor, mains, load sharing and brake *	
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 Mains Supply tables for more information!*

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

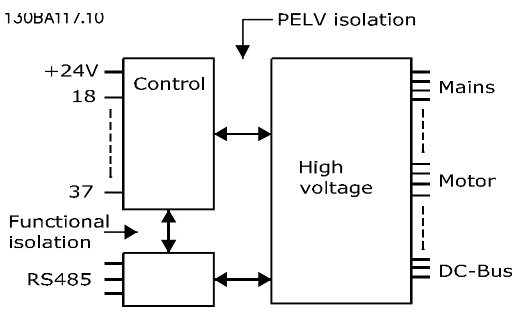
The RS-485 serial communication circuit is functionally separated from other central circuits and galvanically isolated from the supply voltage (PELV).

3

Analog inputs:

Number of analog inputs	2
Terminal number	53, 54
Modes	Voltage or current
Mode select	Switch S201 and switch S202
Voltage mode	Switch S201/switch S202 = OFF (U)
Voltage level	: 0 to + 10 V (scaleable)
Input resistance, R_i	approx. 10 kΩ
Max. voltage	± 20 V
Current mode	Switch S201/switch S202 = ON (I)
Current level	0/4 to 20 mA (scaleable)
Input resistance, R_i	approx. 200 Ω
Max. current	30 mA
Resolution for analog inputs	10 bit (+ sign)
Accuracy of analog inputs	Max. error 0.5% of full scale
Bandwidth	: 200 Hz

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



Analog output:

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

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

Digital inputs:

Programmable digital inputs	4 (6)
Terminal number	18, 19, 27 [1)], 29, 32, 33,
Logic	PNP or NPN
Voltage level	0 - 24 V DC
Voltage level, logic'0' PNP	< 5 V DC
Voltage level, logic'1' PNP	> 10 V DC
Voltage level, logic '0' NPN	> 19 V DC
Voltage level, logic '1' NPN	< 14 V DC
Maximum voltage on input	28 V DC
Input resistance, R_i	approx. 4 kΩ

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

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

Digital output:

Programmable digital/pulse outputs	2
Terminal number	27, 29 [1)]
Voltage level at digital/frequency output	0 - 24 V
Max. output current (sink or source)	40 mA
Max. load at frequency output	1 kΩ
Max. capacitive load at frequency output	10 nF
Minimum output frequency at frequency output	0 Hz
Maximum output frequency at frequency output	32 kHz
Accuracy of frequency output	Max. error: 0.1 % of full scale
Resolution of frequency outputs	12 bit

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

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

Pulse inputs:

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

Control card, 24 V DC output:

Terminal number	12, 13
Max. load	: 200 mA

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

Relay outputs:

Programmable relay outputs	2
Relay 01 Terminal number	1-3 (break), 1-2 (make)
Max. terminal load (AC-1)[1)] on 1-3 (NC), 1-2 (NO) (Resistive load)	240 V AC, 2 A
Max. terminal load (AC-15)[1)] (Inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Max. terminal load (DC-1)[1)] on 1-2 (NO), 1-3 (NC) (Resistive load)	60 V DC, 1A
Max. terminal load (DC-13)[1)] (Inductive load)	24 V DC, 0.1A
Relay 02 Terminal number	4-6 (break), 4-5 (make)
Max. terminal load (AC-1)[1)] on 4-5 (NO) (Resistive load)[2)3)]	400 V AC, 2 A
Max. terminal load (AC-15)[1)] on 4-5 (NO) (Inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Max. terminal load (DC-1)[1)] on 4-5 (NO) (Resistive load)	80 V DC, 2 A
Max. terminal load (DC-13)[1)] on 4-5 (NO) (Inductive load)	24 V DC, 0.1A
Max. terminal load (AC-1)[1)] on 4-6 (NC) (Resistive load)	240 V AC, 2 A
Max. terminal load (AC-15)[1)] on 4-6 (NC) (Inductive load @ cosφ 0.4)	240 V AC, 0.2A
Max. terminal load (DC-1)[1)] on 4-6 (NC) (Resistive load)	50 V DC, 2 A
Max. terminal load (DC-13)[1)] on 4-6 (NC) (Inductive load)	24 V DC, 0.1 A
Min. terminal load on 1-3 (NC), 1-2 (NO), 4-6 (NC), 4-5 (NO)	24 V DC 10 mA, 24 V AC 20 mA
Environment according to EN 60664-1	overvoltage category III/pollution degree 2

1) IEC 60947 part 4 and 5

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

2) Overvoltage Category II

3) UL applications 300 V AC 2A

Control card, 10 V DC output:

Terminal number	50
Output voltage	10.5 V ±0.5 V
Max. load	25 mA

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

Control characteristics:

Resolution of output frequency at 0 - 1000 Hz	: +/- 0.003 Hz
System response time (terminals 18, 19, 27, 29, 32, 33)	: ≤ 2 ms
Speed control range (open loop)	1:100 of synchronous speed
Speed accuracy (open loop)	30 - 4000 rpm: Maximum error of ±8 rpm

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

Surroundings:

Enclosure type A	IP 20/Chassis, IP 21kit/Type 1, IP55/Type12, IP 66
Enclosure type B1/B2	IP 21/Type 1, IP55/Type12, IP 66
Enclosure type B3/B4	IP20/Chassis
Enclosure type C1/C2	IP 21/Type 1, IP55/Type 12, IP66
Enclosure type C3/C4	IP20/Chassis
Enclosure type D1/D2/E1	IP21/Type 1, IP54/Type12
Enclosure type D3/D4/E2	IP00/Chassis
Enclosure kit available ≤ enclosure type A	IP21/TYPE 1/IP 4X top
Vibration test	1.0 g
Max. relative humidity	5% - 95%(IEC 721-3-3; Class 3K3 (non-condensing) during operation
Aggressive environment (IEC 721-3-3), uncoated	class 3C2
Aggressive environment (IEC 721-3-3), coated	class 3C3
Test method according to IEC 60068-2-43 H2S (10 days)	
Ambient temperature	Max. 50 °C

Derating for high ambient temperature, see section on special conditions

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

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 section on special conditions

Control card performance:

Scan interval	: 5 ms

Control card, USB serial communication:

USB standard	1.1 (Full speed)
USB plug	USB type B "device" plug

Connection to PC is carried out via a standard host/device USB cable.
The USB connection is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.
The USB connection is <u>not</u> galvanically isolated from protection earth. Use only isolated laptop/PC as connection to the USB connector on VLT AQUA Drive or an isolated USB cable/converter.

3.2. Efficiency

Efficiency of VLT AQUA (η_{VLT})

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

This also means that the efficiency of the frequency converter does not change even if other U/f characteristics are chosen.
However, the U/f characteristics influence the efficiency of the motor.

The efficiency declines a little when the switching frequency is set to a value of above 5 kHz. The efficiency will also be slightly reduced if the mains voltage is 480 V, or if the motor cable is longer than 30 m.

Efficiency of the motor ($\eta)_{MOTOR}$

The efficiency of a motor connected to the frequency converter depends on magnetising level. In general, the efficiency is just as good as with mains operation. The efficiency of the motor depends on the type of motor.

In the range of 75-100% of the rated torque, the efficiency of the motor is practically constant, both when it is controlled by the frequency converter and when it runs directly on mains.

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

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

Efficiency of the system (η_{SYSTEM}

To calculate the system efficiency, the efficiency of VLT AQUA (η_{VLT}) is multiplied by the efficiency of the motor (η_{MOTOR}):

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

Calculate the efficiency of the system at different loads based on the graph above.

3.3. Acoustic noise

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

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

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

3

Enclosure	At reduced fan speed (50%) [dBA] ***	Full fan speed [dBA]
A2	51	60
A3	51	60
A5	54	63
B1	61	67
B2	58	70
B3	-	-
B4	-	-
C1	52	62
C2	55	65
C3	-	-
C4	-	-
D1+D3	74	76
D2+D4	73	74
E1/E2 *	73	74
E1/E2 **	82	83
* 315 kW, 380-480 VAC and 355 kW, 525-600 VAC only! ** Remaining E1+E2 power sizes. *** For D and E sizes, reduced fan speed is at 87%, measured at 200 V.		

3.4. Peak voltage on motor

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

- the motor cable (type, cross-section, length screened or unscreened)
- inductance

The natural induction causes an overshoot U_{PEAK} in the motor voltage before it stabilizes itself at a level depending on the voltage in the intermediate circuit. The rise time and the peak voltage U_{PEAK} affect the service life of the motor. If the peak voltage is too high, especially motors without phase coil insulation are affected. If the motor cable is short (a few metres), the rise time and peak voltage are lower.
If the motor cable is long (100 m), the rise time and peak voltage increases.

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

To obtain approximate values for cable lengths and voltages not mentioned below, use the following rules of thumb:

1. Rise time increases/decreases proportionally with cable length.
2. U_{PEAK} = DC link voltage x 1.9
   (DC link voltage = Mains voltage x 1.35).
3. $$dU \Big/ dt = \frac{0.8 \times U_{PEAK}}{Risetime}$$

Data are measured according to IEC 60034-17.
Cable lengths are in metres.

FC 202, P7K5T2

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
5	230	0.13	0.510	3.090
50	230	0.23		2.034
100	230	0.54	0.580	0.865
150	230	0.66	0.560	0.674

FC 202, P11KT2

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
36	240	0.264	0.624	1.890
136	240	0.536	0.596	0.889
150	240	0.568	0.568	0.800

FC 202, P15KT2

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
30	240	0.556	0.650	0.935
100	240	0.592	0.594	0.802
150	240	0.708	0.587	0.663

FC 202, P18KT2

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
36	240	0.244	0.608	1.993
136	240	0.568	0.580	0.816
150	240	0.720	0.574	0.637

FC 202, P22KT2

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
36	240	0.244	0.608	1.993
136	240	0.568	0.580	0.816
150	240	0.720	0.574	0.637

FC 202, P30KT2

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
15	240	0.194	0.626	2.581
50	240	0.252	0.574	1.822
150	240	0.488	0.538	0.882

3

FC 202, P37KT2

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
30	240	0.300	0.598	1.594
100	240	0.536	0.566	0.844
150	240	0.776	0.546	0.562

FC 202, P45KT2

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
30	240	0.300	0.598	1.594
100	240	0.536	0.566	0.844
150	240	0.776	0.546	0.562

FC 202, P1K5T4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
5	690	0.640	0.690	0.862
50	985	0.470		0.985
150	1045	0.760	1.045	0.947

FC 202, P4K0T4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
5	400	0.172	0.890	4.156
50	400	0.310		2.564
150	400	0.370	1.190	1.770

FC 202, P7K5T4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
5	500	0.04755	0.739	8.035
50	500	0.207		4.548
150	500	0.6742	1.030	2.828

FC 202, P11KT4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
15	480	0.192	1.300	5.416
100	480	0.612	1.300	1.699
150	480	0.512	1.290	2.015

FC 202, P15KT4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
36	480	0.396	1.210	2.444
100	480	0.844	1.230	1.165
150	480	0.696	1.160	1.333

FC 202, P18KT4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
36	480	0.396	1.210	2.444
100	480	0.844	1.230	1.165
150	480	0.696	1.160	1.333

FC 202, P22KT4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
36	480	0.312		2.846
100	480	0.556	1.250	1.798
150	480	0.608	1.230	1.618

FC 202, P30KT4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
15	480	0.288		3.083
100	480	0.492	1.230	2.000
150	480	0.468	1.190	2.034

FC 202, P37KT4

Cable length [m]	Mains voltage	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
5	480	0.368	1.270	2.853
50	480	0.536	1.260	1.978
100	480	0.680	1.240	1.426
150	480	0.712	1.200	1.334

FC 202, P45KT4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
5	480	0.368	1.270	2.853
50	480	0.536	1.260	1.978
100	480	0.680	1.240	1.426
150	480	0.712	1.200	1.334

FC 202, P55KT4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
15	480	0.256	1.230	3.847
50	480	0.328	1.200	2.957
100	480	0.456	1.200	2.127
150	480	0.960	1.150	1.052

FC 202, P75KT4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
5	480	0.371	1.170	2.523

FC 202, P90KT4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
5	480	0.371	1.170	2.523

High Power Range:

3

FC 202, P110 - P250, T4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
70	400	0.34	1.040	2.447

FC 202, P315 - P450, T4

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
30	500	0.71	1.165	1.389
30	400	0.61	0.942	1.233

FC 202, P132 - P400, T7

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
30	690	0.59	1.425	1.983
30	575	0.66	1.159	1.428
30	690 1)	1.72	1.329	0.640
1) With Danfoss dU/dt filter.				

FC 202, P450 - P630, T7

Cable length [m]	Mains voltage [V]	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
30	690	0.57	1.540	2.230
30	575	0.25		2.510
30	690 1)	1.13	1.629	1.150
1) With Danfoss dU/dt filter.				

3.5. Special Conditions

3.5.1. Purpose of derating

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.

3.5.2. Derating for Ambient Temperature

The average temperature ($T_{AMB, AVG}$) measured over 24 hours must be at least 5 °C lower than the maximum allowed ambient temperature ($T_{AMB,MAX}$).

If the frequency converter is operated at high ambient temperatures, the continuous output current should be decreased.

The derating depends on the switching pattern, which can be set to 60 AVM or SFAVM in parameter 14-00.

A enclosures

60 AVM - Pulse Width Modulation

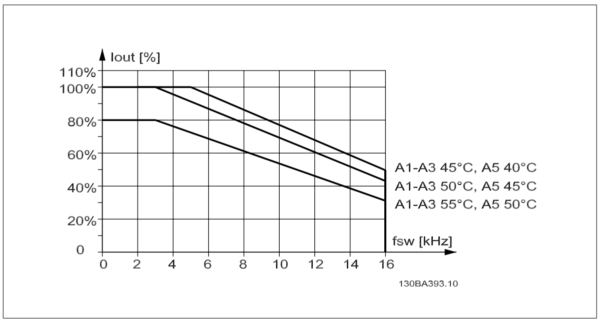


Illustration 3.1: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure A, using 60 AVM

SFAVM - Stator Frequency Asyncron Vector Modulation

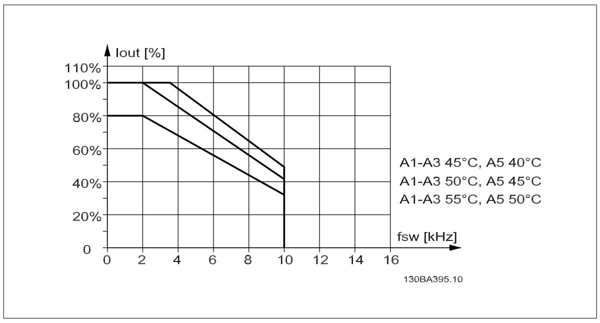


Illustration 3.2: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure A, using SFAVM

In enclosure A, the length of the motor cable has a relatively high impact on the recommended derating. Therefore, the recommended derating for an application with max. 10 m motor cable is also shown.

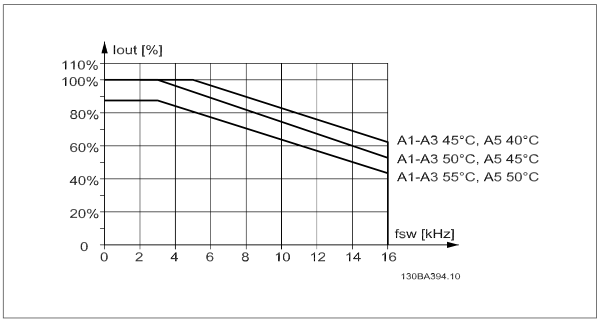


Illustration 3.3: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure A, using 60 AVM and maximum 10 m motor cable

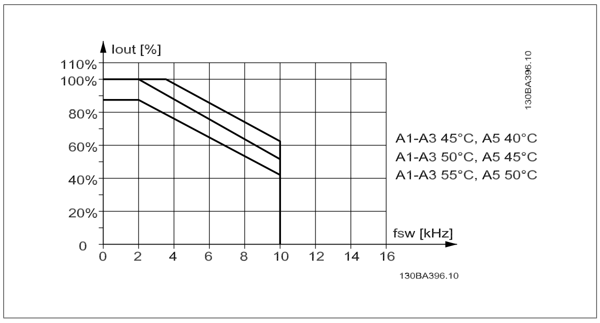


Illustration 3.4: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure A, using SFAVM and maximum 10 m motor cable

3

B enclosures

60 AVM - Pulse Width Modulation

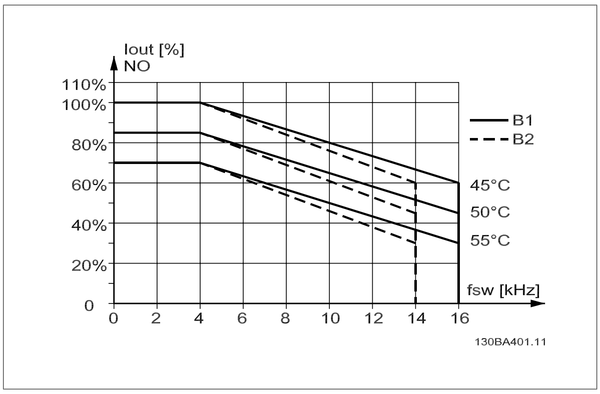


Illustration 3.5: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure B, using 60 AVM in Normal torque mode (110% over torque)

SFAVM - Stator Frequency Asyncron Vector Modulation

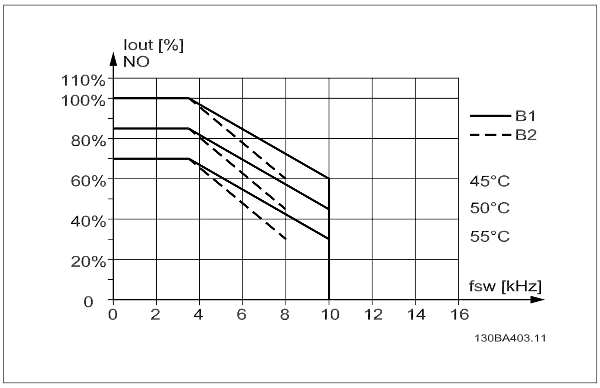


Illustration 3.6: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure B, using SFAVM in Normal torque mode (110% over torque)

C enclosures

Please note: For 90 kW in IP55 and IP66 the max. ambient temperature is 5° C lower.

60 AVM - Pulse Width Modulation

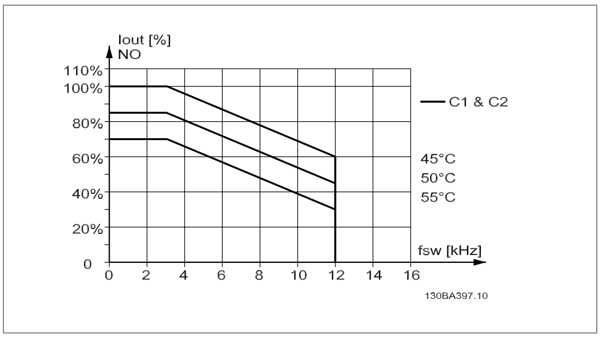


Illustration 3.7: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure C, using 60 AVM in Normal torque mode (110% over torque)

SFAVM - Stator Frequency Asyncron Vector Modulation

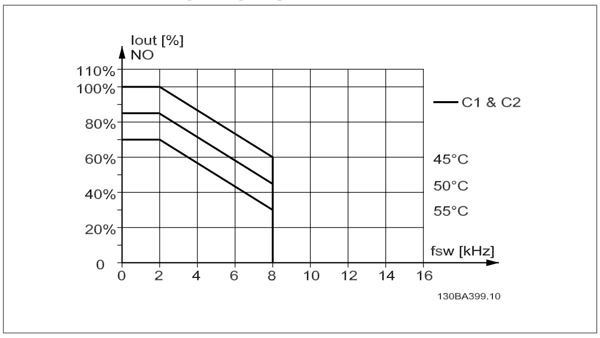


Illustration 3.8: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure C, using SFAVM in Normal torque mode (110% over torque)

D enclosures

60 AVM - Pulse Width Modulation, 380 - 480 V

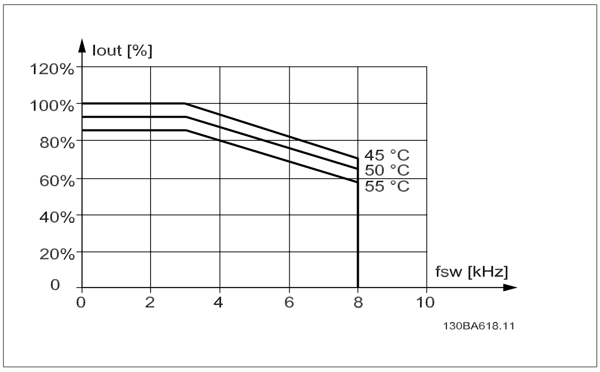


Illustration 3.9: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure D at 480 V, using 60 AVM in Normal torque mode (110% over torque)

SFAVM - Stator Frequency Asyncron Vector Modulation

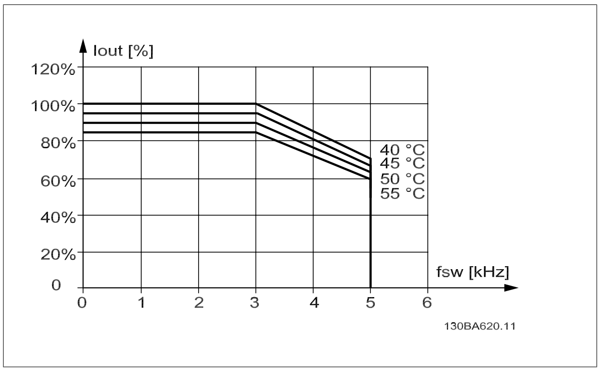


Illustration 3.10: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure D at 480 V, using SFAVM in Normal torque mode (110% over torque)

60 AVM - Pulse Width Modulation, 525 - 600 V (except P315)

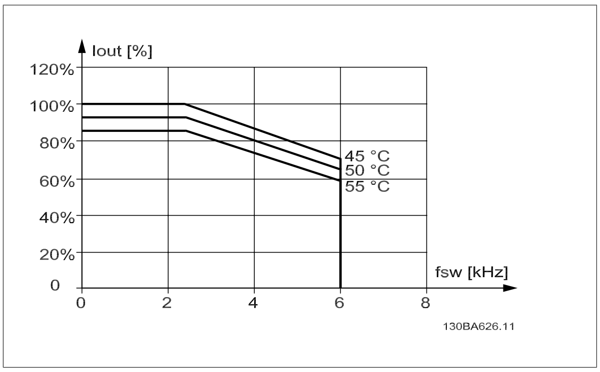


Illustration 3.11: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure D at 600 V, using 60 AVM in Normal torque mode (110% over torque). Note: *not* valid for P315.

SFAVM - Stator Frequency Asyncron Vector Modulation

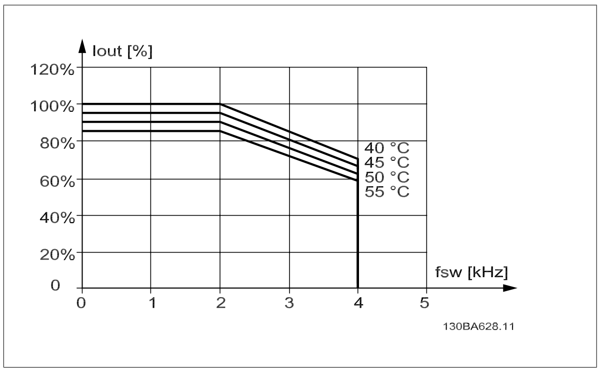


Illustration 3.12: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure D at 600 V, using SFAVM in Normal torque mode (110% over torque). Note: *not* valid for P315.

60 AVM - Pulse Width Modulation, 525 - 600 V, P315

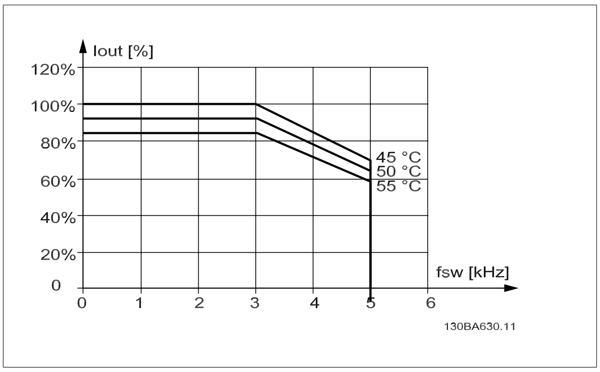


Illustration 3.13: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure D at 600 V, using 60 AVM in Normal torque mode (110% over torque). Note: P315 *only*.

SFAVM - Stator Frequency Asyncron Vector Modulation

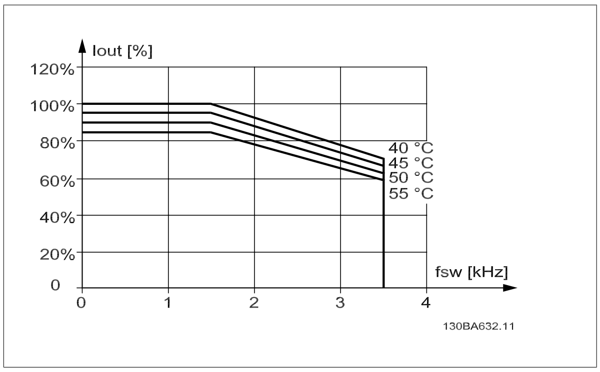


Illustration 3.14: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure D at 600 V, using SFAVM in Normal torque mode (110% over torque). Note: P315 *only*.

E enclosures

60 AVM - Pulse Width Modulation, 380 - 480 V

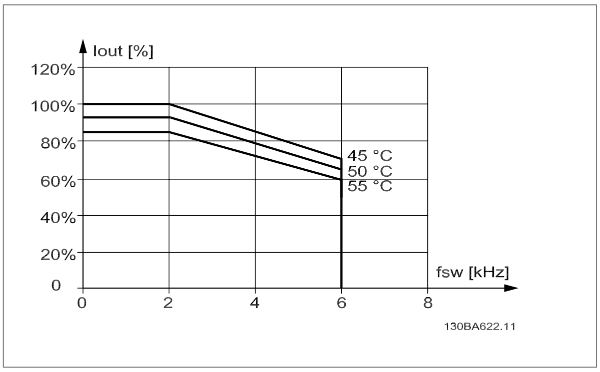


Illustration 3.15: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure E at 480 V, using 60 AVM in Normal torque mode (110% over torque)

SFAVM - Stator Frequency Asyncron Vector Modulation

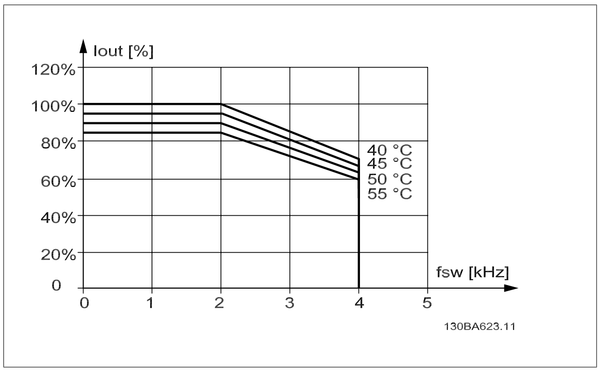


Illustration 3.16: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure E at 480 V, using SFAVM in Normal torque mode (110% over torque)

3

60 AVM - Pulse Width Modulation, 525 - 600 V

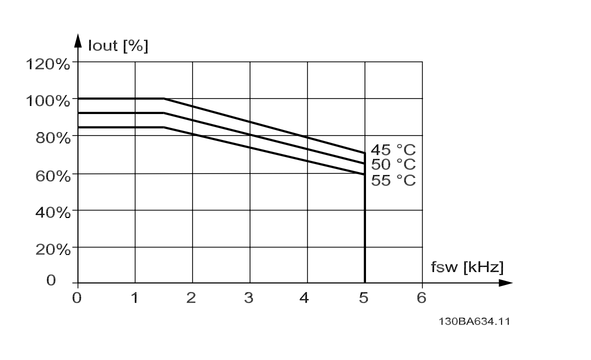


Illustration 3.17: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure E at 600 V, using 60 AVM in Normal torque mode (110% over torque).

SFAVM - Stator Frequency Asyncron Vector Modulation

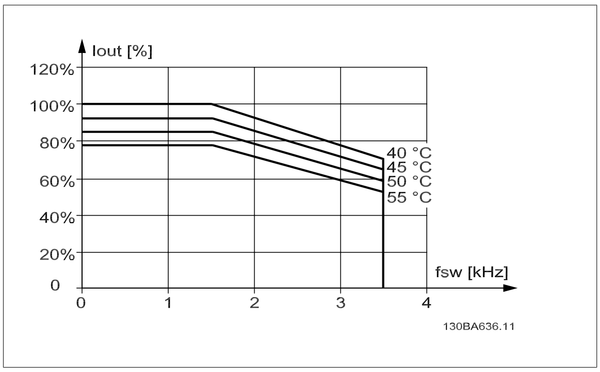


Illustration 3.18: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure E at 600 V, using SFAVM in Normal torque mode (110% over torque).

3.5.3. Derating for Low Air Pressure

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

At altitudes higher than 2 km, please contact regarding PELV.

Below 1000 m altitude no derating is necessary but above 1000 m the ambient temperature (T_{AMB}) or max. output current (I_{out}) should be derated in accordance with the shown diagram.

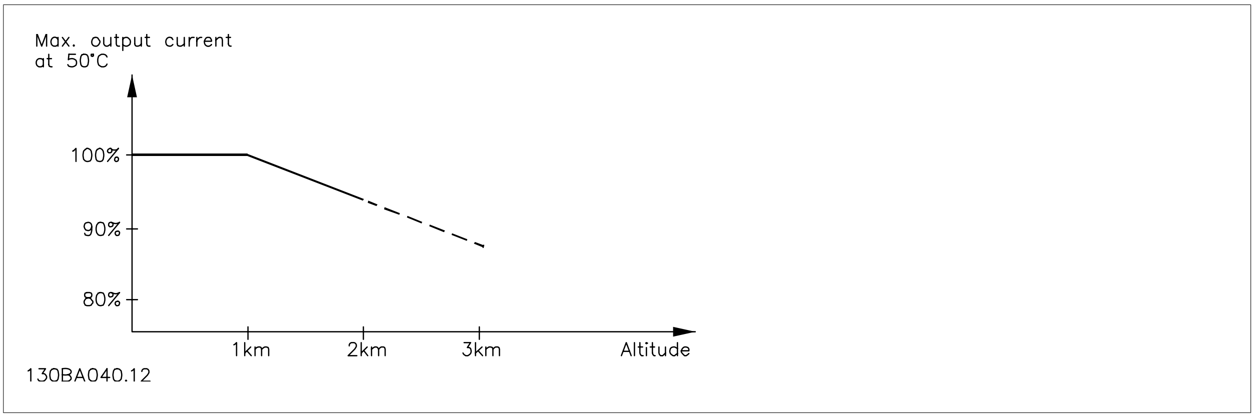


Illustration 3.19: Derating of output current versus altitude at $T_{AMB, MAX}$. By altitudes above 2 km, please contact regarding PELV.

An alternative is to lower the ambient temperature at high altitudes and thereby ensure 100% output current at high altitudes.

3

3.5.4. 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 s a motor may over-heat at low speeds due to less cooling air from the motor integral fan.
Therefore, if the motor is to be run continuously at an RPM value lower than half of the rated value, the motor must be supplied with additional air-cooling (or a motor designed for this type of operation may be used).

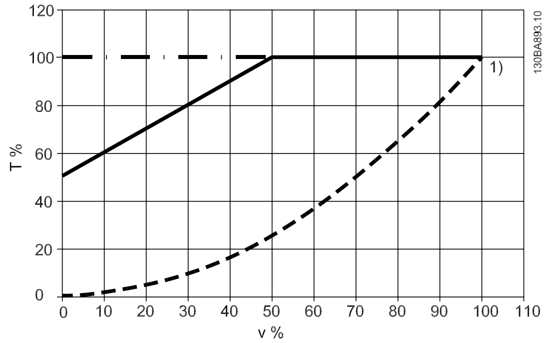
An alternative is to reduce the load level of the motor by choosing a larger motor. However, the design of the frequency converter puts a limit to the motor size.

Variable (Quadratic) torque applications (VT)

In VT applications such as centrifugal pumps and fans, where the torque is proportional to the square of the speed and the power is proportional to the cube of the speed, there is no need for additional cooling or de-rating of the motor.

In the graphs shown below, the typical VT curve is below the maximum torque with de-rating and maximum torque with forced cooling at all speeds.

Maximum Load for a Standard Motor at 40 °C driven by a frequency converter type VLT FCxxx



Legend: — — — —Typical torque at VT load —•—•—•—Max torque with forced cooling ———Max torque

Note 1) Over-syncronous speed operation will result in the available motor torque decreasing inversely proportional with the increase in speed. This must be considered during the design phase to avoid over-loading of the motor.

3.5.5. Derating for Installing Long Motor Cables or Cables with Larger Cross-Section

The maximum cable length for this frequency converter is 300 m unscreened and 150 m screened cable.

The frequency converter has been designed to work using a motor cable with a rated cross-section. If a cable with a larger cross-section is used, reduce the output current by 5% for every step the cross-section is increased.
(Increased cable cross-section leads to increased capacity to earth, and thus an increased earth leakage current).

3.5.6. 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.

3

3.6. Options and Accessories

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

3.6.1. Mounting of Option Modules in Slot B

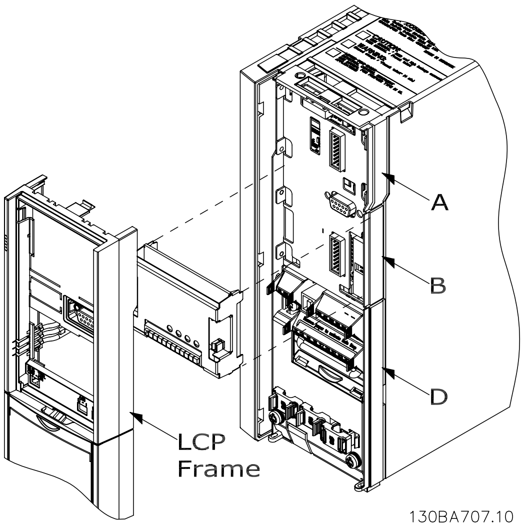
The power to the frequency converter must be disconnected.

For A2 and A3 enclosures:

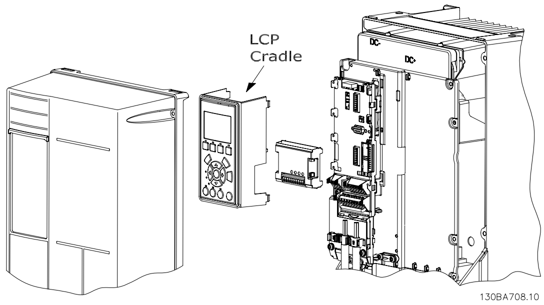
- Remove the (Local Control Panel), the terminal cover, and the frame from the frequency converter.
- Fit the MCB10x option card into slot B.
- Connect the control cables and relieve the cable by the enclosed cable strips.
  Remove the knock out in the extended frame delivered in the option set, so that the option will fit under the extended frame.
- Fit the extended frame and terminal cover.
- Fit the or blind cover in the extended frame.
- Connect power to the frequency converter.
- Set up the input/output functions in the corresponding parameters, as mentioned in the section *General Technical Data*.

For B1, B2, C1 and C2 enclosures:

- Remove the and the cradle
- Fit the MCB 10x option card into slot B
- Connect the control cables and relieve the cable by the enclosed cable strips
- Fit the cradle
- Fit the



A2, A3 and B3 enclosures



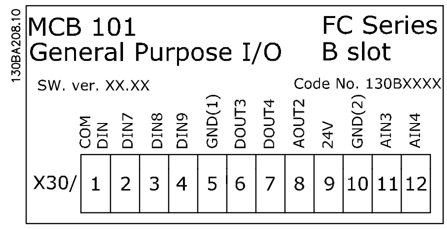
A5, B1, B2, B4, C1, C2, C3 and C4 enclosures

3.6.2. General Purpose Input Output Module MCB 101

MCB 101 is used for extension of the number of digital and analog inputs and outputs of the VLT AQUA Drive.

Contents: MCB 101 must be fitted into slot B in the VLT AQUA Drive.

- MCB 101 option module
- Extended LCP frame
- Terminal cover



Galvanic Isolation in the MCB 101

Digital/analog inputs are galvanically isolated from other inputs/outputs on the MCB 101 and in the control card of the drive. Digital/analog outputs in the MCB 101 are galvanically isolated from other inputs/outputs on the MCB 101, but not from these on the control card of the drive.

If the digital inputs 7, 8 or 9 are to be switched by use of the internal 24 V power supply (terminal 9) the connection between terminal 1 and 5 which is illustrated in the drawing has to be established.

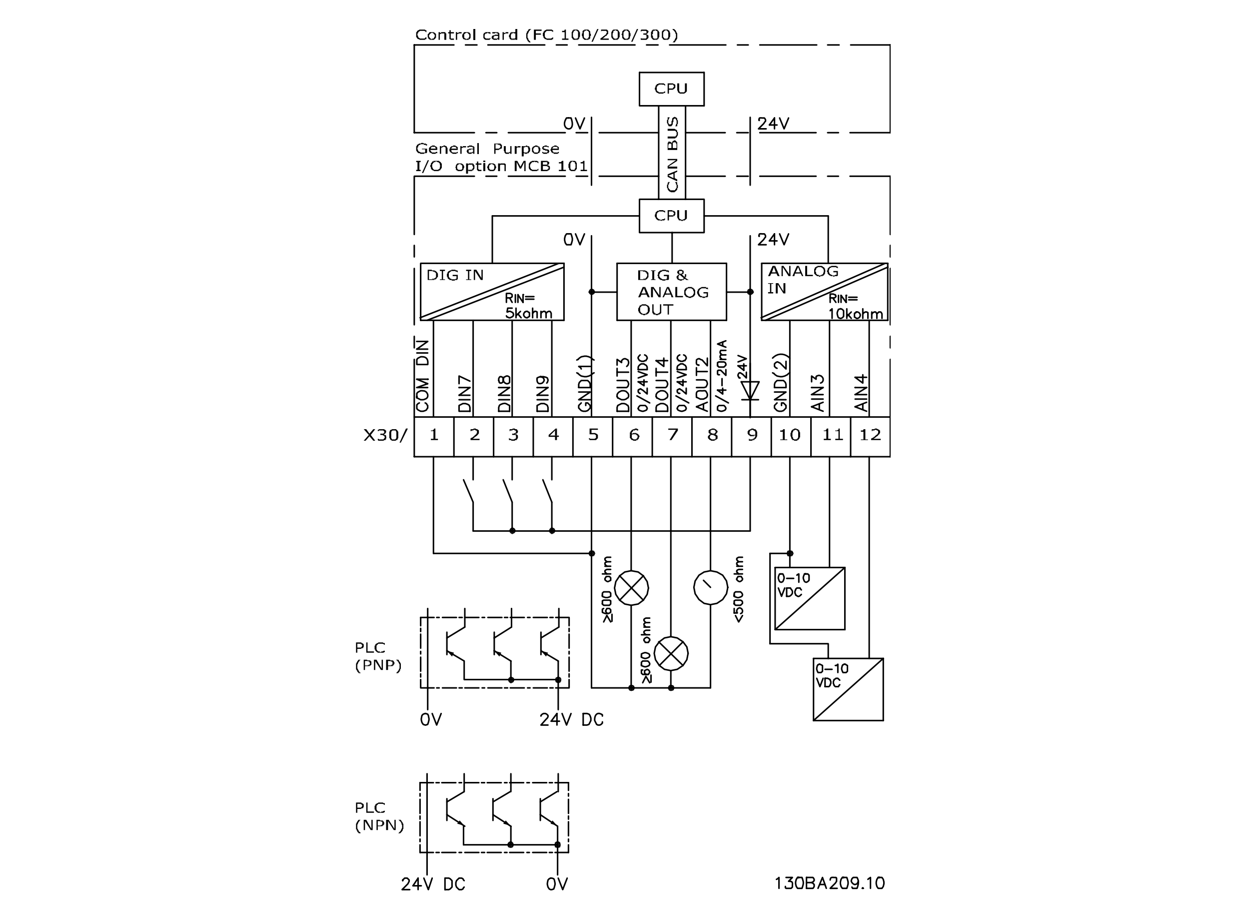


Illustration 3.20: Principle Diagram

3

3.6.3. Digital inputs - Terminal X30/1-4

Parameters for set-up: 5-16, 5-17 and 5-18

Number of digital inputs	Voltage level	Voltage levels	Tolerance	Max. Input impedance
3	0-24 V DC	PNP type: Common = 0 V Logic "0": Input < 5 V DC Logic "0": Input > 10 V DC NPN type: Common = 24 V Logic "0": Input > 19 V DC Logic "0": Input < 14 V DC	± 28 V continuous ± 37 V in minimum 10 sec.	Approx. 5 k ohm

3.6.4. Analog voltage inputs - Terminal X30/10-12

Parameters for set-up: 6-3*, 6-4* and 16-76

Number of analog voltage inputs	Standardized input signal	Tolerance	Resolution	Max. Input impedance
2	0-10 V DC	± 20 V continuously	10 bits	Approx. 5 K ohm

3.6.5. Digital outputs - Terminal X30/5-7

Parameters for set-up: 5-32 and 5-33

Number of digital outputs	Output level	Tolerance	Max.impedance
2	0 or 24 V DC	± 4 V	≥ 600 ohm

3.6.6. Analog outputs - Terminal X30/5+8

Parameters for set-up: 6-6* and 16-77

Number of analog outputs	Output signal level	Tolerance	Max.impedance
1	0/4 - 20 mA	± 0.1 mA	< 500 ohm

3.6.7. Relay Option MCB 105

The MCB 105 option includes 3 pieces of SPDT contacts and must be fitted into option slot B.

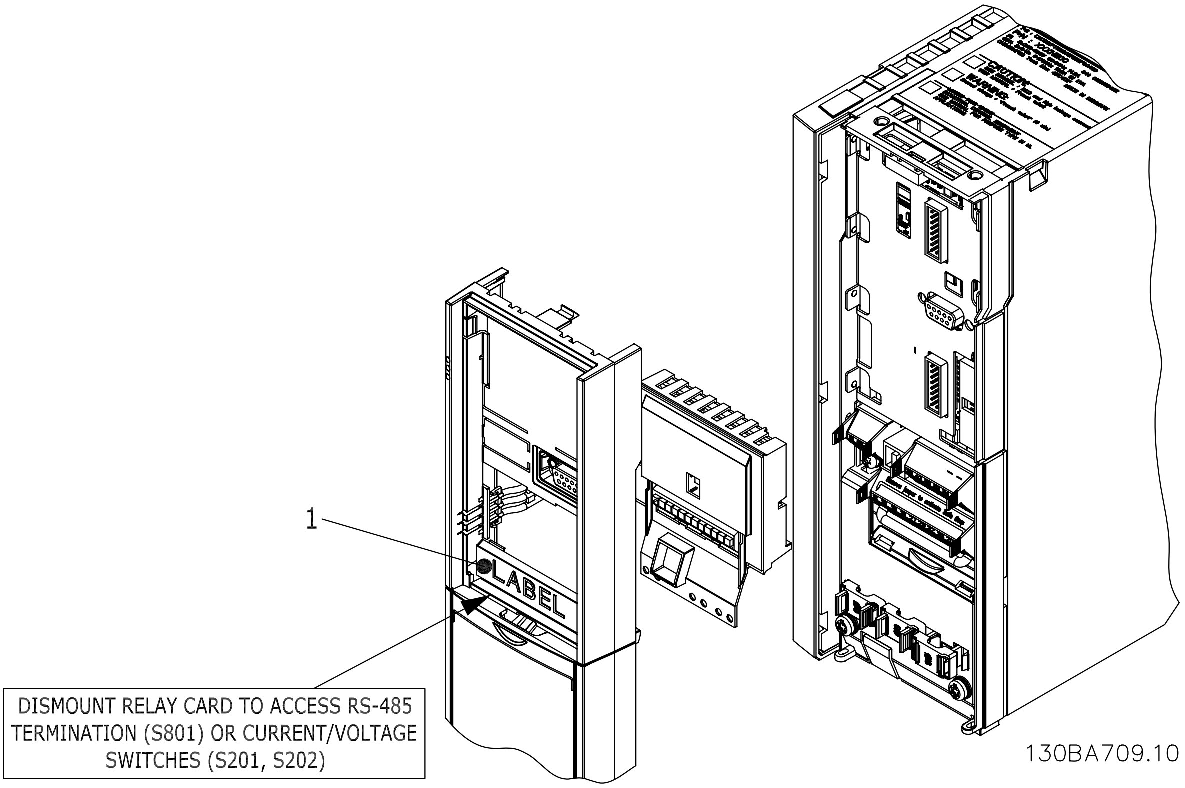
Electrical Data:	
Max terminal load (AC-1) 1) (Resistive load)	240 V AC 2A
Max terminal load (AC-15) 1) (Inductive load @ cosφ 0.4)	240 V AC 0.2 A
Max terminal load (DC-1) 1) (Resistive load)	24 V DC 1 A
Max terminal load (DC-13) 1) (Inductive load)	24 V DC 0.1 A
Min terminal load (DC)	5 V 10 mA
Max switching rate at rated load/min load	6 min^{-1}/20 sec^{-1}

1) IEC 947 part 4 and 5

When the relay option kit is ordered separately the kit includes:

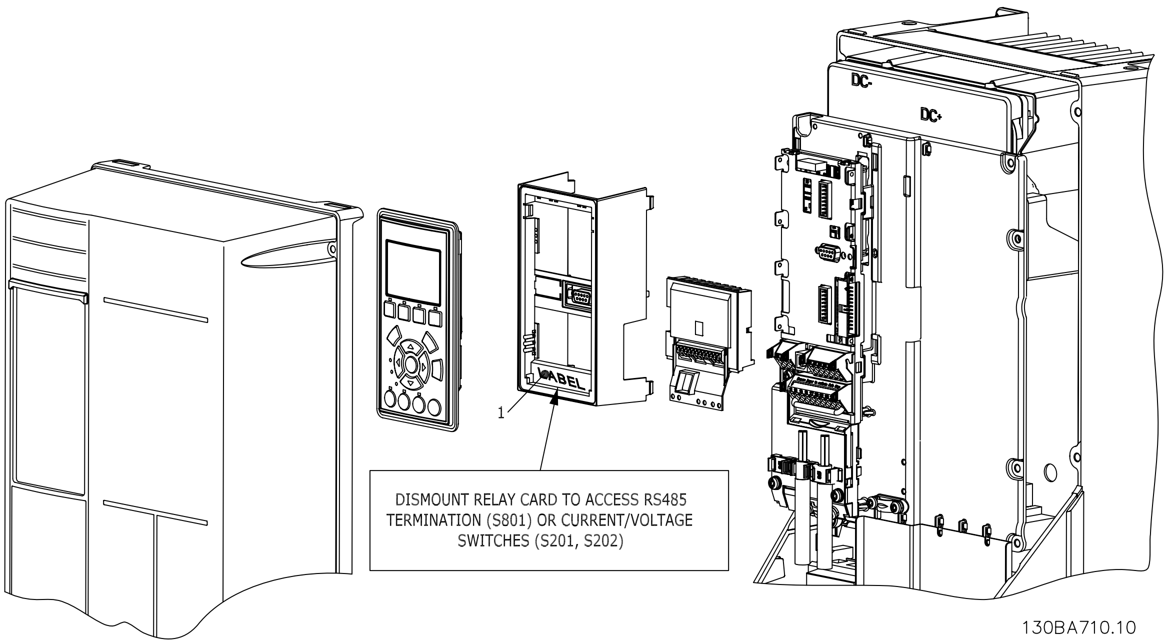
- Relay Module MCB 105
- Extended frame and enlarged terminal cover
- Label for covering access to switches S201, S202 and S801
- Cable strips for fastening cables to relay module

3



A2-A3-B3	A5-B1-B2-B4-C1-C2-C3-C4

[1] **IMPORTANT**! The label MUST be placed on the frame as shown (UL approved).

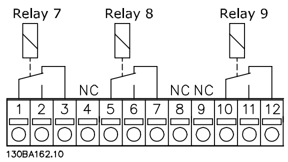


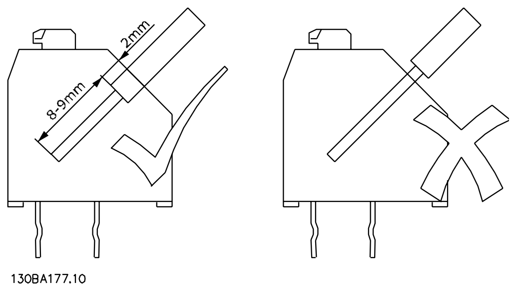
Warning Dual supply

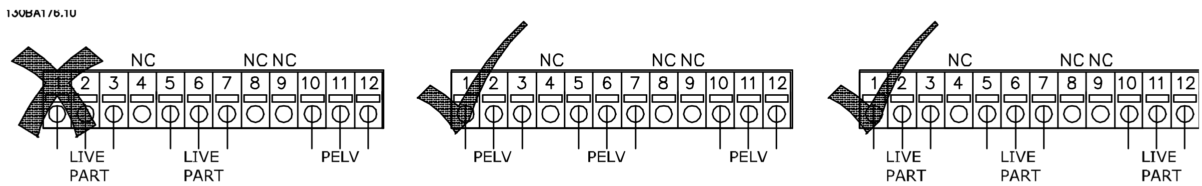
How to add the MCB 105 option:

- See mounting instructions in the beginning of section *Options and Accessories*
- The power to the live part connections on relay terminals must be disconnected.
- Do not mix live parts (high voltage) with control signals (PELV).
- Select the relay functions in par. 5-40 Function *Relay* [6-8], par. 5-41 On *Delay, Relay* [6-8] and par. 5-42 Off *Delay, Relay* [6-8].

NB! (Index [6] is relay 7, index [7] is relay 8, and index [8] is relay 9)







Do not combine low voltage parts and PELV systems.

3.6.8. 24 V Back-Up Option MCB 107 (Option D)

External 24 V DC Supply

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

External 24 V DC supply specification:

Input voltage range	24 V DC ±15 % (max. 37 V in 10 s)
Max. input current	2.2 A
Average input current for the frequency converter	0.9 A
Max cable length	75 m
Input capacitance load	< 10 uF
Power-up delay	< 0.6 s

The inputs are protected.

Terminal numbers:

Terminal 35: - external 24 V DC supply.

Terminal 36: + external 24 V DC supply.

Follow these steps:

1. Remove the or Blind Cover
2. Remove the Terminal Cover
3. Remove the Cable Decoupling Plate and the plastic cover underneath
4. Insert the 24 V DC Back-up External Supply Option in the Option Slot
5. Mount the Cable Decoupling Plate
6. Attach the Terminal Cover and the or Blind Cover.

When MCB 107, 24 V back-up option is supplying the control circuit, the internal 24 V supply is automatically disconnected.

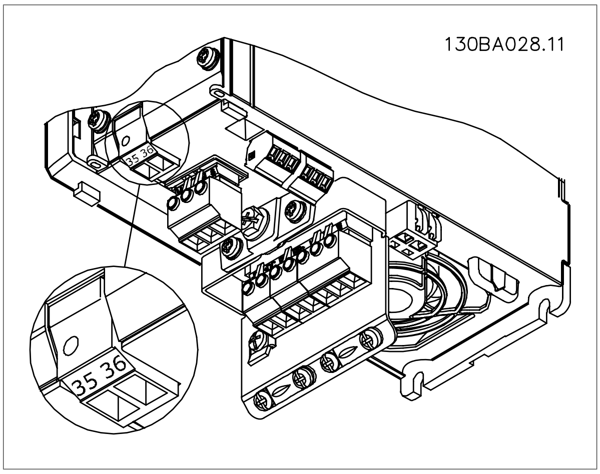


Illustration 3.21: Connection to 24 V back-up supplier (A2-A3).

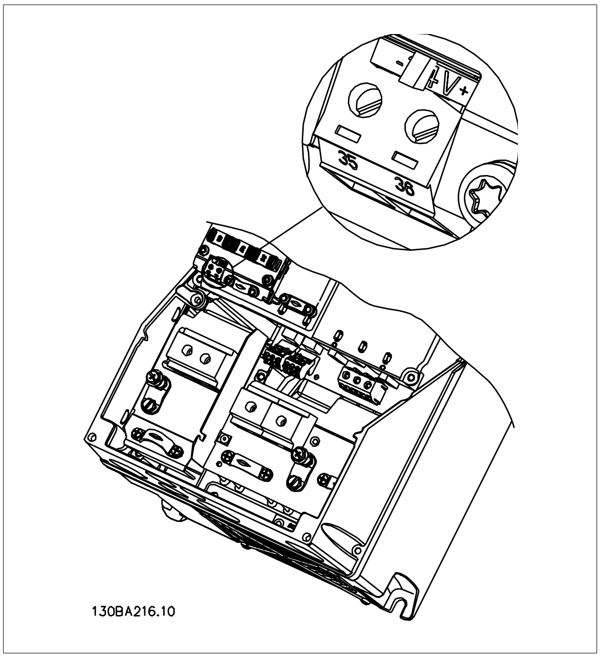


Illustration 3.22: Connection to 24 V back-up supplier (A5-C2).

3.6.9. Analog I/O option MCB 109

The Analog I/O card is supposed to be used in e.g. the following cases:

- Providing battery back-up of clock function on control card
- As general extension of analog I/O selection available on control card, e.g. for multi-zone control with three pressure transmitters
- Turning frequency converter into de-central I/O block supporting Building Management System with inputs for sensors and outputs for operating dampers and valve actuators
- Support Extended PID controllers with I/Os for set point inputs, transmitter/sensor inputs and outputs for actuators.

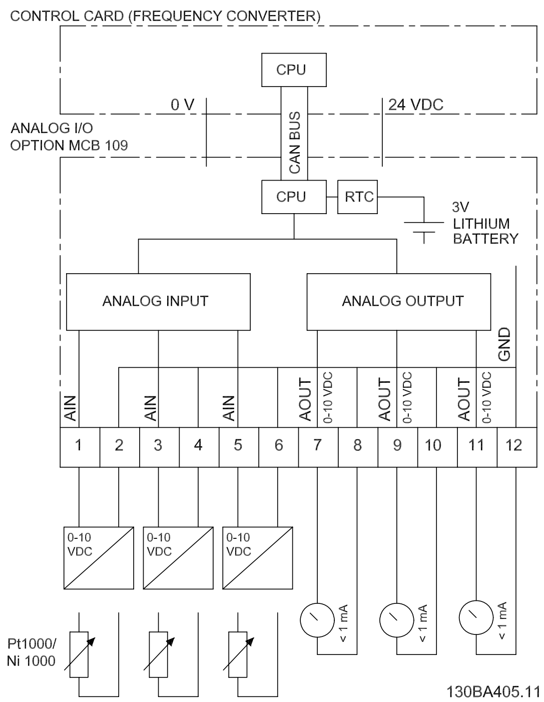


Illustration 3.23: Principle diagram for Analog I/O mounted in frequency converter.

Analog I/O configuration

3 x Analog Inputs, capable of handling following:

- 0 - 10 VDC

OR

- 0-20 mA (voltage input 0-10V) by mounting a 510Ω resistor across terminals (see NB!)
- 4-20 mA (voltage input 2-10V) by mounting a 510Ω resistor across terminals (see NB!)
- Ni1000 temperature sensor of 1000 Ω at 0° C. Specifications according to DIN43760
- Pt1000 temperature sensor of 1000 Ω at 0° C. Specifications according to IEC 60751

3 x Analog Outputs supplying 0-10 VDC.

NB!

Please note the values available within the different standard groups of resistors:
E12: Closest standard value is 470Ω, creating an input of 449.9Ω and 8.997V.
E24: Closest standard value is 510Ω, creating an input of 486.4Ω and 9.728V.
E48: Closest standard value is 511Ω, creating an input of 487.3Ω and 9.746V.
E96: Closest standard value is 523Ω, creating an input of 498.2Ω and 9.964V.

Analog inputs - terminal X42/1-6

Parameter group for read out: 18-3* See also *Programming Guide.*

Parameter groups for set-up: 26-0*, 26-1*, 26-2* and 26-3* See also *Programming Guide.*

3 x Analog inputs	Operating range	Resolu-tion	Accuracy	Sam-pling	Max load	Impedance
Used as temperature sensor input	-50 to +150 °C	11 bits	-50 °C ±1 Kelvin +150 °C ±2 Kelvin	3 Hz	-	-
Used as voltage input	0 - 10 VDC	10 bits	0.2% of full scale at cal. temperature	2.4 Hz	+/- 20 V continuously	Approximately 5 kΩ

When used for voltage, analog inputs are scalable by parameters for each input.

When used for temperature sensor, analog inputs scaling is preset to necessary signal level for specified temperature span.

When analog inputs are used for temperature sensors, it is possible to read out feedback value in both °C and °F.

When operating with temperature sensors, maximum cable length to connect sensors is 80 m non-screened / non-twisted wires.

Analog outputs - terminal X42/7-12

Parameter group for read out and write: 18-3* See also *Programming Guide*

Parameter groups for set-up: 26-4*, 26-5* and 26-6* See also *Programming Guide*

3 x Analog outputs	Output signal level	Resolution	Linearity	Max load
Volt	0-10 VDC	11 bits	1% of full scale	1 mA

Analog outputs are scalable by parameters for each output.

The function assigned is selectable via a parameter and have same options as for analog outputs on control card.

For a more detailed description of parameters, please refer to the *Programming Guide*.

Real-time clock (RTC) with back-up

The data format of RTC includes year, month, date, hour, minutes and weekday.

Accuracy of clock is better than ± 20 ppm at 25° C.

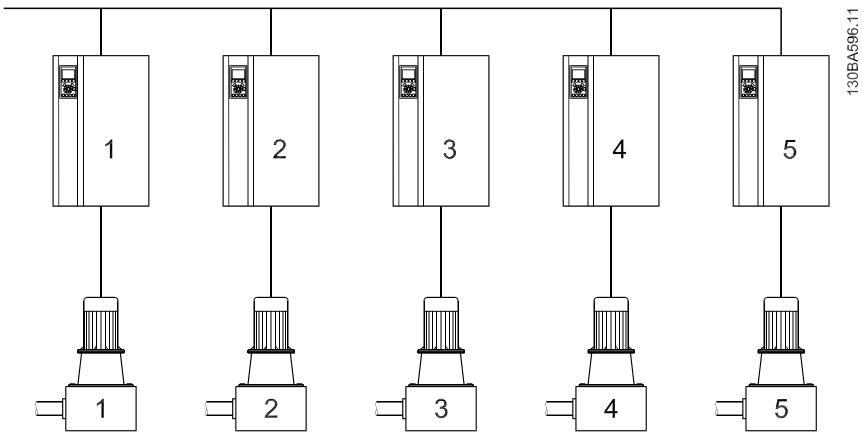
The built-in lithium back-up battery lasts on average for minimum 10 years, when frequency converter is operating at 40 °C ambient temperature. If battery pack back-up fails, analog I/O option must be exchanged.

3.6.10. Introduction to the Extended Cascade Controller

Cascade control is a common control system used to control parallel pumps or fans in an energy efficient way.

The Extended Cascade Controller option provides the capability to control multiple pumps configured in parallel in a way that makes them appear as a single larger pump.

When using the Extended Cascade Controller, the individual pumps are automatically turned on (staged) and turned off (de-staged) as needed in order to satisfy the required system output for flow or pressure. The speed of pumps connected to VLT AQUA Drives is also controlled to provide a continuous range of system output.



The Extended Cascade Controller is an optional hardware and software component that can be added to the VLT AQUA Drive. It consists of an option board containing 3 relays that is installed in the B option location on the Drive. Once the option is installed the parameters needed to support the Extended Cascade Controller functions will be available through the control panel in the 27-** parameter group. The Extended Cascade Controller offers more functionality than the Basic Cascade Controller. It can be used to extend the Basic Cascade with 3 relays.

While the Cascade controller is designed for pumping applications and this document describes the cascade controller for this application, it is also possible to use the Extended Cascade Controller for any application requiring multiple motors configured in parallel.

3.6.11. General Description

The Extended Cascade Controller software runs from a single VLT AQUA Drive with the Extended Cascade Controller option card installed. This Drive is referred to as the Master Drive. It controls a set of pumps each controlled by a Danfoss VLT Drive or connected directly to mains through a contactor or through a soft starter.

Each additional VLT Drive in the system is referred to as a Follower Drive. These Drives do not need the Extended Cascade Controller option card installed. They are operated in open loop mode and receive their speed reference from the Master Drive. The pumps connected to these Drives are referred to as Variable Speed pumps.

Each additional pump connected to mains through a contactor or through a soft starter is referred to as a Fixed Speed pump.

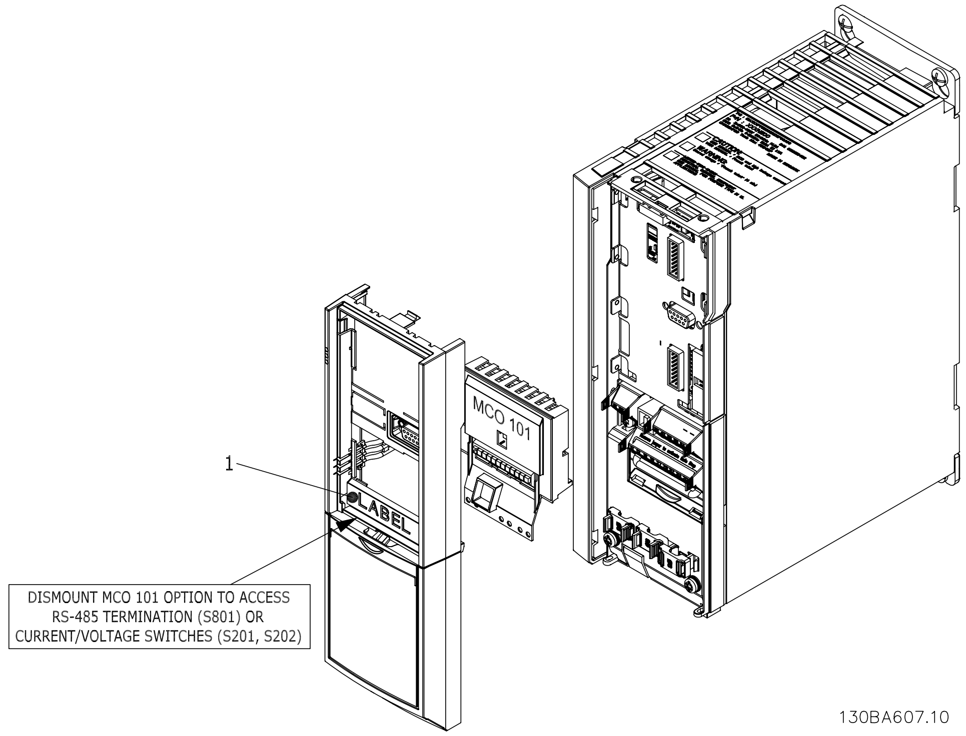
Each pump, variable speed or fixed speed, is controlled by a relay in the Master Drive. The VLT AQUA Drive with the Extended Cascade Controller option card installed has five relays available for controlling pumps. 2 relays standard in the drive and additional 3 relays on the option card MCO 101.

The Extended Cascade Controller is capable of controlling a mix of variable speed and fixed speed pumps. Possible configurations are described in more detail in the next section. For simplicity of description within this manual, Pressure and Flow will be used to describe the variable output of the set of pumps controlled by the cascade controller.

3.6.12. Extended Cascade Control MCO 101

The MCO 101 option includes 3 pieces of change over contacts and can be fitted into option slot B.

Electrical Data:	
Max terminal load (AC)	240 V AC 2A
Max terminal load (DC)	24 V DC 1 A
Min terminal load (DC)	5 V 10 mA
Max switching rate at rated load/min load	6 min^{-1}/20 sec^{-1}



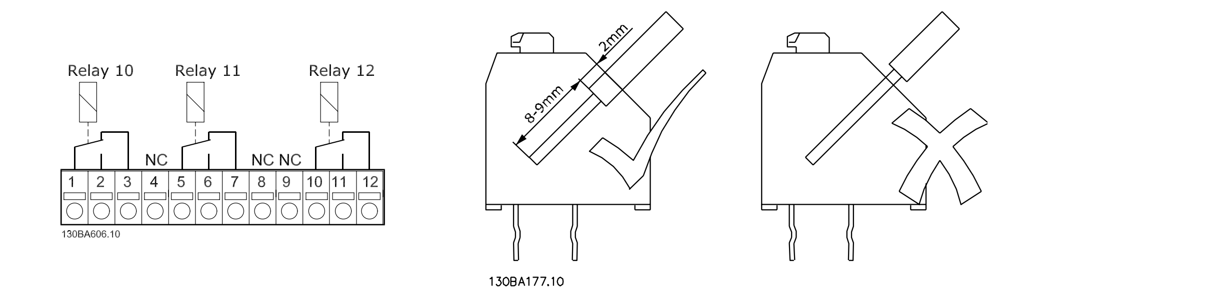
Warning Dual supply

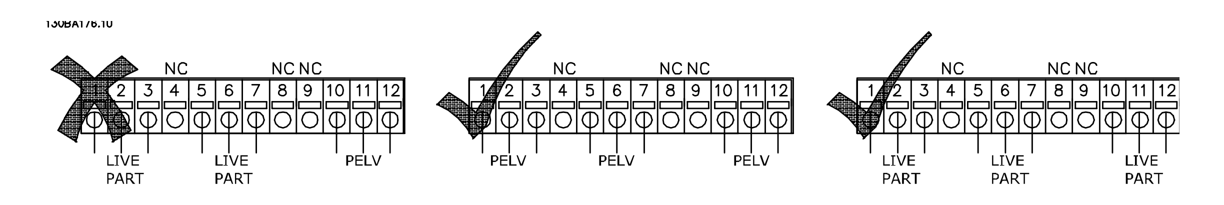
NB!
The label MUST be placed on the LCP frame as shown (UL approved).

How to add the MCO 101 option:

- The power to the frequency converter must be disconnected.
- The power to the live part connections on relay terminals must be disconnected.
- Remove the LCP, the terminal cover and the cradle from the FC 202.
- Fit the MCO 101 option in slot B.
- Connect the control cables and relief the cables by the enclosed cable strips.
- Various systems must not be mixed.
- Fit the extended cradle and terminal cover.
- Replace the LCP
- Connect power to the frequency converter.

Wiring the Terminals





Do not combine low voltage parts and PELV systems.

3.6.13. Brake Resistors

In applications where the motor is used as a brake, energy is generated in the motor and send back into the frequency converter. If the energy can not be transported back to the motor it will increase the voltage in the converter DC-line. In applications with frequent braking and/or high inertia loads this increase may lead to an over voltage trip in the converter and finally a shut down. Brake resistors are used to dissipate the excess energy resulting from the regenerative braking. The resistor is selected in respect to its ohmic value, its power dissipation rate and its physical size. offers a wide variety of different resistors that are specially designed to our frequency converters. See the section *Control with brake function* for the dimensioning of brake resistors. Code numbers can be found in the section *How to order*.

3.6.14. Remote mounting Kit for

The Local Control Panel can be moved to the front of a cabinet by using the remote build in kit. The enclosure is the IP65. The fastening screws must be tightened with a torque of max. 1 Nm.

Technical data	
Enclosure:	IP 65 front
Max. cable length between and unit:	3 m
Communication std:	RS 485

Ordering no. 130B1113

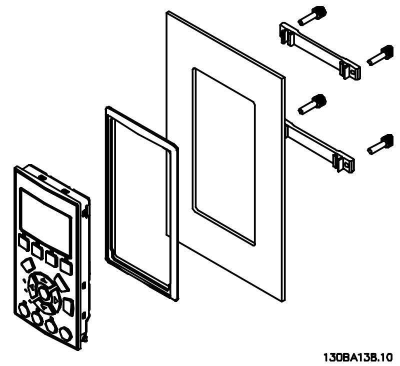


Illustration 3.24: LCP Kit with graphical LCP, fasteners, 3 m cable and gasket.

Ordering no. 130B1114

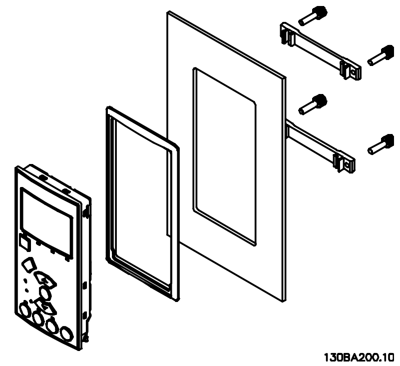
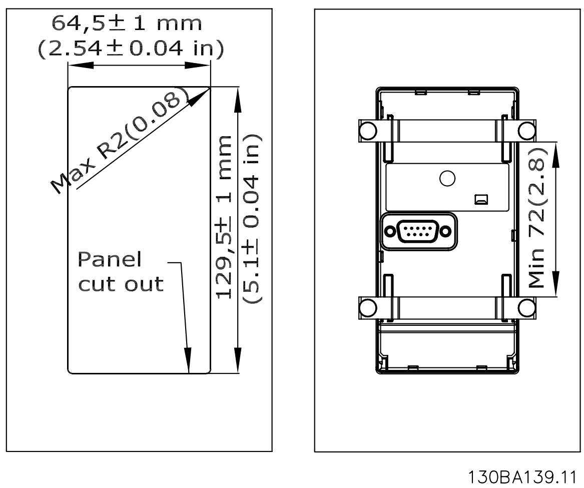


Illustration 3.25: LCP Kit with numerical LCP, fasternes and gasket.

LCP Kit without LCP is also available. Ordering number: 130B1117

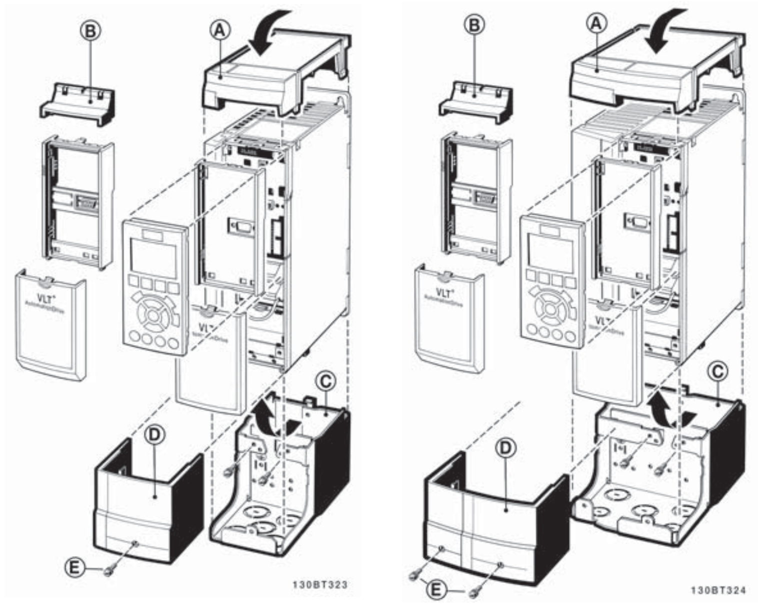


3.6.15. IP 21/IP 4X/ TYPE 1 Enclosure Kit

IP 20/IP 4X top/ TYPE 1 is an optional enclosure element available for IP 20 Compact units, enclosure size A2-A3 up to 7.5 kW.
If the enclosure kit is used, an IP 20 unit is upgraded to comply with enclosure IP 21/ 4X top/TYPE 1.

The IP 4X top can be applied to all standard IP 20 VLT AQUA variants.

A – Top cover
B – Brim
C – Base part
D – Base cover
E – Screw(s)
Place the top cover as shown. If an A or B option is used the brim must be fitted to cover the top inlet. Place the base part C at the bottom of the drive and use the clamps from the accessory bag to correctly fasten the cables. Holes for cable glands:
Size A2: 2x M25 and 3xM32
Size A3: 3xM25 and 3xM32



3.6.16. Input Filters

Harmonic current distortion is caused by the 6-pulse diode rectifier of the variable speed drive. The harmonic currents are affecting the installed serial equipment identical to reactive currents. Consequently harmonic current distortion can result in overheating of the supply transformer, cables etc. Depending on the impedance of the power grid, harmonic current distortion can lead to voltage distortion also affecting other equipment powered by the same transformer. Voltage distortion is increasing losses, causes premature aging and worst of all erratic operation. The majority of harmonics are reduced by the built-in DC coil but if additional reduction is needed, Danfoss offers two types of passive filters.

The Danfoss AHF 005 and AHF 010 are advanced harmonic filters, not to be compared with traditional harmonic trap filters. The Danfoss harmonic filters have been specially designed to match the Danfoss frequency converters.

AHF 010 is reducing the harmonic currents to less than 10% and the AHF 005 is reducing harmonic currents to less than 5% at 2% background distortion and 2% imbalance.

3.6.17. Output Filters

The high speed switching of the frequency converter produces some secondary effects, which influence the motor and the enclosed environment. These side effects are addressed by two different filter types, -the du/dt and the Sine-wave filter.

du/dt filters
Motor insulation stresses are often caused by the combination of rapid voltage and current increase. The rapid energy changes can also be reflected back to the DC-line in the inverter and cause shut down. The du/dt filter is designed to reduce the voltage rise time/the rapid energy change in the motor and by that intervention avoid premature aging and flashover in the motor insulation. du/dt filters have a positive influence on the radiation of magnetic noise in the cable that connects the drive to the motor. The voltage wave form is still pulse shaped but the du/dt ratio is reduced in comparison with the installation without filter.

Sine-wave filters
Sine-wave filters are designed to let only low frequencies pass. High frequencies are consequently shunted away which results in a sinusoidal phase to phase voltage waveform and sinusoidal current waveforms.

With the sinusoidal waveforms the use of special frequency converter motors with reinforced insulation is no longer needed. The acoustic noise from the motor is also damped as a consequence of the wave condition.

Besides the features of the du/dt filter, the sine-wave filter also reduces insulation stress and bearing currents in the motor thus leading to prolonged motor lifetime and longer periods between services. Sine-wave filters enable use of longer motor cables in applications where the motor is installed far from the drive. The length is unfortunately limited because the filter does not reduce leakage currents in the cables.

4. How to Order

4.1. Ordering form

4.1.1. Drive Configurator

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

For the VLT AQUA, you can order standard drives and drives with integral options by sending a type code string describing the product a to the Danfoss sales office, i.e.:

FC-202P18KT4E21H1XGCXXXSXXXXAGBKCXXXXDX

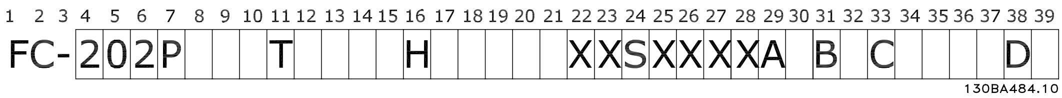
The meaning of the characters in the string can be located in the pages containing the ordering numbers in the chapter *How to Select Your VLT*. In the example above, a Profibus LON works option and a General purpose I/O option is included in the drive.

Ordering numbers for VLT AQUA Drive standard variants can also be located in the chapter *How to Select Your VLT*.

From the Internet based Drive Configurator, you can configure the right drive for the right application and generate the type code string. The Drive Configurator will automatically generate an eight-digit sales number to be delivered to your local sales office.
Furthermore, you can establish a project list with several products and send it to a Danfoss sales representative.

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

4.1.2. Type Code String



Description	Pos	Possible choice
Product group & VLT Series	1-6	FC 202
Power rating	8-10	0.25 - 630 kW
Number of phases	11	Three phases (T)
Mains voltage	11-12	S2: 220-240 VAC single phase S4: 380-480 VAC single phase T 2: 200-240 VAC T 4: 380-480 VAC T 6: 525-600 VAC T 7: 525-690 VAC
Enclosure	13-15	E20: IP20 E21: IP 21/NEMA Type 1 E55: IP 55/NEMA Type 12 E2M: IP21/NEMA Type 1 w/mains shield E5M: IP 55/NEMA Type 12 w/mains shield E66: IP66 F21: IP21 kit without backplate G21: IP21 kit with backplate P20: IP20/Chassis with backplate P21: IP21/NEMA Type 1 w/backplate P55: IP55/NEMA Type 12 w/backplate
RFI filter	16-17	HX: No RFI filter H1: RFI filter class A1/B H2: RFI filter class A2 H3: RFI filter class A1/B (reduced cable length) H4: RFI filter class A2/A1
Brake	18	X: No brake chopper included B: Brake chopper included T: Safe Stop U: Safe + brake
Display	19	G: Graphical Local Control Panel (GLCP) N: Numeric Local Control Panel (NLCP) X: No Local Control Panel
Coating PCB	20	X. No coated PCB C: Coated PCB
Mains option	21	D: Loadsharing X: No Mains disconnect switch 1: With Mains disconnect switch 8: Mains Disconnect + Loadsharing
Adaptation	22	Reserved
Adaptation	23	Reserved
Software release	24-27	Actual software
Software language	28	
A options	29-30	AX: No options A0: MCA 101 Profibus DP V1 A4: MCA 104 DeviceNet
B options	31-32	BX: No option BK: MCB 101 General purpose I/O option BP: MCB 105 Relay option BO:MCB 109 Analog I/O option
C0 options MCO	33-34	CX: No options
C1 options	35	X: No options
C option software	36-37	XX: Standard software
D options	38-39	DX: No option D0: DC back-up
The various options are described further in the *VLT AQUA Drive Design Guide*.		

Table 4.1: Type code description.

4.2. Ordering Numbers

4.2.1. Ordering Numbers: Options and Accessories

Type	Description	Ordering no.	
Miscellaneous hardware			
DC link connector	Terminal block for DC link connection on frame size A2/A3	130B1064	
IP 21/4X top/TYPE 1 kit	Enclosure, frame size A2: IP21/IP 4X Top/TYPE 1	130B1122	
IP 21/4X top/TYPE 1 kit	Enclosure, frame size A3: IP21/IP 4X Top/TYPE 1	130B1123	
Profibus D-Sub 9	Connector kit for IP20	130B1112	
Profibus top entry kit	Top entry kit for Profibus connection - only A enclosures	130B0524 1)	
Terminal blocks	Screw terminal blocks for replacing spring loaded terminals 1 pc 10 pin 1 pc 6 pin and 1 pc 3 pin connectors	130B1116	
Backplate	IP21 / NEMA 1 enclosure Top Cover A2	130B1132	
Backplate	IP21 / NEMA 1 enclosure Top Cover A3	130B1133	
Backplate	A5 IP55 / NEMA 12	130B1098	
Backplate	B1 IP21 / IP55 / NEMA 12	130B3383	
Backplate	B2 IP21 / IP55 / NEMA 12	130B3397	
Backplate	C1 IP21 / IP55 / NEMA 12	130B3910	
Backplate	C2 IP21 / IP55 / NEMA 12	130B3911	
Backplate	A5 IP66 / NEMA 4x	130B3242	
Backplate	B1 IP66 / NEMA 4x	130B3434	
Backplate	B2 IP66 / NEMA 4x	130B3465	
Backplate	C1 IP66 / NEMA 4x	130B3468	
Backplate	C2 IP66 / NEMA 4x	130B3491	
LCP			
LCP 101	Numerical Local Control Panel (NLCP)	130B1124	
LCP 102	Graphical Local Control Panel (GLCP)	130B1107	
LCP cable	Separate LCP cable, 3 m	175Z0929	
LCP kit	Panel mounting kit including graphical LCP, fasteners, 3 m cable and gasket	130B1113	
LCP kit	Panel mounting kit including numerical LCP, fasteners and gasket	130B1114	
LCP kit	Panel mounting kit for all LCPs including fasteners, 3 m cable and gasket	130B1117	
LCP kit	Panel mounting kit for all LCPs including fasteners and gasket - without cable	130B1170	
Options for Slot A Uncoated /	**Coated**	**Uncoated**	**Coated**
MCA 101	Profibus option DP V0/V1	130B1100	130B1200
MCA 104	DeviceNet option	130B1102	130B1202
MCA 108	LON works	130B1106	130B1206
Options for Slot B			
MCB 101	General purpose Input Output option	130B1125	
MCB 105	Relay option	130B1110	
MCB 109	Analog I/O option	130B1143	130B1243
MCO 101	Extended Cascade Control	130B1118	130B1218
Option for Slot C			
MCO 102	Advanced Cascade Control	130B1154	130B1254
Option for Slot D			
MCB 107	24 V DC back-up	130B1108	130B1208
External Options			
Ethernet IP	Ethernet master	175N2584	
Spare Parts			
Control board VLT AQUA Drive	With Safe Stop Function		130B1167
Control board VLT AQUA Drive	Without Safe Stop Function		130B1168
Fan A2	Fan, frame size A2	130B1009	
Fan A3	Fan, frame size A3	130B1010	
Fan A5	Fan, frame size A5	130B1017	
Fan B1	Fan external, frame size B1	130B1013	
Fan B2	Fan external, frame size B2	130B1015	
Fan B3	Fan external, frame size B3		130B3563
Fan B4	Fan external, frame size B4		130B3699
Fan B4	Fan external, frame size B5		130B3701
Fan C1	Fan external, frame size C1	130B3865	
Fan C2	Fan external, frame size C2	130B3867	
Fan C3	Fan external, frame size C3		130B4292
Fan C4	Fan external, frame size C4		130B4294
Accessory bag A2	Accessory bag, frame size A2	130B0509	
Accessory bag A3	Accessory bag, frame size A3	130B0510	
Accessory bag A5	Accessory bag, frame size A5	130B1023	
Accessory bag B1	Accessory bag, frame size B1	130B2060	
Accessory bag B2	Accessory bag, frame size B2	130B2061	
1) Only IP21 / > 11 kW			

Type	Description	Ordering no.

Miscellaneous hardware			
Accessory bag B3	Accessory bag, frame size B3	130B0980	
Accessory bag B4	Accessory bag, frame size B4	130B1300	Small
Accessory bag B4	Accessory bag, frame size B4	130B1301	Big
Accessory bag C1	Accessory bag, frame size C1	130B0046	
Accessory bag C2	Accessory bag, frame size C2	130B0047	
Accessory bag C3	Accessory bag, frame size C3	130B0981	
Accessory bag C4	Accessory bag, frame size C4	130B0982	Small
Accessory bag C4	Accessory bag, frame size C4	130B0983	Big

Options can be ordered as factory built-in options, see ordering information.

For information on fieldbus and application option compatibility with older software versions, please contact your Danfoss supplier.

4

4.2.2. Ordering Numbers: Harmonic Filters

Harmonic filters are used to reduce mains harmonics.

- AHF 010: 10% current distortion
- AHF 005: 5% current distortion

380-415V, 50Hz

$I_{AHF,N}$	Typical Motor Used [kW]	ordering number		Frequency converter size
		AHF 005	AHF 010	
10 A	1.1 - 4	175G6600	175G6622	P1K1, P4K0
19 A	5.5 - 7.5	175G6601	175G6623	P5K5 - P7K5
26 A	11	175G6602	175G6624	P11K
35 A	15 - 18.5	175G6603	175G6625	P15K - P18K
43 A	22	175G6604	175G6626	P22K
72 A	30 - 37	175G6605	175G6627	P30K - P37K
101A	45 - 55	175G6606	175G6628	P45K - P55K
144 A	75	175G6607	175G6629	P75K
180 A	90	175G6608	175G6630	P90K
217 A	110	175G6609	175G6631	P110
289 A	132 - 160	175G6610	175G6632	P132 - P160
324 A		175G6611	175G6633	
370 A	200	175G6688	175G6691	P200
506 A	250	175G6609 + 175G6610	175G6631 + 175G6632	P250
578 A	315	2x 175G6610	2x 175G6632	P315
648 A	400	2x175G6611	2x175G6633	P400

380 - 415V, 60Hz

$I_{AHF,N}$	Typical Motor Used [HP]	ordering number		Frequency converter size
		AHF 005	AHF 010	
19 A	10 - 15	130B2460	130B2472	P5K5 - P7K5
26 A	20	130B2461	130B2473	P11K
35 A	25 - 30	130B2462	130B2474	P15K, P18K
43 A	40	130B2463	130B2475	P22K
72 A	50 - 60	130B2464	130B2476	P30K - P37K
101A	75	130B2465	130B2477	P45K - P55K
144 A	100 - 125	130B2466	130B2478	P75K
180 A	150	130B2467	130B2479	P90K
217 A	200	130B2468	130B2480	P110
289 A	250	130B2469	130B2481	P132
324 A	300	130B2470	130B2482	P160
370 A	350	130B2471	130B2483	P200
506 A	450	130B2468 + 130B2469	130B2480 + 130B2481	P250
578 A	500	2x 130B2469	2x 130B2481	P315
648 A	500	2x130B2470	2x130B2482	P355

440-480V, 60Hz

$I_{AHF,N}$	Typical Motor Used [HP]	ordering number		Frequency converter size
		AHF 005	AHF 010	
19 A	10 - 15	175G6612	175G6634	P11K
26 A	20	175G6613	175G6635	P15K
35 A	25 - 30	175G6614	175G6636	P18K, P22K
43 A	40	175G6615	175G6637	P30K
72 A	50 - 60	175G6616	175G6638	P37K - P45K
101A	75	175G6617	175G6639	P55K
144 A	100 - 125	175G6618	175G6640	P75K
180 A	150	175G6619	175G6641	P90
217 A	200	175G6620	175G6642	P110
289 A	250	175G6621	175G6643	P132 - P160
324 A	300	175G6689	175G6692	
370 A	350	175G6690	175G6693	P200
434 A	350	2x175G6620	2x175G6642	P250
578 A	500	2x 175G6621	2x 175G6643	P315 - P355
659 A	550-600	175G6690 + 175G6621	175G6693 + 175G6643	P400

Matching the frequency converter and filter is pre-calculated based on 400V/480V and on a typical motor load (4 pole) and 110 % torque.

500-525V, 50Hz

$I_{AHF,N}$	Typical Motor Used [kW]	ordering number		Frequency converter size
		AHF 005	AHF 010	
10 A	0.75 - 5.5	175G6644	175G6656	PK75 - P5K5
19 A	7.5 - 11	175G6645	175G6657	P7K5 - P11K
26 A	15 18.5	175G6646	175G6658	P15K - P18K
35 A	22	175G6647	175G6659	P22K
43 A	30	175G6648	175G6660	P30K
72 A	37 -45	175G6649	175G6661	P37K - P45K
101 A	55 - 75	175G6650	175G6662	P55K - P75K
144 A	90 - 110	175G6651	175G6663	P90K - P110
180 A	132	175G6652	175G6664	P132
217 A	160	175G6653	175G6665	P160
289 A	200	175G6654	175G6666	P200
324 A	250	175G6655	175G6667	P250
370 A	315	2x175G6653	2x175G6665	P315 - P400
578 A	400	2X 175G6654	2X 175G6666	P500 - P560

690V, 50Hz

$I_{AHF,N}$	Typical Motor Used [kW]	ordering number		Frequency converter size
		AHF 005	AHF 010	
43	37 - 45	130B2328	130B2293	
72	55 - 75	130B2330	130B2295	P37K - P45K
101	90	130B2331	130B2296	P55K - P75K
144 A	110 - 132	130B2333	130B2298	P90K - P110
180 A	160	130B2334	130B2299	P132
217 A	200	130B2335	130B2300	P160
289 A	250	130B2331+2333	130B2301	P200
324 A	315	130B2333+2334	130B2302	P250
370 A	400	130B2334+2335	130B2304	P315

4.2.3. Ordering Numbers: Sine Wave Filter Modules, 200-500 VAC

Mains supply 3 x 200 to 500 V

Frequency converter size			Minimum switching frequency	Maximum output frequency	Part No. IP20	Part No. IP00	Rated filter current at 50Hz
200-240 V	**380-440 V**	**440-500 V**					
PK25	PK37	PK37	5 kHz	120 Hz	130B2439	130B2404	2.5 A
PK37	PK55	PK55	5 kHz	120 Hz	130B2439	130B2404	2.5 A
	PK75	PK75	5 kHz	120 Hz	130B2439	130B2404	2.5 A
PK55	P1K1	P1K1	5 kHz	120 Hz	130B2441	130B2406	4.5 A
	P1K5	P1K5	5 kHz	120 Hz	130B2441	130B2406	4.5 A
PK75	P2K2	P2K2	5 kHz	120 Hz	130B2443	130B2408	8 A
P1K1	P3K0	P3K0	5 kHz	120 Hz	130B2443	130B2408	8 A
P1K5			5 kHz	120 Hz	130B2443	130B2408	8 A
	P4K0	P4K0	5 kHz	120 Hz	130B2444	130B2409	10 A
P2K2	P5K5	P5K5	5 kHz	120 Hz	130B2446	130B2411	17 A
P3K0	P7K5	P7K5	5 kHz	120 Hz	130B2446	130B2411	17 A
P4K0			5 kHz	120 Hz	130B2446	130B2411	17 A
P5K5	P11K	P11K	4 kHz	60 Hz	130B2447	130B2412	24 A
P7K5	P15K	P15K	4 kHz	60 Hz	130B2448	130B2413	38 A
	P18K	P18K	4 kHz	60 Hz	130B2448	130B2413	38 A
P11K	P22K	P22K	4 kHz	60 Hz	130B2307	130B2281	48 A
P15K	P30K	P30K	3 kHz	60 Hz	130B2308	130B2282	62 A
P18K	P37K	P37K	3 kHz	60 Hz	130B2309	130B2283	75 A
P22K	P45K	P55K	3 kHz	60 Hz	130B2310	130B2284	115 A
P30K	P55K	P75K	3 kHz	60 Hz	130B2310	130B2284	115 A
P37K	P75K	P90K	3 kHz	60 Hz	130B2311	130B2285	180 A
P45K	P90K	P110	3 kHz	60 Hz	130B2311	130B2285	180 A
	P110	P132	3 kHz	60 Hz	130B2312	130B2286	260 A
	P132	P160	3 kHz	60 Hz	130B2312	130B2286	260 A
	P160	P200	3 kHz	60 Hz	130B2313	130B2287	410 A
	P200	P250	3 kHz	60 Hz	130B2313	130B2287	410 A
	P250	P315	3 kHz	60 Hz	130B2314	130B2288	480 A
	P315	P355	2 kHz	60 Hz	130B2315	130B2289	660 A
	P355	P400	2 kHz	60 Hz	130B2315	130B2289	660 A
	P400	P450	2 kHz	60 Hz	130B2316	130B2290	750 A
	P450	P500	2 kHz	60 Hz	130B2317	130B2291	880 A
	P500	P560	2 kHz	60 Hz	130B2317	130B2291	880 A
	P560	P630	2 kHz	60 Hz	130B2318	130B2292	1200 A
	P630	P710	2 kHz	60 Hz	130B2318	130B2292	1200 A

NB!

When using Sine-wave filters, the switching frequency should comply with filter specifications in par. 14-01 Switching *Frequency*.

4.2.4. Ordering Numbers: du/dt Filters, 380-480 VAC

Mains supply 3x380 to 3x480 V

Frequency converter size		Minimum switching frequency	Maximum output frequency	Part No. IP20	Part No. IP00	Rated filter current at 50 Hz
380-440V	**441-480V**					
11 kW	11 kW	4 kHz	60 Hz	130B2396	130B2385	24 A
15 kW	15 kW	4 kHz	60 Hz	130B2397	130B2386	45 A
18.5 kW	18.5 kW	4 kHz	60 Hz	130B2397	130B2386	45 A
22 kW	22 kW	4 kHz	60 Hz	130B2397	130B2386	45 A
30 kW	30 kW	3 kHz	60 Hz	130B2398	130B2387	75 A
37 kW	37 kW	3 kHz	60 Hz	130B2398	130B2387	75 A
45 kW	55 kW	3 kHz	60 Hz	130B2399	130B2388	110 A
55 kW	75 kW	3 kHz	60 Hz	130B2399	130B2388	110 A
75 kW	90 kW	3 kHz	60 Hz	130B2400	130B2389	182 A
90 kW	110 kW	3 kHz	60 Hz	130B2400	130B2389	182 A
110 kW	132 kW	3 kHz	60 Hz	130B2401	130B2390	280 A
132 kW	160 kW	3 kHz	60 Hz	130B2401	130B2390	280 A
160 kW	200 kW	3 kHz	60 Hz	130B2402	130B2391	400 A
200 kW	250 kW	3 kHz	60 Hz	130B2402	130B2391	400 A
250 kW	315 kW	3 kHz	60 Hz	130B2277	130B2275	500 A
315 kW	355 kW	2 kHz	60 Hz	130B2278	130B2276	750 A
355 kW	400 kW	2 kHz	60 Hz	130B2278	130B2276	750 A
400 kW	450 kW	2 kHz	60 Hz	130B2278	130B2276	750 A
450 kW	500 kW	2 kHz	60 Hz	130B2405	130B2393	910 A
500 kW	560 kW	2 kHz	60 Hz	130B2405	130B2393	910 A
560 kW	630 kW	2 kHz	60 Hz	130B2407	130B2394	1500 A
630 kW	710 kW	2 kHz	60 Hz	130B2407	130B2394	1500 A
710 kW	800 kW	2 kHz	60 Hz	130B2407	130B2394	1500 A
800 kW	1000 kW	2 kHz	60 Hz	130B2407	130B2394	1500 A
1000 kW	1100 kW	2 kHz	60 Hz	130B2410	130B2395	2300 A

4.2.5. Ordering Numbers: Brake Resistors

Ordering Numbers: Brake Resistors

Mains 200-240 VAC (T2-LP+MP)				VLT AQUA Drive										
				Selected resistor										
				Standard IP 20								Aluminium Housed (Flatpack) IP65		
				Duty Cycle 10%				Duty Cycle 40%						
Size:	P_{motor}	R_{min}	$R_{br,nom}$	R_{rec}	$P_{br\ max}$	Order no.	Period	R_{rec}	$P_{br\ max}$	Order no.	Period	R_{rec} per item	Duty cycle	Order no.
	[kW]	[Ω]	[Ω]	[Ω]	[kW]	175Uxxxx	[s]	[Ω]	[kW]	175Uxxxx	[s]	[Ω/w]	%	175Uxxxx
PK25	0.25	-	-	-	-	-	-	-	-	-	-	-	-	-
PK37	0.37	420	467	425	0.095	1841	120	425	0.43	1941	120	430/100	40	1002
PK55	0.55	284	315	310	0.25	1842	120	310	0.80	1942	120	330/100	27	1003
PK55	0.55	284	315	310	0.25	1842	120	310	0.80	1942	120	310/200	55	0984
PK75	0.75	190	211	210	0.285	1843	120	210	1.35	1943	120	220/100	20	1004
PK75	0.75	190	211	210	0.285	1843	120	210	1.35	1943	120	210/200	37	0987
P1K1	1.1	90	104	90	0.095	1821	120	90	0.43	1921	120	100/100	10	1006
P1K1	1.1	90	104	90	0.095	1821	120	90	0.43	1921	120	100/200	19	0991
P1K5	1.5	65	75.7	65	0.25	1822	120	65	0.80	1922	120	75/200	14	0992
P2K2	2.2	46	51	50	0.285	1823	120	50	1.00	1923	120	50/200	10	0993
P3K0	3	33	37	35	0.43	1824	120	35	1.35	1924	120	35/200	7	0994
P3K0	3	33	37	35	0.43	1824	120	35	1.35	1924	120	72/200	14	2X0992[1)]
P3K7	3.7	25	29.6	25	0.8	1825	120	25	3.00	1925	120	60/200	11	2X0996
P5K5	5.5	18	19.7	20	1	1826	120	20	-	-	-	-	-	-
P7K5	7.5	13	14.3	15	2	1827	120	15	-	-	-	-	-	-
P11K	11	9	9.6	10	2.8	1828	120	10	-	-	-	-	-	-
P15K	15	6.3	7.0	7	4	1829	120	7	-	-	-	-	-	-
P18K	18.5	5.3	5.7	6	4.8	1830	120	6	-	-	-	-	-	-
P22K	22	4.2	5.0	4.7	6	1954	300	4.7	-	-	-	-	-	-
P30K	30	2.9	3.7	3.3	8	1955	300	3.3	-	-	-	-	-	-
P37K	37	2.4	3.0	2.7	10	1956	300	2.7	-	-	-	-	-	-
P45K	45													

Ordering Numbers: Brake Resistors

Mains 380-480 VAC (T4-LP+MP+HP)				VLT AQUA Drive										
				Selected resistor										
				Standard IP 20								Aluminium Housed (Flatpack) IP65		
				Duty Cycle 10% [1)]				Duty Cycle 40% [2)]						
Size:	P_{motor}	R_{min}	$R_{br,nom}$	R_{rec}	$P_{br\ max}$	Order no.	Period	R_{rec}	$P_{br\ max}$	Order no.	Period	R_{rec} per item	Duty cycle	Order no.
	[kW]	[Ω]	[Ω]	[Ω]	[kW]	175Uxxxx	[s]	[Ω]	[kW]	175Uxxxx	[s]	[Ω/W]	%	175Uxxxx
PK37	0.37	620	1098/1360	620	0.065	1840	120	620	0.26	1940	120	830/100	30	1000
PK55	0.55	620	739/915	620	0.065	1840	120	620	0.26	1940	120	830/100	20	1000
PK75	0.75	601	539/668	620	0.065	1840	120	620	0.26	1940	120	620/100	14	1001
PK75	0.75	601	539/668	620	0.065	1840	120	620	0.26	1940	120	620/200	27	0982
P1K1	1.1	408	366/453	425	0.095	1841	120	425	0.43	1941	120	430/100	10	1002
P1K1	1.1	408	452.8	425	0.095	1841	120	425	0.43	1941	120	430/200	20	0983
P1K5	1.5	297	267/330	310	0.25	1842	120	310	0.80	1942	120	310/200	14	0984
P2K2	2.2	200	180/223	210	0.29	1843	120	210	1.35	1943	120	210/200	10	0987
P3K0	3	145	130/161	150	0.43	1844	120	150	2	1944	120	150/200	7	0989
P3K0	3	145	130/161	150	0.43	1844	120	150	2	1944	120	300/200	14	2X0985[1)]
P4K0	4	108	97/120	110	0.60	1845	120	110	2	1945	120	240/200	10	2X0986[1)]
P5K5	5.5	77	69.4/86	80	0.85	1846	120	80	3	1946	120	160/200	8	2X0988[1)]
P7K5	7.5	56	50.3/62.4	65	1	1847	120	65	5	1947	120	130/200	6	2X0990[1)]
P11K	11													
P15K	15	38	38.8/42.1	40	2	1848	120	40	5	1948	120	80/240	5	2x0090
P18K	18.5	27	28.1/30.5	30	3	1849	120	30	9	1949	120	72/240	4	2X0091[1)]
P22K	22	22	22.6/24.5	25	4	1850	120	25	13	1950	120	-	-	-
P30K	30	18	18.8/20.3	20	4	1851	120	20	13	1951	120	-	-	-
P37K	37	13.5	14.7/15.9	15	5	1852	120	15	16	1952	120	-	-	-
P45K	45	10.8	11.8/12.8	12	6	1853	120	12	19	1953	120	-	-	-
P55K	55	9.8	9.7/10.5	9.8	15	2008	120	9.8	38	2007	120	-	-	-
P75K	75	7.3	7.9/8.6	7.3	13	0069	120	7.3	38	0068	120	-	-	-
P90K	90	5.7	5.2/6.2	6	15	0067	120	4.7	45	0066	120	-	-	-
P110	110	3.6	5.2	3.8	22	1960	300	3.8	75	2X0072 [3)]	600	-	-	-
P132	132	3	4.2	3.2	27	1961	300	3.2	90	2X0073 [3)]	600	-	-	-
P160	160	2.5	3.5	2.6	32	1962	300	2.6	112	2X0074 [3)]	600	-	-	-
P200	200	2	2.9	2.1	39	1963	300	2.1	135	3X0075 [4)]	600	-	-	-
P250	250	1.6	2.3	3.3	56	2X1061 [3)]	300	3.3		NA	600			
P315	315	1.2	1.9	2.6	72	2X1062 [3)]	300	2.6		NA	600			
P355	355	1.2	1.5	2.6	72	2X1062 [3)]	300	2.6		NA	600			
P400	400	1.2	1.3	2.6	72	2X1062 [3, 5)]	300	2.6		NA	600			
P450	450	1.2	1.3	2.6	72	2X1062 [3, 5)]	300	2.6		NA	600			
P500	500	1.2	1.3	2.6	72	2X1062 [3, 5)]	300	2.6		NA	600			
P560	560	1.2	1.3	2.6	72	2X1062 [3, 5)]	300	2.6		NA	600			
P630	630	1.2	1.3	2.6	72	2X1062 [3, 5)]	300	2.6		NA	600			
P710	710	1.2	1.3	2.6	72	2X1062 [3, 5)]	300	2.6		NA	600			
P800	800	1.2	1.3	2.6	72	2X1062 [3, 5)]	300	2.6		NA	600			
P1M0	1000	1.2	1.3	2.6	72	2X1062 [3, 5)]	300	2.6		NA	600			

[1a)] 10% duty cycle based on 160% braking torque for 30 seconds during 300 second cycles.
[2)] 40% duty cycle based on 100% braking torque for 240 seconds during 600 second cycles.
[3)] Order two resistors as listed.
[4)] Order three resistors as listed.
[5)] Braking torque reduced (below 160%).

4

Ordering Numbers: Brake Resistors

Mains 525-690 VAC (T7-HP)

				VLT AQUA Drive							
				Selected resistor							
				Standard IP 20							
				Duty Cycle 10%				Duty Cycle 40%			
Size:	P_{motor}	R_{min}	$R_{br,nom}$	R_{rec}	$P_{br\ max}$	Order no.	Period	R_{rec}	$P_{br\ max}$	Order no.	Period
	[kW]	[Ω]	[Ω]	[Ω]	[kW]	130Bxxxx	[s]	[Ω]	[kW]	130Bxxxx	[s]
P45K	45	17.1	19.3	18	64	2119	600	18	39	2119	600
P55K	55	14.3	15.8	15	76	2120	600	15	47	2120	600
P75K	75	10.5	11.5	11	104	2121	600	11	64	2121	600
P90K	90	8.6	9.6	9.1	126	2122	600	9.1	77	2122	600
P110	110	7.1	7.8	7.5	153	2123	600	7.5	93	2123	600
P132	132	5.9	6.5	6.2	185	2124	600	6.2	113	2124	600
P160	160	4.8	5.4	5.1	224	2125	600	5.1	137	2125	600
P200	200	3.7	4.3	7.8	147	2X2126 3)	600	7.8	90	2X2126 3)	600
P250	250	3.1	3.4	6.6	173	2X2127 3)	600	6.6	106	2X2127 3)	600
P315	315	2.6	2.7	5.4	212	2X2128 3)	600	5.4	130	2X2128 3)	600
P355	355	1.9	2.4	4		NA	600	4		NA	600
P400	400	1.9	2.2	4		NA	600	4		NA	600
P450	500	1.9	2	4		NA	600	4		NA	600
P500	560	1.9	2	4		NA	600	4		NA	600
P560	630	1.9	2	4		NA	600	4		NA	601
P670	710	1.9	2	4		NA	600	4		NA	602
P750	800	1.9	2	4		NA	600	4		NA	603
P850	900	1.9	2	4		NA	600	4		NA	604
P1M0	1000	1.9	2	4		NA	600	4		NA	605
P1M2	1200	1.9		2.0	4		NA	600	4	NA	605

1) 10% duty cycle based on 160% braking torque for 30 seconds during 300 second cycles.

2) 40% duty cycle based on 100% braking torque for 240 seconds during 600 second cycles.

3) Order two resistors as listed.

4) Order three resistors as listed.

5) Braking torque reduced (below 160%).

5. How to Install

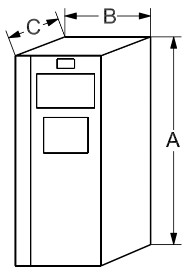
5.1. Mechanical Installation

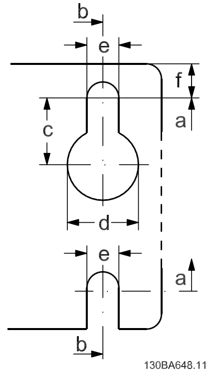
Page intentionally left blank!

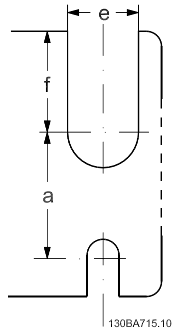
5

5.1.1. Mechanical Front Views

A2	A3	A5	B1	B2	B3	B4	C1	C2	C3	C4
										
IP20/21	IP20/21	IP55/66	IP21/55/66	IP21/55/66	IP20	IP20	IP21/55/66	IP21/55/66	IP20	IP20







Accessory bags containing necessary brackets, screws and connectors are included with the drives upon delivery.

Top and bottom mounting holes. (C3+C4 only)

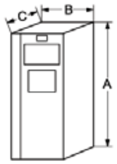
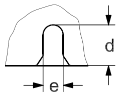
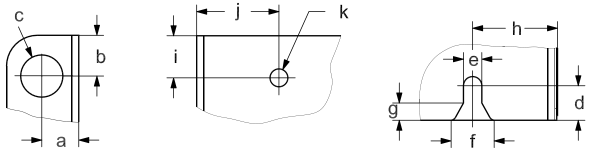
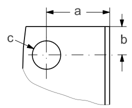
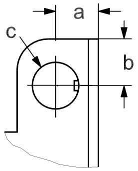
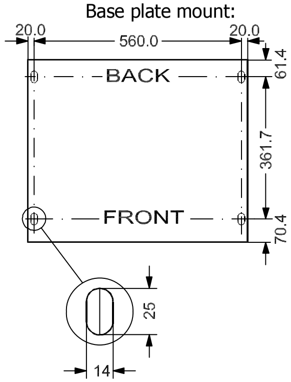
All measurements in mm.
* A5 in IP55/66 only!

5.1.2. Mechanical Dimensions

Mechanical dimensions														
Frame size (kW):		**A2**		**A3**		**A5**	**B1**	**B2**	**B3**	**B4**	**C1**	**C2**	**C3**	**C4**
200-240 V		**0.25-3.0**		**3.7**		**0.25-3.7**	**5.5-11**	**15**	**5.5-11**	**15-18.5**	**18.5-30**	**37-45**	**22-30**	**37-45**
380-480 V		**0.37-4.0**		**5.5-7.5**		**0.37-7.5**	**11-18.5**	**22-30**	**11-18.5**	**22-37**	**37-55**	**75-90**	**45-55**	**75-90**
525-600 V		**-**		**0.75-7.5**		**0.75-7.5**	**11-18.5**	**22-30**	**11-18.5**	**22-37**	**37-55**	**75-90**	**45-55**	**75-90**
IP NEMA		20 Chassis	21 Type 1	20 Chassis	21 Type 1	55/66 Type 12	21/ 55/66 Type 1/12	21/55/66 Type 1/12	20 Chassis	20 Chassis	21/55/66 Type 1/12	21/55/66 Type 1/12	20 Chassis	20 Chassis
Height (mm)														
Enclosure	A**	246	372	246	372	420	480	650	350	460	680	770	490	600
..with de-coupling plate	A2	374	-	374	-	-	-	-	419	595	-	-	630	800
Back plate	A1	268	375	268	375	420	480	650	399	520	680	770	550	660
Distance between mount. holes	a	257	350	257	350	402	454	624	380	495	648	739	521	631
Width (mm)														
Enclosure	B	90	90	130	130	242	242	242	165	231	308	370	308	370
With one C option	B	130	130	170	170	242	242	242	205	231	308	370	308	370
Back plate	B	90	90	130	130	242	242	242	165	231	308	370	308	370
Distance between mount. holes	b	70	70	110	110	215	210	210	140	200	272	334	270	330
Depth (mm)														
Without option A/B	C	205	205	205	205	200	260	260	248	242	310	335	333	333
With option A/B	C*	220	220	220	220	200	260	260	262	242	310	335	333	333
Screw holes (mm)														
	c	8.0	8.0	8.0	8.0	8.2	12	12	8	-	12	12	-	-
Diameter ø	d	11	11	11	11	12	19	19	12	-	19	19	-	-
Diameter ø	e	5.5	5.5	5.5	5.5	6.5	9	9	6.8	8.5	9.0	9.0	8.5	8.5
	f	9	9	9	9	9	9	9	7.9	15	9.8	9.8	17	17
Max weight (kg)		4.9	5.3	6.6	7.0	14	23	27	12	23.5	45	65	35	50

* Depth of enclosure will vary with different options installed.
** The free space requirements are above and below the bare enclosure height measurement A. See section 3.2.3 for further information.

5

D1	D2	D3	D4	E1	E2	F1	F2	F3	F4
 130BA816.10	 130BA817.10	Graphic missing! 130BA864.10	Graphic missing! 130BA864.10	 130BA818.10	Graphic missing! 130BA864.10	Graphic missing! 130BA864.10	Graphic missing! 130BA864.10	 130BA824.10	Graphic missing! 130BA864.10
IP20/21	IP21/55/66	IP20	IP20	IP21/54	IP00	IP21/54	IP00	IP21/54	IP00
 130BA885.10					Bottom mounting hole:  130BA880.10	(Please contact !)			
Lifting eye and mounting holes:  130BA878.10				 130BA881.10	Lifting eye:  130BA879.10				
All measurements in mm				Base plate mount:  130BA651.10					

5

Mechanical dimensions

Enclosure size (kW)		D1	D2	D3	D4	E1	E2	F1	F2	F3	F4
200-240 V 380-480 V 525-600 V		**110-132 110-132**	**160-250 160-315**	**110-132 110-132**	**160-250 160-315**	**315-450 355-560**	**315-450 355-560**	**500-710 560-750**	**800-1000 850-1000**	**500-710 560-750**	**800-1000 850-1000**
IP NEMA		21/54 Type 1/12	21/54 Type 1/12	00 Type 1	00 Type 1	21/54 Type 1/12	00 Type 1	21/54 Type 1/12	21/54 Type 1/12	21/54 Type 1/12	21/54 Type 1/12
Height (mm)											
Back plate	A	1209	1589	1046	1327	2000	1547	2281	2281	2281	2281
Width (mm)											
Back plate	B	420	420	408	408	600	585	1400	2000	1800	2400
Depth (mm)											
	C	380	380	375	375	494	494	607	607	607	607
Dimensions brackets (mm/inch)											
Centre hole to edge	a	22/0.9	22/0.9	22/0.9	22/0.9	56/2.2	23/0.9				
Centre hole to edge	b	25/1.0	25/1.0	25/1.0	25/1.0	25/1.0	25/1.0				
Hole diameter	c	25/1.0	25/1.0	25/1.0	25/1.0	25/1.0	25/1.0				
	d	20/0.8	20/0.8	20/0.8	20/0.8		27/1.1				
	e	11/0.4	11/0.4	11/0.4	11/0.4		13/0.5				
	f	22/0.9	22/0.9	22/0.9	22/0.9						
	g	10/0.4	10/0.4	10/0.4	10/0.4						
	h	51/2.0	51/2.0	51/2.0	51/2.0						
	i	25/1.0	25/1.0	25/1.0	25/1.0						
	j	49/1.9	49/1.9	49/1.9	49/1.9						
Hole diameter	k	11/0.4	11/0.4	11/0.4	11/0.4						
Max weight (kg)		104	151	91	138	313	277	1004	1299	1246	1541

* The front of the frequency converter is slightly convex. C is the shortest distance from back to front (i.e. measured from corner to corner) of the frequency converter. D is the longest distance from back to front (i.e. measured in the middle) of the frequency converter.

5

5.1.3. Mechanical mounting

1. Drill holes in accordance with the measurements given.
2. You must provide screws suitable for the surface on which you want to mount the frequency converter. Retighten all four screws.

The frequency converter allows side-by-side installation.

The back wall must always be solid.

Enclosure	Air space (mm)
A2	
A3	100
A5	
B1	200
B2	
B3	200
B4	200
C1	200
C2	225
C3	200
C4	225

Table 5.1: Required free air space above and below frequency converter

5.1.4. Safety Requirements of Mechanical Installation

! Pay attention to the requirements that apply to integration and field mounting kit. Observe the information in the list to avoid serious damage or injury, especially when installing large units.

The frequency converter is cooled by means of air circulation.
To protect the unit from overheating, it must be ensured that the ambient temperature *does not exceed the maximum temperature stated for the frequency converter* and that the 24-hour average temperature *is not exceeded*. Locate the maximum temperature and 24-hour average in the paragraph *Derating for Ambient Temperature*.
If the ambient temperature is in the range of 45 °C - 55 ° C, derating of the frequency converter will become relevant, see *Derating for Ambient Temperature*.
The service life of the frequency converter is reduced if derating for ambient temperature is not taken into account.

5.1.5. Field Mounting

For field mounting the IP 21/IP 4X top/TYPE 1 kits or IP 54/55 units are recommended.

5.2. Electrical Installation

5.2.1. Cables General

NB!

Cables General

Always comply with national and local regulations on cable cross-sections.

Details of terminal tightening torques.

	Power (kW)			Torque (Nm)					
Enclo-sure	200-240 V	380-480 V	525-690 V	Line	Motor	DC con-nection	Brake	Earth	Relay
A2	0.25 - 3.0	0.37 - 4.0	1.1 - 4.0	1.8	1.8	1.8	1.8	3	0.6
A3	3.7	5.5 - 7.5	5.5 - 7.5	1.8	1.8	1.8	1.8	3	0.6
A5	0.25 - 3.7	0.37 - 7.5	1.1 - 7.5	1.8	1.8	1.8	1.8	3	0.6
B1	5.5 -11	11 - 18	-	1.8	1.8	1.5	1.5	3	0.6
B2	- 15	22 30	- -	2.5 4.5	2.5 4.5	3.7 3.7	3.7 3.7	3 3	0.6 0.6
C1	18.5 - 30	37 - 55	-	10	10	10	10	3	0.6
C2	37 - 45	75 90	- -	14 24	14 24	14 14	14 14	3 3	0.6 0.6
D1/D3	-	110 132	110 132	19 19	19 19	9.6 9.6	9.6 9.6	19	0.6
D2/D4	-	160-250	160-315	19	19	9.6	9.6	19	0.6
E1/E2	-	315-450	355-560	19	19	9.6	9.6	19	0.6

Table 5.2: Tightening of terminals.

5.2.2. Removal of Knockouts for Extra Cables

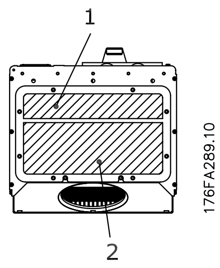
1. Remove cable entry from the frequency converter (Avoiding foreign parts falling into the frequency converter when removing knockouts)
2. Cable entry has to be supported around the knockout you intend to remove.
3. The knockout can now be removed with a strong mandrel and a hammer.
4. Remove burrs from the hole.
5. Mount Cable entry on frequency converter.

5.2.3. Gland/Conduit Entry - IP21 (NEMA 1) and IP54 (NEMA12)

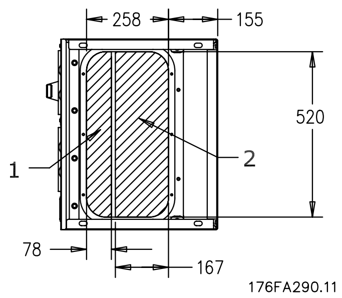
Cables are connected through the gland plate from the bottom. Remove the plate and plan where to place the entry for the glands or conduits. Prepare holes in the marked area on the drawing.

The gland plate must be fitted to the frequency converter to ensure the specified protection degree, as well as ensuring proper cooling of the unit. If the gland plate is not mounted, it may trip the unit.

Enclosure D1 + D2

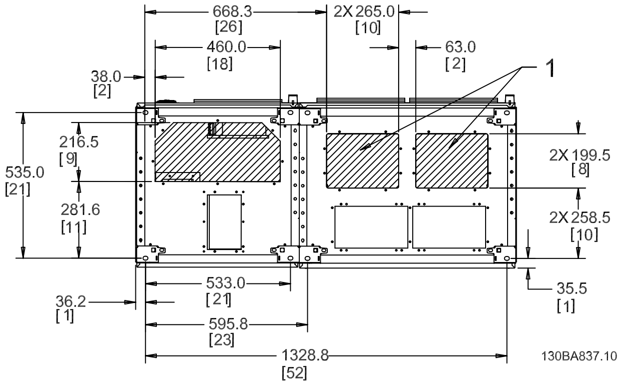


Enclosure E1

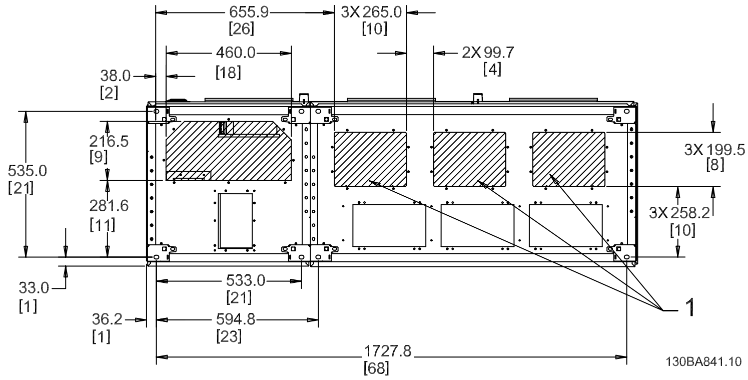


Cable entries viewed from the bottom of the frequency converter - 1) Mains side 2) Motor side

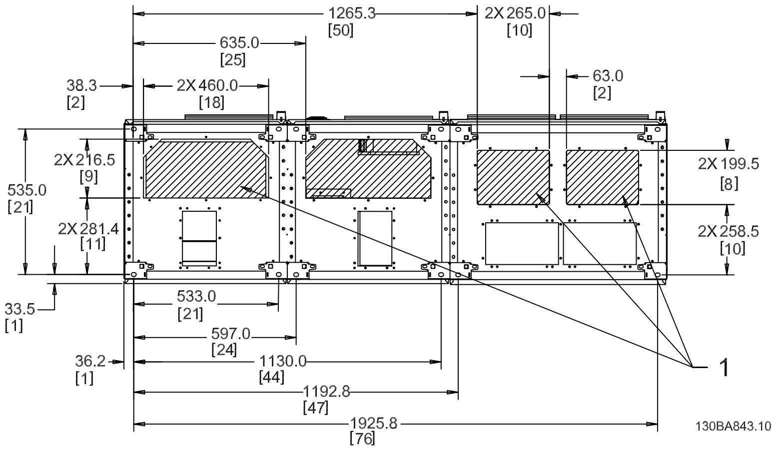
Enclosure F1



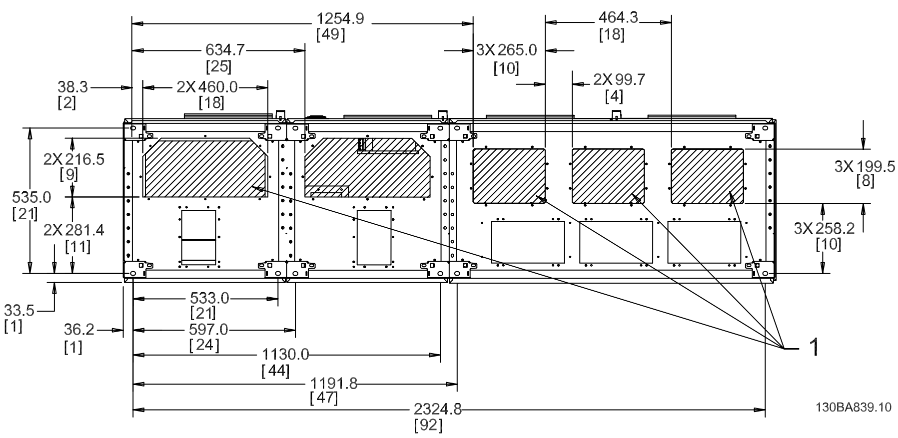
Enclosure F2



Enclosure F3



Enclosure F4



F1-F4: Cable entries viewed from the bottom of the frequency converter - 1) Place conduits in marked areas

5

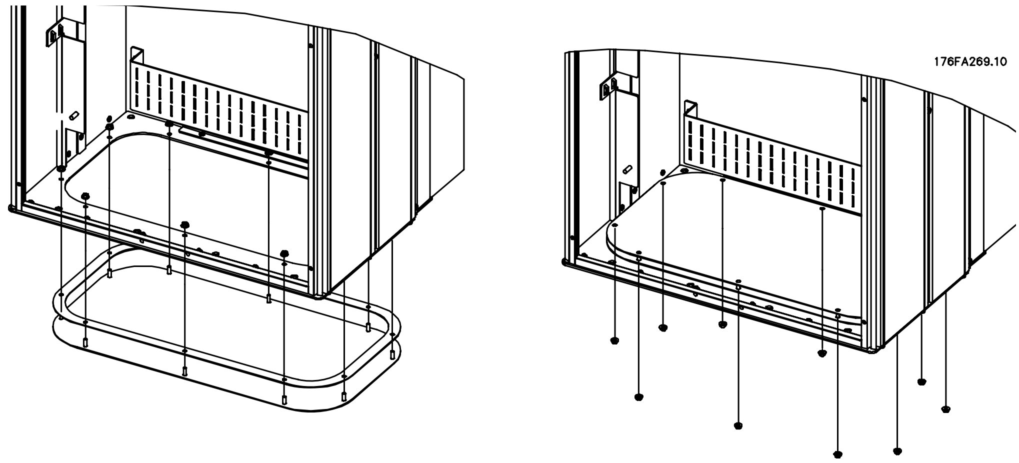


Illustration 5.1: Mounting of bottom plate, E1 enclosure.

The bottom plate of the E1 enclosure can be mounted from either in- or outside of the enclosure, allowing flexibility in the installation process, i.e. if mounted from the bottom the glands and cables can be mounted before the frequency converter is placed on the pedestal.

5.2.4. Connection to Mains and Earthing

NB!
The plug connector for power can be removed.

1. Make sure the frequency converter is properly earthed. Connect to earth connection (terminal 95). Use screw from the accessory bag.
2. Place plug connector 91, 92, 93 from the accessory bag onto the terminals labelled MAINS at the bottom of the frequency converter.
3. Connect mains wires to the mains plug connector.

The earth connection cable cross section must be at least 10 mm^2 or 2 rated mains wires terminated separately according to EN 50178.

The mains connection is fitted to the main switch if this is included.

NB!
Check that mains voltage corresponds to the mains voltage of the frequency converter name plate.

IT Mains
Do not connect 400 V frequency converters with RFI-filters to mains supplies with a voltage between phase and earth of more than 440 V.
For IT mains and delta earth (grounded leg), mains voltage may exceed 440 V between phase and earth.

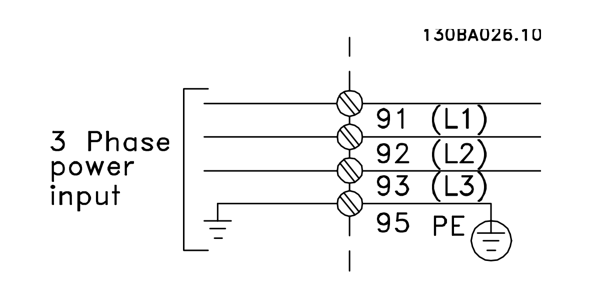


Illustration 5.2: Terminals for mains and earthing.

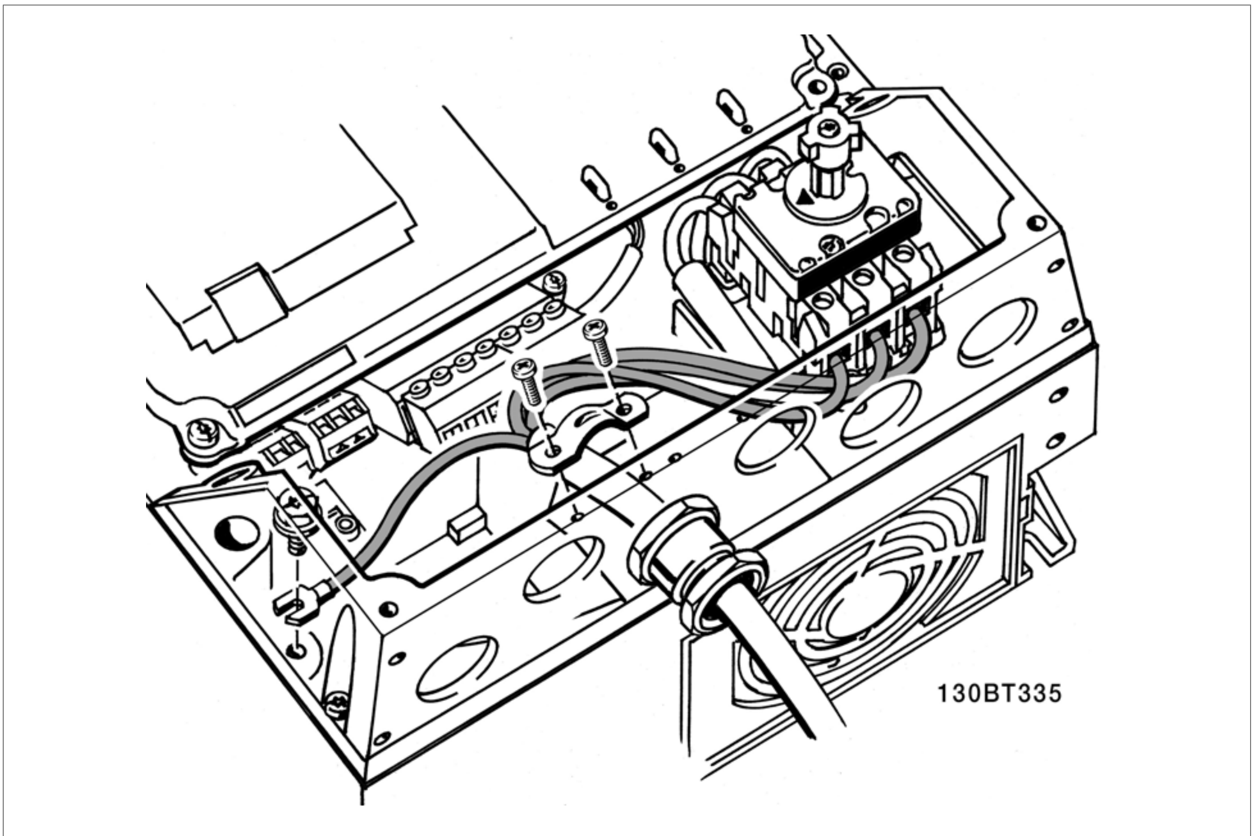


Illustration 5.3: How to connect to mains and earthing with disconnector (A5 enclosure).

5.2.5. Motor Connection

NB!
Motor cable must be screened/armoured. If an unscreened / unarmoured cable is used, some EMC requirements are not complied with. For more information, see *EMC specifications*.

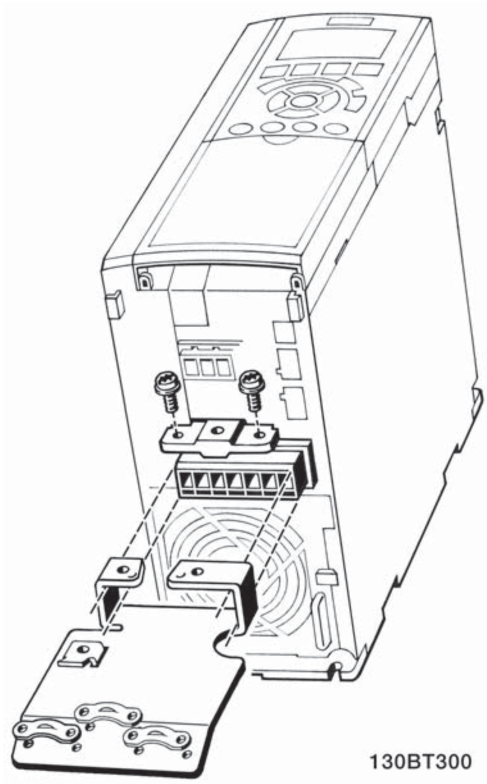
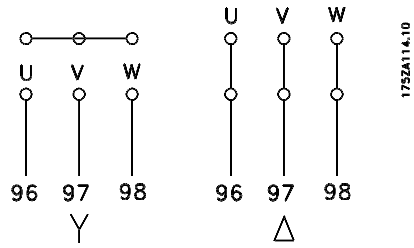


Illustration 5.4: Mounting of decoupling plate.

1. Fasten decoupling plate to the bottom of the frequency converter with screws and washers from the accessory bag.
2. Attach motor cable to terminals 96 (U), 97 (V), 98 (W).
3. Connect to earth connection (terminal 99) on decoupling plate with screws from the accessory bag.
4. Insert terminals 96 (U), 97 (V), 98 (W) and motor cable to terminals labelled MOTOR.
5. Fasten screened cable to decoupling plate with screws and washers from the accessory bag.

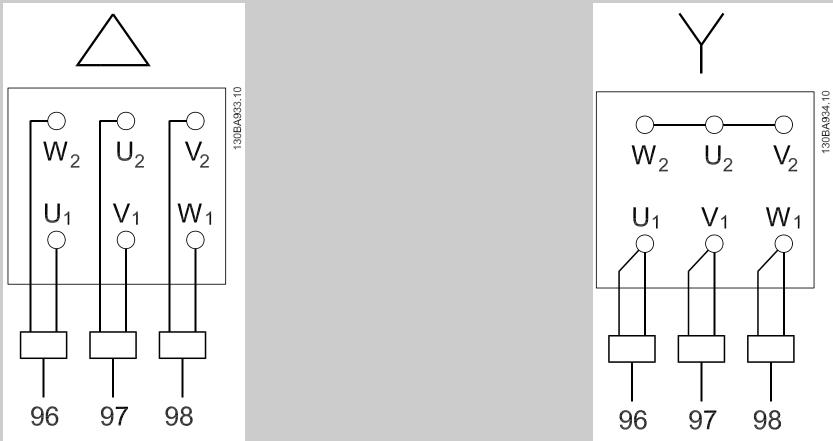
All types of three-phase asynchronous standard motors can be connected to the frequency converter. Normally, small motors are star-connected (230/400 V, D/Y). Large motors are delta-connected (400/600 V, D/Y). Refer to the motor name plate for correct connection mode and voltage.



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

6-wire motor terminal block

High Power Terminal Block Connections



Delta configuration | Star configuration

High power frequency converters can accept two wires per phase.

No.	96	97	98	Motor voltage 0-100%
	U	V	W	of mains voltage.
				3 wires out of motor
	U1	V1	W1	6 wires out of motor, Delta-connected
	W2	U2	V2	
	U1	V1	W1	6 wires out of motor, Star-connected
				U2, V2, W2 to be interconnected separately
				(optional terminal block)
No.	99			Earth connection
	PE			

5.2.6. Motor Cables

See section *General Specifications* for correct 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 decoupling 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.

5.2.7. 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.

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 par. 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.

5.2.8. 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 shortcircuit and overcurrent protected according to the national/international regulations.

Short circuit protection:

The frequency converter must be protected against short-circuit to avoid electrical or fire hazard. Danfoss recommends using the fuses mentioned in tables 5.3 and 5.4 to protect service personnel or other equipment in case of an internal failure in the unit. The frequency converter provides full short circuit protection in case of a short-circuit on the motor output.

Over-current protection:

Provide overload protection to avoid fire hazard due to overheating of the cables in the installation. Over current protection must always be carried out according to national regulations. The frequency converter is equipped with an internal over current protection that can be used for upstream overload protection (UL-applications excluded). See par. 4-18. Fuses must be designed for protection in a circuit capable of supplying a maximum of 100,000 A_{rms} (symmetrical), 500 V/600 V maximum.

Non UL compliance:

If UL/cUL is not to be complied with, Danfoss recommends using the fuses mentioned in table 5.2, which will ensure compliance with EN50178:
In case of malfunction, not following the recommendation may result in unnecessary damage to the frequency converter.

Frequency converter:	Max. fuse size:	Voltage:	Type:
200-240 V			
K25-K75	10A[1]	200-240 V	type gG
1K1-2K2	20A[1]	200-240 V	type gG
3K0	30A[1]	200-240 V	type gG
3K7	30A[1]	200-240 V	type gG
5K5	50A[1]	200-240 V	type gG
7K5	63A[1]	200-240 V	type gG
11K	63A[1]	200-240 V	type gG
15K	80A[1]	200-240 V	type gG
18K5	125A[1]	200-240 V	type gG
22K	125A[1]	200-240 V	type gG
30K	160A[1]	200-240 V	type gG
37K	200A[1]	200-240 V	type aR
45K	250A[1]	200-240 V	type aR
380-480 V			
K37-1K5	10A[1]	380-480 V	type gG
2K2-4K0	20A[1]	380-480 V	type gG
5K5-7K5	30A[1]	380-480 V	type gG
11K	63A[1]	380-480 V	type gG
15K	63A[1]	380-480 V	type gG
18K	63A[1]	380-480 V	type gG
22K	63A[1]	380-480 V	type gG
30K	80A[1]	380-480 V	type gG
37K	100A[1]	380-480 V	type gG
45K	125A[1]	380-480 V	type gG
55K	160A[1]	380-480 V	type gG
75K	250A[1]	380-480 V	type aR
90K	250A[1]	380-480 V	type aR

Table 5.3: Non UL fuses 200 V to 480 V

1) Max. fuses - see national/international regulations for selecting an applicable fuse size.

5

UL Compliance

VLT AQUA	Buss-mann	Buss-mann	Bussmann	SIBA	Littel fuse	Ferraz-Shawmut	Ferraz-Shawmut
200-240 V							
kW	Type RK1	Type J	Type T	Type RK1	Type RK1	Type CC	Type RK1
K25-1K1	KTN-R10	JKS-10	JJN-10	5017906-010	KLN-R10	ATM-R10	A2K-10R
1K5	KTN-R15	JKS-15	JJN-15	5017906-015	KLN-R15	ATM-R15	A2K-15R
2K2	KTN-R20	JKS-20	JJN-20	5012406-020	KLN-R20	ATM-R20	A2K-20R
3K0	KTN-R25	JKS-25	JJN-25	5012406-025	KLN-R25	ATM-R25	A2K-25R
3K7	KTN-R30	JKS-30	JJN-30	5012406-030	KLN-R30	ATM-R30	A2K-30R
5K5	KTN-R50	JKS-50	JJN-50	5012406-050	KLN-R50	-	A2K-50R
7K5	KTN-R50	JKS-60	JJN-60	5012406-050	KLN-R60	-	A2K-50R
11K	KTN-R60	JKS-60	JJN-60	5014006-063	KLN-R60		A2K-60R
15K	KTN-R80	JKS-80	JJN-80	5014006-080	KLN-R80		A2K-80R
18K5	KTN-R125	JKS-150	JJN-125	2028220-125	KLN-R125		A2K-125R
22K	KTN-R125	JKS-150	JJN-125	2028220-125	KLN-R125		A2K-125R
30K	FWX-150	-	-	2028220-150	L25S-150		A25X-150
37K	FWX-200	-	-	2028220-200	L25S-200		A25X-200
45K	FWX-250	-	-	2028220-250	L25S-250		A25X-250

Table 5.4: UL fuses 200 - 240 V

VLT AQUA	Buss-mann	Buss-mann	Bussmann	SIBA	Littel fuse	Ferraz-Shawmut	Ferraz-Shawmut
380-500 V, 525-600							
kW	Type RK1	Type J	Type T	Type RK1	Type RK1	Type CC	Type RK1
11K	KTS-R40	JKS-40	JJS-40	5014006-040	KLS-R40	-	A6K-40R
15K	KTS-R40	JKS-40	JJS-40	5014006-040	KLS-R40	-	A6K-40R
18K	KTS-R50	JKS-50	JJS-50	5014006-050	KLS-R50	-	A6K-50R
22K	KTS-R60	JKS-60	JJS-60	5014006-063	KLS-R60	-	A6K-60R
30K	KTS-R80	JKS-80	JJS-80	2028220-100	KLS-R80	-	A6K-80R
37K	KTS-R100	JKS-100	JJS-100	2028220-125	KLS-R100		A6K-100R
45K	KTS-R125	JKS-150	JJS-150	2028220-125	KLS-R125		A6K-125R
55K	KTS-R150	JKS-150	JJS-150	2028220-160	KLS-R150		A6K-150R
75K	FWH-220	-	-	2028220-200	L50S-225		A50-P225
90K	FWH-250	-	-	2028220-250	L50S-250		A50-P250

Table 5.5: UL fuses 380 - 600 V

KTS-fuses from Bussmann may substitute KTN for 240 V frequency converters.

FWH-fuses from Bussmann may substitute FWX for 240 V frequency converters.

KLSR fuses from LITTEL FUSE may substitute KLNR fuses for 240 V frequency converters.

L50S fuses from LITTEL FUSE may substitute L50S fuses for 240 V frequency converters.

A6KR fuses from FERRAZ SHAWMUT may substitute A2KR for 240 V frequency converters.

A50X fuses from FERRAZ SHAWMUT may substitute A25X for 240 V frequency converters.

Size/Type	Bussmann PN*	Rating	Ferraz	Siba
P250	170M4017	700 A, 700 V	6.9URD31D08A0700	20 610 32.700
P315	170M6013	900 A, 700 V	6.9URD33D08A0900	20 630 32.900
P355	170M6013	900 A, 700 V	6.9URD33D08A0900	20 630 32.900
P400	170M6013	900 A, 700 V	6.9URD33D08A0900	20 630 32.900

Table 5.6: **E enclosures, 380-480 V**

PN	Bussmann	Ferraz	Siba
20220	170M4017	6.9URD31D08A0700	20 610 32.700
20221	170M6013	6.9URD33D08A0900	20 630 32.900

Table 5.7: **Additional Fuses for Non-UL Applications, E enclosures, 380-480 V**

Size/Type	Bussmann PN*	PN	Rating	Losses (W)
P355	170M4017 170M5013	20220	700 A, 700 V	85
P400	170M4017 170M5013	20220	700 A, 700 V	85
P500	170M6013	20221	900 A, 700 V	120
P560	170M6013	20221	900 A, 700 V	120

Table 5.8: **E enclosures, 525-600/690 V**

*170M fuses from Bussmann shown use the -/80 visual indicator, -TN/80 Type T, -/110 or TN/110 Type T indicator fuses of the same size and amperage may be substituted for external use.

*170M fuses from Bussmann shown use the -/80 visual indicator, -TN/80 Type T, -/110 or TN/110 Type T indicator fuses of the same size and amperage may be substituted for external use.

PN	Bussmann	Ferraz	Siba
20220	170M4017	6.9URD31D08A0700	20 610 32.700
20221	170M6013	6.9URD33D08A0900	20 630 32.900

Table 5.10: **Additional Fuses for Non-UL Applications E enclosures, 525-600/690 V**

Suitable for use on a circuit capable of delivering not more than 100 000 rms symmetrical amperes, 500/600/690 Volts maximum when protected by the above fuses.

Circuit Breaker Tables

Circuit Breakers manufactured by General Electric, Cat. No. SKHA36AT0800, 600 Vac maximum, with the rating plugs listed below can be used to meet UL requirements.

Circuit Breaker Tables

Size/Type	Rating plug catalog #	Amps
P110	SRPK800A300	300
P132	SRPK800A350	350
P160	SRPK800A400	400
P200	SRPK800A500	500
P250	SRPK800A600	600

Table 5.12: **D enclosures, 380-480 V**

Non UL compliance

If UL/cUL is not to be complied with, we recommend using the following fuses, which will ensure compliance with EN50178:

In case of malfunction, not following the recommendation may result in unnecessary damage to the frequency converter.

P110 - P200	380 - 500 V	type gG
P250 - P450	380 - 500 V	type gR

Frequency converter	Bussmann	Bussmann	Bussmann	SIBA	Littel fuse	Ferraz-Shawmut	Ferraz-Shawmut
UL Compliance - 200-240 V							
kW	Type RK1	Type J	Type T	Type RK1	Type RK1	Type CC	Type RK1
K25-K37	KTN-R05	JKS-05	JJN-05	5017906-005	KLN-R005	ATM-R05	A2K-05R
K55-1K1	KTN-R10	JKS-10	JJN-10	5017906-010	KLN-R10	ATM-R10	A2K-10R
1K5	KTN-R15	JKS-15	JJN-15	5017906-015	KLN-R15	ATM-R15	A2K-15R
2K2	KTN-R20	JKS-20	JJN-20	5012406-020	KLN-R20	ATM-R20	A2K-20R
3K0	KTN-R25	JKS-25	JJN-25	5012406-025	KLN-R25	ATM-R25	A2K-25R
3K7	KTN-R30	JKS-30	JJN-30	5012406-030	KLN-R30	ATM-R30	A2K-30R
5K5	KTN-R50	JKS-50	JJN-50	5012406-050	KLN-R50	-	A2K-50R
7K5	KTN-R50	JKS-60	JJN-60	5012406-050	KLN-R60	-	A2K-50R
11K	KTN-R60	JKS-60	JJN-60	5014006-063	KLN-R60	A2K-60R	A2K-60R
15K	KTN-R80	JKS-80	JJN-80	5014006-080	KLN-R80	A2K-80R	A2K-80R
18K5	KTN-R125	JKS-150	JJN-125	2028220-125	KLN-R125	A2K-125R	A2K-125R
22K	KTN-R125	JKS-150	JJN-125	2028220-125	KLN-R125	A2K-125R	A2K-125R
30K	FWX-150	-	-	2028220-150	L25S-150	A25X-150	A25X-150
37K	FWX-200	-	-	2028220-200	L25S-200	A25X-200	A25X-200
45K	FWX-250	-	-	2028220-250	L25S-250	A25X-250	A25X-250

Table 5.13: **UL fuses 200 - 240 V**

Frequency converter	Bussmann	Bussmann	Bussmann	SIBA	Littel fuse	Ferraz-Shawmut	Ferraz-Shawmut
UL Compliance - 380-480 V, 525-600							
kW	Type RK1	Type J	Type T	Type RK1	Type RK1	Type CC	Type RK1
K37-1K1	KTS-R6	JKS-6	JJS-6	5017906-006	KLS-R6	ATM-R6	A6K-6R
1K5-2K2	KTS-R10	JKS-10	JJS-10	5017906-010	KLS-R10	ATM-R10	A6K-10R
3K0	KTS-R15	JKS-15	JJS-15	5017906-016	KLS-R16	ATM-R16	A6K-16R
4K0	KTS-R20	JKS-20	JJS-20	5017906-020	KLS-R20	ATM-R20	A6K-20R
5K5	KTS-R25	JKS-25	JJS-25	5017906-025	KLS-R25	ATM-R25	A6K-25R
7K5	KTS-R30	JKS-30	JJS-30	5012406-032	KLS-R30	ATM-R30	A6K-30R
11K	KTS-R40	JKS-40	JJS-40	5014006-040	KLS-R40	-	A6K-40R
15K	KTS-R40	JKS-40	JJS-40	5014006-040	KLS-R40	-	A6K-40R
18K	KTS-R50	JKS-50	JJS-50	5014006-050	KLS-R50	-	A6K-50R
22K	KTS-R60	JKS-60	JJS-60	5014006-063	KLS-R60	-	A6K-60R
30K	KTS-R80	JKS-80	JJS-80	2028220-100	KLS-R80	-	A6K-80R
37K	KTS-R100	JKS-100	JJS-100	2028220-125	KLS-R100		A6K-100R
45K	KTS-R125	JKS-150	JJS-150	2028220-125	KLS-R125		A6K-125R
55K	KTS-R150	JKS-150	JJS-150	2028220-160	KLS-R150		A6K-150R
75K	FWH-220	-	-	2028220-200	L50S-225		A50-P225
90K	FWH-250	-	-	2028220-250	L50S-250		A50-P250

Table 5.14: **UL fuses 380 - 600 V**

KTS-fuses from Bussmann may substitute KTN for 240 V frequency converters.

FWH-fuses from Bussmann may substitute FWX for 240 V frequency converters.

KLSR fuses from LITTEL FUSE may substitute KLNR fuses for 240 V frequency converters.

L50S fuses from LITTEL FUSE may substitute L50S fuses for 240 V frequency converters.

A6KR fuses from FERRAZ SHAWMUT may substitute A2KR for 240 V frequency converters.

A50X fuses from FERRAZ SHAWMUT may substitute A25X for 240 V frequency converters.

High Power Fuse Tables

Size/Type	Bussmann E1958 JFHR2**	Bussmann E4273 T/JDDZ**	SIBA E180276 RKI/JDDZ	LittelFuse E71611 JFHR2**	Ferraz-Shawmut E60314 JFHR2**	Bussmann E4274 H/JDDZ**	Bussmann E125085 JFHR2*	Internal Option Bussmann
P110	FWH-300	JJS-300	2028220-315	L50S-300	A50-P300	NOS-300	170M3017	170M3018
P132	FWH-350	JJS-350	2028220-315	L50S-350	A50-P350	NOS-350	170M3018	170M4016
P160	FWH-400	JJS-400	206xx32-400	L50S-400	A50-P400	NOS-400	170M4012	170M4016
P200	FWH-500	JJS-500	206xx32-500	L50S-500	A50-P500	NOS-500	170M4014	170M4016
P250	FWH-600	JJS-600	206xx32-600	L50S-600	A50-P600	NOS-600	170M4016	170M4016

Table 5.16: **D enclosures, 380-480 V**

5

*170M fuses from Bussmann shown use the -/80 visual indicator, -TN/80 Type T, -/110 or TN/110 Type T indicator fuses of the same size and amperage may be substituted for external use

**Any minimum 480 V UL listed fuse with associated current rating may be used to meet UL requirements.

High Power Fuse Tables

Size/Type	Bussmann E1958 JFHR2**	Bussmann E4273 T/JDDZ**	SIBA E180276 RKI/JDDZ	LittelFuse E71611 JFHR2**	Ferraz-Shawmut E60314 JFHR2**	Bussmann E4274 H/JDDZ**	Bussmann E125085 JFHR2*	Internal Option Bussmann
45K	FWH-300	JJS-300	2028220-315	L50S-300	A50-P300	NOS-300	170M3017	170M3018
55K	FWH-350	JJS-350	2028220-315	L50S-350	A50-P350	NOS-350	170M3018	170M4016
75K	FWH-400	JJS-400	206xx32-400	L50S-400	A50-P400	NOS-400	170M4012	170M4016
90K	FWH-500	JJS-500	206xx32-500	L50S-500	A50-P500	NOS-500	170M4014	170M4016

Table 5.17: **D enclosures, 525-600/690 V**

Size/Type	Bussmann E125085 JFHR2	Amps	SIBA E180276 JFHR2	Ferraz-Shawmut E76491 JFHR2
P110	170M3017	315	2061032.315	6.6URD30D08A0315
P132	170M3018	350	2061032.350	6.6URD30D08A0350
P160	170M4011	350	2061032.350	6.6URD30D08A0350
P200	170M4012	400	2061032.400	6.6URD30D08A0400
P250	170M4014	500	2061032.500	6.6URD30D08A0500
P315	170M5011	550	2062032.550	6.6URD32D08A0550

Table 5.18: **D enclosures, 525-600/690 V**

Size/Type	Bussmann PN*	PN	Rating	Losses (W)
P315	170M5013	20221	900 A, 700 V	120
P355	170M6013	20221	900 A, 700 V	120
P400	170M6013	20221	900 A, 700 V	120
P450	170M6013	20221	900A, 700 V	120

Table 5.20: **E enclosures, 380-480 V**

Size/Type	Bussmann JFHR2*	SIBA Type RK1	FERRAZ-SHAWMUT Type RK1
P355	170M5013/170M4017	2061032.700	900 A, 700 V
P400	170M5013/170M4017	2061032.700	900 A, 700 V
P450	170M6013	2063032.900	900 A, 700 V
P500	170M6013	2063032.900	900A, 700 V
P560	170M6013	2063032.900	

Table 5.21: **E enclosures, 525-600/690 V**

*170M fuses from Bussmann shown, use the -/80 visual indicator, -TN/80 Type T, -/110 or TN/110 Type T indicator fuses of the same size and amperage may be substituted for external use.

*170M fuses from Bussmann shown, use the -/80 visual indicator, -TN/80 Type T, -/110 or TN/110 Type T indicator fuses of the same size and amperage may be substituted for external use.

5.2.9. Access to Control Terminals

5

All terminals to the control cables are located underneath the terminal cover on the front of the frequency converter. Remove the terminal cover by means of a screwdriver (see illustration).

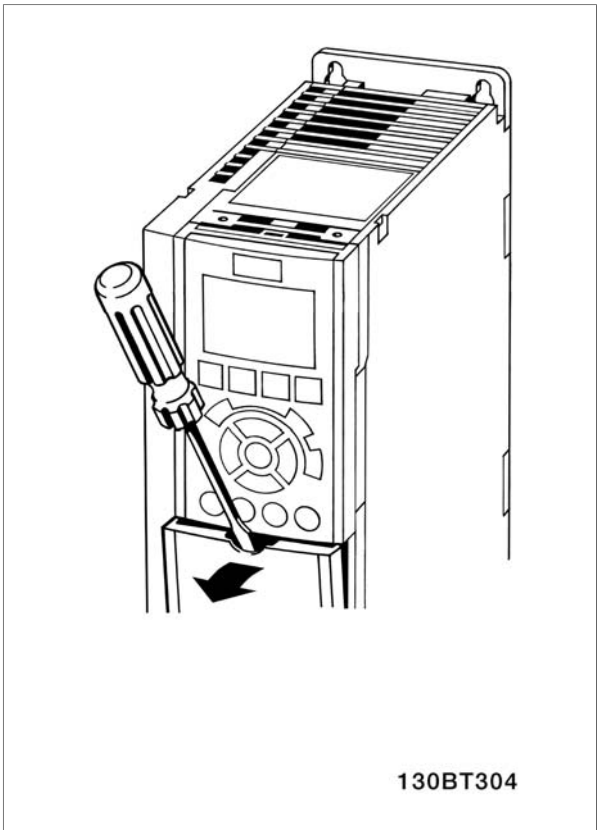


Illustration 5.5: A1, A2, A3,B3, B4, C3 and C4 enclosures

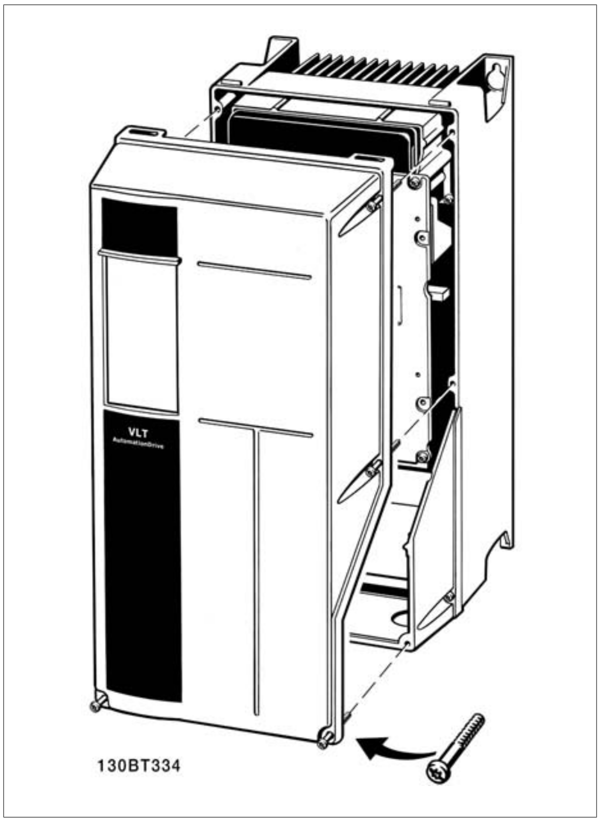


Illustration 5.6: A5, B1, B2, C1 and C2 enclosures

5.2.10. Control Terminals

Drawing reference numbers:

1. 10 pole plug digital I/O.
2. 3 pole plug RS485 Bus.
3. 6 pole analog I/O.
4. USB Connection.

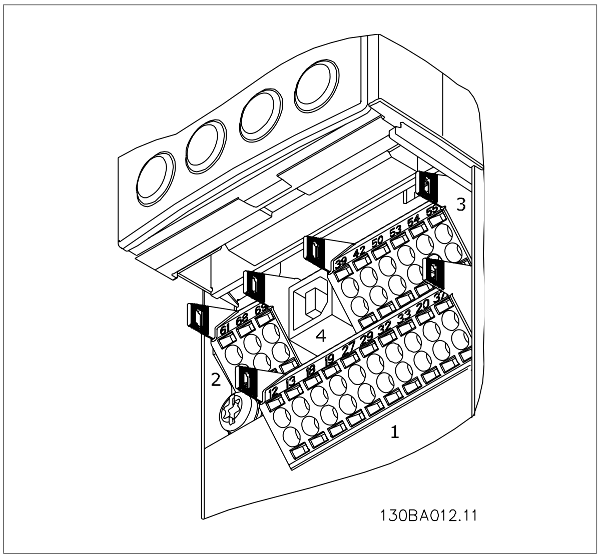


Illustration 5.7: Control terminals (all enclosures)

5.2.11. Electrical Installation, Control Cable Terminals

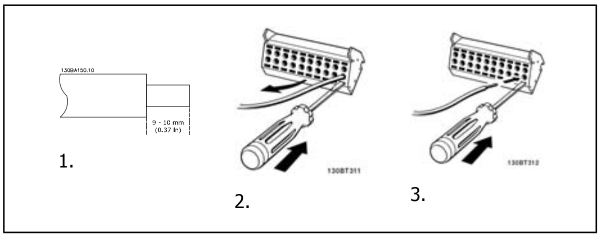
To mount the cable to the terminal:

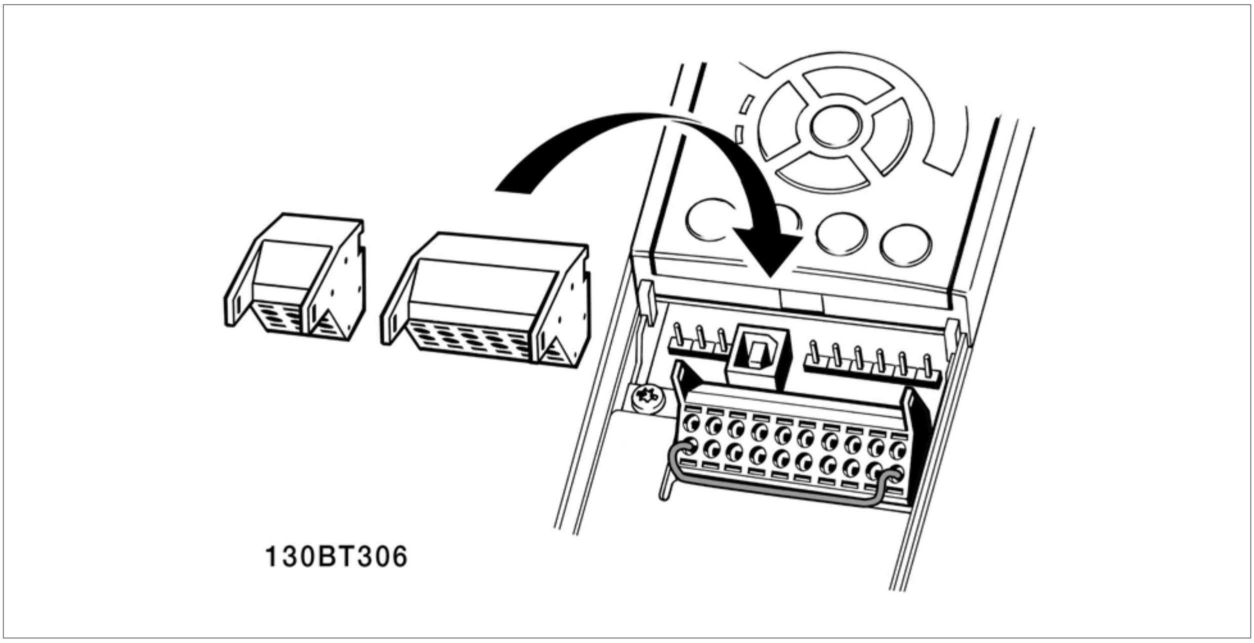
1. Strip isolation of 9-10 mm
2. Insert a screw driver[1)] in the square hole.
3. Insert the cable in the adjacent circular hole.
4. Remove the screw driver. The cable is now mounted to the terminal.

To remove the cable from the terminal:

1. Insert a screw driver[1)] in the square hole.
2. Pull out the cable.

[1)] Max. 0.4 x 2.5 mm





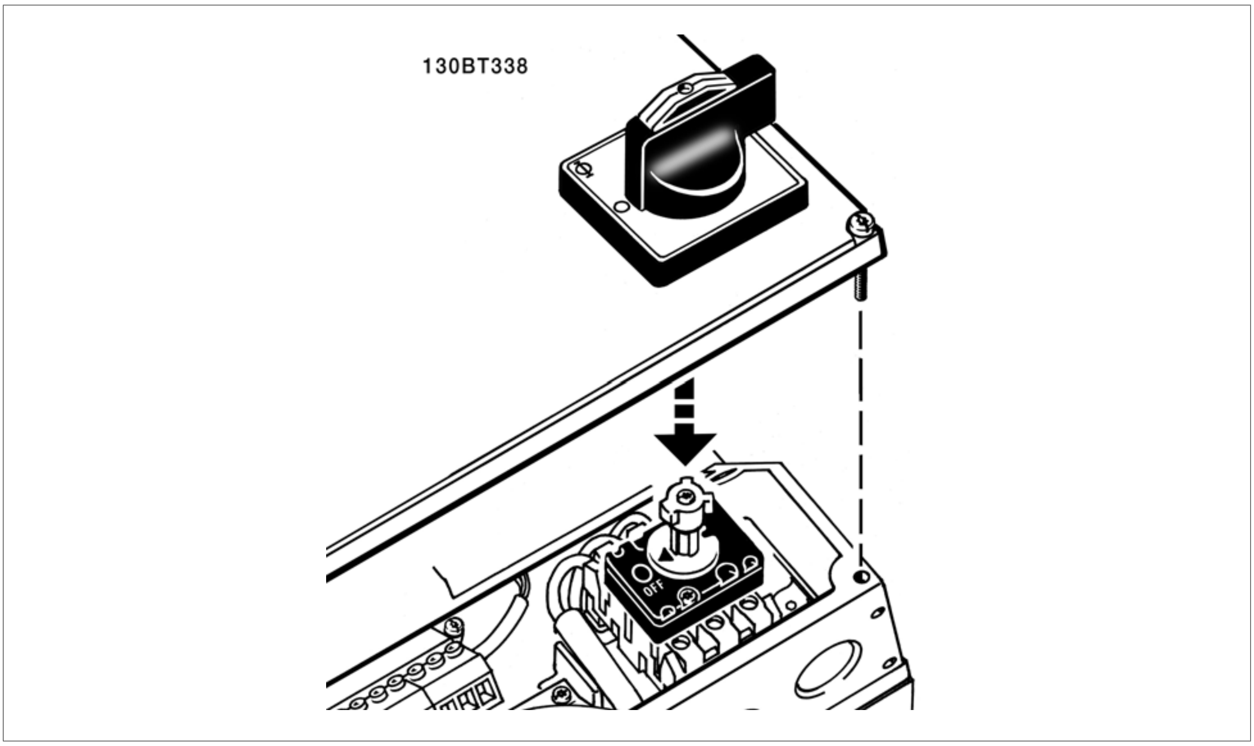


Illustration 5.8: Assembling of IP21 / IP55 / NEMA TYPE 12 housing with mains disconnector.

5.2.12. Basic Wiring Example

1. Mount terminals from the accessory bag to the front of the frequency converter.
2. Connect terminals 18 and 27 to +24 V (terminal 12/13)

Default settings:
18 = Start
27 = stop inverse

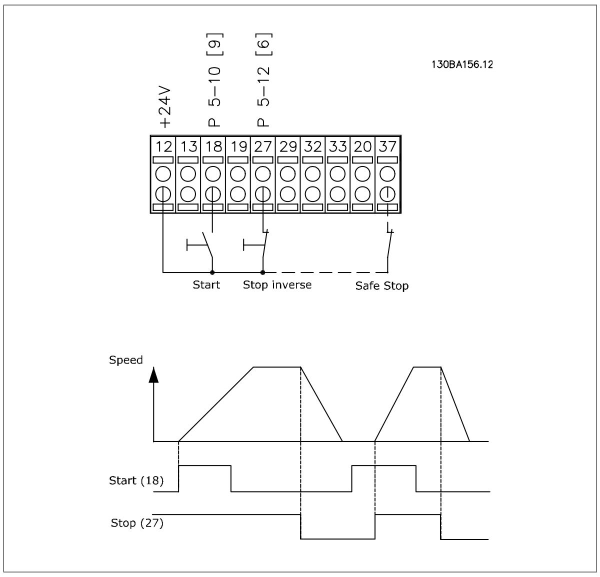


Illustration 5.9: Terminal 37 available with Safe Stop Function only!

5

5

5.2.13. Control Cable Length

Digital in / digital out

Dependent on what kind of electronics is being used, the maximum cable impedance may be calculated based on the 4 kΩ frequency converter input impedance.

Analog in / analog out

Again the electronics used puts a limitation on the cable length.

NB!
Noise is always a factor to be reckoned with.

5.2.14. Electrical Installation, Control Cables

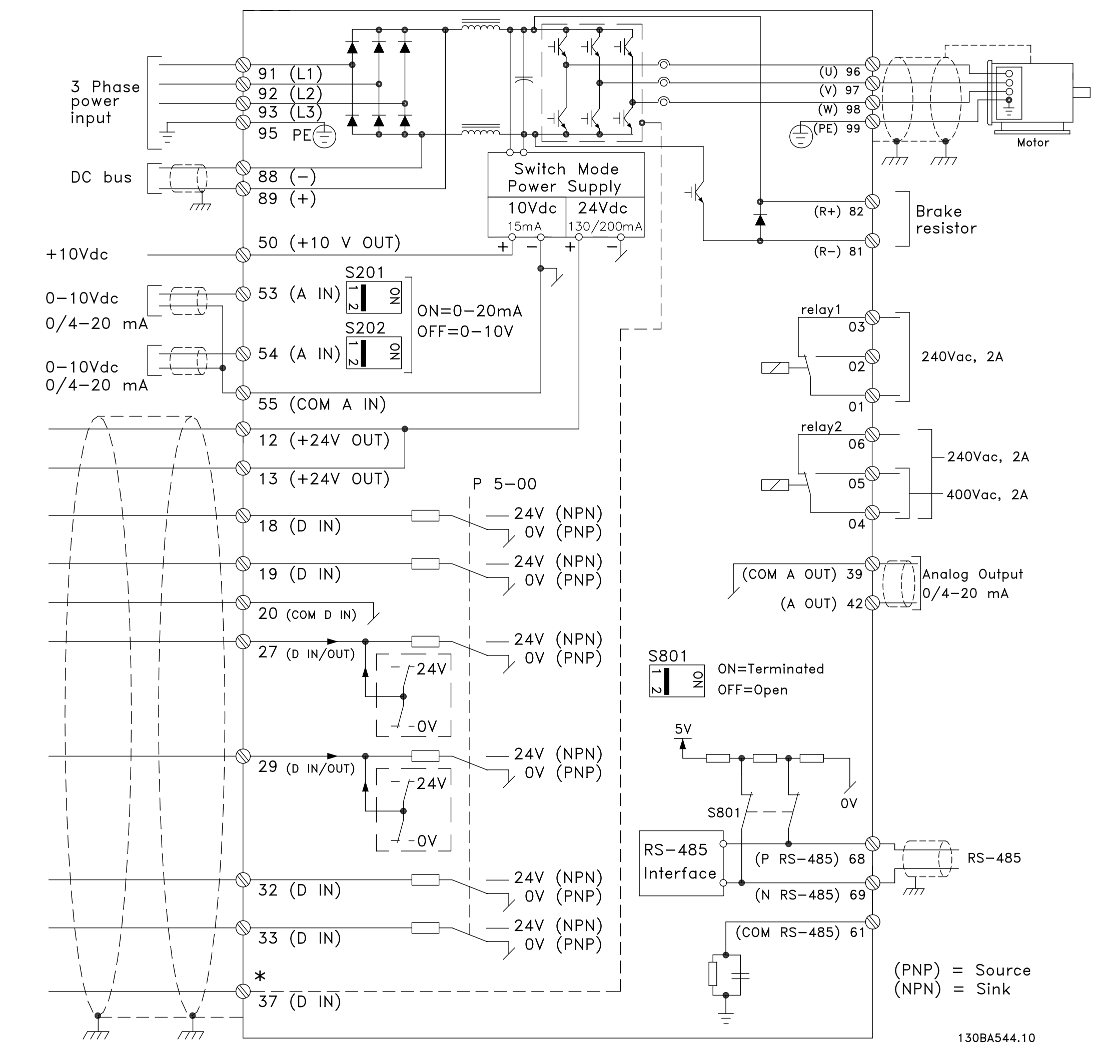


Illustration 5.10: Terminal 37: Safe Stop input available with Safe Stop Function only!

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.

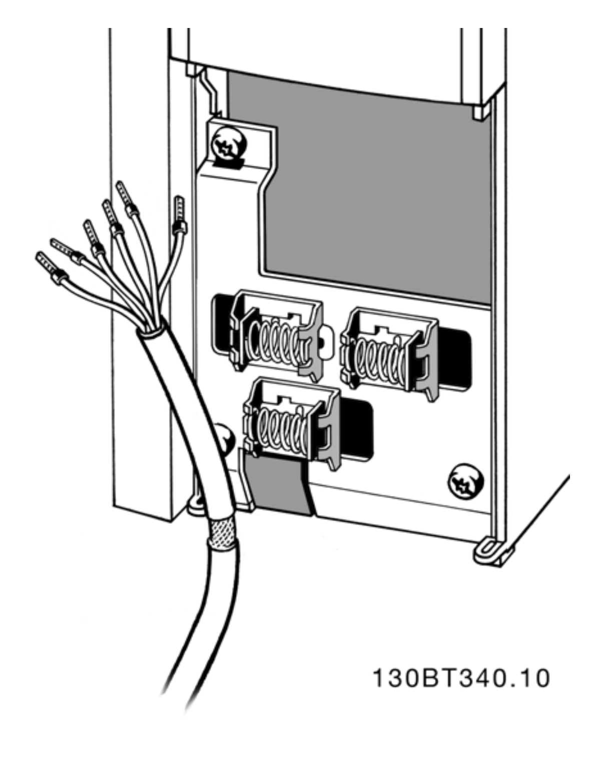
If this occurs, you may have to break the screen or insert a 100 nF capacitor between screen and chassis.

The digital and analog in- and outputs must be connected separately to the VLT AQUA Drive common inputs (terminal 20, 55, 39) to avoid ground currents from both groups to affect other groups. For example, switching on the digital input may disturb the analog input signal.

NB!
Control cables must be screened/armoured.

1. Use a clamp from the accessory bag to connect the screen to the frequency converter de-coupling plate for control cables.

See section entitled *Earthing of Screened/Armoured Control Cables* for the correct termination of control cables.



5

5.2.15. Switches S201, S202, and S801

Switches S201 (A53) and S202 (A54) are used to select a current (0-20 mA) or a voltage (0 to 10 V) configuration of the analog input terminals 53 and 54 respectively.

Switch S801 (BUS TER.) can be used to enable termination on the RS-485 port (terminals 68 and 69).

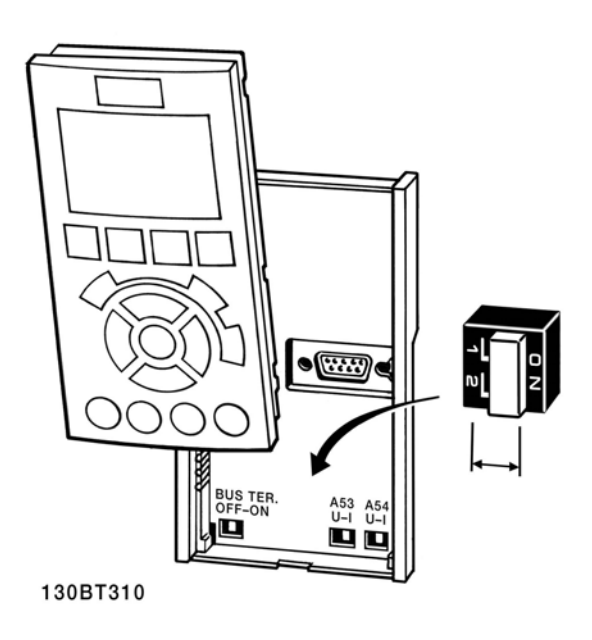
See drawing *Diagram showing all electrical terminals* in section *Electrical Installation.*

Default setting:

S201 (A53) = OFF (voltage input)

S202 (A54) = OFF (voltage input)

S801 (Bus termination) = OFF



5.3. Final Set-Up and Test

5.3.1. Final Set-Up and Test

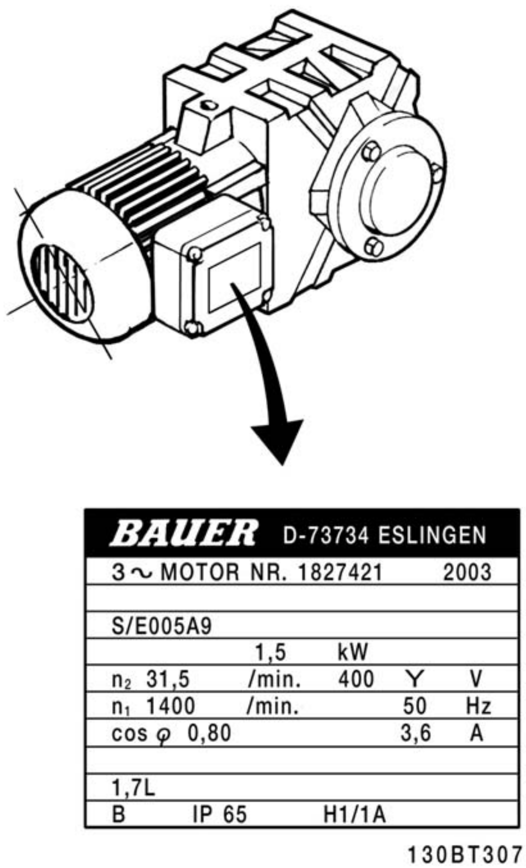
To test the set-up and ensure that the frequency converter is running, follow these steps.

Step 1. Locate the motor name plate.

NB!
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]	par. 1-20 par. 1-21
2.	Motor Voltage	par. 1-22
3.	Motor Frequency	par. 1-23
4.	Motor Current	par. 1-24
5.	Motor Nominal Speed	par. 1-25



Step 3. Activate the Automatic Motor Adaptation (AMA).

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

1. Connect terminal 27 to terminal 12 or set par. 5-12 to 'No function' (par. 5-12 [0])
2. Activate the AMA par. 1-29.
3. Choose between complete or reduced AMA. If an LC filter is mounted, run only the reduced AMA, or remove the LC filter during the AMA 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 AMA is in progress.

Stop the AMA during operation

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

Successful AMA

1. The display shows “Press [OK] to finish AMA”.
2. Press the [OK] key to exit the AMA state.

Unsuccessful AMA

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 AMA, 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.

NB!
Unsuccessful AMA is often caused by incorrectly registered motor name plate data or too big difference between the motor power size and the VLT AQUA Drive power size.

5

Step 4. Set speed limit and ramp time.

Set up the desired limits for speed and ramp time.

Minimum Reference	par. 3-02
Maximum Reference	par. 3-03

Motor Speed Low Limit	par. 4-11 or 4-12
Motor Speed High Limit	par. 4-13 or 4-14

Ramp-up Time 1 [s]	par. 3-41
Ramp-down Time 1 [s]	par. 3-42

5.4.1. Safe Stop Installation

To carry out an installation of a Category 0 Stop (EN60204) in conformance with Safety Category 3 (EN954-1), follow these instructions:

1. The bridge (jumper) between Terminal 37 and 24 V DC of FC 202 must be removed. Cutting or breaking the jumper is not sufficient. Remove it entirely to avoid short-circuiting. See jumper on illustration.
2. Connect terminal 37 to 24 V DC by a short-circuit protected cable. The 24 V DC voltage supply must be interruptible by an EN954-1 Category 3 circuit interrupt device. If the interrupt device and the frequency converter are placed in the same installation panel, you can use a regular cable instead of a protected one.

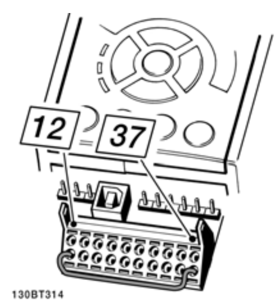


Illustration 5.11: Bridge jumper between terminal 37 and 24 VDC.

The illustration below shows a Stopping Category 0 (EN 60204-1) with safety Cat. 3 (EN 954-1). The circuit interrupt is caused by an opening door contact. The illustration also shows how to connect a non-safety related hardware coast.

5

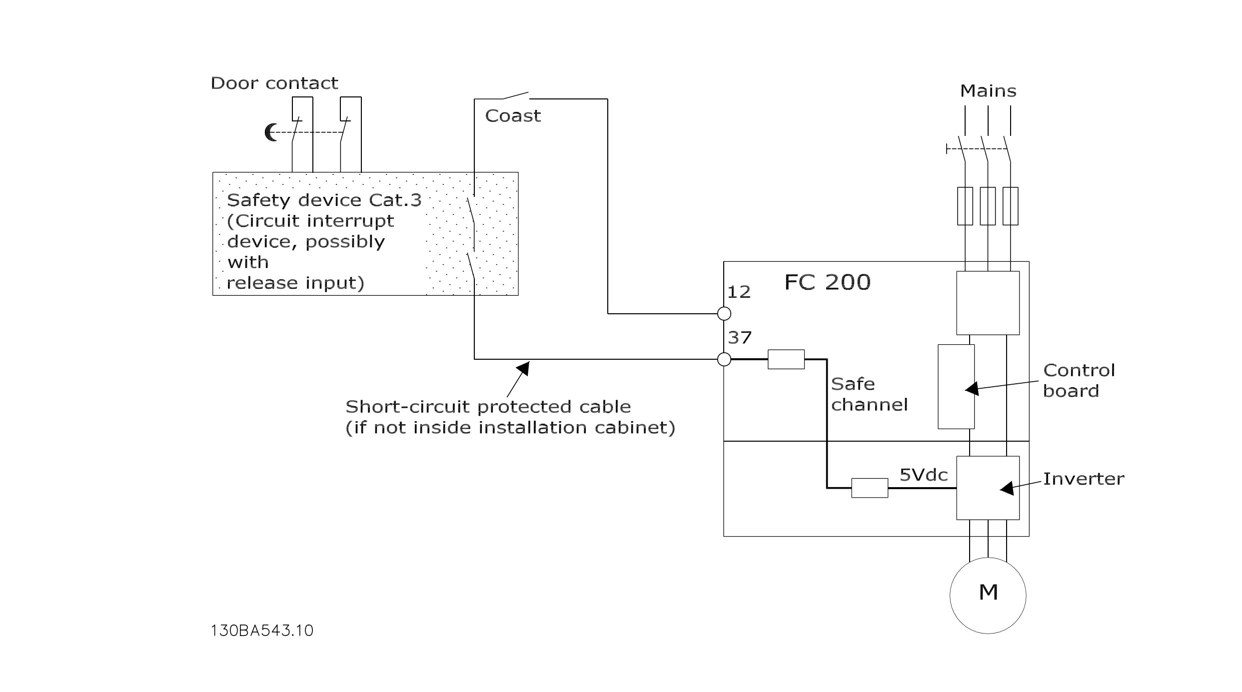


Illustration 5.12: Illustration of the essential aspects of an installation to achieve a Stopping Category 0 (EN 60204-1) with safety Cat. 3 (EN 954-1).

5.4.2. Safe Stop Commissioning Test

After installation and before first operation, perform a commissioning test of an installation or application making use of FC 200 Safe Stop.
Moreover, perform the test after each modification of the installation or application, which the FC 200 Safe Stop is part of.

The commissioning test:

1. Remove the 24 V DC voltage supply to terminal 37 by the interrupt device while the motor is driven by the FC 202 (i.e. mains supply is not interrupted). The test step is passed if the motor reacts with a coast and the mechanical brake (if connected) is activated.
2. Then send Reset signal (via Bus, Digital I/O, or [Reset] key). The test step is passed if the motor remains in the Safe Stop state, and the mechanical brake (if connected) remains activated.
3. Then reapply 24 V DC to terminal 37. The test step is passed if the motor remains in the coasted state, and the mechanical brake (if connected) remains activated.
4. Then send Reset signal (via Bus, Digital I/O, or [Reset] key). The test step is passed if the motor becomes operational again.
5. The commissioning test is passed if all four test steps are passed.

5.5. Additional Connections

5.5.1. DC bus connection

The DC bus terminal is used for DC back-up, with the intermediate circuit being supplied from an external source.

Terminal numbers used:	88, 89

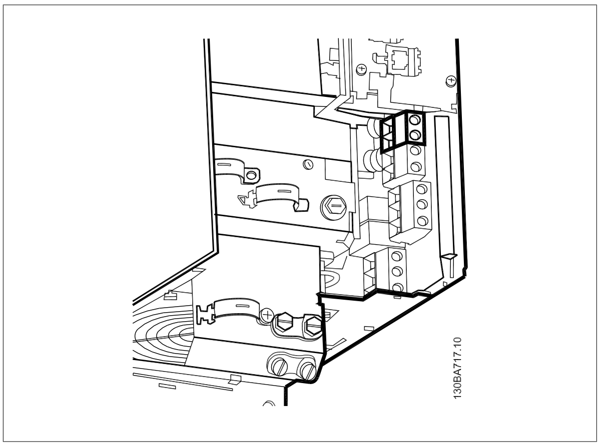


Illustration 5.13: DC bus connections for enclosure B3.

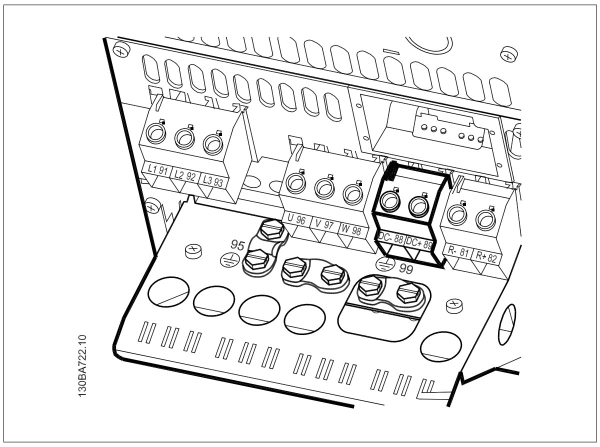


Illustration 5.14: DC bus connections for enclosure B4.

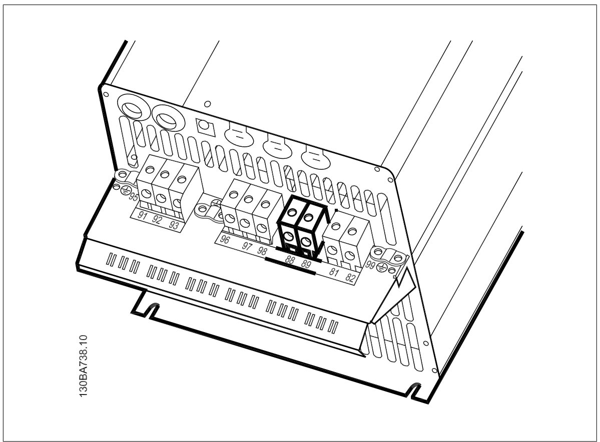


Illustration 5.15: DC bus connections for enclosure C3.

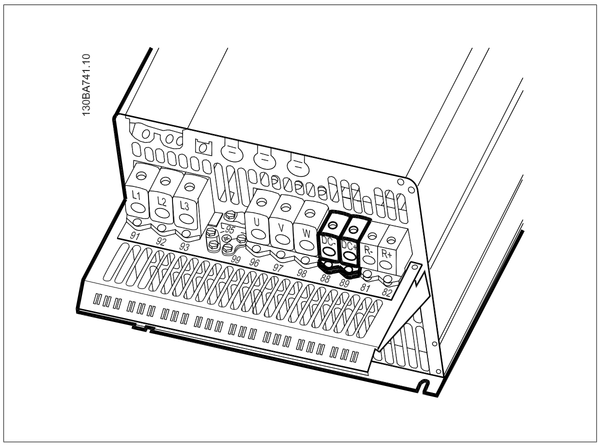


Illustration 5.16: DC bus connections for enclosure enclosure C4.

Please contact if you require further information.

5.5.2. Brake Connection Option

The connection cable to the brake resistor must be screened/armoured.

Enclosure	A+B+C+D+F	A+B+C+D+F
Brake resistor	81	82
Terminals	R-	R+

NB!
Dynamic brake calls for extra equipment and safety considerations. For further information, please contact .

1. Use cable clamps to connect the screen to the metal cabinet of the frequency converter and to the decoupling plate of the brake resistor.
2. Dimension the cross-section of the brake cable to match the brake current.

NB!
Voltages up to 975 V DC (@ 600 V AC) may occur between the terminals.

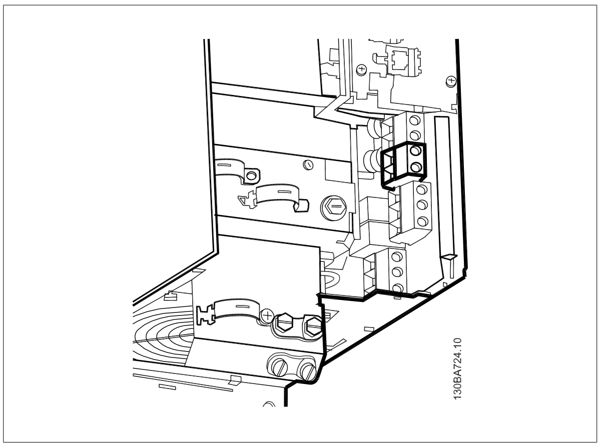


Illustration 5.17: Brake connection terminal for B3.

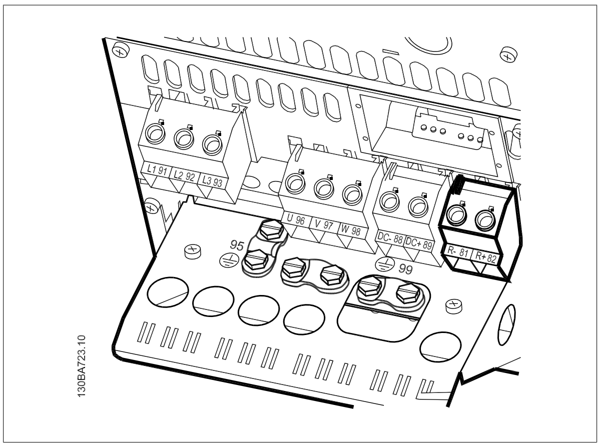


Illustration 5.18: Brake connection terminal for B4.

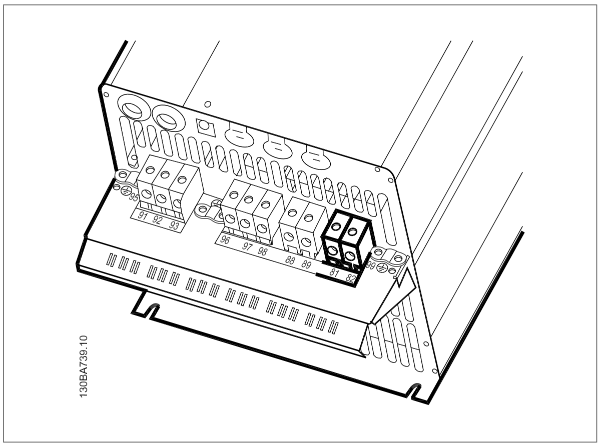


Illustration 5.19: Brake connection terminal for C3.

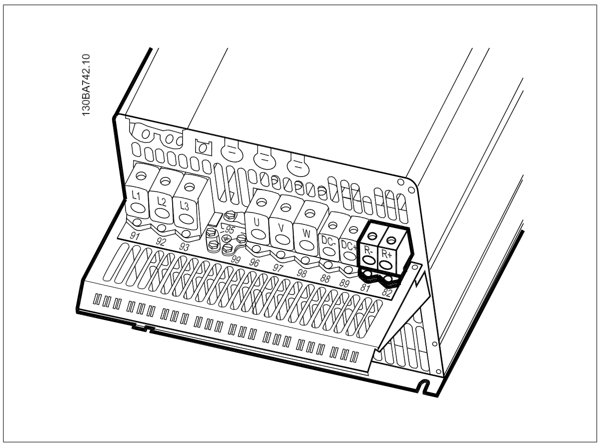


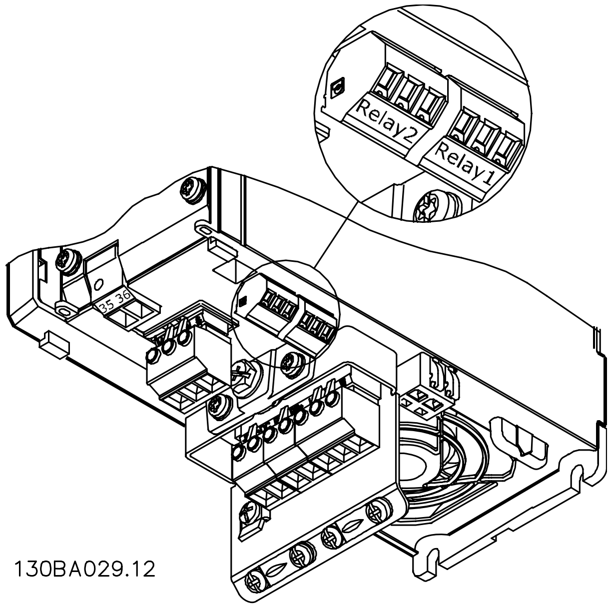
Illustration 5.20: Brake connection terminal for C4.

NB!
If a short circuit in the brake IGBT occurs, prevent power dissipation in the brake resistor by using a mains switch or contactor to disconnect the mains for the frequency converter. Only the frequency converter shall control the contactor.

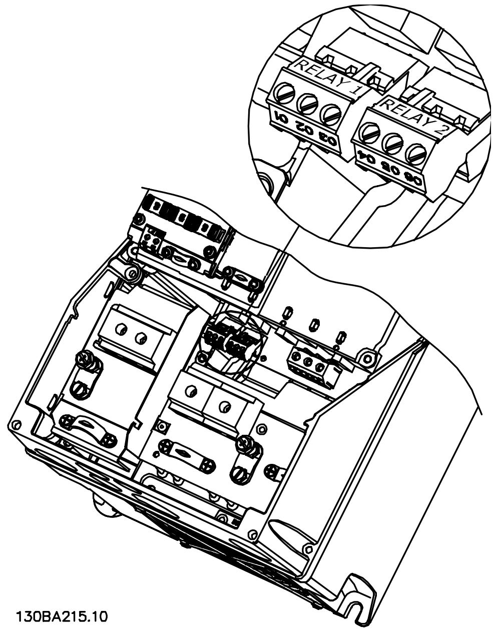
5.5.3. Relay Connection

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

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



Terminals for relay connection
(A2 and A3 enclosures).



Terminals for relay connection
(A5, B1 and B2 enclosures).

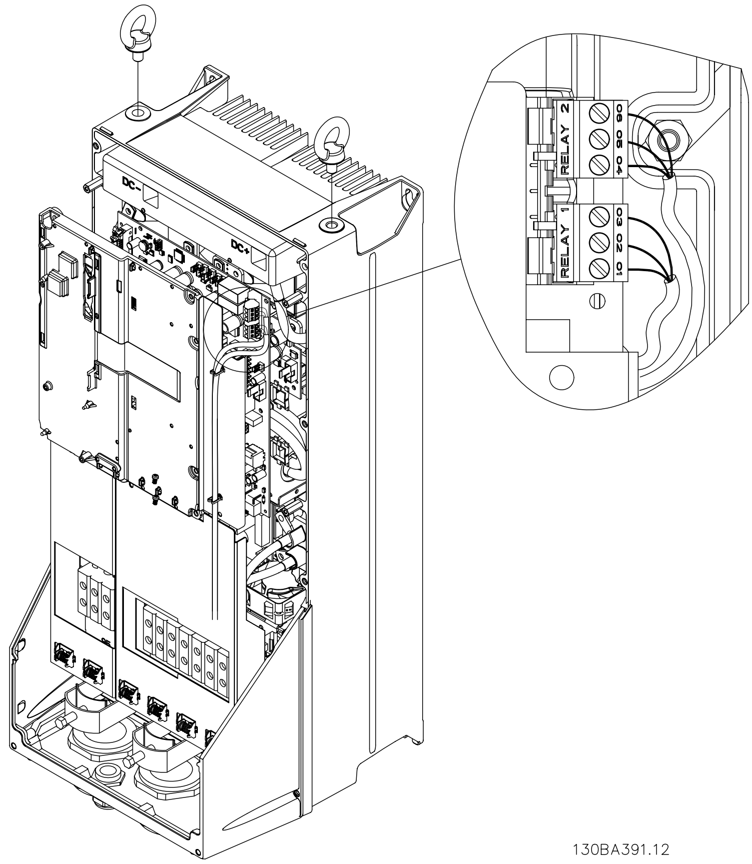


Illustration 5.21: Terminals for relay connection (C1 and C2 enclosures).

The relay connections are shown in the cut-out with relay plugs (from the Accessory Bag) fitted.

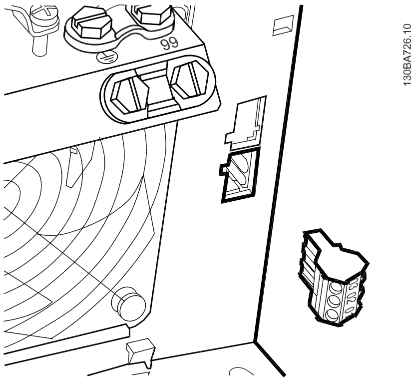


Illustration 5.22: Terminals for relay connections for B3. Only one knock-out is fitted from the factory.

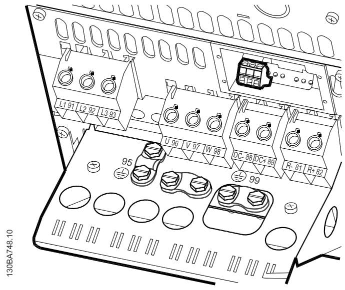


Illustration 5.23: Terminals for relay connections for B4.

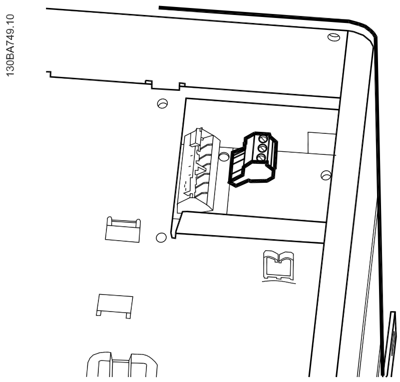


Illustration 5.24: Terminals for relay connections for C3 and C4. Located in the upper right corner of the frequency converter.

5.5.4. Relay Output

Relay 1

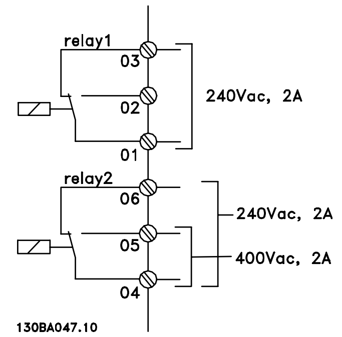
- Terminal 01: common
- Terminal 02: normal open 240 V AC
- Terminal 03: normal closed 240 V AC

Relay 2

- Terminal 04: common
- Terminal 05: normal open 400 V AC
- Terminal 06: normal closed 240 V AC

Relay 1 and relay 2 are programmed in par. 5-40 Function *Relay*, par. 5-41 On *Delay, Relay*, and par. 5-42 Off *Delay, Relay*.

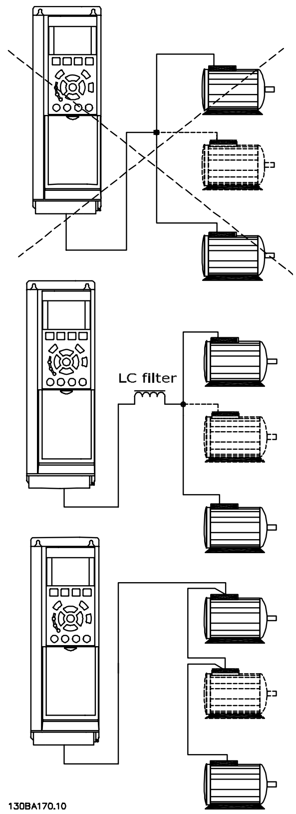
Additional relay outputs by using option module MCB 105.



5.5.5. 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.

NB!
When motors are connected in parallel, par. 1-29 Automatic *Motor Adaptation (AMA)* 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).

5

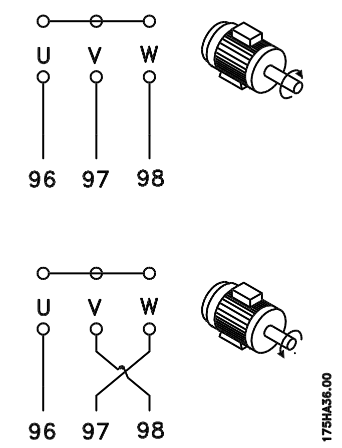
5.5.6. Direction of Motor Rotation

The default setting is clockwise rotation with the frequency converter output connected as follows.

Terminal 96 connected to U-phase
Terminal 97 connected to V-phase
Terminal 98 connected to W-phase

The direction of motor rotation is changed by switching two motor phases.

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



5.5.7. Motor Thermal Protection

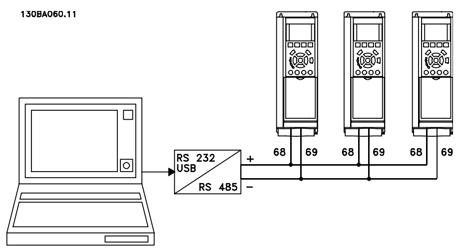
The electronic thermal relay in the frequency converter has received the UL-approval for single motor protection, when par. 1-90 Motor *Thermal Protection* is set for *ETR Trip* and par. 1-24 Motor *Current* is set to the rated motor current (see motor name plate).

5.6. Installation of misc. connections

5.6.1. RS 485 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.

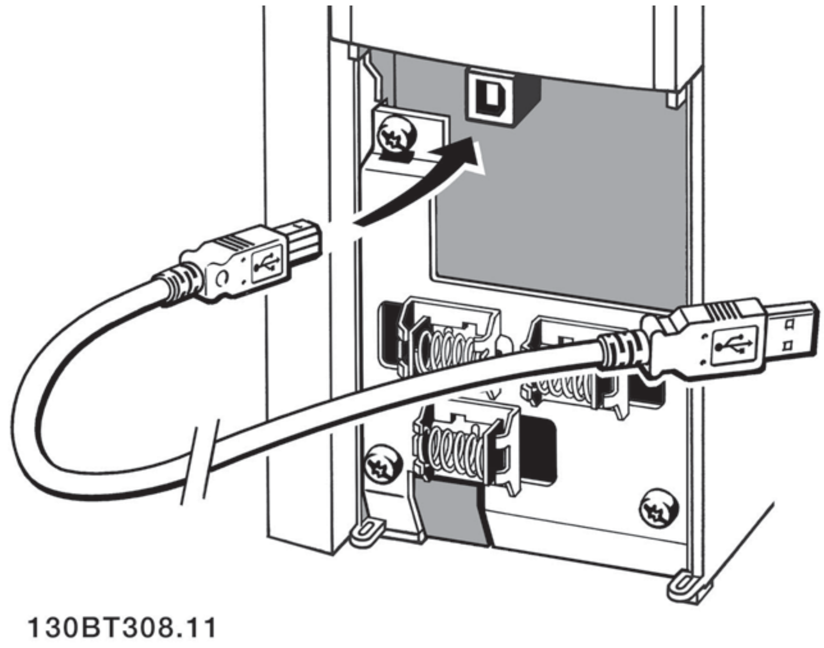
Bus termination
The RS485 bus must be terminated by a resistor network at both ends. For this purpose, set switch S801 on the control card for "ON".
For more information, see the paragraph *Switches S201, S202, and S801*.

NB!
Communication protocol must be set to FC MC par. .

5.6.2. How to Connect a PC to the VLT AQUA Drive

To control or program the frequency converter from a PC, install the MCT 10 Set-up Software.
The PC is connected via a standard (host/device) USB cable, or via the RS-485 interface as shown in the **VLT AQUA Design Guide** *How to Install > Installation of misc. connections*.

NB!
The USB connection is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals. The USB connection is connected to protection earth on the frequency converter. Use only isolated laptop as PC connection to the USB connector on the VLT AQUA Drive.



5

PC Software - MCT 10
All drives are equipped with a serial communication port. We provide a PC tool for communication between PC and frequency converter, VLT Motion Control Tool MCT 10 Set-up Software.

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

The MCT 10 Set-up Software will be useful for:

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

MCT 10
Set-up Software support Profibus DP-V1 via a Master class 2 connection. It makes it possible to on line read/write parameters in a frequency converter via the Profibus network. This will eliminate the need for an extra communication network.

Save Drive Settings:

1. Connect a PC to the unit via USB com port
2. Open 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 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 drive.

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

The 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 Cascade Control Config. Tool

Ordering number:

Please order your CD containing MCT 10 Set-up Software using code number 130B1000.

MCT 10 can also be downloaded from the Danfoss Internet: WWW.DANFOSS.COM, Business Area: Motion Controls.

MCT 31

The MCT 31 harmonic calculation PC tool enables easy estimation of the harmonic distortion in a given application. Both the harmonic distortion of Danfoss frequency converters as well as non-Danfoss frequency converters with different additional harmonic reduction devices, such as Danfoss AHF filters and 12-18-pulse rectifiers, can be calculated.

Ordering number:

Please order your CD containing the MCT 31 PC tool using code number 130B1031.

MCT 31 can also be downloaded from the Danfoss Internet: WWW.DANFOSS.COM, Business Area: Motion Controls.

5.7. Safety

5.7.1. 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.

NB!

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

5.7.2. Safety Earth Connection

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

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

5.8. EMC-correct Installation

5.8.1. Electrical Installation - EMC Precautions

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

Good engineering practice to ensure EMC-correct electrical installation:

- Use only braided screened/armoured motor cables and braided screened/armoured control cables. The screen should provide a minimum coverage of 80%. The screen material must be metal, not limited to but typically copper, aluminium, steel or lead. There are no special requirements for the mains cable.
- Installations using rigid metal conduits are not required to use screened cable, but the motor cable must be installed in conduit separate from the control and mains cables. Full connection of the conduit from the drive to the motor is required. The EMC performance of flexible conduits varies a lot and information from the manufacturer must be obtained.
- Connect the screen/armour/conduit to earth at both ends for motor cables as well as for control cables. In some cases, it is not possible to connect the screen in both ends. If so, connect the screen at the frequency converter. See also *Earthing of Braided Screened/Armoured Control Cables*.
- Avoid terminating the screen/armour with twisted ends (pigtails). It increases the high frequency impedance of the screen, which reduces its effectiveness at high frequencies. Use low impedance cable clamps or EMC cable glands instead.
- Avoid using unscreened/unarmoured motor or control cables inside cabinets housing the drive(s), whenever this can be avoided.

Leave the screen as close to the connectors as possible.

The illustration shows an example of an EMC-correct electrical installation of an IP 20 frequency converter. The frequency converter is fitted in an installation cabinet with an output contactor and connected to a PLC, which is installed in a separate cabinet. Other ways of doing the installation may have just as good an EMC performance, provided the above guide lines to engineering practice are followed.

If the installation is not carried out according to the guideline and if unscreened cables and control wires are used, some emission requirements are not complied with, although the immunity requirements are fulfilled. See the paragraph *EMC test results*.

5

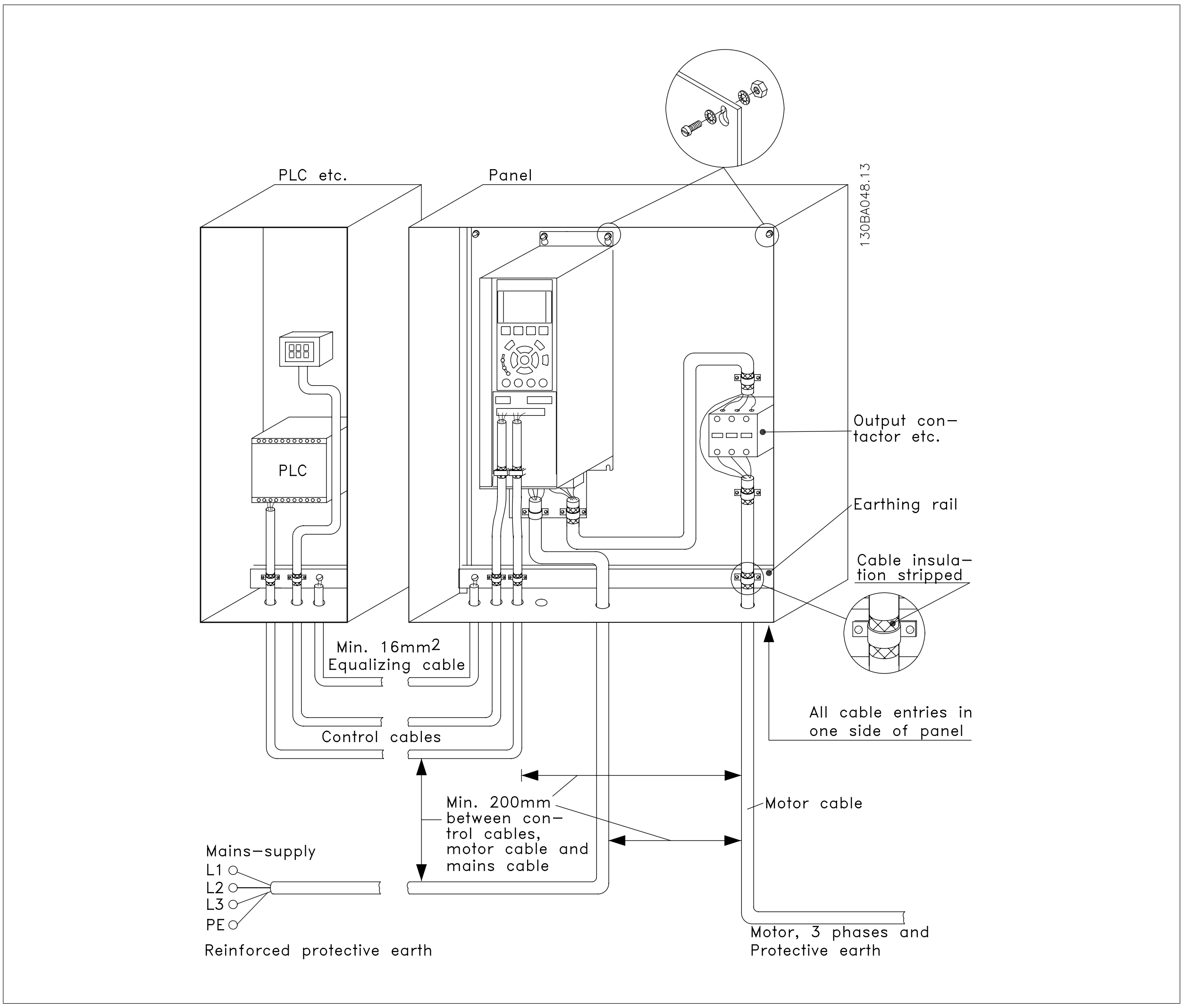


Illustration 5.25: EMC-correct electrical installation of a frequency converter in cabinet.

5.8.2. Use of EMC-Correct Cables

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

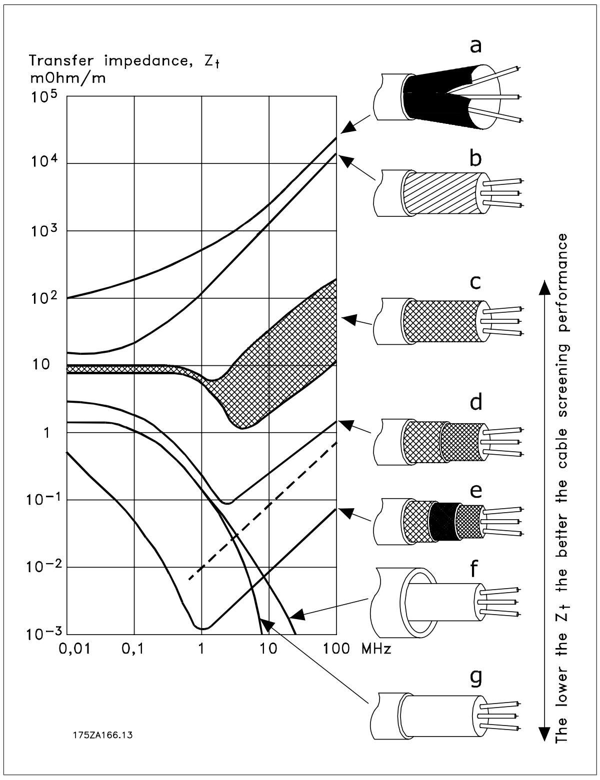
The ability of a cable to reduce the in- and outgoing radiation of electric noise depends on the transfer impedance (Z_T). The screen of a cable is normally designed to reduce the transfer of electric noise; however, a screen with a lower transfer impedance (Z_T) value is more effective than a screen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

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 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 1.1 mm wall thickness.



5.8.3. 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.

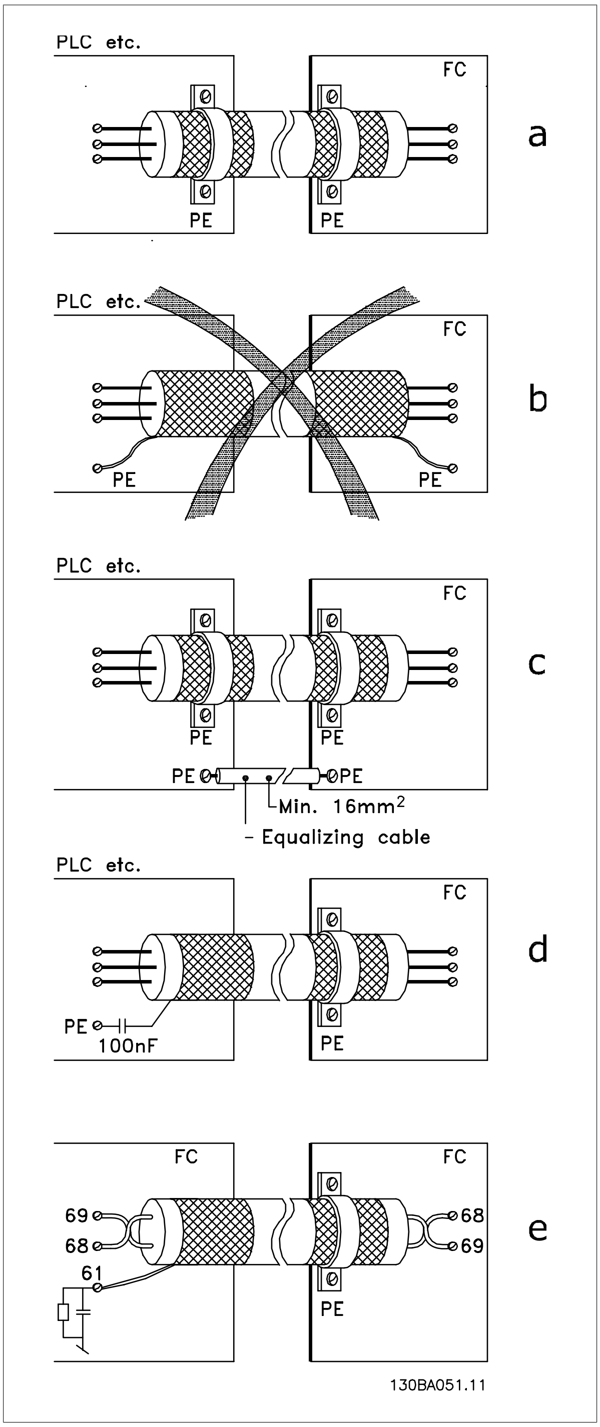
a. **Correct earthing**
Control cables and cables for serial communication must be fitted with cable clamps at both ends to ensure the best possible electrical contact.

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**
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.



5.9.1. Residual Current Device

You can 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, you must observe local regulations. Relays must be suitable for protection of 3-phase equipment with a bridge rectifier and for a brief discharge on power-up see section *Earth Leakage Current* for further information.

6. Application Examples

6.1.1. Start/Stop

Terminal 18 = start/stop par. 5-10 [8] *Start*
Terminal 27 = No operation par. 5-12 [0] *No operation* (Default *coast inverse*

Par. 5-10 *Digital Input, Terminal 18* = *Start* (default)

Par. 5-12 *Digital Input, Terminal 27* = *coast inverse* (default)

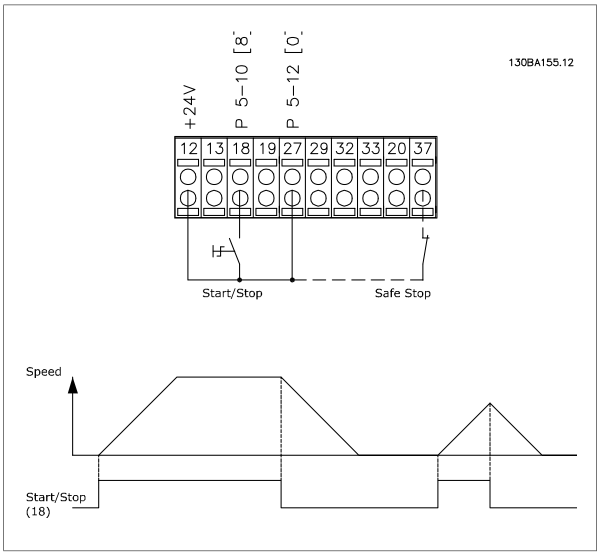


Illustration 6.1: Terminal 37: Available only with Safe Stop Function!

6.1.2. Pulse Start/Stop

Terminal 18 = start/stop par. 5-10 [9] *Latched start*
Terminal 27= Stop par. 5-12 [6] *Stop inverse*

Par. 5-10 *Digital Input, Terminal 18* = *Latched start*

Par. 5-12 *Digital Input, Terminal 27* = *Stop inverse*

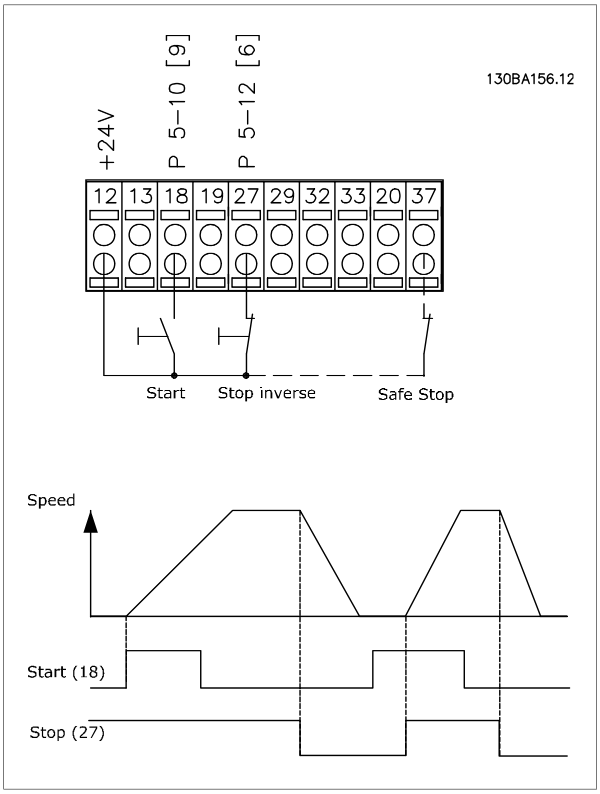


Illustration 6.2: Terminal 37: Available only with Safe Stop Function!

6.1.3. Potentiometer Reference

Voltage reference via a potentiometer.

par. 3-15 Reference *1 Source* [1] = *Analog Input 53*

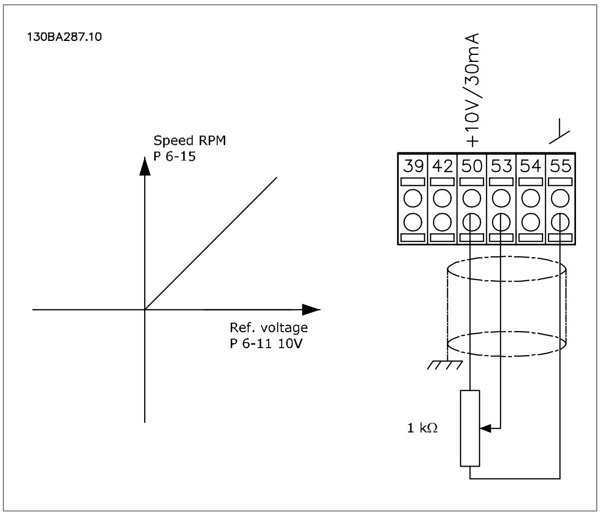
par. 6-10 Terminal *53 Low Voltage* = 0 Volt

par. 6-11 Terminal *53 High Voltage* = 10 Volt

par. 6-14 Terminal *53 Low Ref./Feedb. Value* = 0 RPM

par. 6-15 Terminal *53 High Ref./Feedb. Value* = 1.500 RPM

Switch S201 = OFF (U)



6

6.1.4. Automatic Motor Adaptation (AMA)

AMA is an algorithm to measure the electrical motor parameters on a motor at standstill. This means thatAMA itself does not supply any torque.
AMA is useful when commissioning systems and optimising the adjustment of the frequency converter to the applied motor. This feature is particularly used where the default setting does not apply to the connected motor.
par. 1-29 Automatic *Motor Adaptation (AMA)* allows a choice of complete AMA with determination of all electrical motor parameters or reduced AMA with determination of the stator resistance Rs only.
The duration of a total AMA varies from a few minutes on small motors to more than 15 minutes on large motors.

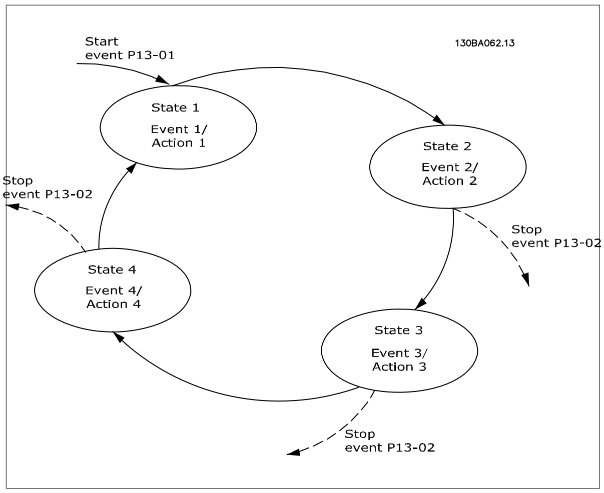
Limitations and preconditions:

- For the AMA to determine the motor parameters optimally, enter the correct motor nameplate data in par. 1-20 Motor *Power [kW]* to par. 1-28 Motor *Rotation Check*.
- For the best adjustment of the frequency converter, carry out AMA on a cold motor. Repeated AMA runs may lead to a heating of the motor, which results in an increase of the stator resistance, Rs. Normally, this is not critical.
- AMA can only be carried out if the rated motor current is minimum 35% of the rated output current of the frequency converter. AMA can be carried out on up to one oversize motor.
- It is possible to carry out a reduced AMA test with a Sine-wave filter installed. Avoid carrying out a complete AMA with a Sine-wave filter. If an overall setting is required, remove the Sine-wave filter while running a total AMA. After completion of the AMA, reinsert the Sine-wave filter.
- If motors are coupled in parallel, use only reduced AMA if any.
- Avoid running a complete AMA when using synchronous motors. If synchronous motors are applied, run a reduced AMA and manually set the extended motor data. The AMA function does not apply to permanent magnet motors.
- The frequency converter does not produce motor torque during an AMA. During an AMA, it is imperative that the application does not force the motor shaft to run, which is known to happen with e.g. wind milling in ventilation systems. This disturbs the AMA function.

The Smart Logic Control (SLC) is essentially a sequence of user defined actions (see par.) executed by the SLC when the associated user defined *event* (see par.) is evaluated as TRUE by the SLC.
Events and *actions* are each numbered and are linked in pairs called states. This means that when *event [1]* is fulfilled (attains the value TRUE), *action [1]* is executed. After this, the conditions of *event [2]* will be evaluated and if evaluated TRUE, *action [2]*will be executed and so on. Events and actions are placed in array parameters.

Only one *event* will be evaluated at any time. If an *event* is evaluated as FALSE, nothing happens (in the SLC) during the present scan interval and no other *events* will be evaluated. This means that when the SLC starts, it evaluates *event [1]* (and only *event [1]*) each scan interval. Only when *event [1]* is evaluated TRUE, the SLC executes *action [1]* and starts evaluating *event [2]*.

It is possible to program from 0 to 20 *events* and *actions*. When the last *event / action* has been executed, the sequence starts over again from *event [1] / action [1]*. The illustration shows an example with three *events / actions*:

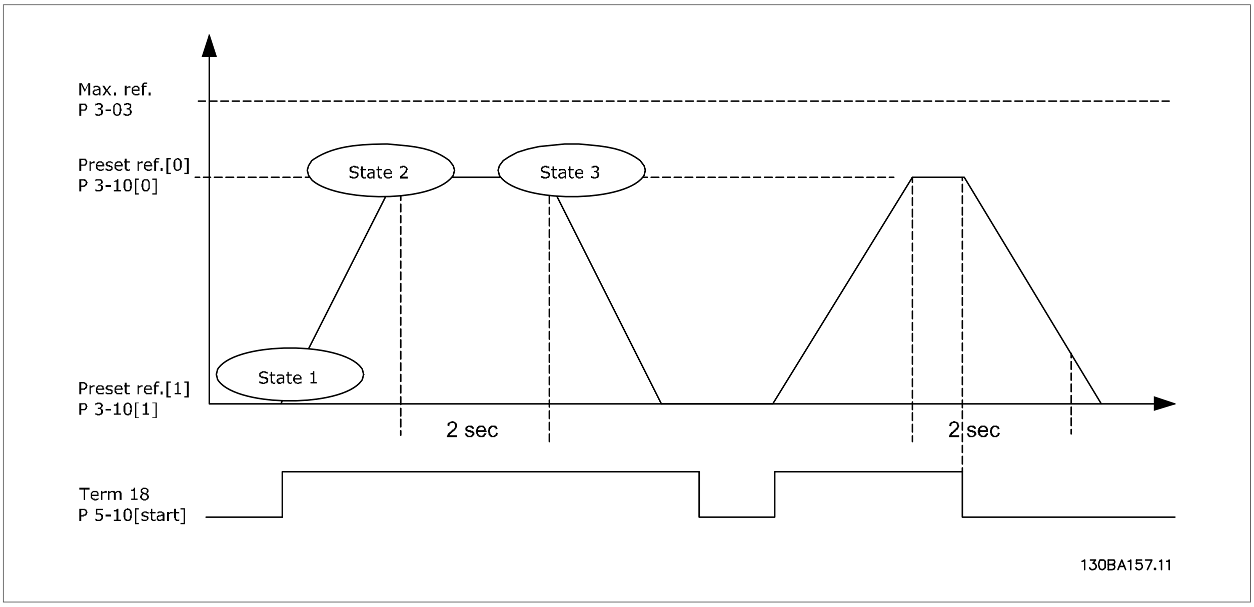


6.1.5. Smart Logic Control Programming

New useful facility in VLT AQUA Drive is the Smart Logic Control (SLC).
In applications where a PLC is generating a simple sequence the SLC may take over elementary tasks from the main control.
SLC is designed to act from event send to or generated in the VLT AQUA Drive . The frequency converter will then perform the pre-programmed action.

6.1.6. SLC Application Example

One sequence 1:
Start – ramp up – run at reference speed 2 sec – ramp down and hold shaft until stop.



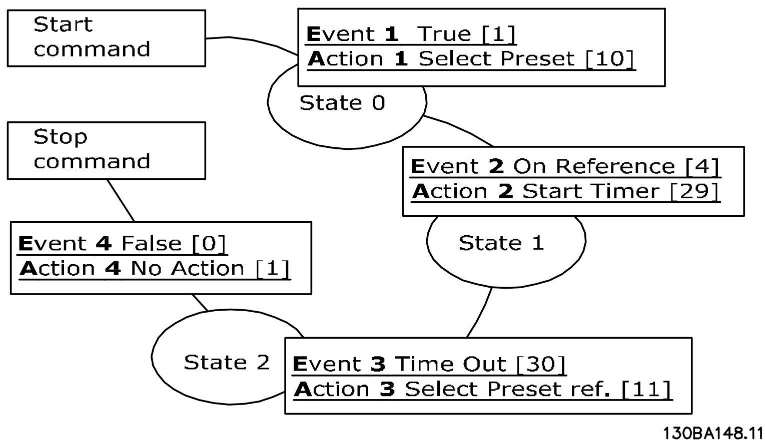
Set the ramping times in par. 3-41 Ramp *1 Ramp Up Time* and par. 3-42 Ramp *1 Ramp Down Time* to the wanted times

$$t_{ramp} = \frac{t_{acc} \times n_{norm}\,(par.\ 1\ -\ 25)}{ref\,[RPM]}$$

Set term 27 to *No Operation* (par. 5-12 Terminal *27 Digital Input*)
Set Preset reference 0 to first preset speed (par. 3-10 Preset *Reference* [0]) in percentage of Max reference speed (par. 3-03 Maximum *Reference*). Ex.: 60%
Set preset reference 1 to second preset speed (par. 3-10 Preset *Reference* [1] Ex.: 0 % (zero).
Set the timer 0 for constant running speed in par. 13-20 SL *Controller Timer* [0]. Ex.: 2 sec.

Set Event 1 in par. 13-51 SL *Controller Event* [1] to *True* [1]
Set Event 2 in par. 13-51 SL *Controller Event* [2] to *On Reference* [4]
Set Event 3 in par. 13-51 SL *Controller Event* [3] to *Time Out 0* [30]
Set Event 4 in par. 13-51 SL *Controller Event* [1] to *False* [0]

Set Action 1 in par. 13-52 SL *Controller Action* [1] to *Select preset 0* [10]
Set Action 2 in par. 13-52 SL *Controller Action* [2] to *Start Timer 0* [29]
Set Action 3 in par. 13-52 SL *Controller Action* [3] to *Select preset 1* [11]
Set Action 4 in par. 13-52 SL *Controller Action* [4] to *No Action* [1]



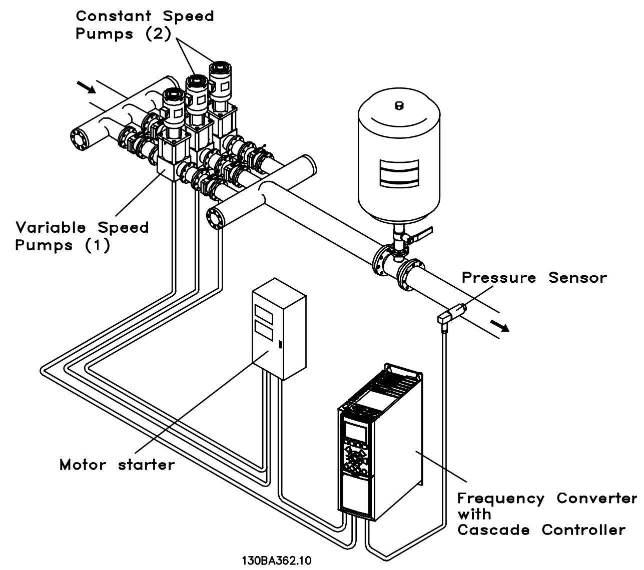
Set the Smart Logic Control in par. 13-00 SL *Controller Mode* to ON.

Start / stop command is applied on terminal 18. If stop signal is applied the frequency converter will ramp down and go into free mode.

6.1.7. BASIC Cascade Controller

The BASIC Cascade Controller is used for pump applications where a certain pressure ("head") or level needs to be maintained over a wide dynamic range. Running a large pump at variable speed over a wide range is not an ideal solution because of low pump efficiency at lower speed. In a practical way, the limit is 25% of the rated full load speed for the pump.

In the BASIC Cascade Controller the frequency converter controls a variable speed (lead) motor as the variable speed pump and can stage up to two additional constant speed pumps on and off. By varying the speed of the initial pump, variable speed control of the entire system is provided. This maintains constant pressure while eliminating pressure surges, resulting in reduced system stress and quieter operation in pumping systems.



Fixed Lead Pump

The motors must be of equal size. The BASIC Cascade Controller allows the frequency converter to control up to 3 equal size pumps using the drives two built-in relays. When the variable pump (lead) is connected directly to the drive, the other 2 pumps are controlled by the two built-in relays. When lead pump alternations is enabled, pumps are connected to the built-in relays and the drive is capable of operating 2 pumps.

Lead Pump Alternation

The motors must be of equal size. This function makes it possible to cycle the drive between the pumps in the system (maximum of 2 pumps). In this operation the run time between pumps is equalized reducing the required pump maintenance and increasing reliability and lifetime of the system. The alternation of the lead pump can take place at a command signal or at staging (adding another pump).

The command can be a manual alternation or an alternation event signal. If the alternation event is selected, the lead pump alternation takes place every time the event occurs. Selections include whenever an alternation timer expires, at a predefined time of day or when the lead pump goes into sleep mode. Staging is determined by the actual system load.

A separate parameter limits alternation only to take place if total capacity required is > 50%. Total pump capacity is determined as lead pump plus fixed speed pumps capacities.

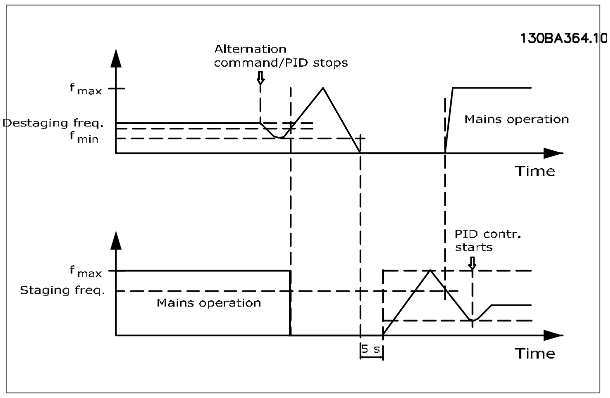
Bandwidth Management

In cascade control systems, to avoid frequent switching of fixed speed pumps, the desired system pressure is kept within a bandwidth rather than at a constant level. The Staging Bandwidth provides the required bandwidth for operation. When a large and quick change in system pressure occurs, the Override Bandwidth overrides the Staging Bandwidth to prevent immediate response to a short duration pressure change. An Override Bandwidth Timer can be programmed to prevent staging until the system pressure has stabilized and normal control established.

When the Cascade Controller is enabled and the drive issues a trip alarm, the system head is maintained by staging and destaging fixed speed pumps. To prevent frequent staging and destaging and minimize pressure fluxuations, a wider Fixed Speed Bandwidth is used instead of the Staging bandwidth.

6.1.8. Pump Staging with Lead Pump Alternation

With lead pump alternation enabled, a maximum of two pumps are controlled. At an alternation command, the PID stops, the lead pump ramps to minimum frequency (f_{min}) and after a delay, it ramps to maximum frequency (f_{max}). When the speed of the lead pump reaches the de-staging frequency, the fixed speed pump will be cut out (de-staged). The lead pump continues to ramp up and then ramps down to a stop and the two relays are cut out.



After a time delay, the relay for the fixed speed pump cuts in (staged) and this pump becomes the new lead pump. The new lead pump ramps up to maximum speed and then down to minimum speed. When ramping down and reaching the staging frequency, the old lead pump is now cut in (staged) on the mains as the new fixed speed pump.

6

If the lead pump has been running at minimum frequency (f_{min}) for a programmed amount of time, with a fixed speed pump running, the lead pump contributes little to the system. When programmed value of the timer expires, the lead pump is removed avoiding water heating problems.

6.1.9. System Status and Operation

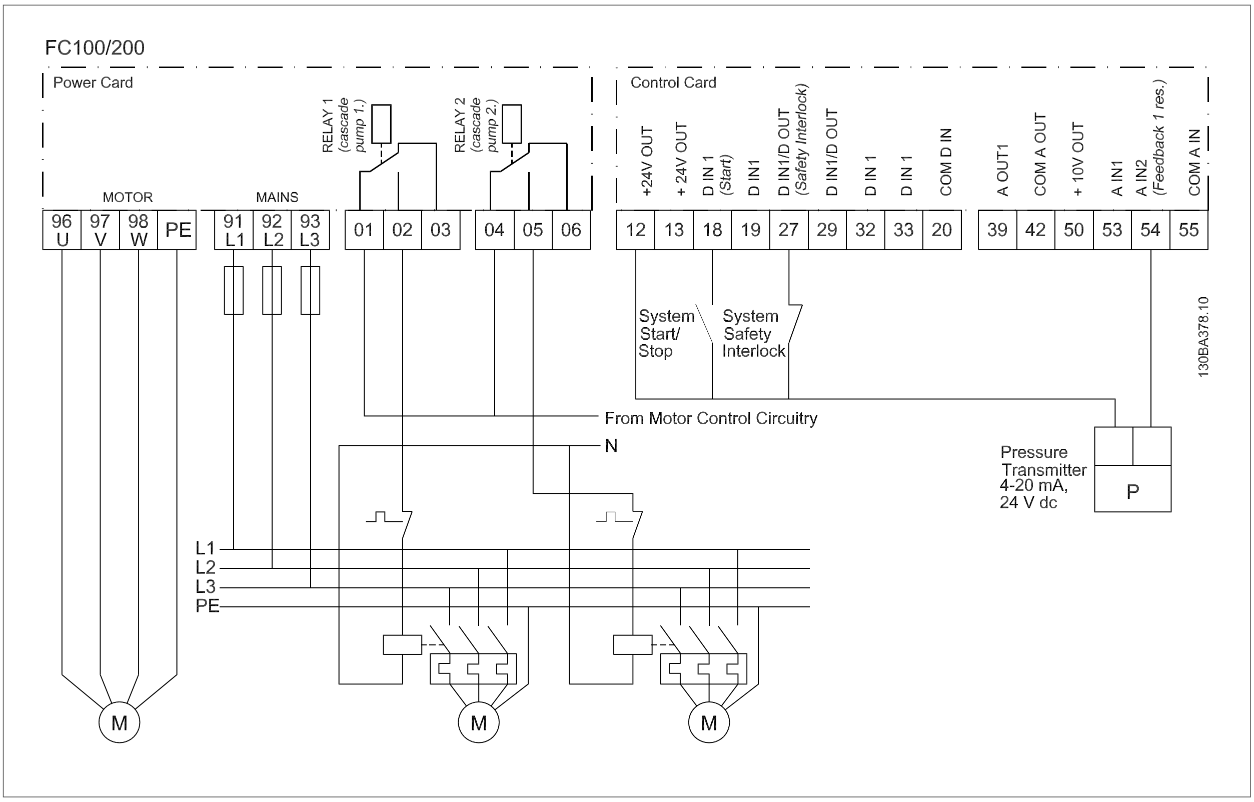
If the lead pump goes into Sleep Mode, the function is displayed on the Local Control Panel. It is possible to alternate the lead pump on a Sleep Mode condition.

When the cascade controller is enabled, the operation status for each pump and the cascade controller is displayed on the Local Control Panel. Information displayed includes:

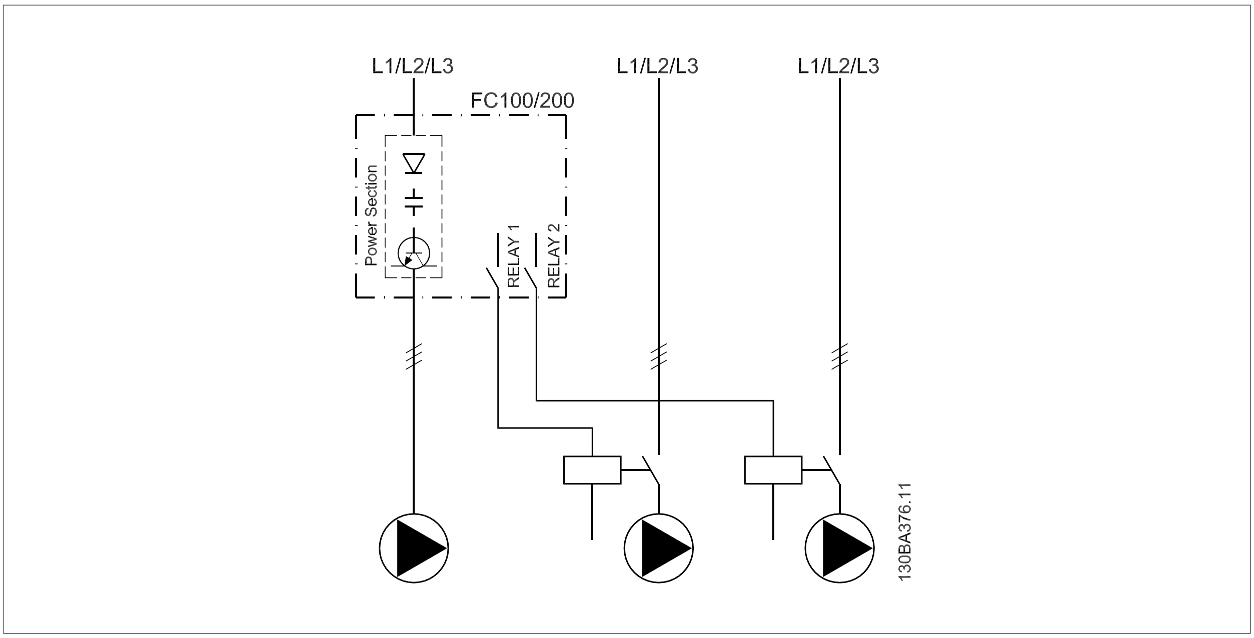
- Pumps Status, is a read out of the status for the relays assigned to each pump. The display shows pumps that are disabled, off, running on the frequency converter or running on the mains/motor starter.
- Cascade Status, is a read out of the status for the Cascade Controller. The display shows the Cascade Controller is disabled, all pumps are off, and emergency has stopped all pumps, all pumps are running, fixed speed pumps are being staged/destaged and lead pump alternation is occurring.
- Destage at No-Flow ensures that all fixed speed pumps are stopped individually until the no-flow status disappears.

6.1.10. Cascade Controller Wiring Diagram

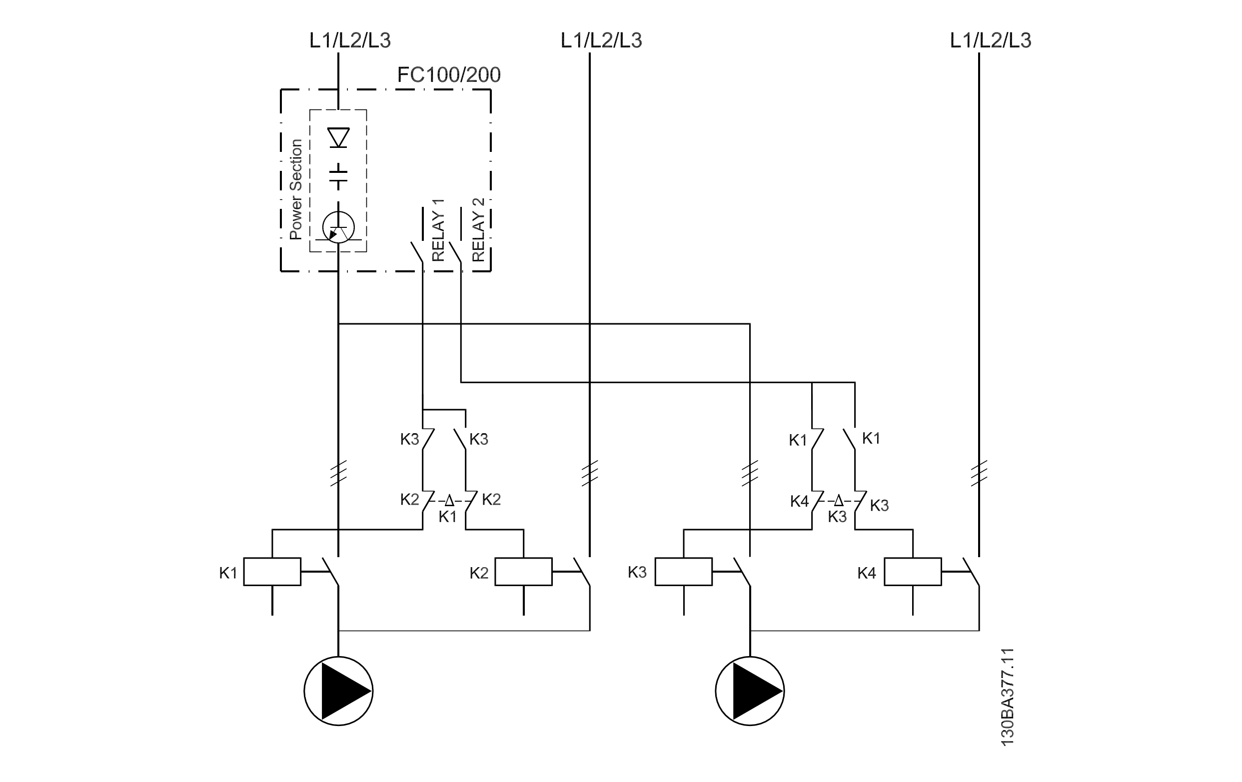
The wiring diagram shows an example with the built in BASIC cascade controller with one variable speed pump (lead) and two fixed speed pumps, a 4-20 mA transmitter and System Safety Interlock.



6.1.11. Fixed Variable Speed Pump Wiring Diagram



6.1.12. Lead Pump Alternation Wiring Diagram



Every pump must be connected to two contactors (K1/K2 and K3/K4) with a mechanical interlock. Thermal relays or other motor protection devices must be applied according to local regulation and/or individual demands.

- RELAY 1 (R1) and RELAY 2 (R2) are the built-in relays in the frequency converter.
- When all relays are de-energized, the first built in relay to be energized will cut in the contactor corresponding to the pump controlled by the relay. E.g. RELAY 1 cuts in contactor K1, which becomes the lead pump.
- K1 blocks for K2 via the mechanical interlock preventing mains to be connected to the output of the frequency converter (via K1).
- Auxiliary break contact on K1 prevents K3 to cut in.
- RELAY 2 controls contactor K4 for on/off control of the fixed speed pump.
- At alternation both relays de-energizes and now RELAY 2 will be energized as the first relay.

6.1.13. Start/Stop conditions

Commands assigned to digital inputs. See *Digital Inputs*, par.5-1*.

	Variable speed pump (lead)	Fixed speed pumps
Start (SYSTEM START /STOP)	Ramps up (if stopped and there is a demand)	Staging (if stopped and there is a demand)
Lead Pump Start	Ramps up if SYSTEM START is active	Not affected
Coast (EMERGENCY STOP)	Coast to stop	Cut out (built in relays are de-energized)
Safety Interlock	Coast to stop	Cut out (built in relays are de-energized)

Function of buttons on Local Control Panel

	Variable speed pump (lead)	Fixed speed pumps
Hand On	Ramps up (if stopped by a normal stop command) or stays in operation if already running	Destaging (if running)
Off	Ramps down	Cut out
Auto On	Starts and stops according to commands via terminals or serial bus	Staging/Destaging

6.1.14. Submersible Pump Application

The system consists of a submersible pump controlled by a Danfoss VLT AQUA Drive and a pressure transmitter. The transmitter gives a 4-20 mA feedback signal to the VLT AQUA Drive, which keeps a constant pressure by controlling the speed of the pump. To design a drive for a submersible pump application, there are a few important issues to take into consideration. Therefore the drive used must be chosen according to motor current.

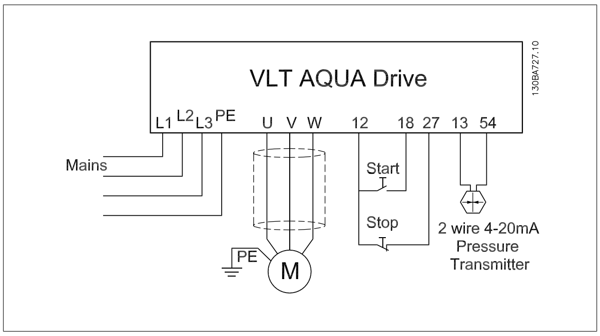
1. The motor is a so called "Can motor" with a stainless steel can between the rotor and stator. There is a larger and a more magnetic resistant air-gap than on a normal motor hence a weaker field which results in the motors being designed with a higher rated current than a norm motor with similar rated power.
2. The pump contains thrust bearings which will be damaged when running below minimum speed which normally will be 30 Hz.
3. The motor reactance is nonlinear in submersible pump motors and therefore Automatic Motor Adaption (AMA) may not be possible. However, normally submersible pumps are operated with very long motor cables that might eliminate the nonlinear motor reactance and enable the drive to perform AMA. If AMA fails, the motor data can be set from parameter group 1-3* (see motor datasheet). Be aware that if AMA has succeeded the drive will compensate for voltage drop in the long motor cables, so if the Advanced motor data are set manually, the length of the motor cable must be taken into considerations to optimize system performance.
4. It is important that the system is operated with a minimum of wear and tear of the pump and motor. A Danfoss Sine-Wave filter can lower the motor insulation stress and increase lifetime (check actual motor insulation and the frequency converter du/dt specification). It is recommended to use a filter to reduce the need for service.
5. EMC performance can be difficult to achieve due to the fact that the special pump cable which is able to withstand the wet conditions in the well normally is unscreened. A solution could be to use a screened cable above the well and fix the screen to the well pipe if it is made of steel (can also be made of plastic). A Sine-Wave filter will also reduce the EMI from unscreened motor cables.

The special "can motor" is used due to the wet installation conditions. The drive needs to be designed for the system according to output current to be able to run the motor at nominal power.

To prevent damage to the thrust bearings of the pump, it is important to ramp the pump from stop to min. speed as quick as possible. Well-known manufacturers of submersible pumps recommend that the pump is ramped to min. speed (30 Hz) in max. 2 -3 seconds. The new VLT© AQUA Drive is designed with initial and final Ramp for these applications. The initial and final ramps are 2 individual ramps, where Initial Ramp, if enabled, will ramp the motor from stop to min. speed and automatically switch to normal ramp, when min. speed is reached. Final ramp will do the opposite from min. speed to stop in a stop situation.

Pipe-Fill mode can be enabled to prevent water hammering. The Danfoss frequency converter is capable of filling vertical pipes using the PID controller to slowly ramp up the pressure with a user specified rate (units/sec). If enabled the drive will, when it reaches min. speed after startup, enter pipe fill mode. The pressure will slowly be ramped up until it reaches a user specified Filled Set Point, where after the drive automatically disables Pipe Fill Mode and continues in normal closed loop operation.
This feature is designed for irrigation applications.

Electrical Wiring

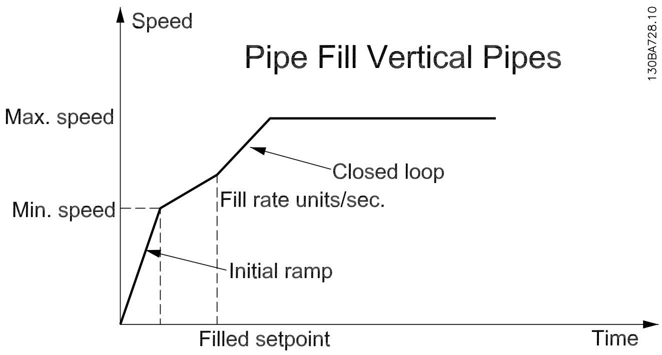


Typical parameter settings	
Typical/recommended settings in brackets().	
Parameters:	
Motor Rated Power	Par. 1-20 / par. 1-21
Motor Rated Voltage	Par. 1-22
Motor Current	Par. 1-24
Motor Rated Speed	Par. 1-28
Enable Reduced Automatic Motor Adaptation (AMA in par. 1-29)	

NB!
Note the analog input 2, (terminal (54) format must be set to mA. (switch 202).

Min. Reference	Par. 3-01	(30 Hz)
Max. Reference	Par. 3-02	(50/60 Hz)
Initial Ramp Up Time	Par. 3-84	(2 sec.)
Final Ramp Down Time	Par. 3-88	(2 sec.)
Normal Ramp Up Time	Par. 3-41	(8 sec. depending on size)
Normal Ramp Down Time	Par. 3-42	(8 sec. depending on size)
Motor Min. Speed	Par. 4-11	(30 Hz)
Motor Max. Speed	Par. 4-13	(50/60 Hz)
Use the “Closed Loop” wizard under “Quick Menu_Funtion_Setup”, to easily set up the feedback settings in the PID controller.		

Pipe Fill Mode		
Pipe Fill Enable	Par. 29-00	
Pipe Fill Rate	Par. 29-04	(Feedback units/sec.)
Filled Set Point	Par. 29-05	(Feedback units)



6

6.1.15. Master/Follower Operation Application

Application Description

The system used as example contains 4 equal sized pumps in a water distribution system. They are each connected to a Danfoss VLT AQUA Drive. A pressure transmitter with an analogue output format of 4-20mA is used as feedback and connected to the drive named the 'master drive'. The master drive also includes the Danfoss *VLT Extended Cascade Controller Option MCB-101*. The purpose of the system is to maintain a constant pressure in the system.

Arguments for using a 'master / follower' setup instead of the standard cascade control mode could be:

- In old and weak pipe system where huge pressure surges can lead to leakage, the high performance of the master / follower mode can be a real benefit.
- In constant pressure water systems the pumps can be operated in the most energy efficient way by using Master / follower operation.
- In systems with large variances in flow, the fast reacting Master / Follower mode will safely and fast maintain a constant pressure.
- Very easy installation - no need for external equipment. The drives can be delivered in IP55 or even IP66, which means no need for panels, except for fuses.

Issues to keep in mind

Compared to traditional cascade control the number of running pumps is controlled by speed instead of feedback. To obtain the highest energy saving the stage on and off speed must be set correctly according to the system. To understand the principle better, please note figure 1.

The stage on and off speed is set by the user for each stage. The right speed depends on the application and the system. In VLT AQUA software version higher than 1.1, the speed will be auto-tuned by the drive. The right settings can also be determined by using the Danfoss PC software called MUSEC, which is downloadable from our homepage: www.danfoss.com
For a start the settings showed in table 1.1 can be used in most applications.

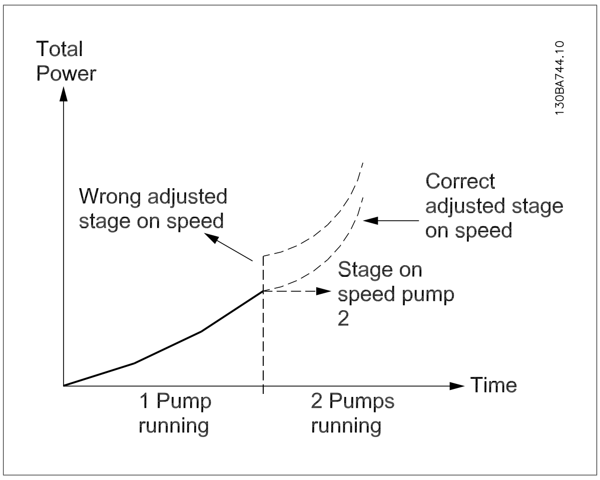


Illustration 6.3: Total power consumption.

	Stage on speed [Hz] (Par. 27-31)	Stage off speed [Hz] (Par. 27-33)
Stage 1	40	Min. speed
Stage 2	42	36
Stage 3	45	38
Stage 4	47	40

Table 6.1: Example of stage on and stage off speed

Electrical wiring

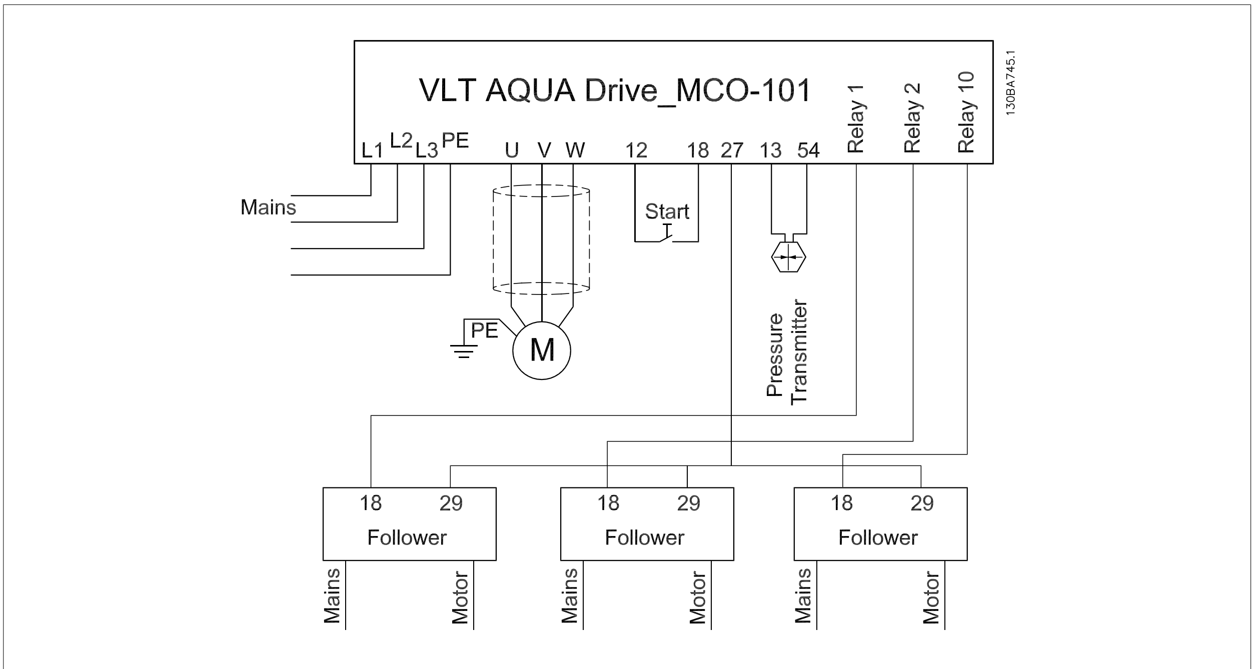


Illustration 6.4: Electrical wiring. Terminal 27 on master drive is used as pulse output reference. Terminal 29 on the follower drives is used as pulse input reference. All follower drives are connected to mains and motor the same way as the master drive symbolized with the text: *Mains* and *Motor*.

NB!
In the example it is assumed that the pressure transmitter used as feedback sensor, has a range from 0-10 bar.

Parameter settings:

Display settings - Master drive:		
Display Line 1.1 Small	0-20	Reference [1601]
Display Line 1.2 Small	0-21	Feedback [1652]
Display Line 1.3 Small	0-22	Motor current [1614]
Display Line 2 Large	0-23	Frequency [1613]
Display Line 3 Large	0-24	Cascade reference [2791]

Display settings - Follower drives:		
Display Line 1.1 Smal	0-20	External Reference [1650]
Display Line 3 Large	0-24	Frequency [1613]

NB!
Please note: the format of the analogue input is set using switch S201 below the LCP.

6

Basic settings for both Master and Follower drives:

Parameters:	
Change from RPM to Hz as speed unit	0-02
Motor rated power	1-20 / par. 1-21 (kW / HP)
Motor rated voltage	1-22
Motor Current	1-24
Motor Rated Speed	1-25
Motor Rotation Check	1-28
Enable Automatic Motor Adaptation	1-29

Ramp Up Time	3-41	(5 sec.* Depending on size) Must be the same in Master and Follower!
Ramp Down Time	3-42	(5 sec.* Depending on size) Must be the same in Master and Follower!
Motor Speed Low Limit [Hz]	4-12	(30 Hz)
Motor Speed High Limit [Hz]	4-14	(50 Hz) Must be the same in Master and Follower!

Settings for the Master drive only

1. Use the “Closed Loop” Wizard under “Quick Menu_Function Setup”, to easily set up the feedback settings and the PID controller.
2. Set up the master configuration in par. 27-**

Enable Master/Follower	27-10	
Set number of drives	27-11	
Set the staging speed according to table 1	27-3*	
Configure Relay 1	27-70	Drive 2 Enable
Configure Relay 2	27-70	Drive 3 Enable
Configure Relay 10	27-70	Drive 4 Enable
Minimum Reference	3-02	0 [bar]
Maximum Reference	3-03	10 [bar]
Terminal 27 Mode	5-01	Output [1]
Terminal 27 Digital Output	5-30	Pulse output [55]
Terminal 27 Pulse Output Variable	5-60	Cascade Reference [116]
Pulse Output Maximum Frequency #27	5-62	5000 [Hz]

Settings for the Follower drives only		
Set Reference 1 Source	3-15	Pulse input 29 [7]
Set Terminal 29 Digital Input	5-13	Pulse input [32]
Set Term. 29 Low Frequency	5-50	0 [Hz]
Set Term. 29 high frequency	5-51	5000 [Hz]

Operation

When the system is set to operation, the master drive will automatically run "time balance" with all drives running with the needed number of pumps depending on the demand. If, for some reason the user wants to prioritize which motors should be preferred, it is possible to prioritize the pumps in par. 27-16 in three levels. (Priority 1, Priority 2 and spare pump). Pumps with priority 2 will only be staged on when there is no priority 1 pump available.
It might be necessary to fine adjust the *stage on/off* speed to optimise the energy consumption.

7. RS-485 Installation and Set-up

7.1. RS-485 Installation and Set-up

7.1.1. Overview

RS-485 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.
Network segments are divided up by repeaters. 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 ground connection of the screen at every node is very important, including at high frequencies. This can be achieved by connecting a large surface of the screen to ground, for example by means of a cable clamp or a conductive cable gland. It may be necessary to apply potential-equalizing cables to maintain the same ground potential throughout the network, particularly in installations where there are long lengths of cable.
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: 120 Ohm
Cable length: Max. 1200 m (including drop lines)
Max. 500 m station-to-station

7.1.2. Network Connection

Connect the frequency converter to the RS-485 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.

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

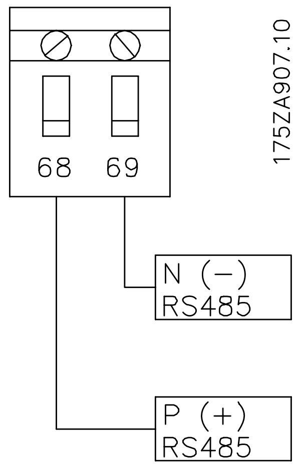
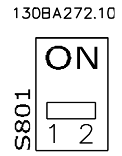


Illustration 7.1: Network Terminal Connection

7.1.3. VLT AQUA Hardware Setup

Use the terminator dip switch on the main control board of the frequency converter to terminate the RS-485 bus.



Terminator Switch Factory Setting

NB!
The factory setting for the dip switch is OFF.

7.1.4. VLT AQUA Parameter Settings for Modbus Communication

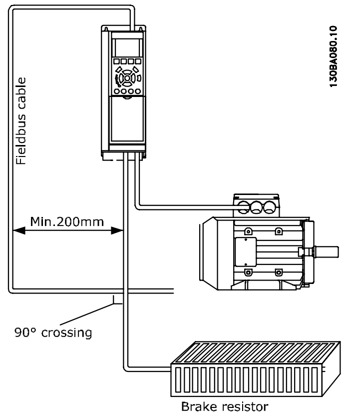
The following parameters apply to the RS-485 interface (FC-port):

Parameter Number	Parameter name	Function
8-30	Protocol	Select the application protocol to run on the RS-485 interface
8-31	Address	Set the node address. Note: The address range depends on the protocol selected in par. 8-30
8-32	Baud Rate	Set the baud rate. Note: The default baud rate depends on the protocol selected in par. 8-30
8-33	PC port parity/Stop bits	Set the parity and number of stop bits. Note: The default selection depends on the protocol selected in par. 8-30
8-35	Min. response delay	Specify a minimum delay time between receiving a request and transmitting a response. This can be used for overcoming modem turnaround delays.
8-36	Max. response delay	Specify a maximum delay time between transmitting a request and receiving a response.
8-37	Max. inter-char delay	Specify a maximum delay time between two received bytes to ensure timeout if transmission is interrupted.

7.1.5. EMC Precautions

The following EMC precautions are recommended in order to achieve interference-free operation of the RS-485 network.

NB!
Relevant national and local regulations, for example regarding protective earth connection, must be observed. The RS-485 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 200 mm (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 RS-485 cable must cross motor and brake resistor cables at an angle of 90 degrees.



7.2. FC Protocol Overview

The FC protocol, also referred to as FC bus or Standard bus, is the 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 individual slaves are selected by the master 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 RS-485, thus utilizing the RS-485 port built into the frequency converter. The FC protocol supports different telegram formats; a short format of 8 bytes for process data, and a long format of 16 bytes that also includes a parameter channel. A third telegram format is used for texts.

7.2.1. VLT AQUA 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 a variety of preset speeds
- Run in reverse
- Change of the active set-up
- Control of the two 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 PID controller is used.

7.3. Network Configuration

7.3.1. VLT AQUA Frequency Converter Set-up

Set the following parameters to enable the FC protocol for the VLT AQUA.

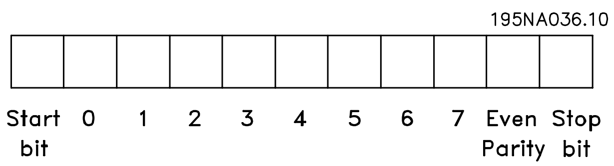
Parameter Number	Parameter name	Setting
8-30	Protocol	FC
8-31	Address	1 - 126
8-32	Baud Rate	2400 - 115200
8-33	Parity/Stop bits	Even parity, 1 stop bit (default)

7.4. FC Protocol Message Framing Structure

7.4.1. Content of a Character (byte)

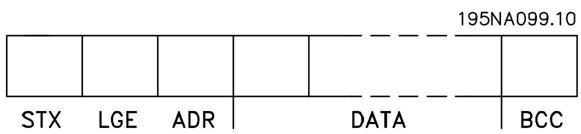
Each character transferred begins with a start bit. Then 8 data bits are transferred, corresponding to a byte. Each character is secured via a parity bit, which is set at "1" when it reaches parity (i.e. when there is an equal number of 1's in the 8 data bits and the parity bit in total). A character is completed by a stop bit, thus consisting of 11 bits in all.

7



7.4.2. Telegram Structure

Each telegram begins with a start character (STX)=02 Hex, followed by a byte denoting the telegram length (LGE) and a byte denoting the frequency converter address (ADR). A number of data bytes (variable, depending on the type of telegram) follows. The telegram is completed by a data control byte (BCC).



7.4.3. 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).

7.4.4. Frequency Converter Address (ADR)

Two different address formats are used.
The address range of the frequency converter is either 1-31 or 1-126.

1. Address format 1-31:
Bit 7 = 0 (address format 1-31 active)
Bit 6 is not used
Bit 5 = 1: Broadcast, address bits (0-4) are not used
Bit 5 = 0: No Broadcast
Bit 0-4 = Frequency converter address 1-31

2. 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.

7.4.5. Data Control Byte (BCC)

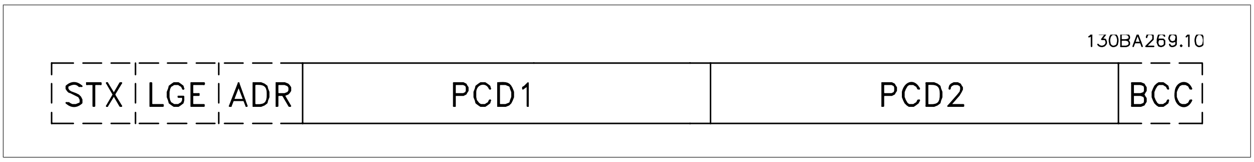
The checksum is calculated as an XOR-function. Before the first byte in the telegram is received, the Calculated Checksum is 0.

7.4.6. The Data Field

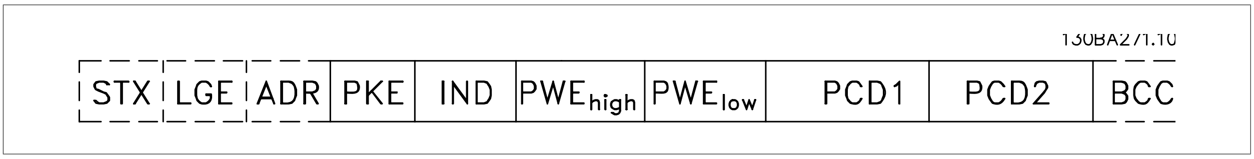
The structure of data blocks depends on the type of telegram. There are three telegram types, and the type applies for both control telegrams (master=>slave) and response telegrams (slave=>master).

The three types of telegram are:

Process block (PCD):
The PCD is made up of a data block of four bytes (2 words) and contains:
- Control word and reference value (from master to slave)
- Status word and present output frequency (from slave to master).

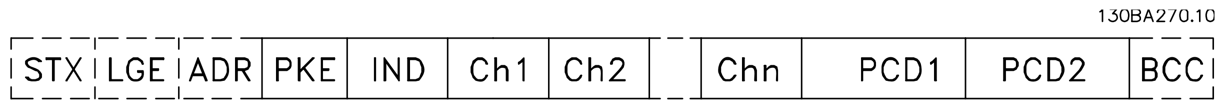


Parameter block:
The parameter block is used to transfer parameters between master and slave. The data block is made up of 12 bytes (6 words) and also contains the process block.



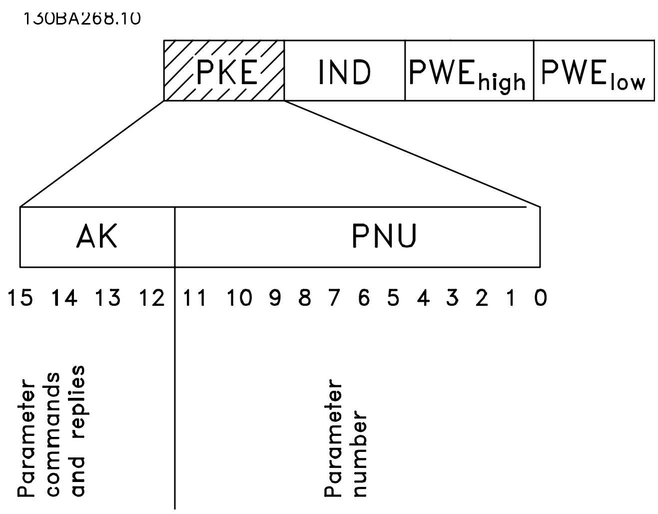
Text block:

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



7.4.7. The PKE Field

The PKE field contains two sub-fields: 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/write 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 (PWE):

PWE low (Hex)	Fault Report
0	The parameter number used does not exit
1	There is no write access to the defined parameter
2	Data value exceeds the parameter's limits
3	The sub index used does not exit
4	The parameter is not the array type
5	The data type does not match the defined parameter
11	Data change in the defined parameter is not possible in the frequency converter's present mode. Certain parameters can only be changed when the motor is turned off
82	There is no bus access to the defined parameter
83	Data change is not possible because factory setup is selected

7.4.8. Parameter Number (PNU)

Bits no. 0-10 transfer parameter numbers. The function of the relevant parameter is defined in the parameter description in the chapter How to Programme.

7

7.4.9. Index (IND)

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

NB!
Only the low byte is used as an index.

7.4.10. Parameter Value (PWE)

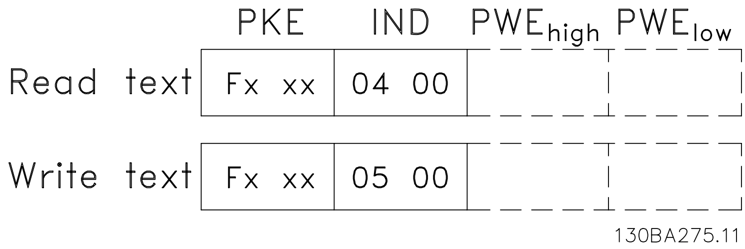
The parameter value block consists of 2 words (4 bytes), and the value depends on the defined command (AK). The master prompts for a parameter value when the PWE block contains no value. To change a parameter value (write), write the new value in the PWE block and send from the master to the slave.

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 not a numerical value but several data options, e.g. par.   where [0] corresponds to English, and [4] corresponds to Danish, select the data value by entering the value in the PWE block. See Example - Selecting a data value. Serial communication is only capable of reading parameters containing data type 9 (text string).

par. 15-40 FC *Type* to par. 15-53 Power *Card Serial Number* contain data type 9.
For example, read the unit size and mains voltage range in par. 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”.

Some parameters contain text that can be written to via the serial bus. To write a text via the PWE block, set the parameter command (AK) to 'F' Hex. The index characters high-byte must be “5”.



7.4.11. Data Types Supported by VLT AQUA

Data types	Description
3	Integer 16
4	Integer 32
5	Unsigned 8
6	Unsigned 16
7	Unsigned 32
9	Text string
10	Byte string
13	Time difference
33	Reserved
35	Bit sequence

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

7.4.12. 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.

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

Conversion table

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

7.4.13. 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 outp. frequency

7.5. Examples

7.5.1. Writing a parameter value

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

PKE = E19E Hex - Write single word in par. 4-14 Motor *Speed High Limit [Hz]*
IND = 0000 Hex
PWEHIGH = 0000 Hex
PWELOW = 03E8 Hex - Data value 1000, corresponding to 100 Hz, see Conversion.

The telegram will look like this:

130BA092.10

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

Note: par. 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 will be:

130BA093.10

119E H	0000 H	0000 H	03E8 H
PKE	IND	PWE_{high}	PWE_{low}

7.5.2. Reading a parameter value

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

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

130BA094.10

1155 H	0000 H	0000 H	0000 H
PKE	IND	PWE_{high}	PWE_{low}

If the value in par. 3-41 Ramp *1 Ramp Up Time* is 10 s, the response from the slave to the master will be:

130BA267.10

1155 H	0000 H	0000 H	03E8 H
PKE	IND	PWE_{high}	PWE_{low}

NB!
3E8 Hex corresponds to 1000 decimal. The conversion index for par. 3-41 Ramp *1 Ramp Up Time* is -2, i.e. 0.01.

7.6. Modbus RTU Overview

7.6.1. Assumptions

These operating instructions assume that the installed controller supports the interfaces in this document and that all the requirements stipulated in the controller, as well as the frequency converter, are strictly observed, along with all limitations therein.

7.6.2. 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.

7.6.3. 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 includes i.a. how it will respond to requests from another device, and how errors will be 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 will learn its device address, recognise a message addressed to it, determine the kind of action to be taken, and extract any data or other information contained in the message. If a reply is required, the controller will construct the reply message and send 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 will occur.

7.7. Network Configuration

7.7.1. VLT AQUA with Modbus RTU

To enable Modbus RTU on the VLT AQUA, set the following parameters:

Parameter Number	Parameter name	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)

7.8. Modbus RTU Message Framing Structure

7.8.1. Frequency Converter with Modbus RTU

The controllers are set up to communicate on the Modbus network using RTU (Remote Terminal Unit) mode, with each 8-bit byte in a message containing two 4-bit hexadecimal characters. The format for each byte is shown below.

<table>
<tr><td>Start bit</td><td colspan="8">Data bit</td><td>Stop/
parity</td><td>Stop</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Coding System	8-bit binary, hexadecimal 0-9, A-F. Two 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)

7.8.2. 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 below.

Typical Modbus RTU Message Structure

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

7.8.3. 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.

7.8.4. 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.

7.8.5. 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 *Function Codes Supported by Modbus RTU* and *Exception Codes.*

7.8.6. 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.

7.8.7. 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.

7.8.8. Coil Register Addressing

7

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 below)	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 below)	Slave to master
49-64	Open loop mode: Frequency converter output frequency Closed loop mode: Frequency converter feedback signal	Slave to master
65	Parameter write control (master to slave) 0 = Parameter changes are written to the RAM of the frequency converter 1 = Parameter changes are written to the RAM and EEPROM of the frequency converter.	Master to slave
66-65536	Reserved	

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	Set up MSB	
16	No reversing	Reversing
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
Frequency converter status word (FC profile)		

Holding registers

Register Number	Description
00001-00006	Reserved
00007	Last error code from an FC data object interface
00008	Reserved
00009	Parameter index*
00100-00999	000 parameter group (parameters 001 through 099)
01000-01999	100 parameter group (parameters 100 through 199)
02000-02999	200 parameter group (parameters 200 through 299)
03000-03999	300 parameter group (parameters 300 through 399)
04000-04999	400 parameter group (parameters 400 through 499)
...	...
49000-49999	4900 parameter group (parameters 4900 through 4999)
500000	Input data: Frequency converter control word register (CTW).
50010	Input data: Bus reference register (REF).
...	...
50200	Output data: Frequency converter status word register (STW).
50210	Output data: Frequency converter main actual value register (MAV).

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

7.8.9. How to Control VLT AQUA

This section describes codes which can be used in the function and data fields of a Modbus RTU message. For a complete description of all the message fields please refer to the section *Modbus RTU Message Framing Structure.*

7.8.10. 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

7

7.8.11. Database Error Codes

In the event of an error, the following error codes may appear in the data field of a response message. For a full explanation of the structure of an exception (i.e. error) response, please refer to the section *Modbus RTU Message Framing Structure, Function Field.*

Error Code in data field (decimal)	Database Error Code description
00	The parameter number does not exit
01	There is no write access to the parameter
02	The data value exceeds the parameter limits
03	The sub-index in use does not exit
04	The parameter is not of the array type
05	The data type does not match the parameter called
06	Only reset
07	Not changeable
11	No write access
17	Data change in the parameter called is not possible in the present mode
18	Other error
64	Invalid data address
65	Invalid message length
66	Invalid data length or value
67	Invalid function code
130	There is no bus access to the parameter called
131	Data change is not possible because factory set-up is selected

7.9. How to Access Parameters

7.9.1. 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.

7.9.2. 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).

7.9.3. IND

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

7.9.4. 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.

7.9.5. 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 *Parameters section*.

7.9.6. 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).

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).

7.10. Examples

The following examples illustrate various Modbus RTU commands. If an error occurs, please refer to the Exception Codes section.

7.10.1. 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)
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)	-

7.10.2. Force/Write Single Coil (05 HEX)

Description

This function forces a writes a 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 (coil no. 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)	-

7.10.3. 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. 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)	-

7

Response

The normal response returns the slave address, function code, starting address, and quantity of coiles 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)	-

7.10.4. 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.

Field Name	Example (HEX)
Slave Address	01
Function	03 (read holding registers)
Starting Address HI	00
Starting Address LO	00 (coil address 17)
No. of Points HI	00
No. of Points LO	03
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.

Field Name	Example (HEX)
Slave Address	01
Function	03
Byte Count	06
Data HI (Register 40001)	55
Data LO (Register 40001)	AA
Data HI (Register 40002)	55
Data LO (Register 40002)	AA
Data HI (Register 40003)	55
Data LO (Register 40003)	AA
Error Check (CRC)	-

7.10.5. 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.

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

Response

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	00
Register Address LO	01
Preset Data HI	00
Preset Data LO	03
Error Check (CRC)	-

7.10.6. 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 parameter 1-05 = 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)	-

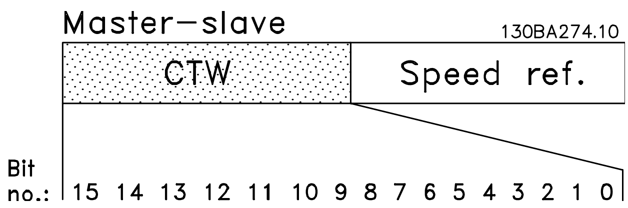
Response

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)	-

7.11. Danfoss FC Control Profile

7.11.1. Control Word According to FC Profile(par. 8-10 Control *Profile* = 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	No function	Relay 01 active
12	No function	Relay 02 active
13	Parameter set-up	selection lsb
14	Parameter set-up	selection msb
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 par. 3-10 Preset *Reference* according to the following table:

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

NB!

Make a selection in par. 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 par. 2-01 DC *Brake Current* and par. 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.

NB!

Make a selection in par. 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 par. 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 (par. 5-10 Terminal *18 Digital Input* to par. 5-15 Terminal *33 Digital Input*) programmed to *Speed up* and *Slow down*.

NB!

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 (par. 5-10 Terminal *18 Digital Input* to par. 5-15 Terminal *33 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.

NB!

Make a selection in par. 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 par. 3-19 Jog *Speed [RPM]*.

Bit 09, Selection of ramp 1/2:

Bit 09 = "0": Ramp 1 is active (par. 3-41 Ramp *1 Ramp Up Time* to par. 3-42 Ramp *1 Ramp Down Time*). Bit 09 = "1": Ramp 2 (par. 3-51 Ramp *2 Ramp Up Time* to par. 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 par. 5-40 Function *Relay*.

Bit 12, Relay 04:

Bit 12 = "0": Relay 04 is not activated. Bit 12 = "1": Relay 04 is activated provided that *Control word bit 12* is chosen in par. 5-40 Function *Relay*.

Bit 13/14, Selection of set-up:

Use bits 13 and 14 to choose from the four menu set-ups according to the shown table: .

Set-up	Bit 14	Bit 13
1	0	0
2	0	1
3	1	0
4	1	1

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

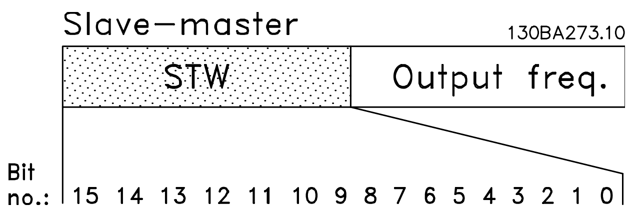
NB!

Make a selection in par. 8-55 Set-up *Select* to define how Bit 13/14 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 par. 8-54 Reversing *Select*. Bit 15 causes reversing only when Ser. communication, Logic or or Logic and is selected.

7.11.2. Status Word According to FC Profile (STW) (par. 8-10 Control *Profile* = 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 24 V 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 par. 3-13 Reference *Site* 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 par. 4-11 Motor *Speed Low Limit [RPM]* or par. 4-13 Motor *Speed High Limit [RPM]*. 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 0 Hz.

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.

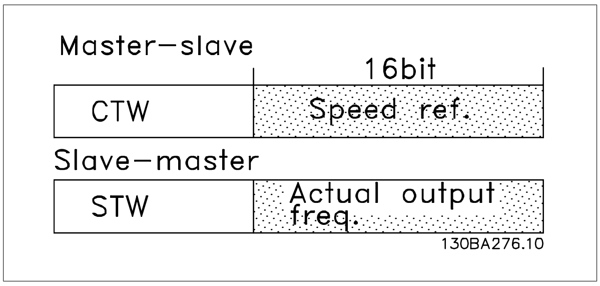
Bit 14, Torque OK/limit exceeded:
Bit 14 = ’0’: The motor current is lower than the torque limit selected in par. 4-18 Current *Limit*. Bit 14 = ’1’: The torque limit in par. 4-18 Current *Limit* is exceeded.

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%.

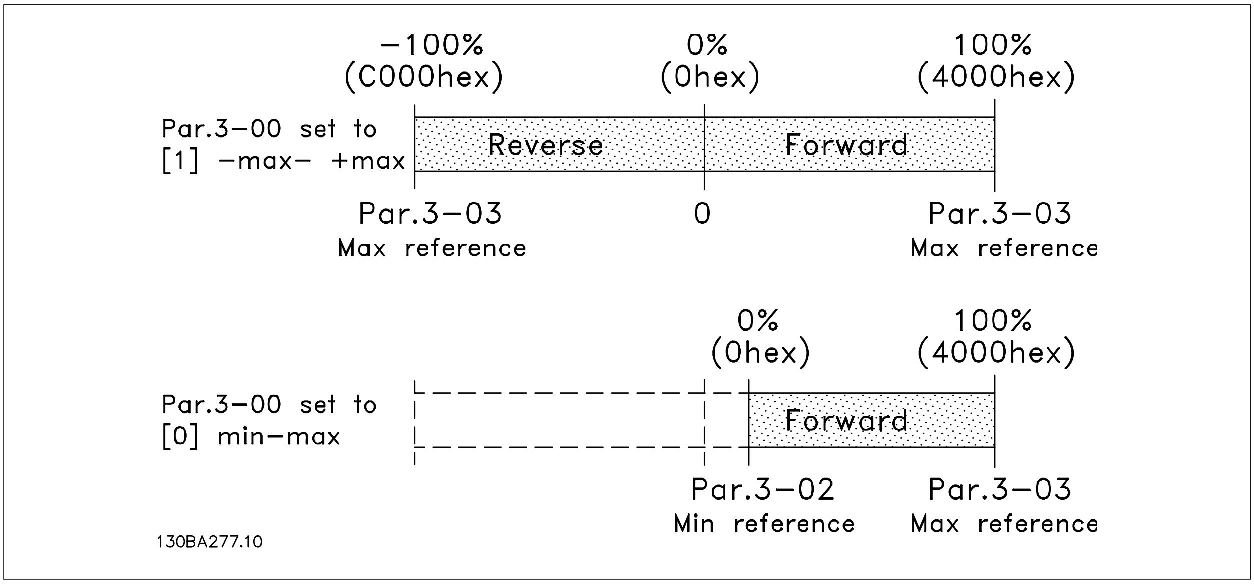
NB!
All bits in the STW are set to ’0’ if the connection between the Interbus option and the frequency converter is lost, or an internal communication problem has occurred.

7.11.3. 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. Troubleshooting

A warning or an alarm is signalled by the relevant LED on the front of the frequency converter and indicated by a code on the display.

A warning remains active until its cause is no longer present. Under certain circumstances operation of the motor may still be continued. Warning messages may be critical, but are not necessarily so.

In the event of an alarm, the frequency converter will have tripped. Alarms must be reset to restart operation once their cause has been rectified.

This may be done in four ways:

1. By using the [RESET] control button on the LCP control panel.
2. Via a digital input with the "Reset" function.
3. Via serial communication/optional fieldbus.
4. By resetting automatically using the [Auto Reset] function, which is a default setting for VLT AQUA Drive. see par. 14-20 *Reset Mode* in **VLT AQUA Programming Guide**

NB!
After a manual reset using the [RESET] button on the LCP, the [AUTO ON] button must be pressed to restart the motor.

8

If an alarm cannot be reset, the reason may be that its cause has not been rectified, or the alarm is trip-locked (see also table on following page).

Alarms that are trip-locked offer additional protection, means that the mains supply must be switched off before the alarm can be reset. After being switched back on, the frequency converter is no longer blocked and may be reset as described above once the cause has been rectified.

Alarms that are not trip-locked can also be reset using the automatic reset function in parameter 14-20 (Warning: automatic wake-up is possible!)

If a warning and alarm is marked against a code in the table on the following page, this means that either a warning occurs before an alarm, or it can be specified whether it is a warning or an alarm that is to be displayed for a given fault.

This is possible, for instance, in parameter 1-90 *Motor Thermal Protection.* After an alarm or trip, the motor carries on coasting, and the alarm and warning flash on the frequency converter. Once the problem has been rectified, only the alarm continues flashing.

No.	Description	Warning	Alarm/Trip	Alarm/Trip Lock	Parameter Reference
1	10 Volts low	X			
2	Live zero error	(X)	(X)		6-01
3	No motor	(X)			1-80
4	Mains phase loss	(X)	(X)	(X)	14-12
5	DC link voltage high	X			
6	DC link voltage low	X			
7	DC over voltage	X	X		
8	DC under voltage	X	X		
9	Inverter overloaded	X	X		
10	Motor ETR over temperature	(X)	(X)		1-90
11	Motor thermistor over temperature	(X)	(X)		1-90
12	Torque limit	X	X		
13	Over Current	X	X	X	
14	Earth fault	X	X	X	
15	Hardware mesh mash		X	X	
16	Short Circuit		X	X	
17	Control word timeout	(X)	(X)		8-04
25	Brake resistor short-circuited	X			
26	Brake resistor power limit	(X)	(X)		2-13
27	Brake chopper short-circuited	X	X		
28	Brake check	(X)	(X)		2-15
29	Power board over temp	X	X	X	
30	Motor phase U missing	(X)	(X)	(X)	4-58
31	Motor phase V missing	(X)	(X)	(X)	4-58
32	Motor phase W missing	(X)	(X)	(X)	4-58
33	Inrush fault		X	X	
34	Fieldbus communication fault	X	X		
38	Internal fault		X	X	
47	24 V supply low	X	X	X	
48	1.8 V supply low		X	X	
50	AMA calibration failed		X		
51	AMA check U_{nom} and I_{nom}		X		
52	AMA low I_{nom}		X		
53	AMA motor too big		X		
54	AMA motor too small		X		
55	AMA parameter out of range		X		
56	AMA interrupted by user		X		
57	AMA timeout		X		
58	AMA internal fault	X	X		
59	Current limit	X			
61	Tracking Error	(X)	(X)		4-30
62	Output Frequency at Maximum Limit	X			
64	Voltage Limit	X			
65	Control Board Over-temperature	X	X	X	

Alarm Word and Extended Status Word

Bit	Hex	Dec	Alarm Word	Warning Word	Extended Status Word
0	00000001	1	Brake Check	Brake Check	Ramping
1	00000002	2	Pwr. Card Temp	Pwr. Card Temp	AMA Running
2	00000004	4	Earth Fault	Earth Fault	Start CW/CCW
3	00000008	8	Ctrl.Card Temp	Ctrl.Card Temp	Slow Down
4	00000010	16	Ctrl. Word TO	Ctrl. Word TO	Catch Up
5	00000020	32	Over Current	Over Current	Feedback High
6	00000040	64	Torque Limit	Torque Limit	Feedback Low
7	00000080	128	Motor Th Over	Motor Th Over	Output Current High
8	00000100	256	Motor ETR Over	Motor ETR Over	Output Current Low
9	00000200	512	Inverter Overld.	Inverter Overld.	Output Freq High
10	00000400	1024	DC under Volt	DC under Volt	Output Freq Low
11	00000800	2048	DC over Volt	DC over Volt	Brake Check OK
12	00001000	4096	Short Circuit	DC Voltage Low	Braking Max
13	00002000	8192	Inrush Fault	DC Voltage High	Braking
14	00004000	16384	Mains ph. Loss	Mains ph. Loss	Out of Speed Range
15	00008000	32768	AMA Not OK	No Motor	OVC Active
16	00010000	65536	Live Zero Error	Live Zero Error	
17	00020000	131072	Internal Fault	10V Low	
18	00040000	262144	Brake Overload	Brake Overload	
19	00080000	524288	U phase Loss	Brake Resistor	
20	00100000	1048576	V phase Loss	Brake IGBT	
21	00200000	2097152	W phase Loss	Speed Limit	
22	00400000	4194304	Fieldbus Fault	Fieldbus Fault	
23	00800000	8388608	24 V Supply Low	24V Supply Low	
24	01000000	16777216	Mains Failure	Mains Failure	
25	02000000	33554432	1.8V Supply Low	Current Limit	
26	04000000	67108864	Brake Resistor	Low Temp	
27	08000000	134217728	Brake IGBT	Voltage Limit	
28	10000000	268435456	Option Change	Unused	
29	20000000	536870912	Drive Initialised	Unused	
30	40000000	1073741824	Safe Stop	Unused	

Table 8.2: Description of Alarm Word, Warning Word and Extended Status Word

8

The alarm words, warning words and extended status words can be read out via serial bus or optional fieldbus for diagnosis. See also par. 16-90, 16-92 and 16-94.

Index

N

O

P

R

V

W

Z