# Contents


## 1. How to Read this Design Guide 3

Copyright, Limitation of Liability and Revision Rights 3
Approvals 4
Symbols 4
Abbreviations 4
Definitions 5

## 2. Introduction to VLT AQUA Drive 11

CE labelling 12
Air humidity 15
Aggressive Environments 15
Vibration and shock 15
VLT AQUA Controls 20
PID 22
General aspects of EMC 31
Immunity Requirements 34
Galvanic isolation (PELV) 35
PELV - Protective Extra Low Voltage 35
Earth leakage current 36
Control with brake function 37
Mechanical brake control 38
Extreme running conditions 38
Safe Stop Operation (optional) 41

## 3. VLT AQUA Selection 43

General Specifications 43
Efficiency 57
Special Conditions 63
Options and Accessories 68
General Description 77

## 4. How to Order 83

Ordering form 83
Type Code String 84
Ordering Numbers 85

## 5. How to Install 93

Mechanical Installation 93
Electrical Installation 99
Final Set-Up and Test 116
Final Set-Up and Test 116

Safe Stop Installation 117
Safe Stop Commissioning Test 118
Additional Connections 118
DC bus connection 118
Brake Connection Option 119
Relay Connection 120
Installation of misc. connections 124
Safety 126
EMC-correct Installation 127
Residual Current Device 131

**6. Application Examples** 133
Potentiometer Reference 134
Automatic Motor Adaptation (AMA) 134
SLC Application Example 135
System Status and Operation 138
Cascade Controller Wiring Diagram 138
Fixed Variable Speed Pump Wiring Diagram 139
Lead Pump Alternation Wiring Diagram 140
Submersible Pump Application 142
Master/Follower Operation Application 143

**7. RS-485 Installation and Set-up** 147
RS-485 Installation and Set-up 147
FC Protocol Overview 149
Network Configuration 150
FC Protocol Message Framing Structure 150
Examples 155
Modbus RTU Overview 156
VLT AQUA with Modbus RTU 156
Modbus RTU Message Framing Structure 156
How to Access Parameters 161
Examples 162
Danfoss FC Control Profile 168

**8. Troubleshooting** 173

**Index** 177

# 1. How to Read this Design Guide



### 1.1.1. Copyright, Limitation of Liability and Revision Rights

This publication contains information proprietary to . By accepting and using this manual the user agrees that the information contained herein will be used solely for operating equipment from or equipment from other vendors provided that such equipment is intended for communication with equipment over a serial communication link. This publication is protected under the Copyright laws of Denmark and most other countries.

does not warrant that a software program produced according to the guidelines provided in this manual will function properly in every physical, hardware or software environment.

Although has tested and reviewed the documentation within this manual, makes no warranty or representation, neither expressed nor implied, with respect to this documentation, including its quality, performance, or fitness for a particular purpose.

In no event shall be liable for direct, indirect, special, incidental, or consequential damages arising out of the use, or the inability to use information contained in this manual, even if advised of the possibility of such damages. In particular, is not responsible for any costs, including but not limited to those incurred as a result of lost profits or revenue, loss or damage of equipment, loss of computer programs, loss of data, the costs to substitute these, or any claims by third parties.

reserves the right to revise this publication at any time and to make changes to its contents without prior notice or any obligation to notify former or present users of such revisions or changes.

1

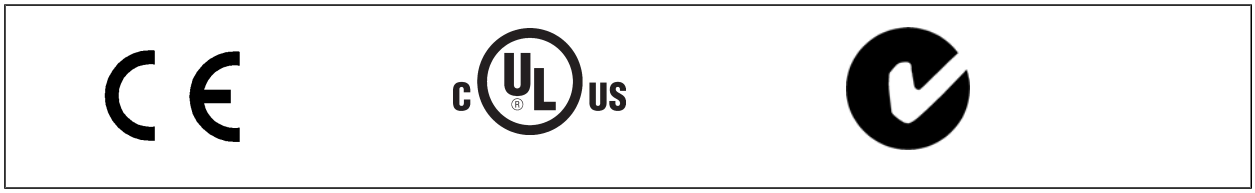
### 1.1.2. Available Literature for VLT AQUA Drive

- 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<br>You can start and stop the connected motor by means of LCP and the digital inputs.<br>Functions are divided into two groups.<br>Functions in group 1 have higher priority than functions in group 2. | Group 1 Reset, Coasting stop, Reset and Coasting stop, Quick-stop, DC braking, Stop and the "Off" key.<br>Group 2 Start, Pulse start, Reversing, Start reversing, Jog and Freeze output |

**Motor:**

$f_{JOG}$

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

$f_M$

The motor frequency.

$f_{MAX}$

The maximum motor frequency.

$f_{MIN}$

The minimum motor frequency.

$f_{M,N}$

1

The rated motor frequency (nameplate data).

$I_M$
The motor current.

$I_{M,N}$
The rated motor current (nameplate data).

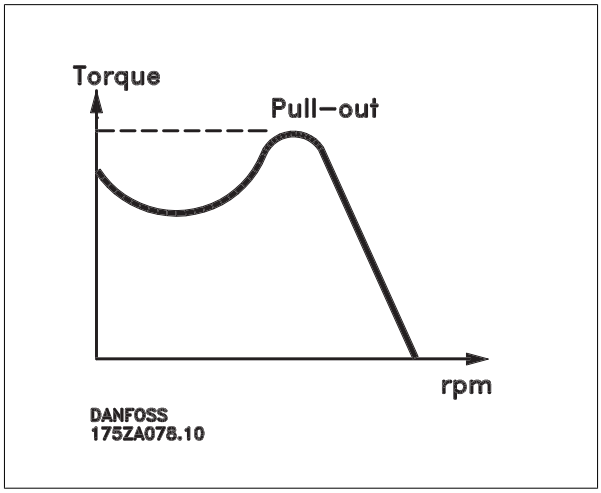
$n_{M,N}$
The rated motor speed (nameplate data).

$P_{M,N}$
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).




$\eta_{VLT}$
The efficiency of the frequency converter is defined as the ratio between the power output and the power input.

Start-disable command
A stop command belonging to the group 1 control commands - see 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 Stator Flux oriented Asynchronous Vector Modulation (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°A synchronous V ector M odulation (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 |

# 2.7. Advantages

## 2.7.1. Why use a frequency converter for controlling fans and pumps?

2

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.

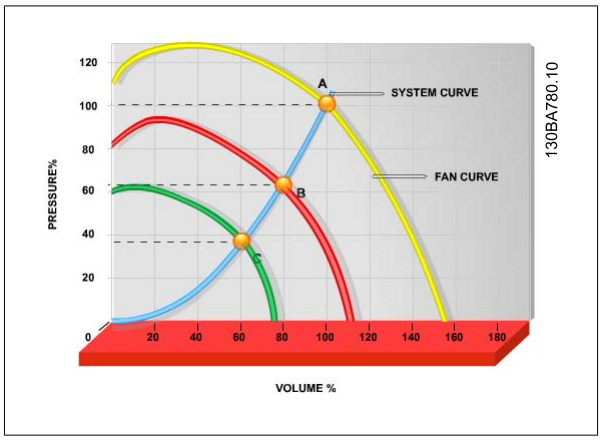



Illustration 2.1: The graph is showing fan curves (A, B and C) for reduced fan volumes.

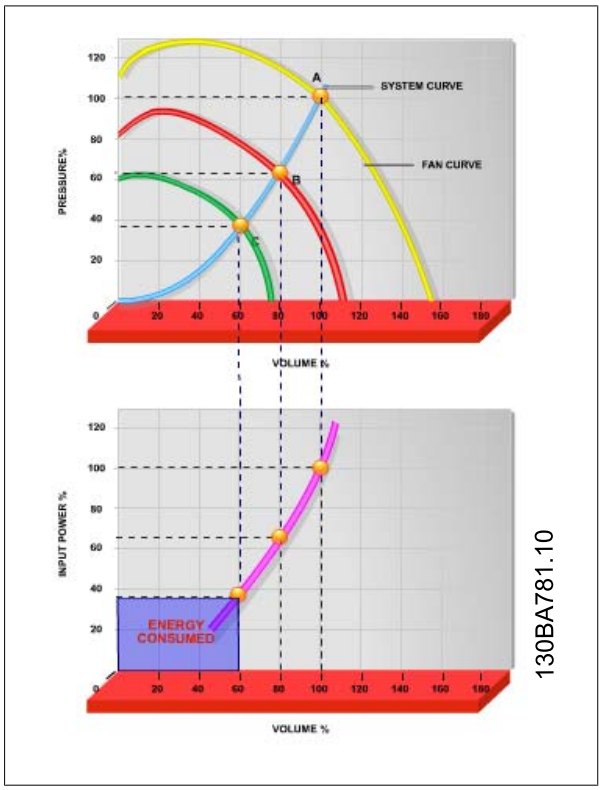



Illustration 2.2: When using a frequency converter to reduce fan capacity to 60% - more than 50% energy savings may be obtained in typical applications.

## 2.7.3. Example of energy savings

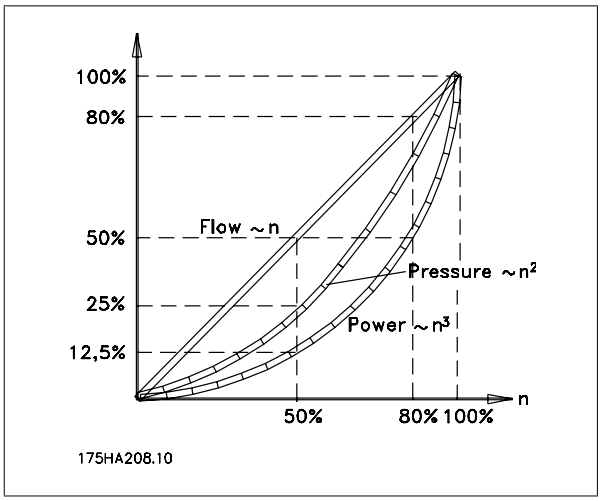
As can be seen from the figure (the laws of proportionality), the flow is controlled by changing the rpm. By reducing the speed only 20% from the rated speed, the flow is also reduced by 20%. This is because the flow is directly proportional to the rpm. The consumption of electricity, however, is reduced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




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

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

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

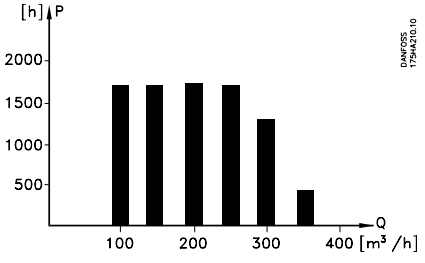
## 2.7.4. Example with varying flow over 1 year

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.

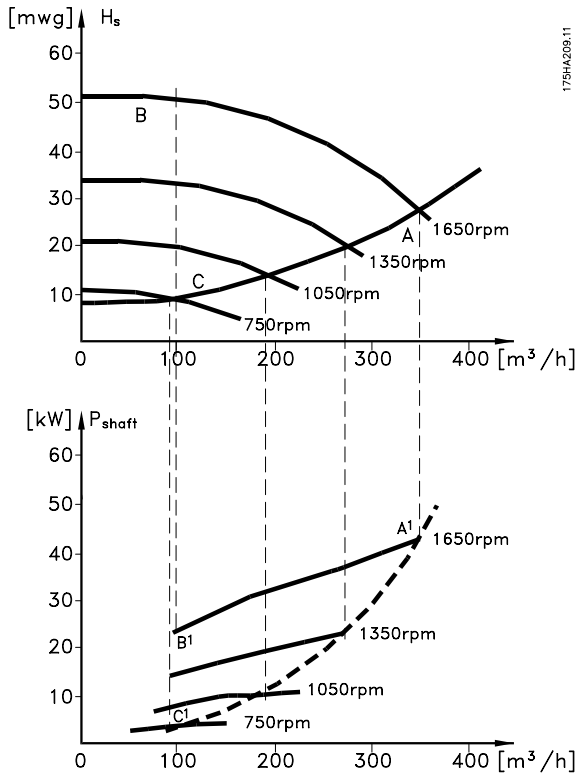
Energy savings

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

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.

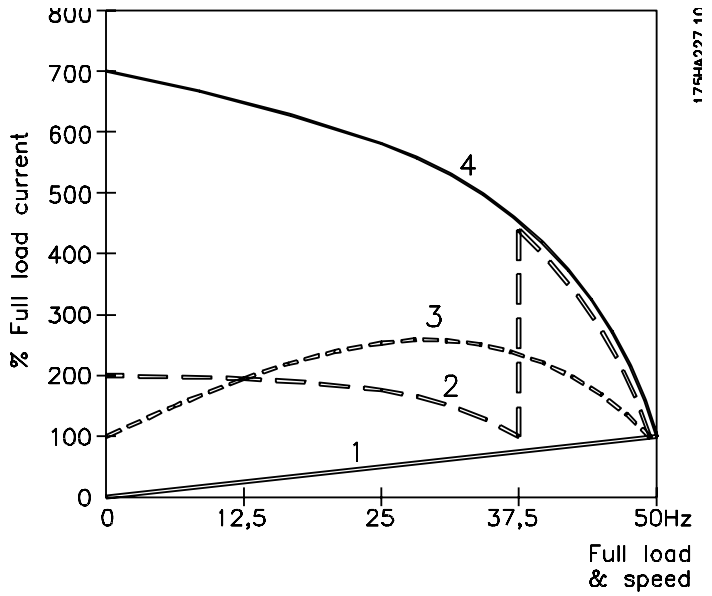
## 2.7.6. Cos φ compensation

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

# 2.8. VLT AQUA Controls

## 2.8.1. Control Principle

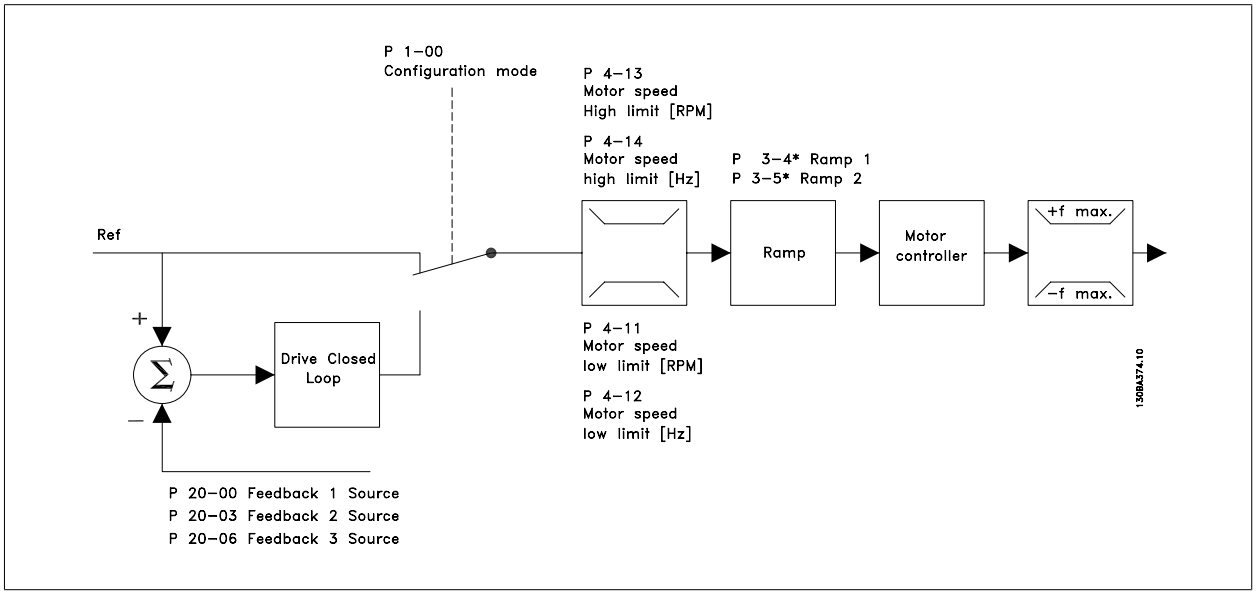
2

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:



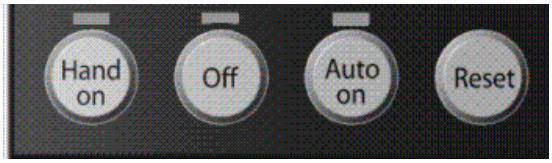

In the configuration shown in the illustration above, par. 1-00 is set to *Open loop* [0]. The resulting reference from the reference handling system is received and fed through the ramp limitation and speed limitation before being sent to the motor control. The output of the motor control is then limited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

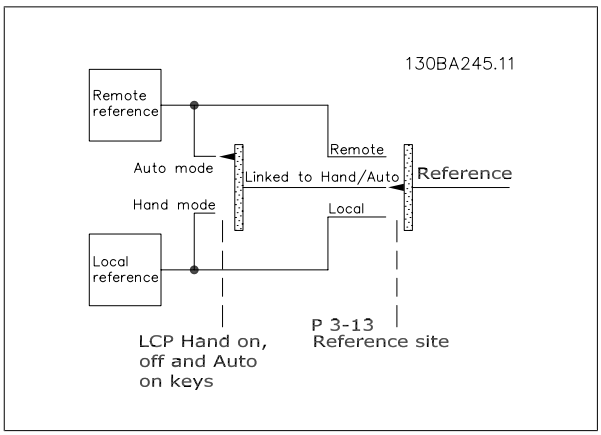
Select *Closed loop* [3] in par. 1-00 to use the PID controller for closed loop control of e.g. flow, level or pressure in the controlled application. The PID parameters are located in par. group 20-**.

## 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).

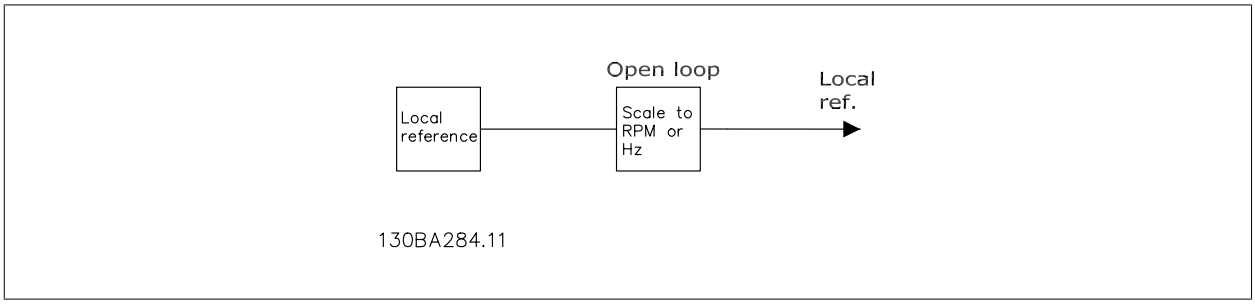
| **Hand Off Auto Keys** | **Reference Site par. 3-13 Reference *Site*** | **Active Reference** |
|---|---|---|
| Hand | Linked to Hand / Auto | Local |
| Hand -> Off | Linked to Hand / Auto | Local |
| Auto | Linked to Hand / Auto | Remote |
| Auto -> Off | Linked to Hand / Auto | Remote |
| All keys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



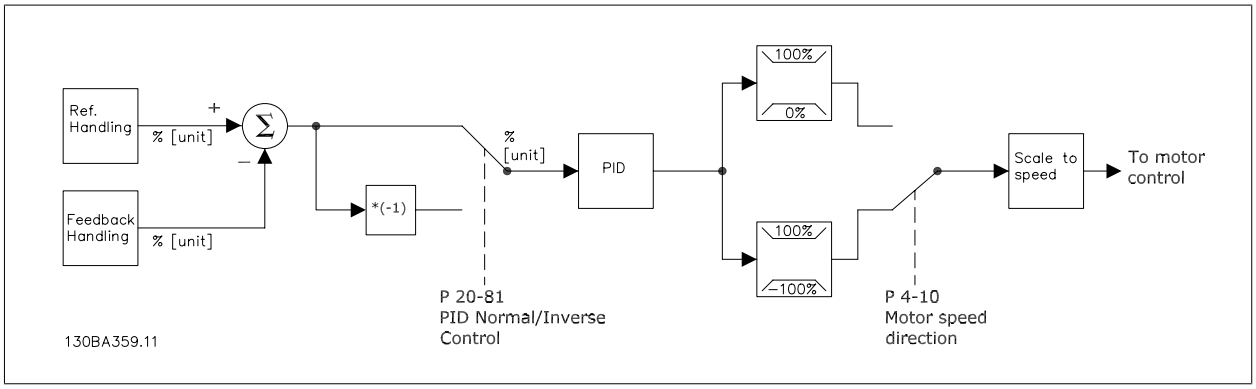
# 2.9. PID

## 2.9.1. Closed Loop (PID) Controller

2

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

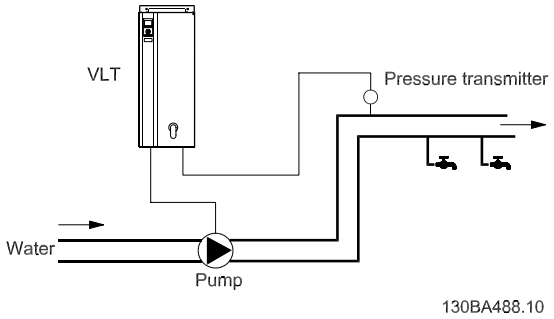
The drive's Closed Loop Controller is capable of handling more complex applications, such as situations where a conversion function is applied to the feedback signal or situations where multiple feedback signals and/or setpoint references are used. The below table summarizes the additional parameters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

2

| Parameter | Par. No. | Description of function |
|---|---|---|
| Feedback 2 Source<br>Feedback 3 Source | 20-03<br>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<br>Feedback 2 Conversion<br>Feedback 3 Conversion | 20-01<br>20-04<br>20-07 | These are used to convert the feedback signal from one type to another, for example from pressure to flow.<br>$Flow = \sqrt{Pressure}$ |
| 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<br>Setpoint 2<br>Setpoint 3<br>Setpoint Adjustment Factor | 20-21<br>20-22<br>20-23<br>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.<br>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]<br>PID Start Speed [Hz] | 20-82<br>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<br>Square-linear Curve Approximation<br>Work Point Calculation<br>Speed at No-Flow [RPM]<br>Speed at No-Flow [Hz]<br>Speed at Design Point [RPM]<br>Speed at Design Point [Hz]<br>Pressure at No-Flow Speed<br>Pressure at Rated Speed<br>Flow at Design Point<br>Flow at Rated Speed | 22-80<br>22-81<br>22-82<br>22-83<br>22-84<br>22-85<br>22-86<br>22-87<br>22-88<br>22-89<br>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 :<br>Analog Input 53<br>Analog Input 54<br>Digital (pulse) input 29<br>Digital (pulse) input 33 | 6-16<br>6-26<br>5-54<br>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:<br>$F_{cut-off} = \frac{1}{2\pi T_{lowpass}}$<br>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. |

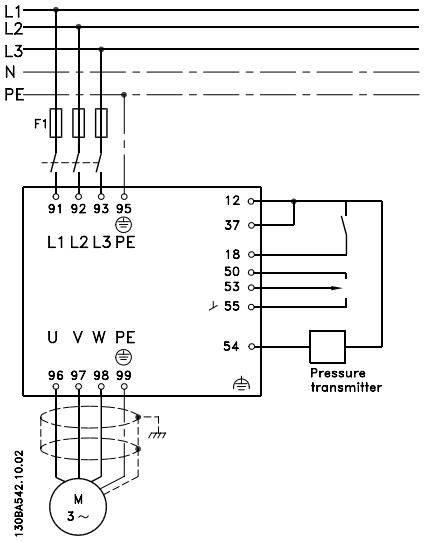
### 2.9.3. Example of Closed Loop PID Control

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

### 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<br>3-42 | 60 sec.<br>60 sec.<br>Depends on motor/load size!<br>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<br>4-14<br>4-19 | 10 Hz, *Motor min speed*<br>50 Hz, *Motor max speed*<br>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<br>3-03 | 0 Bar<br>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<br>6-11<br>6-14<br>6-15 | 0 V<br>10 V (default)<br>0 Bar<br>10 Bar |
| Scale Analog Input 54 for pressure sensor (0 - 10 Bar, 4 - 20 mA) | 6-22<br>6-23<br>6-24<br>6-25 | 4 mA<br>20 mA (default)<br>0 Bar<br>10 Bar |
| 7) Tune the PID controller parameters. | | |
| Adjust the drive's Closed Loop Controller, if needed. | 20-93<br>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.

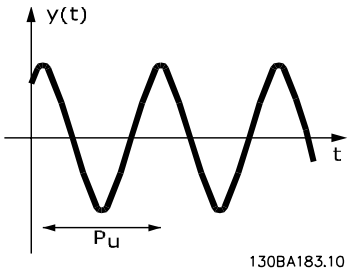



Illustration 2.3: **Figure 1: Marginally stable system**

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 * $P_u$ |

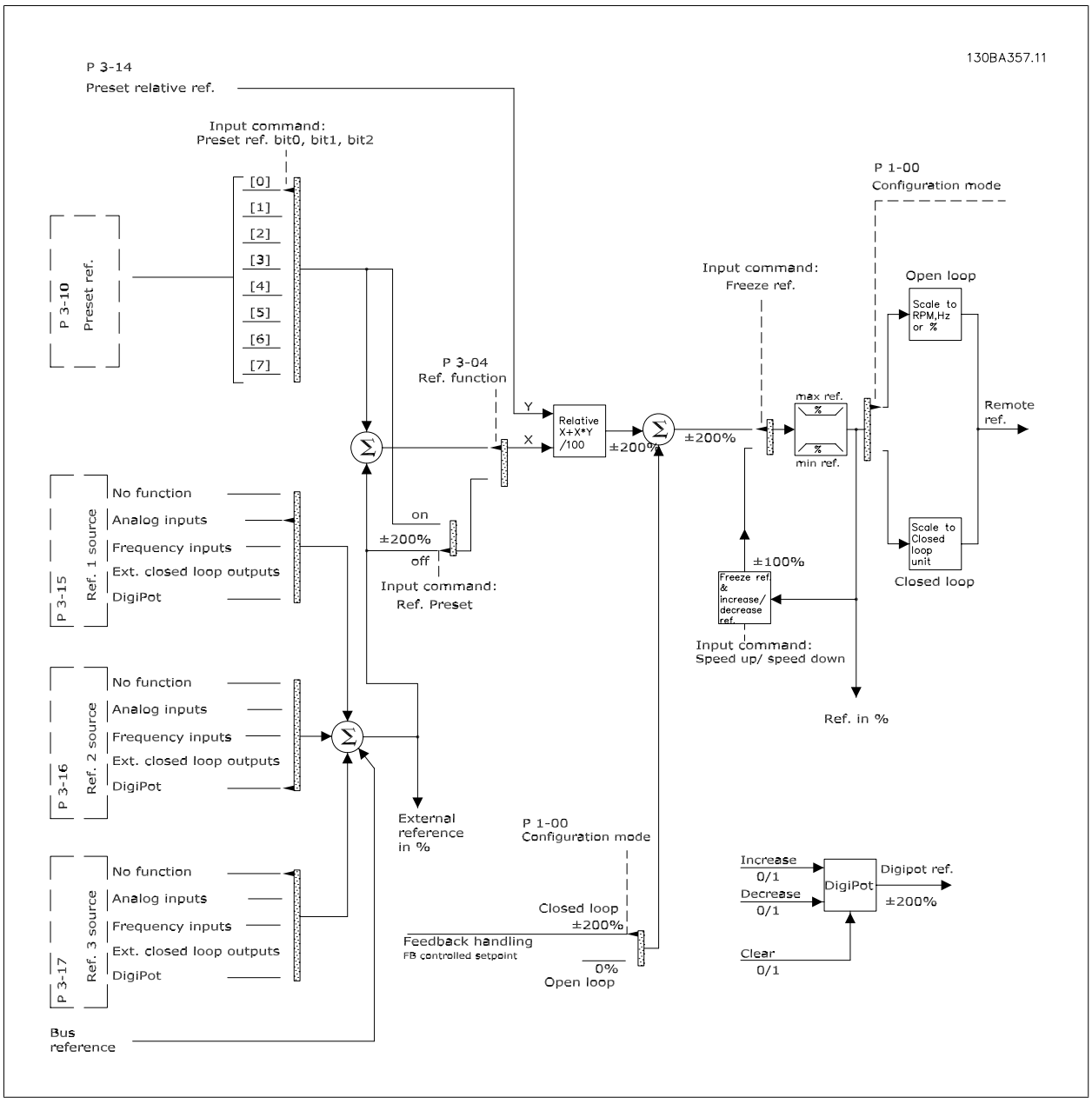
2

*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:

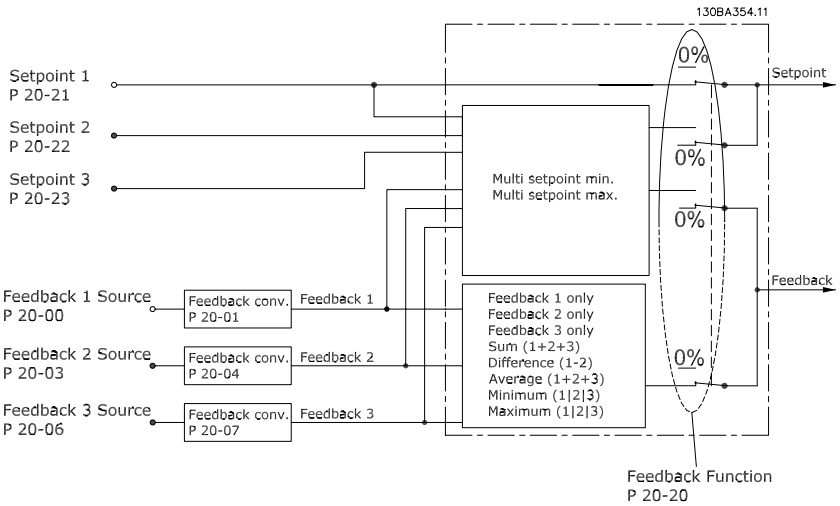
$$Reference = X + X \times \left(\frac{Y}{100}\right)$$

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.

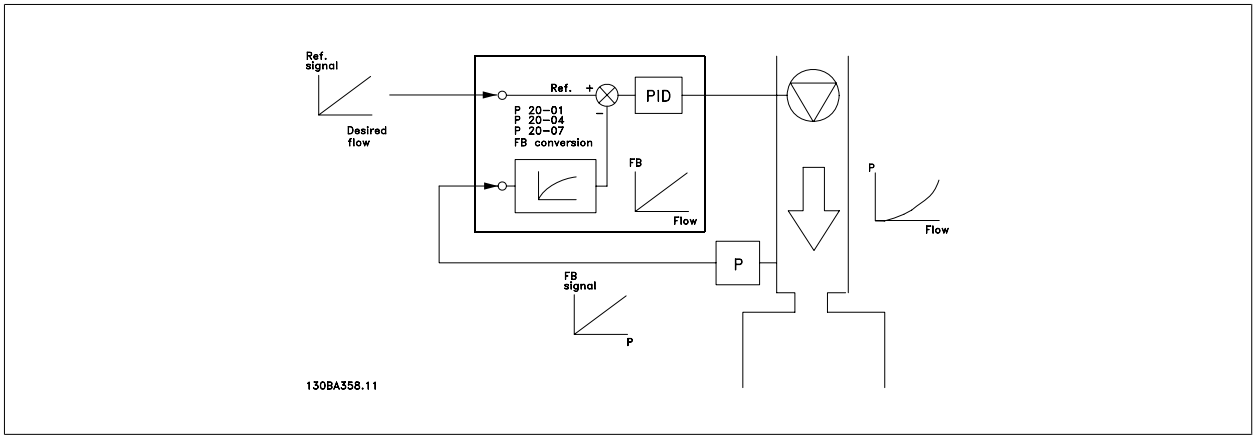
If *Multi Setpoint Min* [13] is selected, the setpoint/feedback pair with the largest difference controls the speed of the drive. *Multi Setpoint Maximum* [14] attempts to keep all zones at or below their respective setpoints, while *Multi Setpoint Min* [13] attempts to keep all zones at or above their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

2

**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.



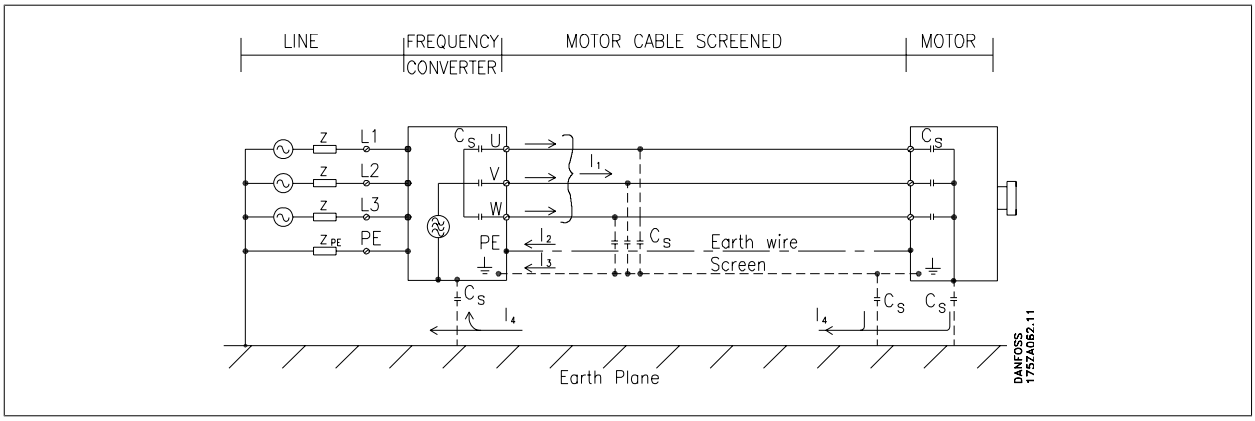
# 2.10. General aspects of EMC

## 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.<br>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 | - | - | - | - | - |

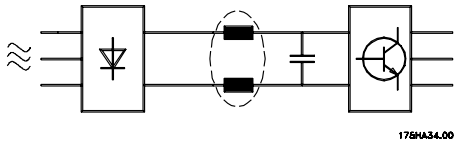
Table 2.1: EMC Test Results (Emission)

### 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:

$$THD\ \% = \sqrt{U\frac{2}{5} + U\frac{2}{7} + \ldots + U\frac{2}{N}}$$

($U_N$% 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<br>4 kV/12 Ω CM | — | — | 10 $V_{RMS}$ |
| Motor | 4 kV CM | 4 kV/2 Ω[1)] | — | — | 10 $V_{RMS}$ |
| Brake | 4 kV CM | 4 kV/2 Ω[1)] | — | — | 10 $V_{RMS}$ |
| Load sharing | 4 kV CM | 4 kV/2 Ω[1)] | — | — | 10 $V_{RMS}$ |
| Control wires | 2 kV CM | 2 kV/2 Ω[1)] | — | — | 10 $V_{RMS}$ |
| Standard bus | 2 kV CM | 2 kV/2 Ω[1)] | — | — | 10 $V_{RMS}$ |
| Relay wires | 2 kV CM | 2 kV/2 Ω[1)] | — | — | 10 $V_{RMS}$ |
| Application and Fieldbus options | 2 kV CM | 2 kV/2 Ω[1)] | — | — | 10 $V_{RMS}$ |
| cable | 2 kV CM | 2 kV/2 Ω[1)] | — | — | 10 $V_{RMS}$ |
| External 24 V DC | 2 kV CM | 0.5 kV/2 Ω DM<br>1 kV/12 Ω CM | — | — | 10 $V_{RMS}$ |
| Enclosure | — | — | 8 kV AD<br>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.

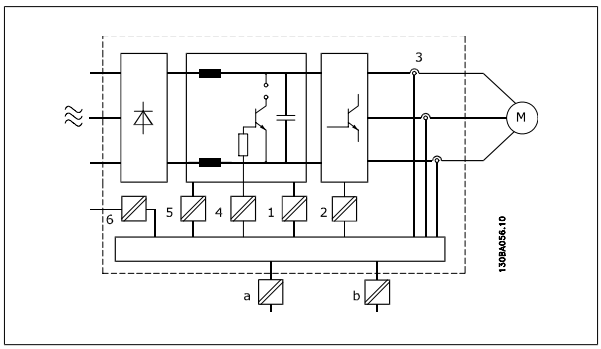



Illustration 2.4: Galvanic isolation

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



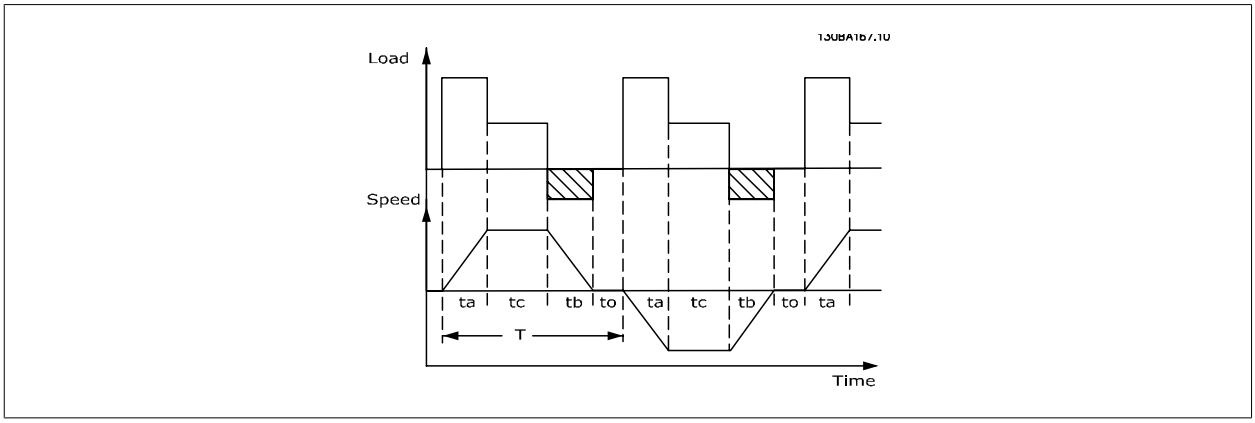
In certain applications, for instance centrifuges, it is desirable to bring the motor to a stop more rapidly than can be achieved through controlling via ramp down or by free-wheeling. In such applications, dynamic braking with a braking resistor may be utilized. Using a braking resistor ensures that 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:

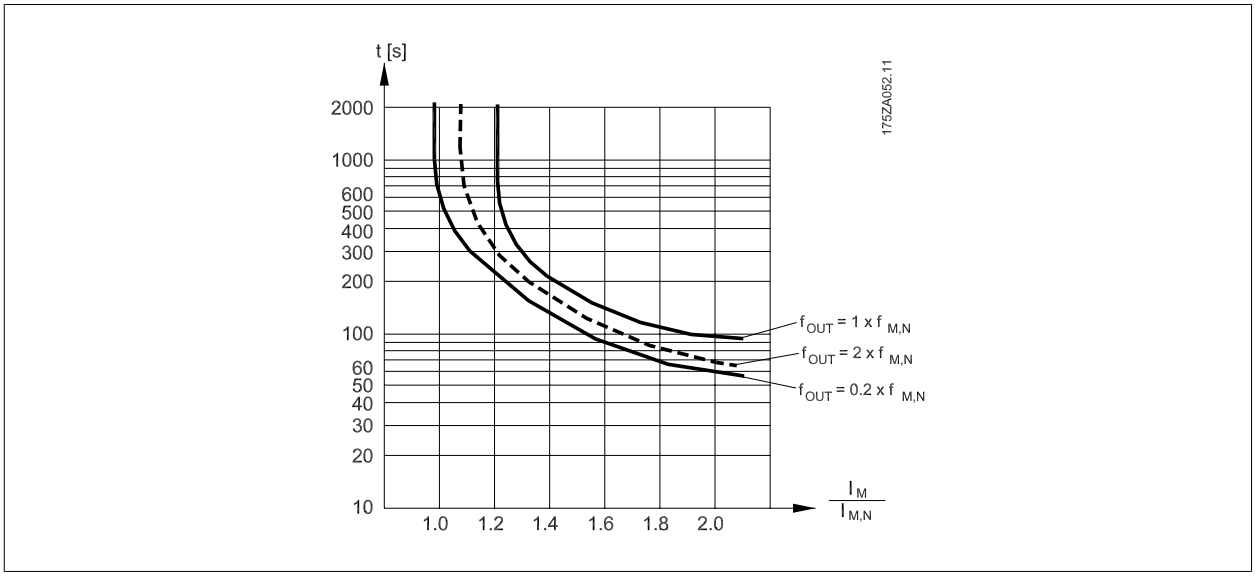


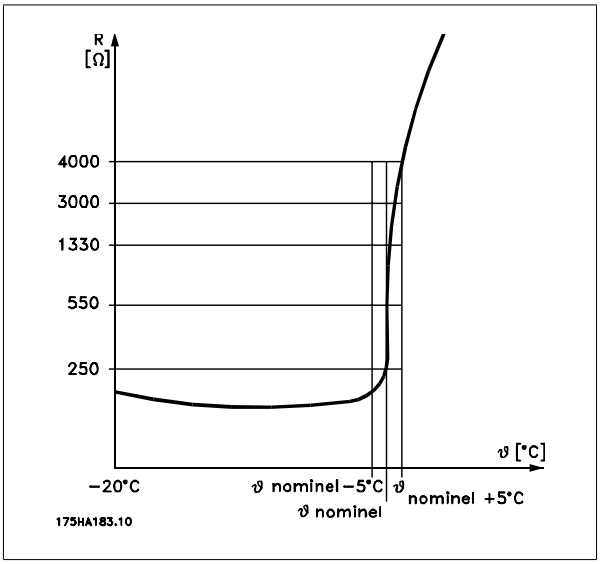

Illustration 2.5: The X-axis is showing the ratio between $I_{motor}$ and $I_{motor}$ nominal. The Y- axis is showing the time in seconds before the ETR cuts off and trips the drive. The curves are showing the characteristic nominal speed at twice the nominal speed and at 0,2x the nominal speed.

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.

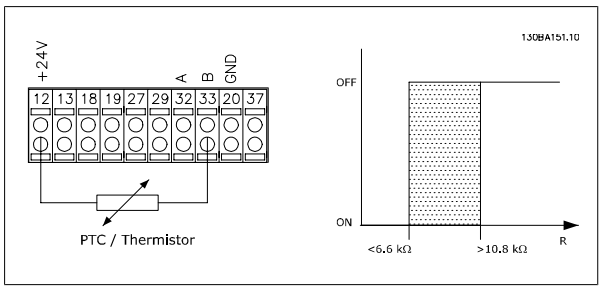
Integrate a thermistor (PTC sensor) in the motor for winding protection.

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).

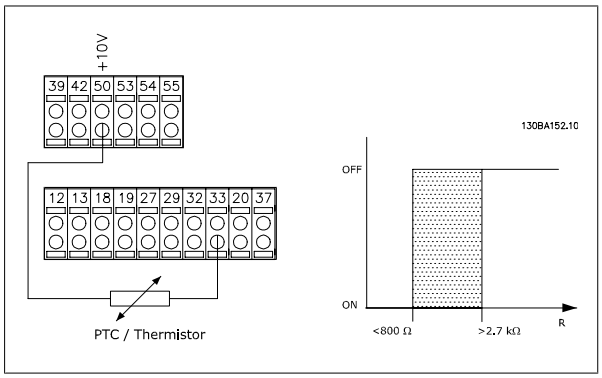


2

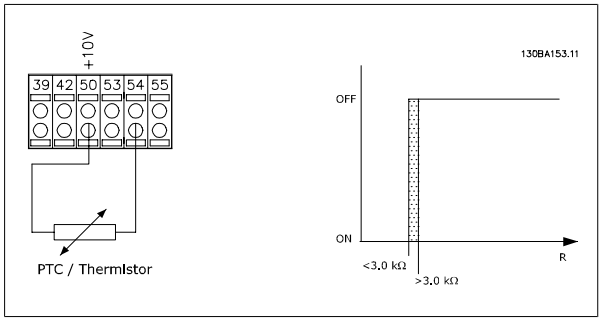
Using a digital input and 24 V as power supply:
Example: The frequency converter trips when the motor temperature is too high.
Parameter set-up:
Set par. 1-90 Motor *Thermal Protection* to *Thermistor Trip* [2]
Set par. 1-93 Thermistor *Source* to *Digital Input 33* [6]




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**<br>Digital/analog | **Supply Voltage**<br>Volt | **Threshold**<br>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*.

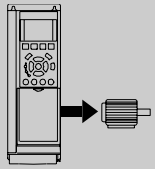
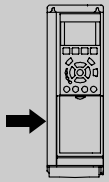
3

# 3. VLT AQUA Selection

## 3.1. General Specifications

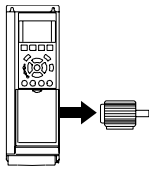
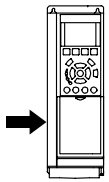
## 3.1.1. Mains Supply 1 x 200 - 240 VAC

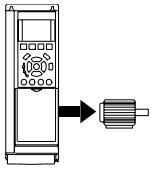
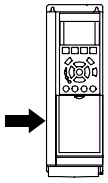
**Mains Supply 1 x 200 - 240 VAC - Normal overload 110% for 1 minute**

| Frequency converter<br>Typical Shaft Output [kW] | | P5K<br>5 | P7K<br>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<br>(1 x 200-240 V) [A] | 24.2 | 30.8 | 59.4 | 88 |
| | Intermittent<br>(1 x 200-240 V) [A] | 26.6 | 33.4 | 65.3 | 96.8 |
| | Continuous kVA<br>(208 V AC) [kVA] | 5.00 | 6.40 | 12.27 | 18.30 |
| | Max. cable size:<br>(mains, motor, brake)<br>[[mm²/ AWG] 2) | 10/7 | 35/2 | 50/1/0 | 95/4/0 |
| **Max. input current** | | | | | |
|  | Continuous<br>(1 x 200-240 V ) [A] | 46 | 59 | 111 | 172 |
| | Intermittent<br>(1 x 200-240 V ) [A] | 50.6 | 64.9 | 122.1 | 189.2 |
| | Max. pre-fuses1)[A] | 80 | 100 | 150 | 200 |
| | Environment | | | | |
| | Estimated power loss<br>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 |

MG.20.N4.02 - VLT® is a registered Danfoss trademark

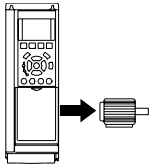
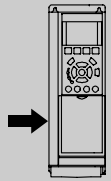
## 3.1.2. Mains Supply 3 x 200 - 240 VAC

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **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-fuses[1] [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 |

| **Mains supply 3 x 200 - 240 VAC - Normal overload 110% for 1 minute** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| IP 20 / NEMA Chassis<br>(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<br>(3 x 200-240 V ) [A] | 24.2 | 30.8 | 46.2 | 59.4 | 74.8 | 88.0 | 115 | 143 | 170 |
| | Intermittent<br>(3 x 200-240 V ) [A] | 26.6 | 33.9 | 50.8 | 65.3 | 82.3 | 96.8 | 127 | 157 | 187 |
| | Continuous<br>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:<br>(mains, motor, brake)<br>[mm$^2$ /AWG] [2)] | | 10/7 | | 35/2 | | 50/1/0 | | 95/4/0 | 120/250 MCM |
| **Max. input current** | | | | | | | | | | |
|  | Continuous<br>(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<br>(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<br>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 |

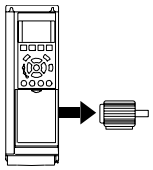
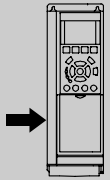
## 3.1.3. Mains Supply 1 x 380 - 480 VAC

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

| Frequency converter<br>Typical Shaft Output [kW] | | P7K5<br>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<br>(1 x 380-440 V) [A] | 16 | 24 | 44 | 73 |
| | Intermittent<br>(1 x 380-440 V) [A] | 17.6 | 26.4 | 48.4 | 80.3 |
| | Continuous<br>(1 x 441-480 V) [A] | 14.5 | 21 | 40 | 65 |
| | Intermittent<br>(1 x 441-480 V) [A] | 15.4 | 23.1 | 44 | 71.5 |
| | Continuous kVA<br>(400 V AC) [kVA] | 11.0 | 16.6 | 30.5 | 50.6 |
| | Continuous kVA<br>(460 V AC) [kVA] | 11.6 | 16.7 | 31.9 | 51.8 |
| | Max. cable size:<br>(mains, motor, brake)<br>[[mm$^2$/ AWG] [2)] | 10/7 | 35/2 | 50/1/0 | 120/4/0 |
| **Max. input current** | | | | | |
|  | Continuous<br>(1 x 380-440 V ) [A] | 33 | 48 | 94 | 151 |
| | Intermittent<br>(1 x 380-440 V ) [A] | 36 | 53 | 103 | 166 |
| | Continuous<br>(1 x 441-480 V) [A] | 30 | 41 | 85 | 135 |
| | Intermittent<br>(1 x 441-480 V) [A] | 33 | 46 | 93 | 148 |
| | Max. pre-fuses[1)][A] | 63 | 80 | 160 | 250 |
| | Environment | | | | |
| | Estimated power loss<br>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

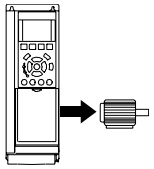
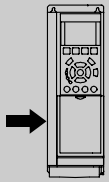
**Mains Supply 3 x 380 - 480 VAC - Normal overload 110% for 1 minute**

| 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 |

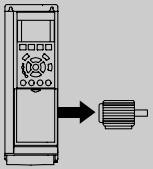
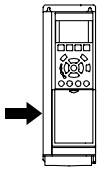


MG.20.N4.02 - VLT® is a registered Danfoss trademark

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

| Frequency converter<br>Typical Shaft Output [kW] | | P11K<br>11 | P15K<br>15 | P18K<br>18.5 | P22K<br>22 | P30K<br>30 | P37K<br>37 | P45K<br>45 | P55K<br>55 | P75K<br>75 | P90K<br>90 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Typical Shaft Output [HP] at 460 V | | 15 | 20 | 25 | 30 | 40 | 50 | 60 | 75 | 100 | 125 |
| IP 20 / NEMA Chassis<br>(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<br>(3 x 380-440 V) [A] | 24 | 32 | 37.5 | 44 | 61 | 73 | 90 | 106 | 147 | 177 |
| | Intermittent<br>(3 x 380-440 V) [A] | 26.4 | 35.2 | 41.3 | 48.4 | 67.1 | 80.3 | 99 | 117 | 162 | 195 |
| | Continuous<br>(3 x 441-480 V) [A] | 21 | 27 | 34 | 40 | 52 | 65 | 80 | 105 | 130 | 160 |
| | Intermittent<br>(3 x 441-480 V) [A] | 23.1 | 29.7 | 37.4 | 44 | 61.6 | 71.5 | 88 | 116 | 143 | 176 |
| | Continuous kVA<br>(400 V AC) [kVA] | 16.6 | 22.2 | 26 | 30.5 | 42.3 | 50.6 | 62.4 | 73.4 | 102 | 123 |
| | Continuous kVA<br>(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:<br>(mains, motor, brake)<br>[[mm²/ AWG] [2)] | | 10/7 | | 35/2 | | | 50/1/0 | | 120/4/0 | 120/4/0 |
| **Max. input current** | | | | | | | | | | | |
|  | Continuous<br>(3 x 380-440 V ) [A] | 22 | 29 | 34 | 40 | 55 | 66 | 82 | 96 | 133 | 161 |
| | Intermittent<br>(3 x 380-440 V ) [A] | 24.2 | 31.9 | 37.4 | 44 | 60.5 | 72.6 | 90.2 | 106 | 146 | 177 |
| | Continuous<br>(3 x 441-480 V) [A] | 19 | 25 | 31 | 36 | 47 | 59 | 73 | 95 | 118 | 145 |
| | Intermittent<br>(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<br>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 |

**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<br>2x2/0 | | 2x185<br>2x350 mcm | | | 4x240<br>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-fuses[1][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-fuses[1] [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.

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!*

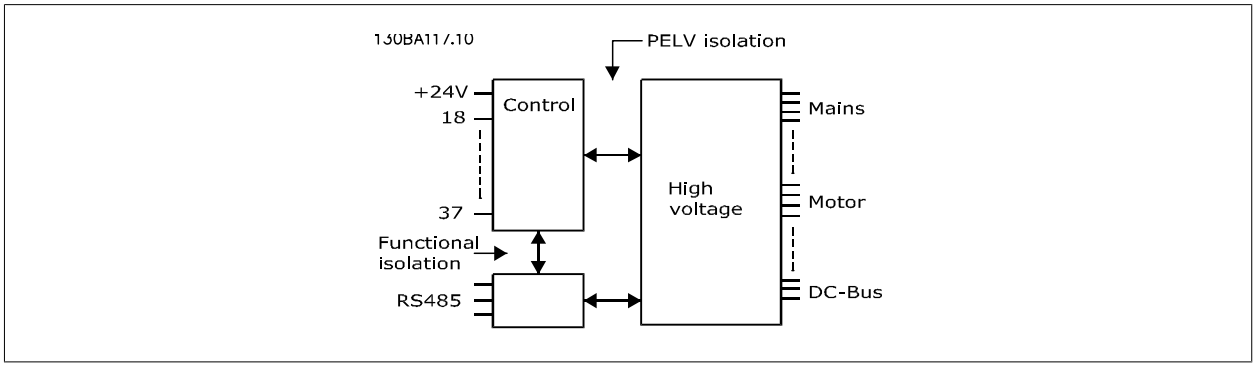
| Control card, RS-485 serial communication: | |
|---|---|
| Terminal number | 68 (P,TX+, RX+), 69 (N,TX-, RX-) |
| Terminal number 61 | Common for terminals 68 and 69 |

*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 not 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 ($\eta_{VLT}$)**

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

This also means that the efficiency of the frequency converter does not change even if other U/f characteristics are 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 ($\eta_{SYSTEM}$**

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

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

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:

| 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. $$dU \Big| dt = \frac{0.8 \times U_{PEAK}}{Risetime}$$

3

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:**

**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**

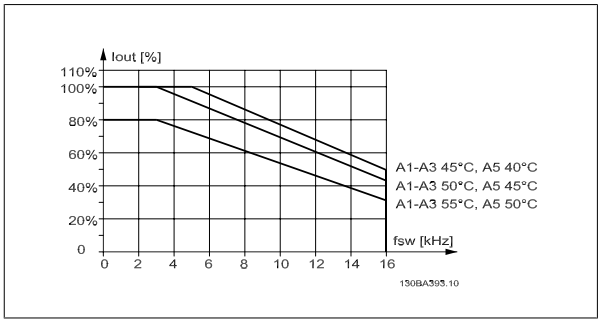



Illustration 3.1: Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure A, using 60 AVM

**SFAVM - Stator Frequency Asyncron Vector Modulation**

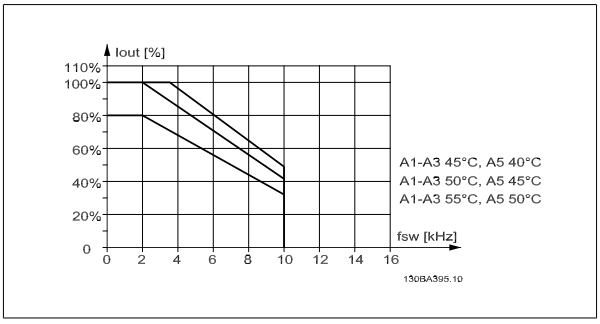



Illustration 3.2: Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure A, using SFAVM

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.

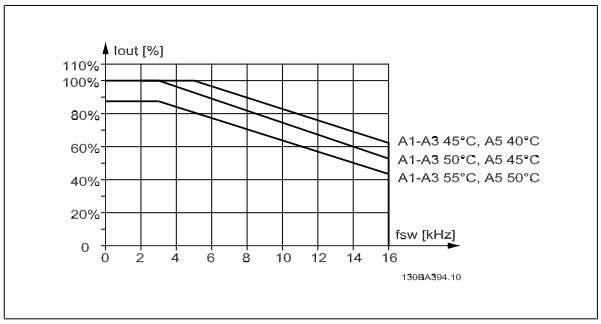



Illustration 3.3: Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure A, using 60 AVM and maximum 10 m motor cable

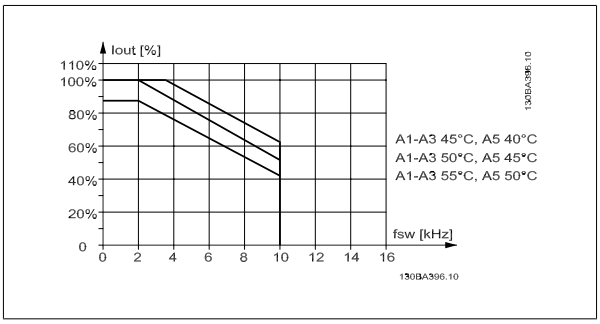



Illustration 3.4: Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure A, using SFAVM and maximum 10 m motor cable

3

**B enclosures**

**60 AVM - Pulse Width Modulation**

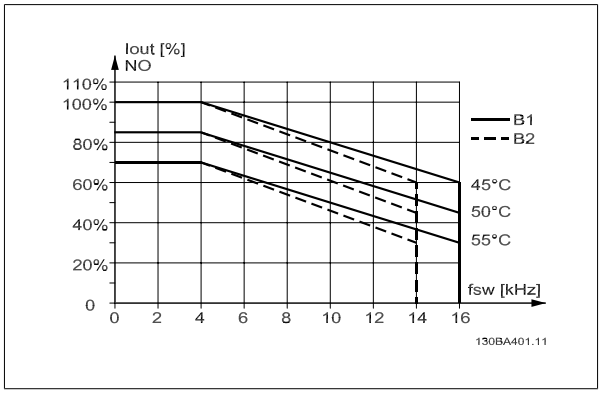



Illustration 3.5: Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure B, using 60 AVM in Normal torque mode (110% over torque)

**SFAVM - Stator Frequency Asyncron Vector Modulation**

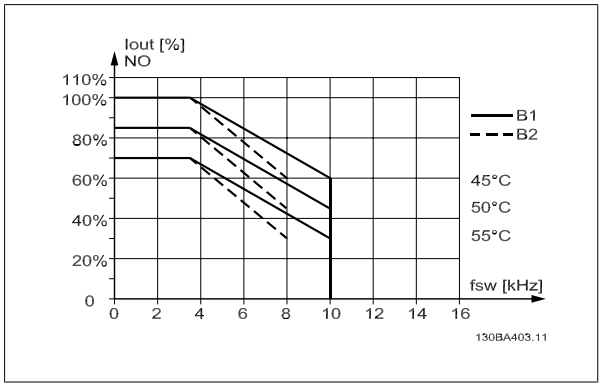



Illustration 3.6: Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure B, using SFAVM in Normal torque mode (110% over torque)

**C enclosures**

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

**60 AVM - Pulse Width Modulation**

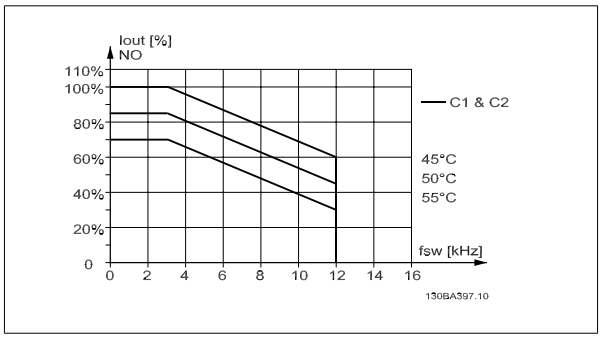



Illustration 3.7: Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure C, using 60 AVM in Normal torque mode (110% over torque)

**SFAVM - Stator Frequency Asyncron Vector Modulation**

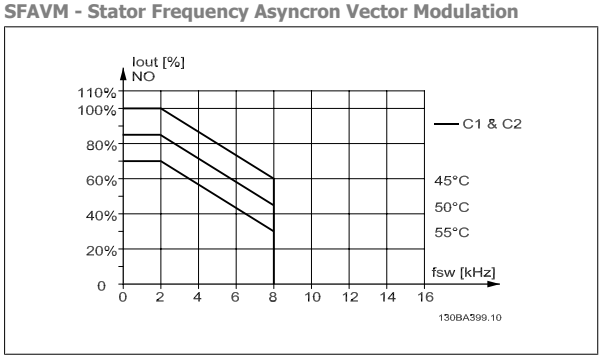



Illustration 3.8: Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure C, using SFAVM in Normal torque mode (110% over torque)

**D enclosures**

**60 AVM - Pulse Width Modulation, 380 - 480 V**

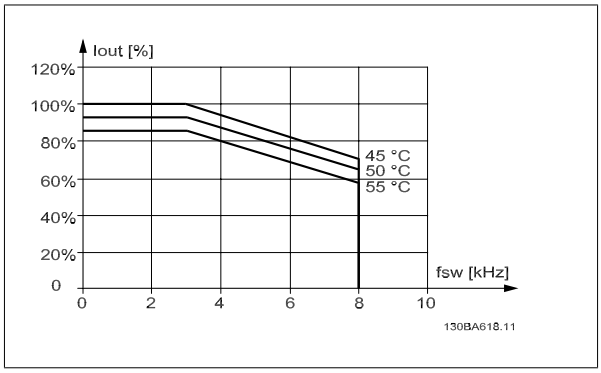



Illustration 3.9: Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure D at 480 V, using 60 AVM in Normal torque mode (110% over torque)

**SFAVM - Stator Frequency Asyncron Vector Modulation**

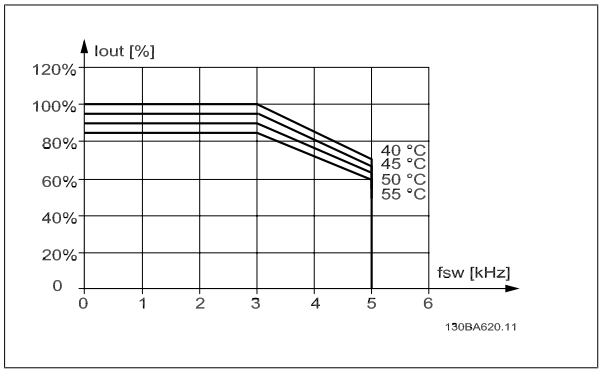



Illustration 3.10: Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure D at 480 V, using SFAVM in Normal torque mode (110% over torque)

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

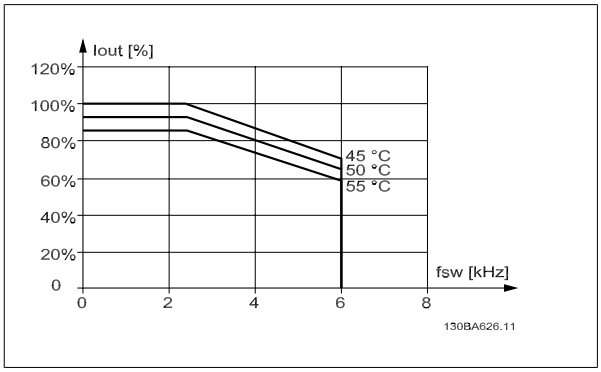



Illustration 3.11: Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure D at 600 V, using 60 AVM in Normal torque mode (110% over torque). Note: *not* valid for P315.

**SFAVM - Stator Frequency Asyncron Vector Modulation**

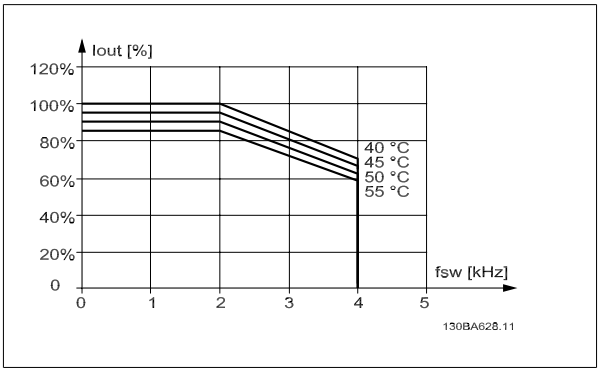



Illustration 3.12: Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure D at 600 V, using SFAVM in Normal torque mode (110% over torque). Note: *not* valid for P315.

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

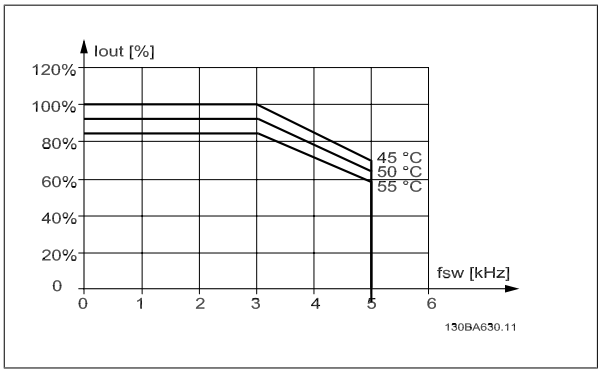



Illustration 3.13: Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure D at 600 V, using 60 AVM in Normal torque mode (110% over torque). Note: P315 *only*.

**SFAVM - Stator Frequency Asyncron Vector Modulation**

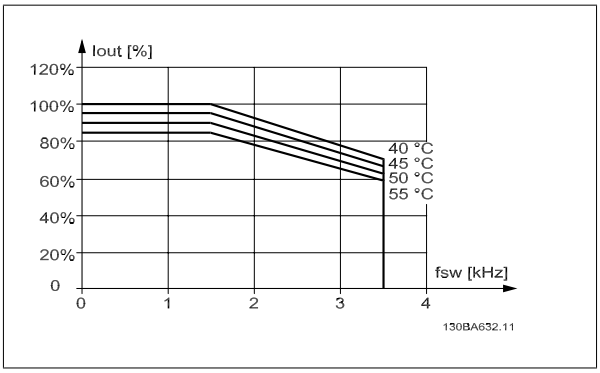



Illustration 3.14: Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure D at 600 V, using SFAVM in Normal torque mode (110% over torque). Note: P315 *only*.

**E enclosures**

**60 AVM - Pulse Width Modulation, 380 - 480 V**

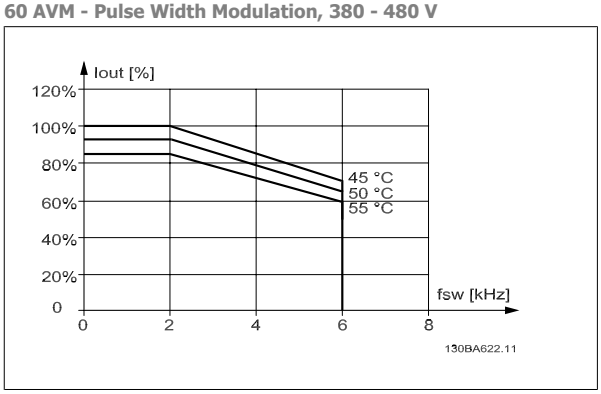



Illustration 3.15: Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure E at 480 V, using 60 AVM in Normal torque mode (110% over torque)

**SFAVM - Stator Frequency Asyncron Vector Modulation**

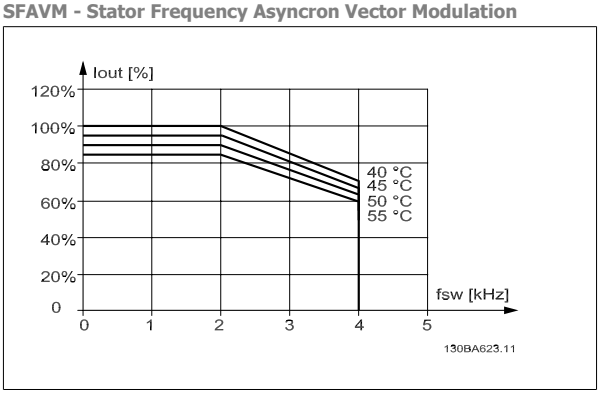



Illustration 3.16: Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure E at 480 V, using SFAVM in Normal torque mode (110% over torque)

3

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

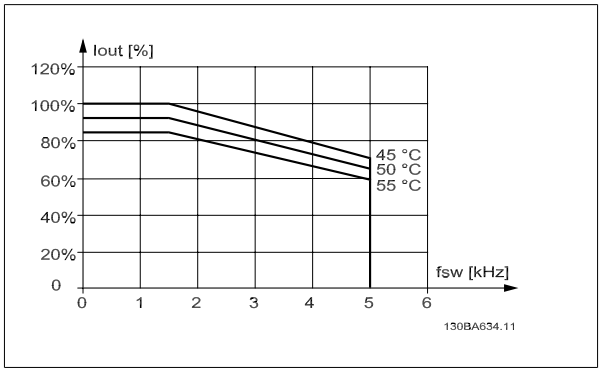



Illustration 3.17: Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure E at 600 V, using 60 AVM in Normal torque mode (110% over torque).

**SFAVM - Stator Frequency Asyncron Vector Modulation**

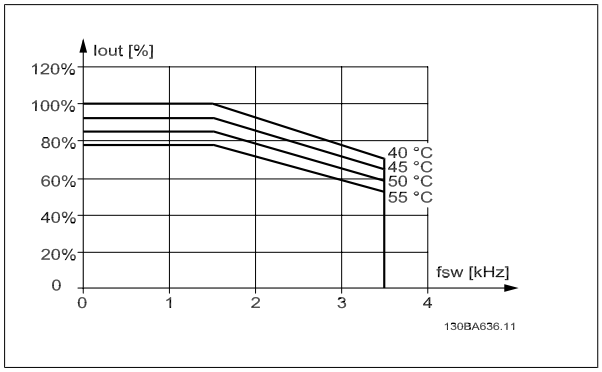



Illustration 3.18: Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure E at 600 V, using SFAVM in Normal torque mode (110% over torque).

### 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.

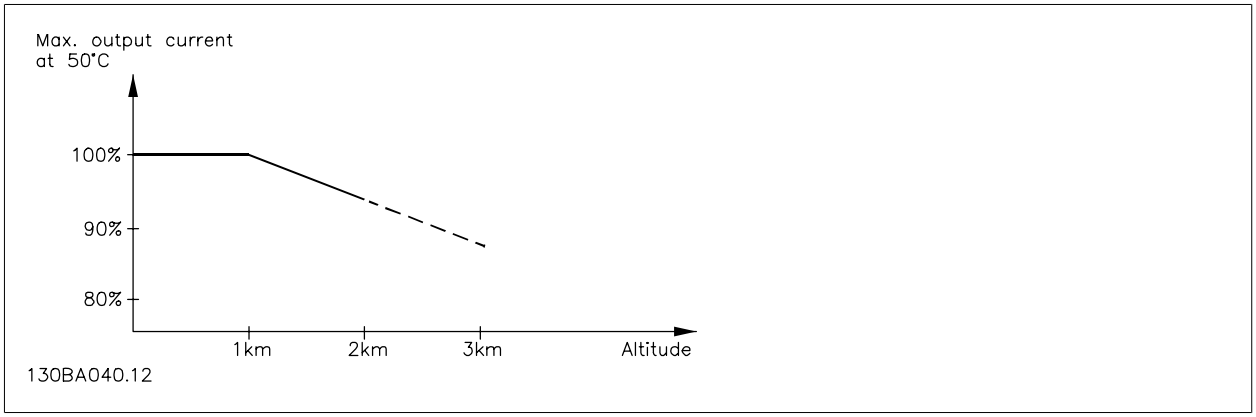



Illustration 3.19: Derating of output current versus altitude at $T_{AMB, MAX}$. By altitudes above 2 km, please contact regarding PELV.

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

## 3.5.4. 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).

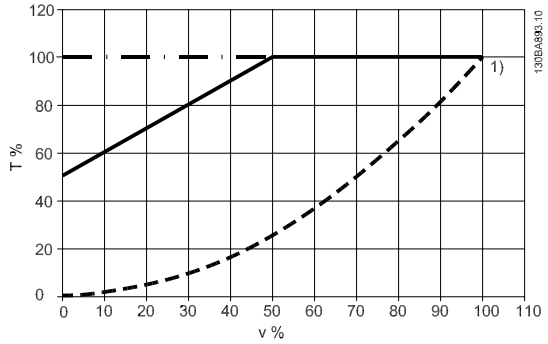
An alternative is to reduce the load level of the motor by choosing a larger motor. However, the design of the frequency converter puts a limit to the motor size.

**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

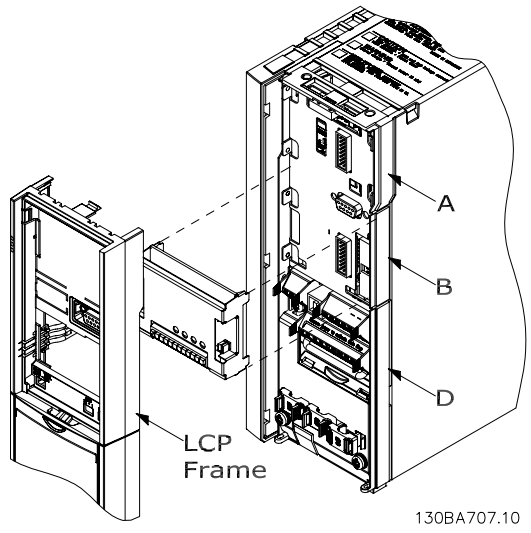
The power to the frequency converter must be disconnected.

For A2 and A3 enclosures:

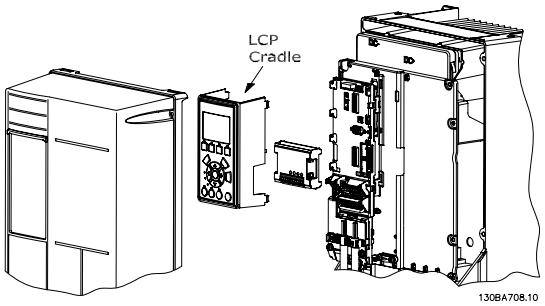
- Remove the  (Local Control Panel), the terminal cover, and the  frame from the frequency converter.
- Fit the MCB10x option card into slot B.
- Connect the control cables and relieve the cable by the enclosed cable strips.
  Remove the knock out in the extended  frame delivered in the option set, so 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



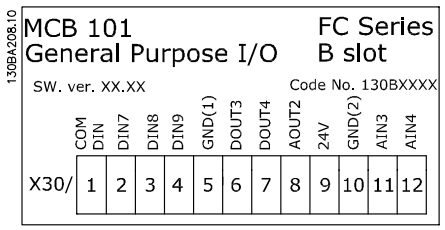

A5, B1, B2, B4, C1, C2, C3 and C4 enclosures

## 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.

3

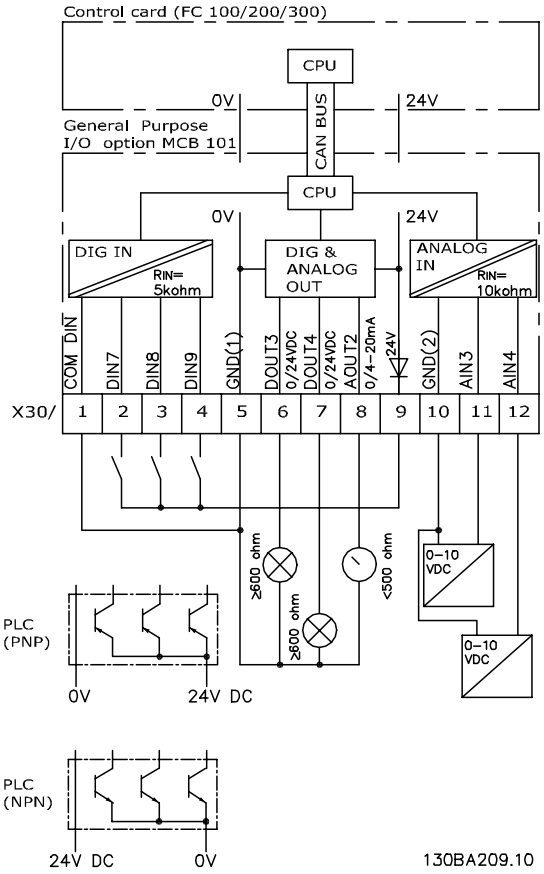



Illustration 3.20: Principle Diagram

### 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:<br>Common = 0 V<br>Logic "0": Input < 5 V DC<br>Logic "0": Input > 10 V DC<br>NPN type:<br>Common = 24 V<br>Logic "0": Input > 19 V DC<br>Logic "0": Input < 14 V DC | ± 28 V continuous<br>± 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.

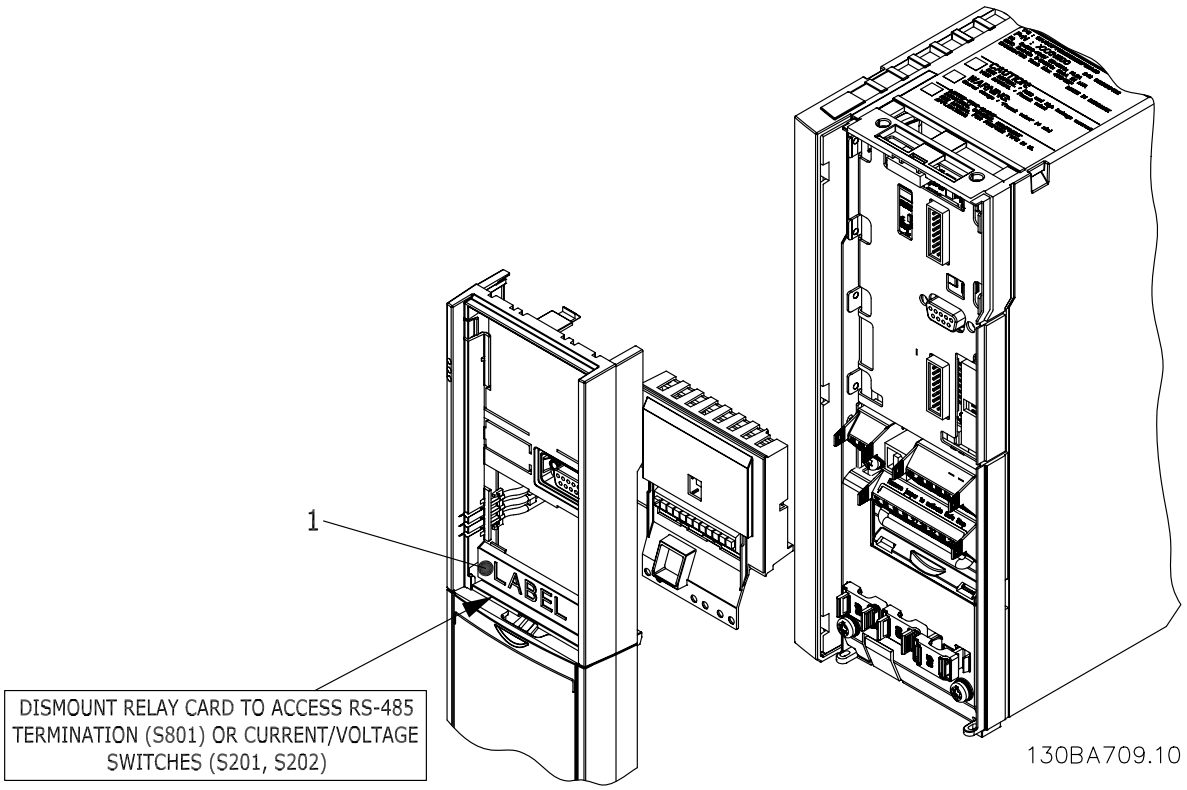
| Electrical Data: | |
|---|---|
| Max terminal load (AC-1) [1] (Resistive load) | 240 V AC 2A |
| Max terminal load (AC-15 ) [1] (Inductive load @ cosφ 0.4) | 240 V AC 0.2 A |
| Max terminal load (DC-1) [1] (Resistive load) | 24 V DC 1 A |
| Max terminal load (DC-13) [1] (Inductive load) | 24 V DC 0.1 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:

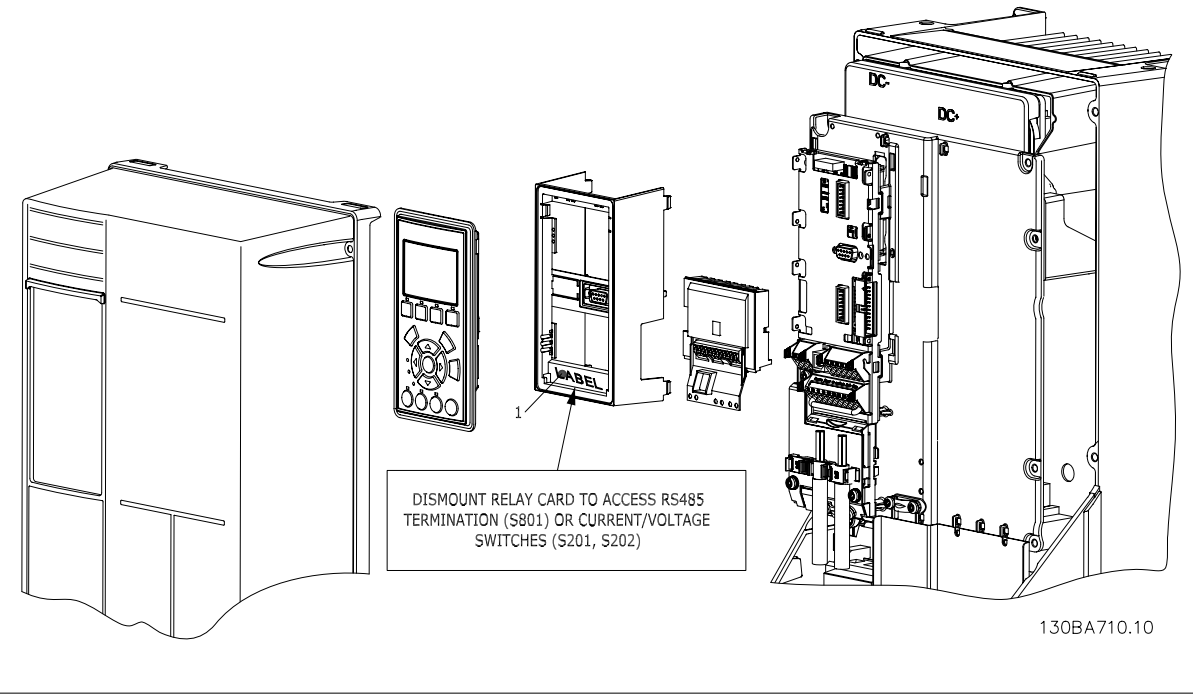
- Relay Module MCB 105
- Extended frame and enlarged terminal cover
- Label for covering access to switches S201, S202 and S801
- Cable strips for fastening cables to relay module

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).

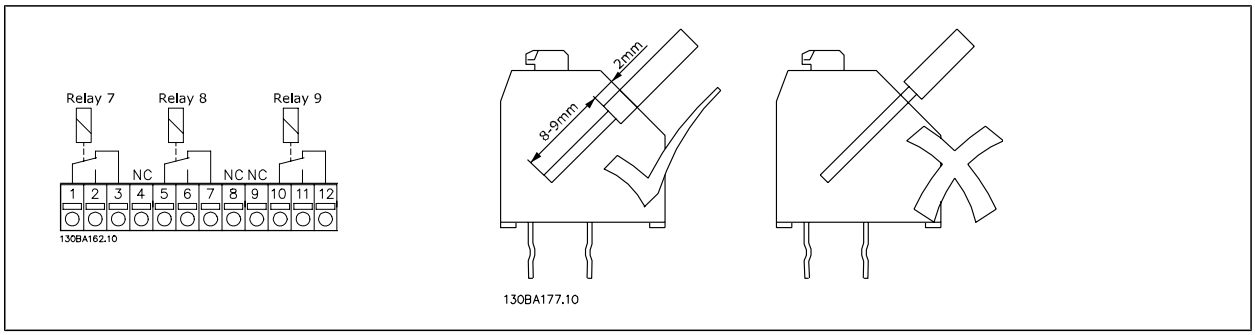


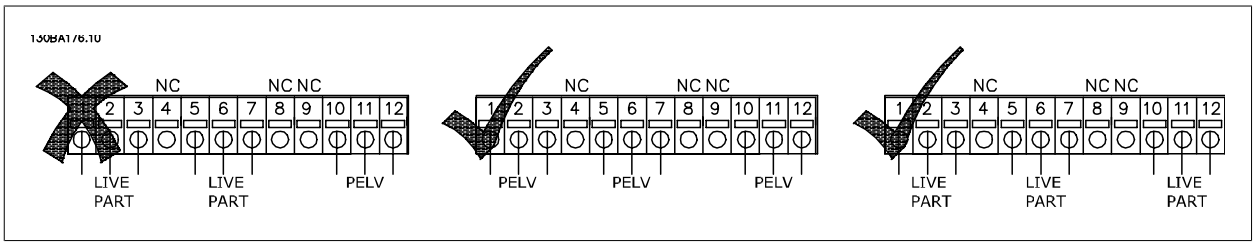
Warning Dual supply

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.

3

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.

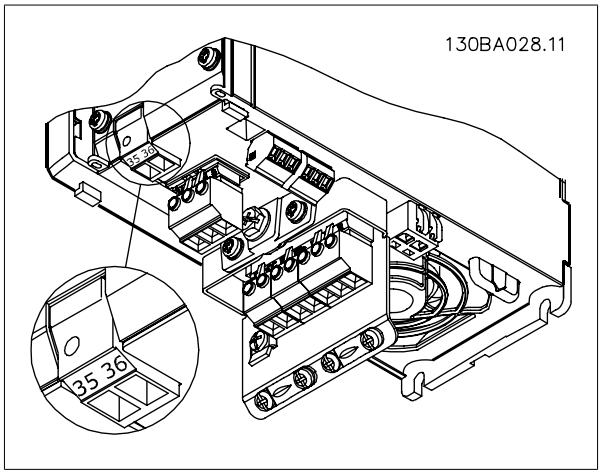



Illustration 3.21: Connection to 24 V back-up supplier (A2-A3).

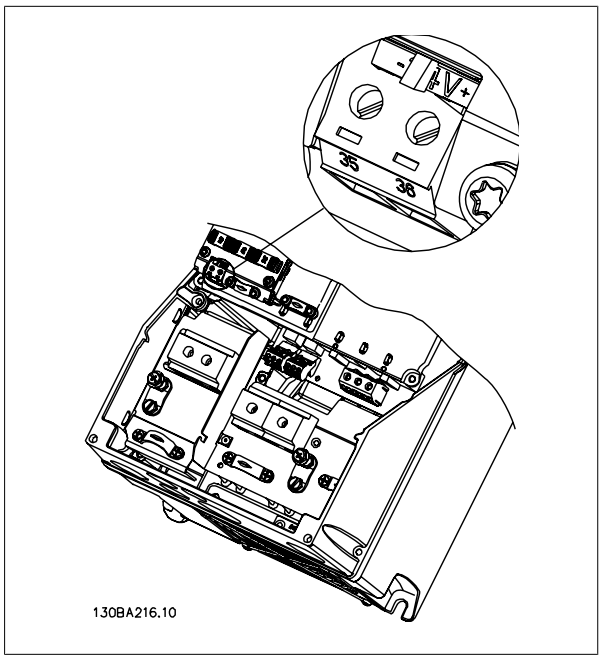



Illustration 3.22: Connection to 24 V back-up supplier (A5-C2).

## 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.



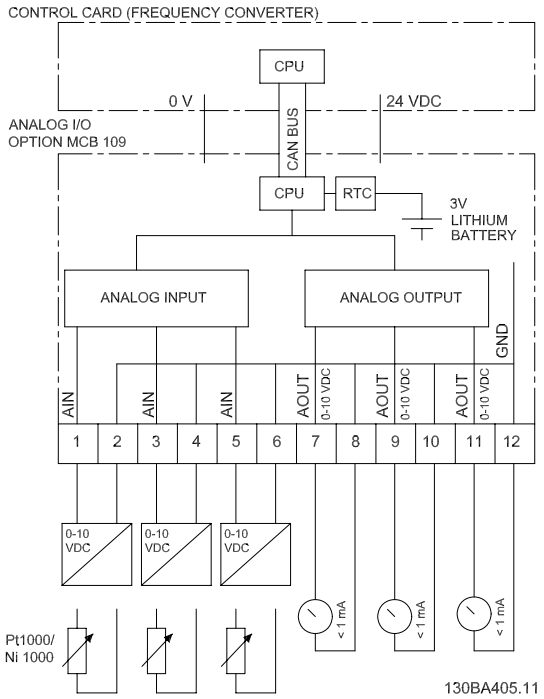



Illustration 3.23: Principle diagram for Analog I/O mounted in frequency converter.

**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.

3

**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.

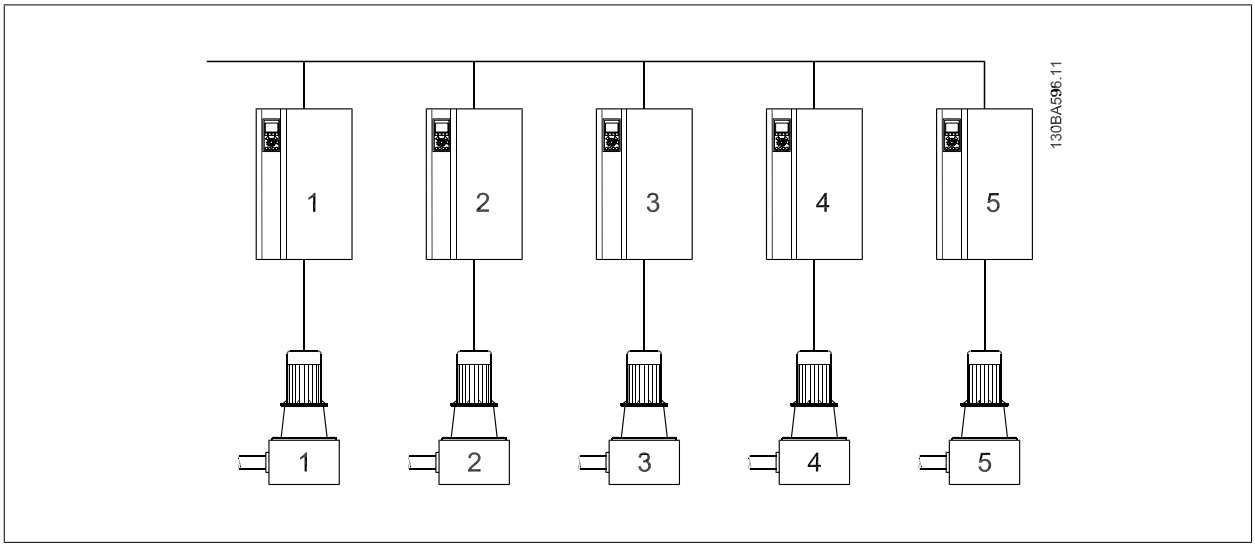
## 3.6.10. Introduction to the Extended Cascade Controller

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.

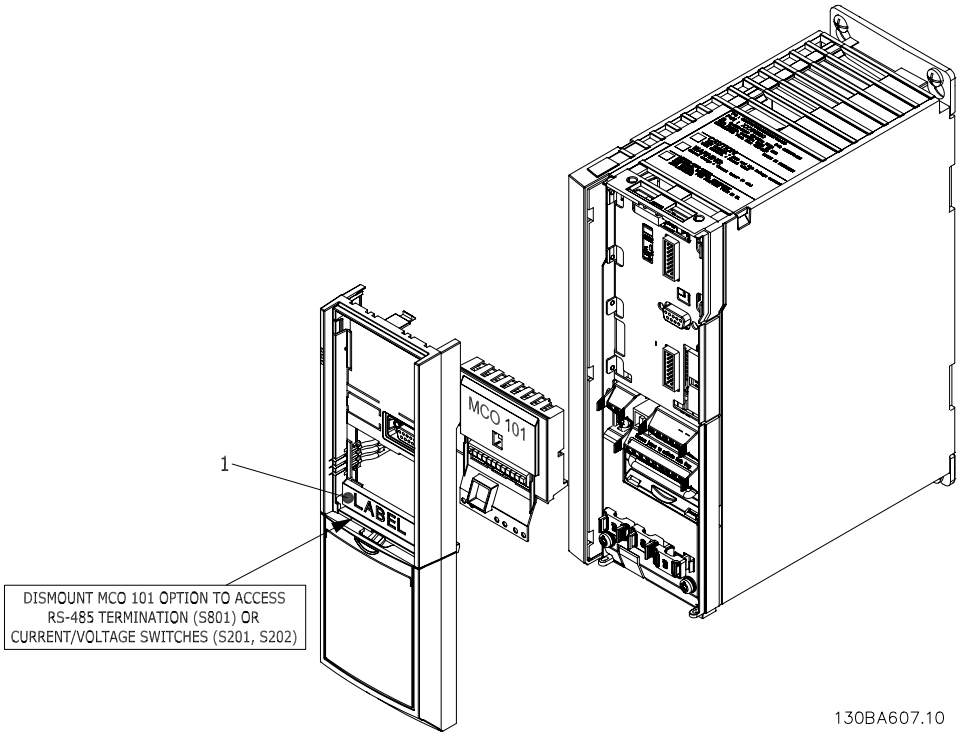
Each pump, variable speed or fixed speed, is controlled by a relay in the Master Drive. The VLT AQUA Drive with the Extended Cascade Controller option card installed has five relays available for controlling pumps. 2 relays standard in the drive and additional 3 relays on the option card MCO 101.

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 $sec^{-1}$ |



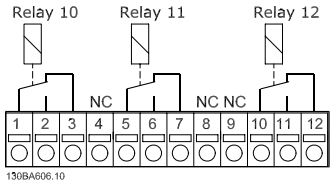

Warning Dual supply

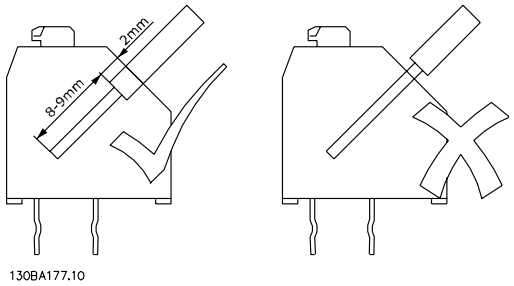
**NB!**
The label MUST be placed on the LCP frame as shown (UL approved).

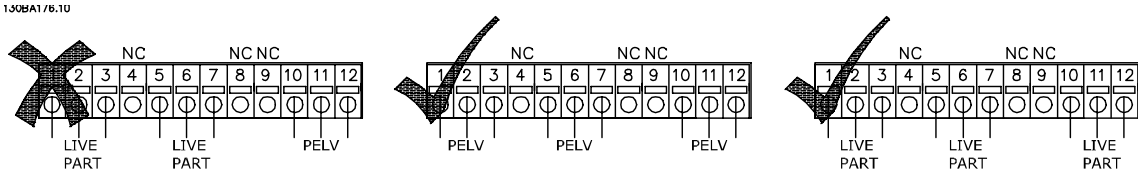
How to add the MCO 101 option:

- 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

## 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**

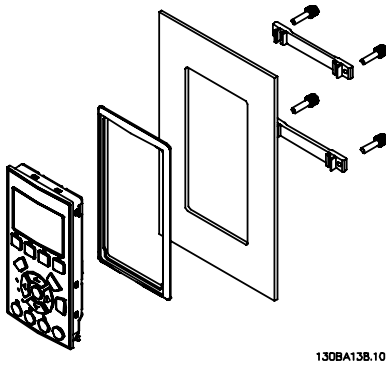



Illustration 3.24: LCP Kit with graphical LCP, fasteners, 3 m cable and gasket.

**Ordering no. 130B1114**

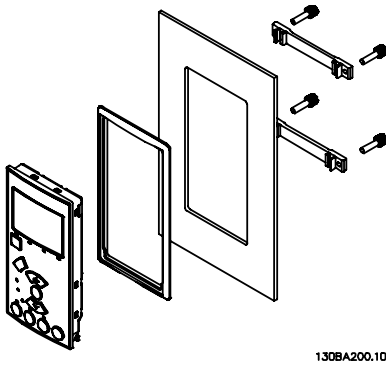
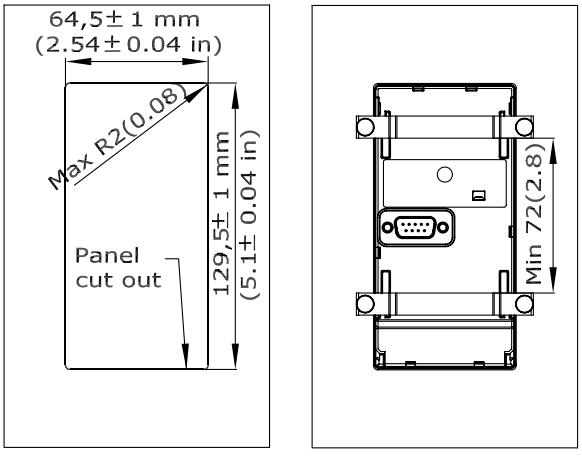



Illustration 3.25: LCP Kit with numerical LCP, fasternes and gasket.

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



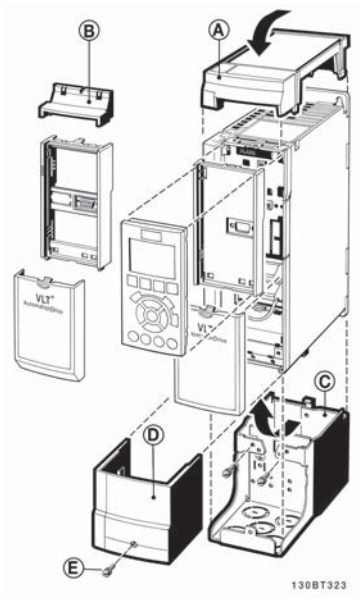
## 3.6.15. IP 21/IP 4X/ TYPE 1 Enclosure Kit

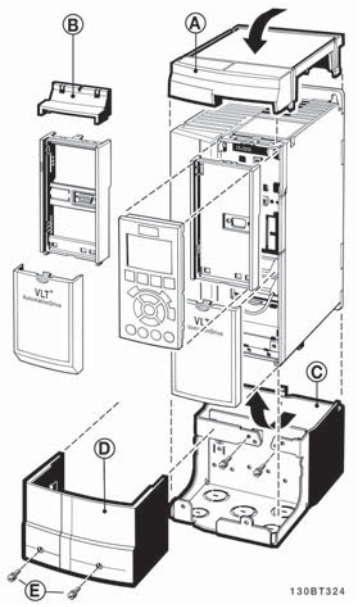
IP 20/IP 4X top/ TYPE 1 is an optional enclosure element available for IP 20 Compact units, enclosure size A2-A3 up to 7.5 kW.
If the enclosure kit is used, an IP 20 unit is upgraded to comply with enclosure IP 21/ 4X top/TYPE 1.

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

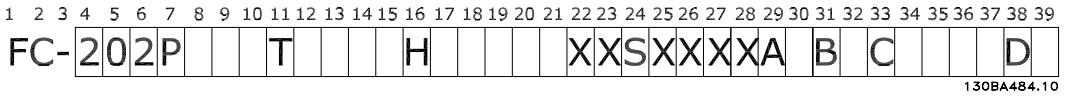
The meaning of the characters in the string can be located in the pages containing the ordering numbers in the chapter *How to Select Your VLT*. In the example above, a Profibus LON works option and a General purpose I/O option is included in the drive.

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<br>S4: 380-480 VAC single phase<br>T 2: 200-240 VAC<br>T 4: 380-480 VAC<br>T 6: 525-600 VAC<br>T 7: 525-690 VAC |
| Enclosure | 13-15 | E20: IP20<br>E21: IP 21/NEMA Type 1<br>E55: IP 55/NEMA Type 12<br>E2M: IP21/NEMA Type 1 w/mains shield<br>E5M: IP 55/NEMA Type 12 w/mains shield<br>E66: IP66<br>F21: IP21 kit without backplate<br>G21: IP21 kit with backplate<br>P20: IP20/Chassis with backplate<br>P21: IP21/NEMA Type 1 w/backplate<br>P55: IP55/NEMA Type 12 w/backplate |
| RFI filter | 16-17 | HX: No RFI filter<br>H1: RFI filter class A1/B<br>H2: RFI filter class A2<br>H3: RFI filter class A1/B (reduced cable length)<br>H4: RFI filter class A2/A1 |
| Brake | 18 | X: No brake chopper included<br>B: Brake chopper included<br>T: Safe Stop<br>U: Safe + brake |
| Display | 19 | G: Graphical Local Control Panel (GLCP)<br>N: Numeric Local Control Panel (NLCP)<br>X: No Local Control Panel |
| Coating PCB | 20 | X. No coated PCB<br>C: Coated PCB |
| Mains option | 21 | D: Loadsharing<br>X: No Mains disconnect switch<br>1: With Mains disconnect switch<br>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<br>A0: MCA 101 Profibus DP V1<br>A4: MCA 104 DeviceNet |
| B options | 31-32 | BX: No option<br>BK: MCB 101 General purpose I/O option<br>BP: MCB 105 Relay option<br>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<br>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 | | | | | | | | | | | | | |





MG.20.N4.02 - VLT® is a registered Danfoss trademark

**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%).

**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%).

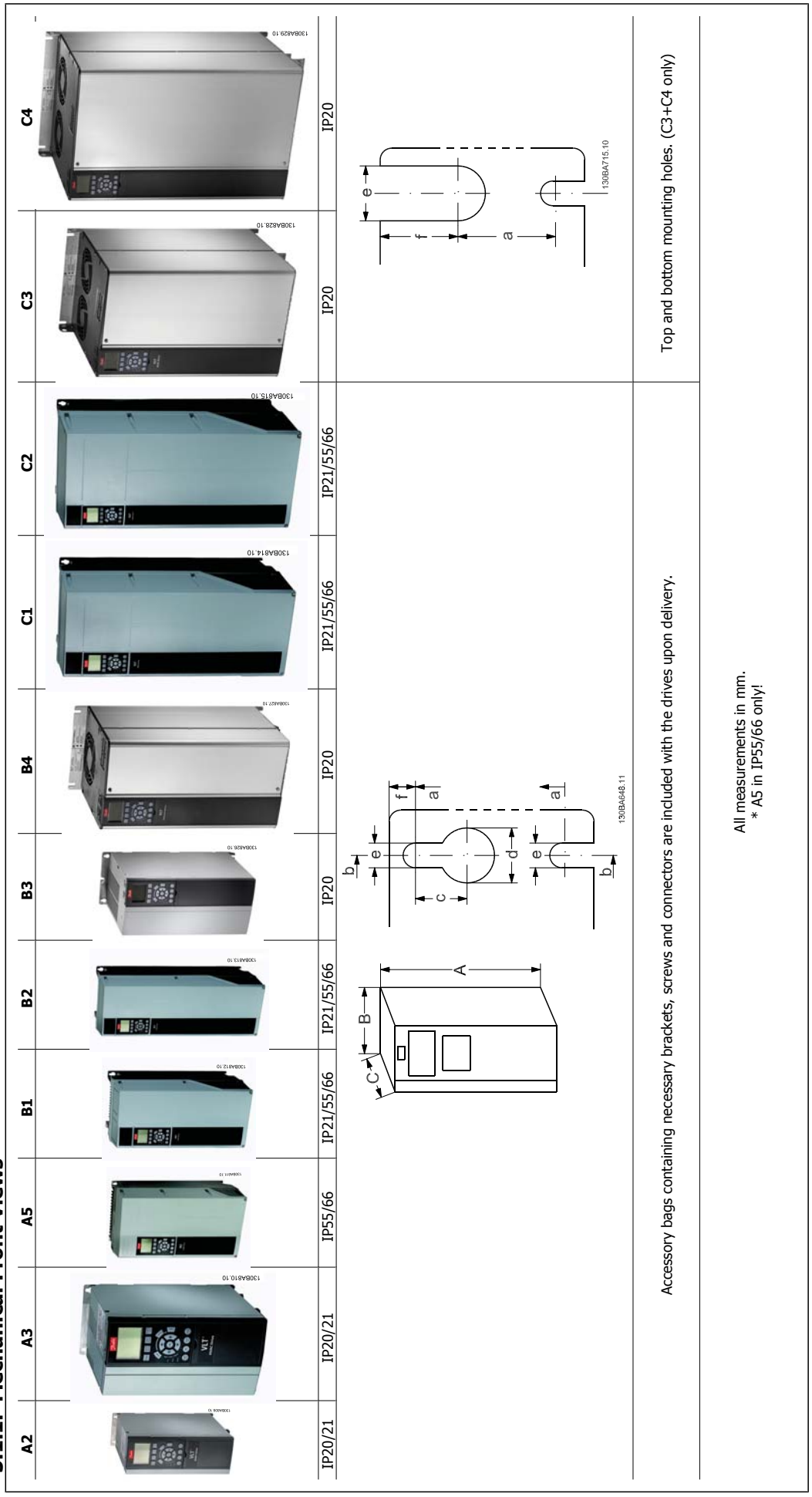
# 5. How to Install

## 5.1. Mechanical Installation

**Page intentionally left blank!**

5

## 5.1.1. Mechanical Front Views

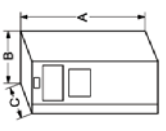
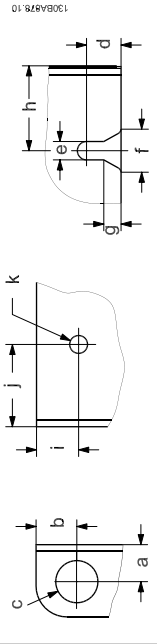
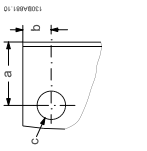
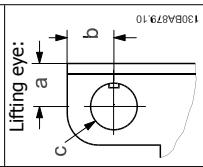
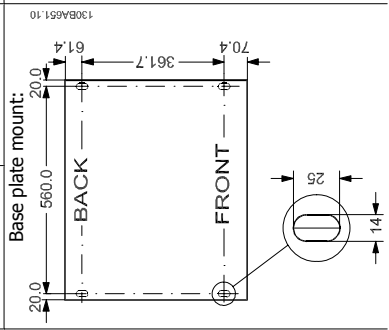


## 5.1.2. Mechanical Dimensions

| 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 | | 20 | 21 | 20 | 21 | 55/66 | 21/ 55/66 | 21/55/66 | 20 | 20 | 21/55/66 | 21/55/66 | 20 | 20 |
| NEMA | | Chassis | Type 1 | Chassis | Type 1 | Type 12 | Type 1/12 | Type 1/12 | Chassis | Chassis | Type 1/12 | Type 1/12 | Chassis | 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| |  |  | Graphic missing! 130BA864.10 | Graphic missing! 130BA864.10 |  | Graphic missing! 130BA864.10 | Graphic missing! 130BA864.10 | Graphic missing! 130BA864.10 |  | Graphic missing! 130BA864.10 |
| | IP20/21 | IP21/55/66 | IP20 | IP20 | IP21/54 | IP00 | IP21/54 | IP00 | IP21/54 | IP00 |
| |  | | (Please contact !) | | | | | | | |
| |  | | | |  |  | | | | |
| |  | | | | | | | | | |

All measurements in mm



MG.20.N4.02 - VLT® is a registered Danfoss trademark

| Mechanical dimensions | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Enclosure size (kW)** | | **D1** | **D2** | **D3** | **D4** | **E1** | **E2** | **F1** | **F2** | **F3** | **F4** |
| **200-240 V**<br>**380-480 V**<br>**525-600 V** | | **110-132**<br>**110-132** | **160-250**<br>**160-315** | **110-132**<br>**110-132** | **160-250**<br>**160-315** | **315-450**<br>**355-560** | **315-450**<br>**355-560** | **500-710**<br>**560-750** | **800-1000**<br>**850-1000** | **500-710**<br>**560-750** | **800-1000**<br>**850-1000** |
| IP<br>NEMA | | 21/54<br>Type 1/12 | 21/54<br>Type 1/12 | 00<br>Type 1 | 00<br>Type 1 | 21/54<br>Type 1/12 | 00<br>Type 1 | 21/54<br>Type 1/12 | 21/54<br>Type 1/12 | 21/54<br>Type 1/12 | 21/54<br>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. | | | | | | | | | | | |

### 5.1.3. 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 | 100 |
| A3 | |
| 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<br>30 | -<br>- | 2.5<br>4.5 | 2.5<br>4.5 | 3.7<br>3.7 | 3.7<br>3.7 | 3<br>3 | 0.6<br>0.6 |
| C1 | 18.5 - 30 | 37 - 55 | - | 10 | 10 | 10 | 10 | 3 | 0.6 |
| C2 | 37 - 45 | 75<br>90 | -<br>- | 14<br>24 | 14<br>24 | 14<br>14 | 14<br>14 | 3<br>3 | 0.6<br>0.6 |
| D1/D3 | - | 110<br>132 | 110<br>132 | 19<br>19 | 19<br>19 | 9.6<br>9.6 | 9.6<br>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.

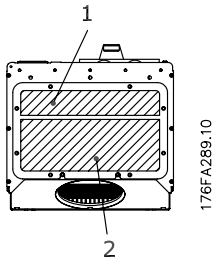
## 5.2.2. Removal of Knockouts for Extra Cables

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.

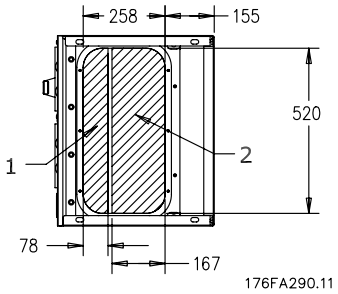
## 5.2.3. Gland/Conduit Entry - IP21 (NEMA 1) and IP54 (NEMA12)

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**

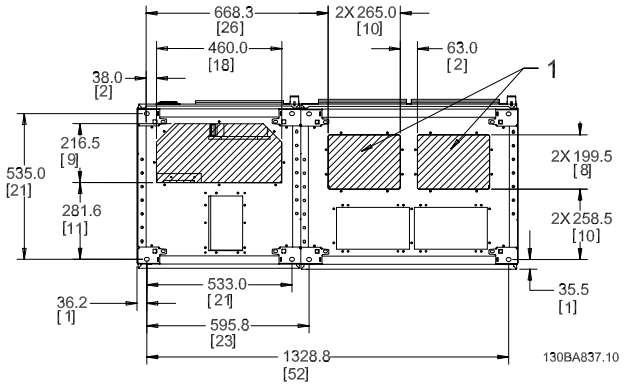



**Enclosure E1**

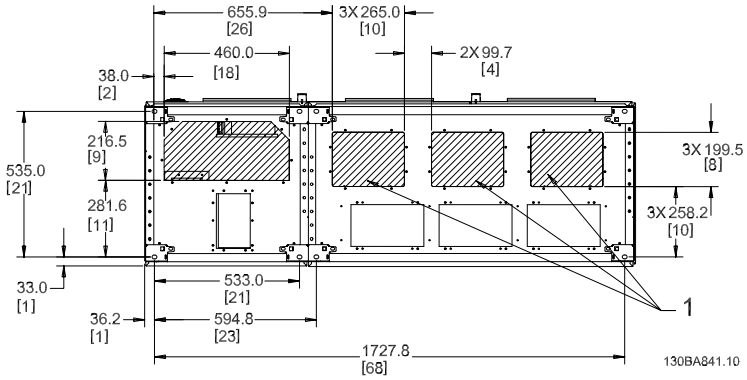



Cable entries viewed from the bottom of the frequency converter - 1) Mains side 2) Motor side

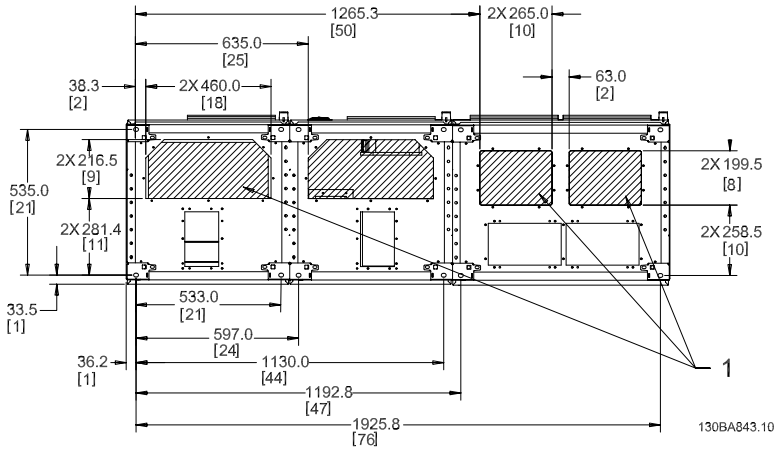
**Enclosure F1**



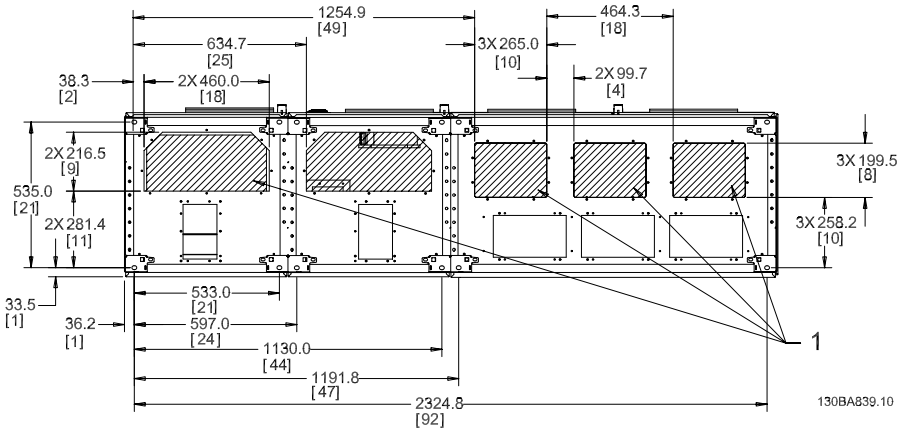

**Enclosure F2**




**Enclosure F3**




**Enclosure F4**




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

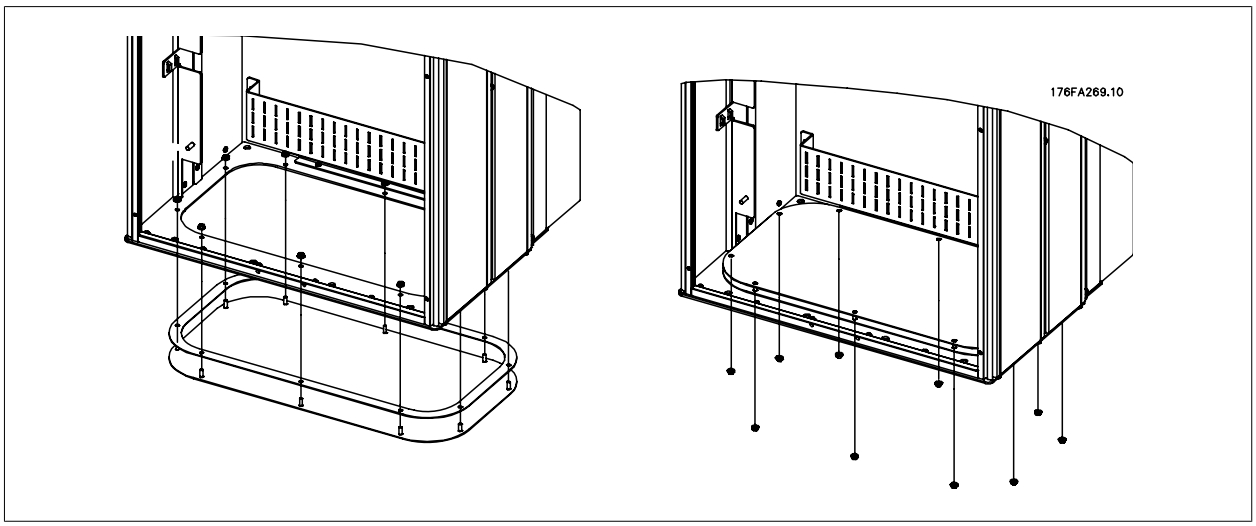



Illustration 5.1: Mounting of bottom plate, E1 enclosure.

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.

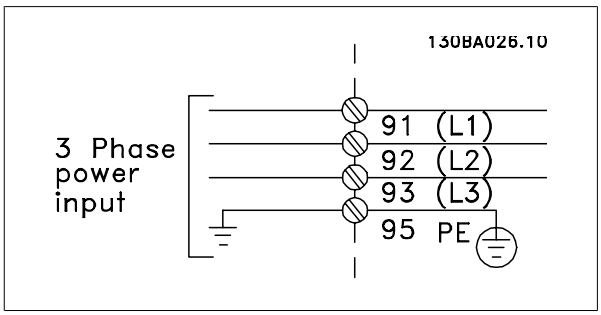



Illustration 5.2: Terminals for mains and earthing.

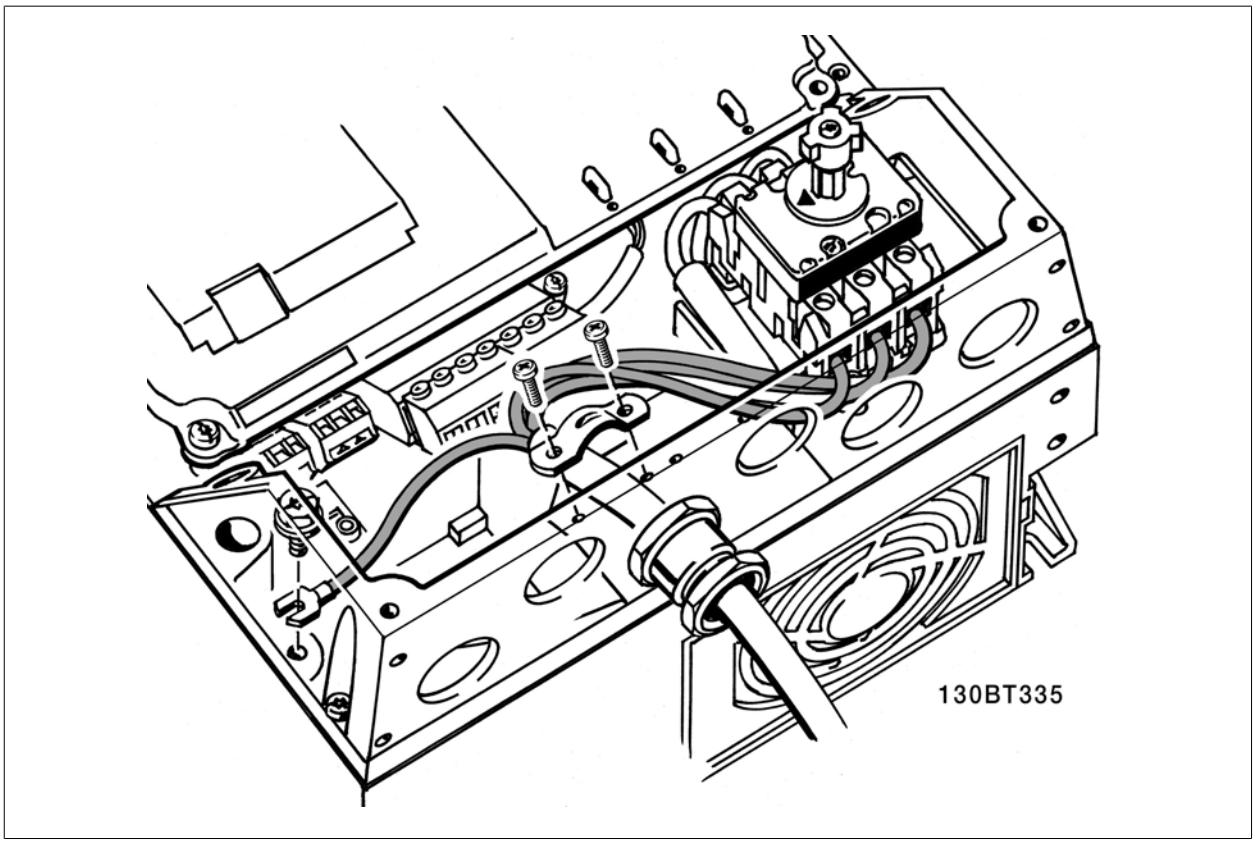



Illustration 5.3: How to connect to mains and earthing with disconnector (A5 enclosure).

## 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*.

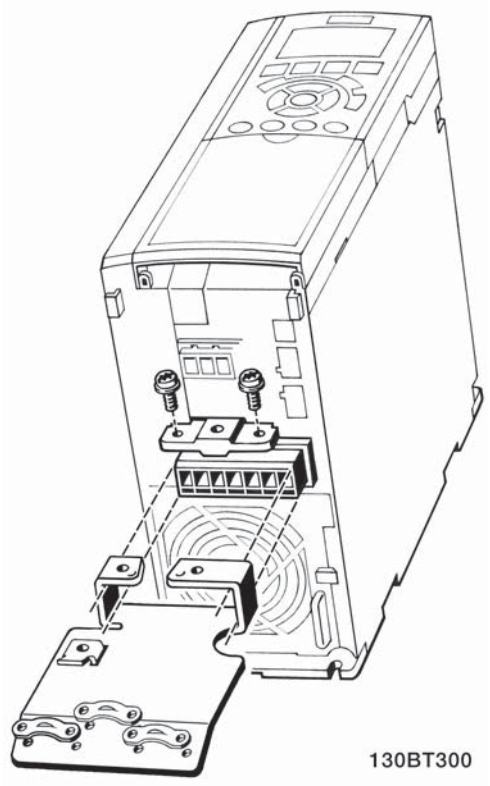
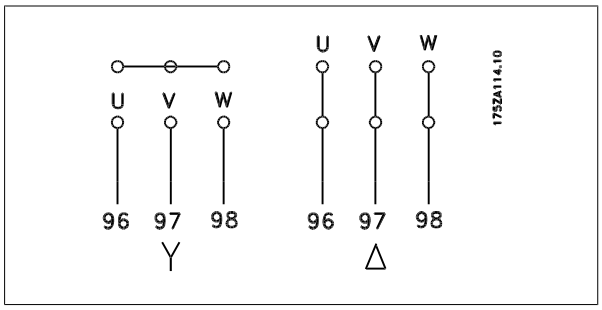



Illustration 5.4: Mounting of decoupling plate.

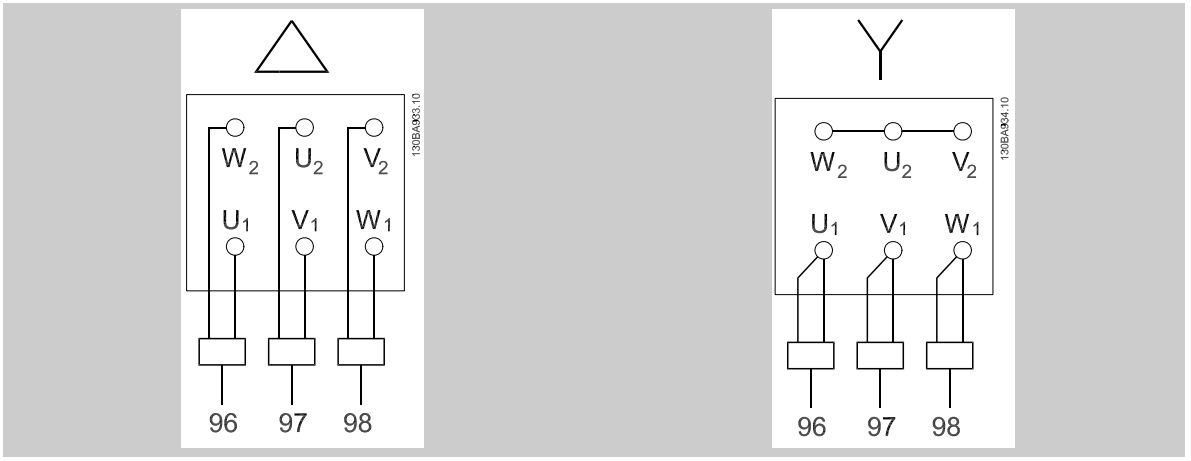
1. Fasten decoupling plate to the bottom of the frequency converter with screws and washers from the accessory bag.
2. Attach motor cable to terminals 96 (U), 97 (V), 98 (W).
3. Connect to earth connection (terminal 99) on decoupling plate with screws from the accessory bag.
4. Insert terminals 96 (U),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




| 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.

**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<br>170M5013 | 20220 | 700 A, 700 V | 85 |
| P400 | 170M4017<br>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

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).



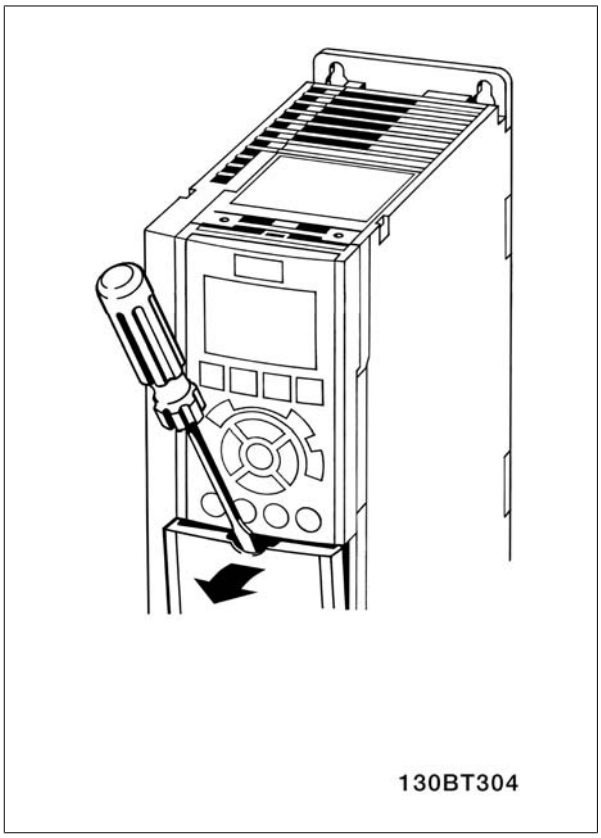



Illustration 5.5: A1, A2, A3,B3, B4, C3 and C4 enclosures

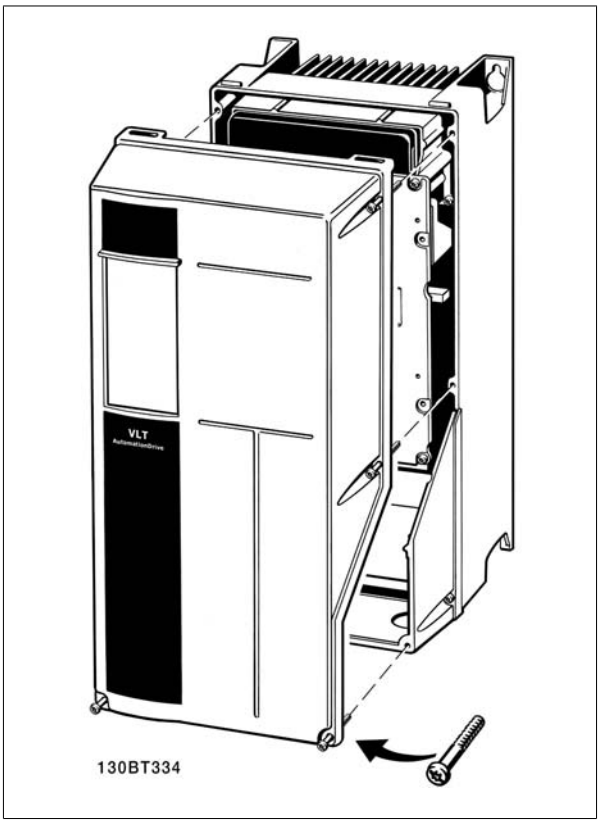



Illustration 5.6: A5, B1, B2, C1 and C2 enclosures

## 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.

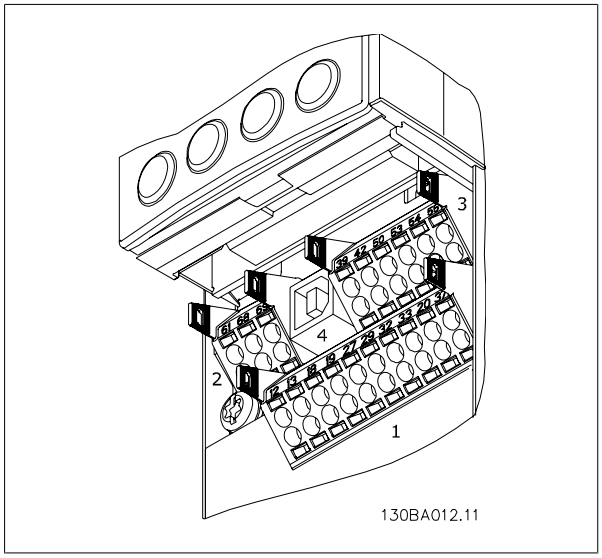



Illustration 5.7: Control terminals (all enclosures)

## 5.2.11. Electrical Installation, Control Cable Terminals

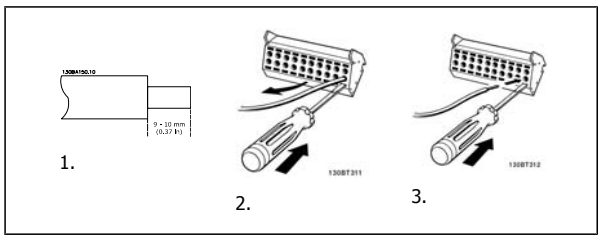
To mount the cable to the terminal:

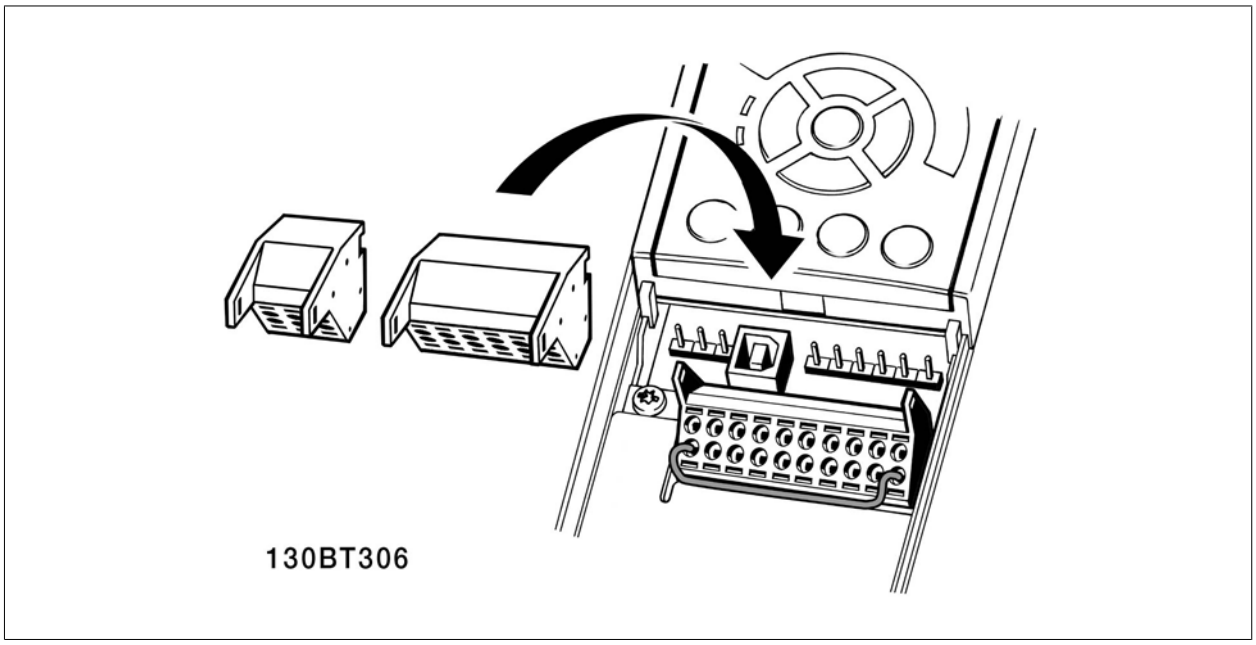
1. Strip isolation of 9-10 mm
2. Insert a screw driver[1)] in the square hole.
3. Insert the cable in the adjacent circular hole.
4. Remove the screw driver. The cable is now mounted to the terminal.

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



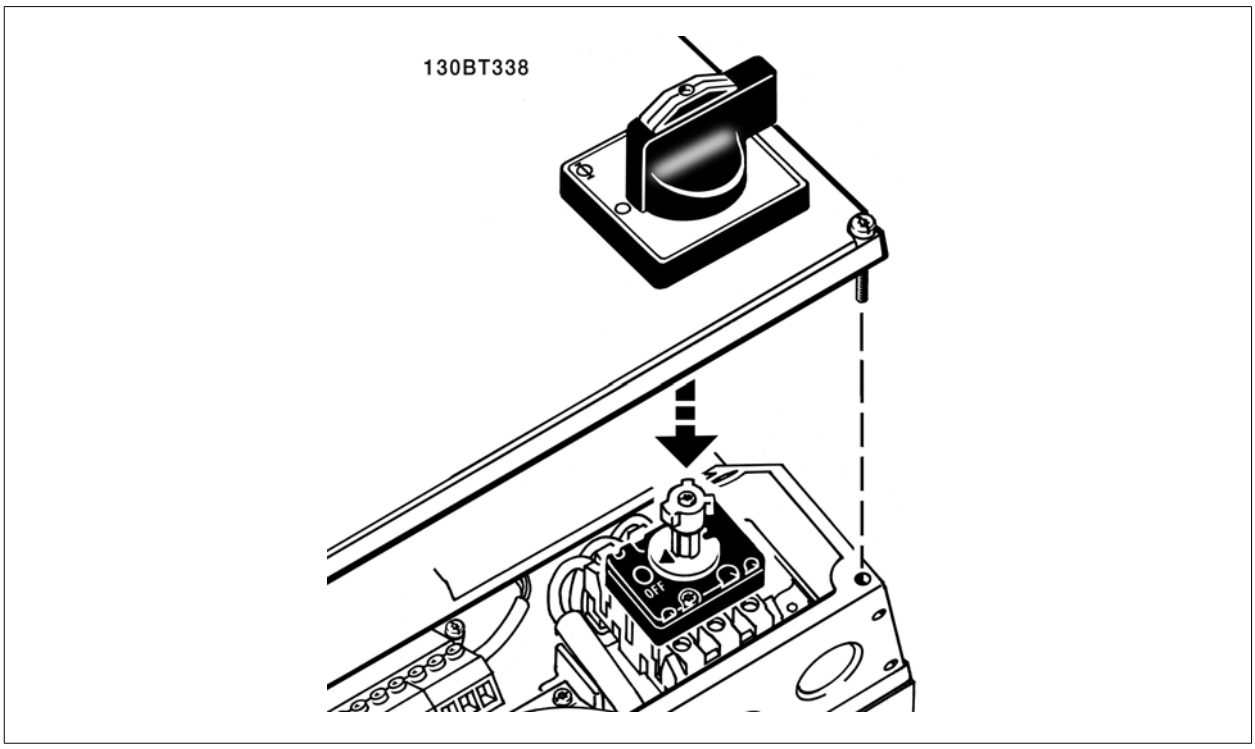



Illustration 5.8: Assembling of IP21 / IP55 / NEMA TYPE 12 housing with mains disconnector.

## 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

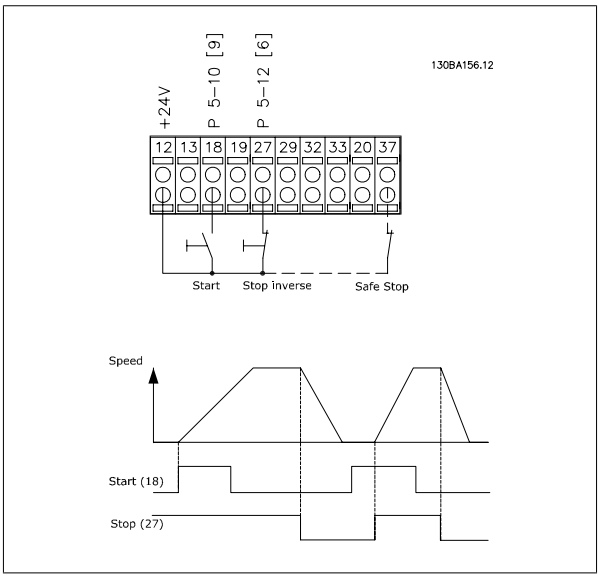



Illustration 5.9: Terminal 37 available with Safe Stop Function only!

## 5.2.13. 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

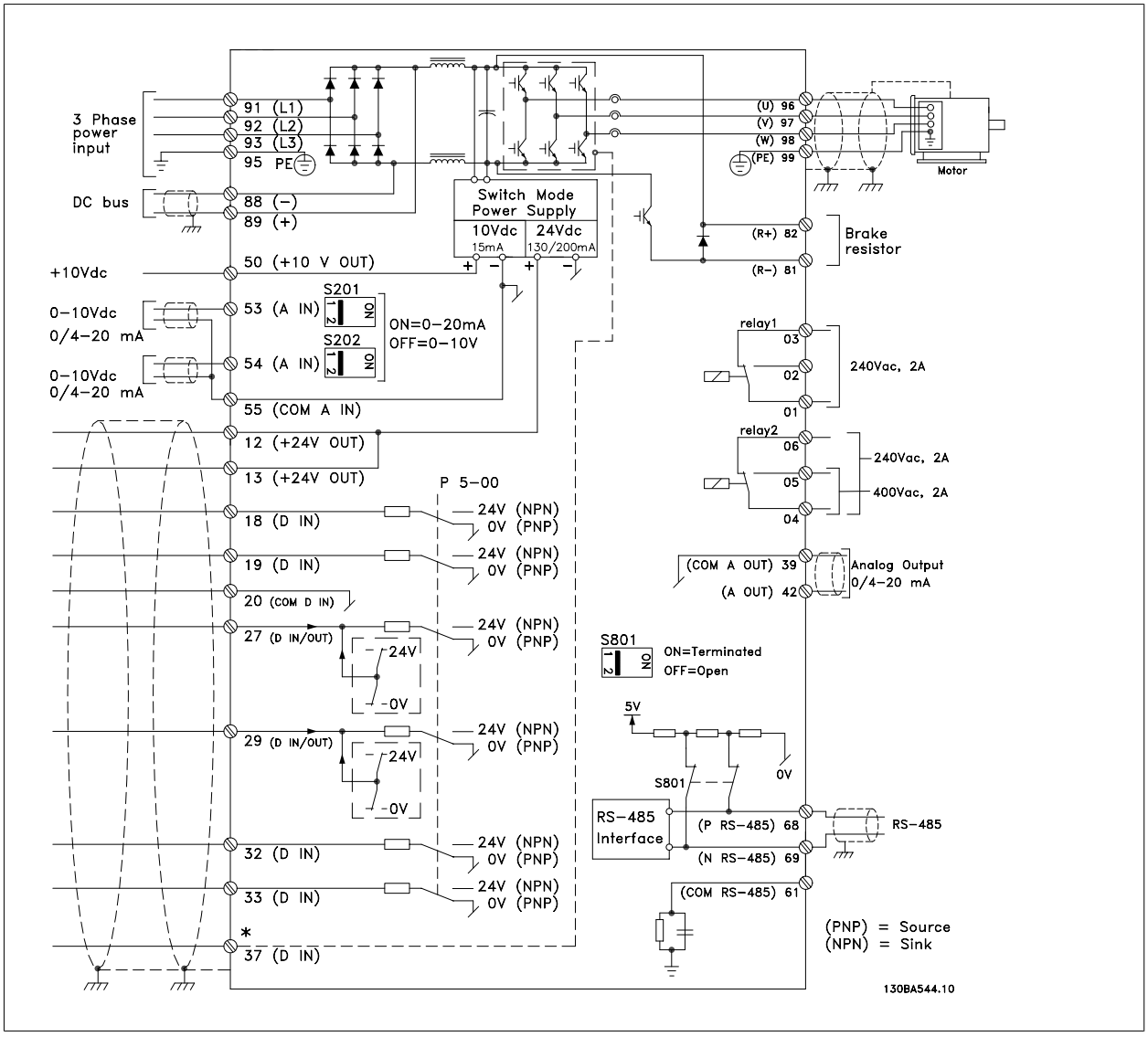



Illustration 5.10: Terminal 37: Safe Stop input available with Safe Stop Function only!

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.

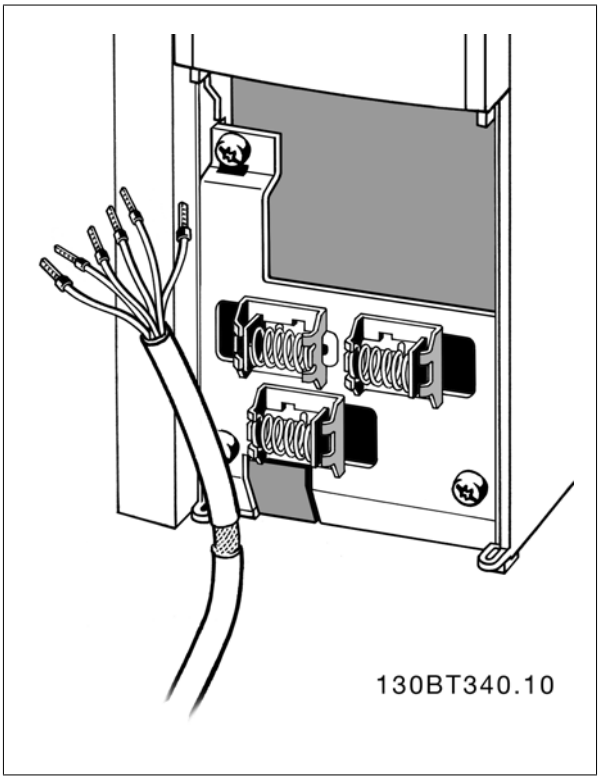
If this occurs, you may have to break the screen or insert a 100 nF capacitor between screen and chassis.

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.




## 5.2.15. 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).

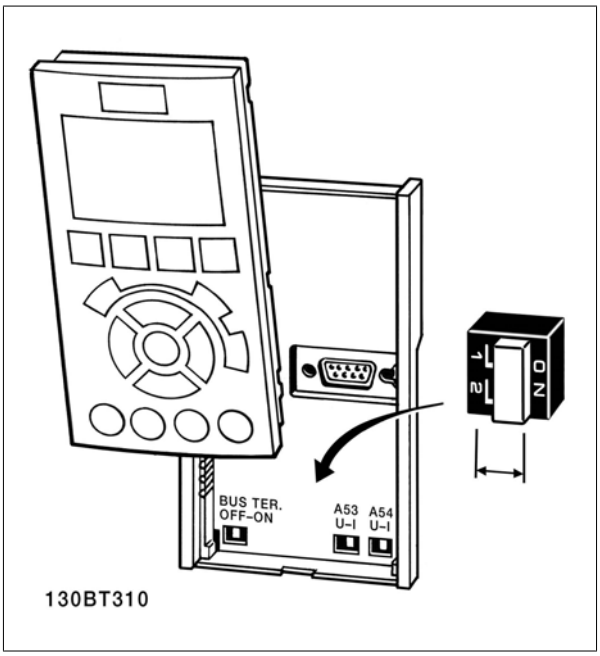
See drawing *Diagram showing all electrical terminals* in section *Electrical Installation.*

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

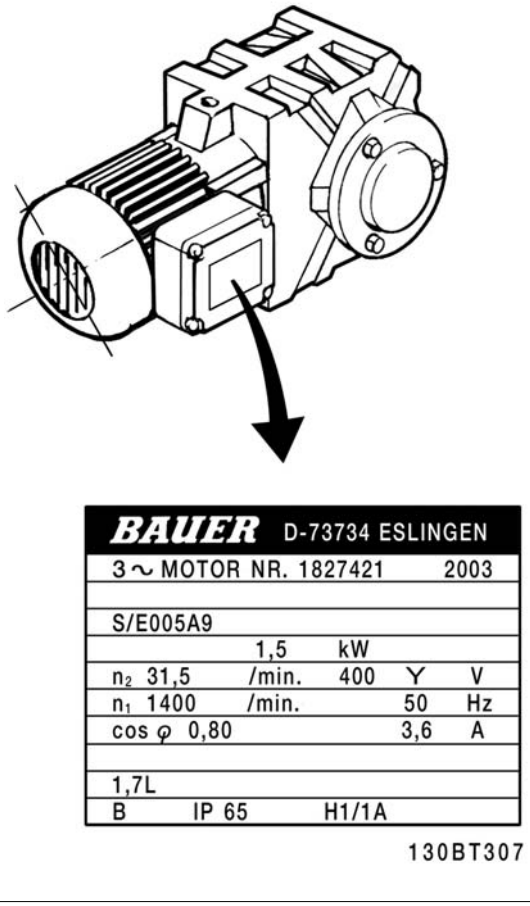
To test the set-up and ensure that the frequency converter is running, follow these steps.

**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.

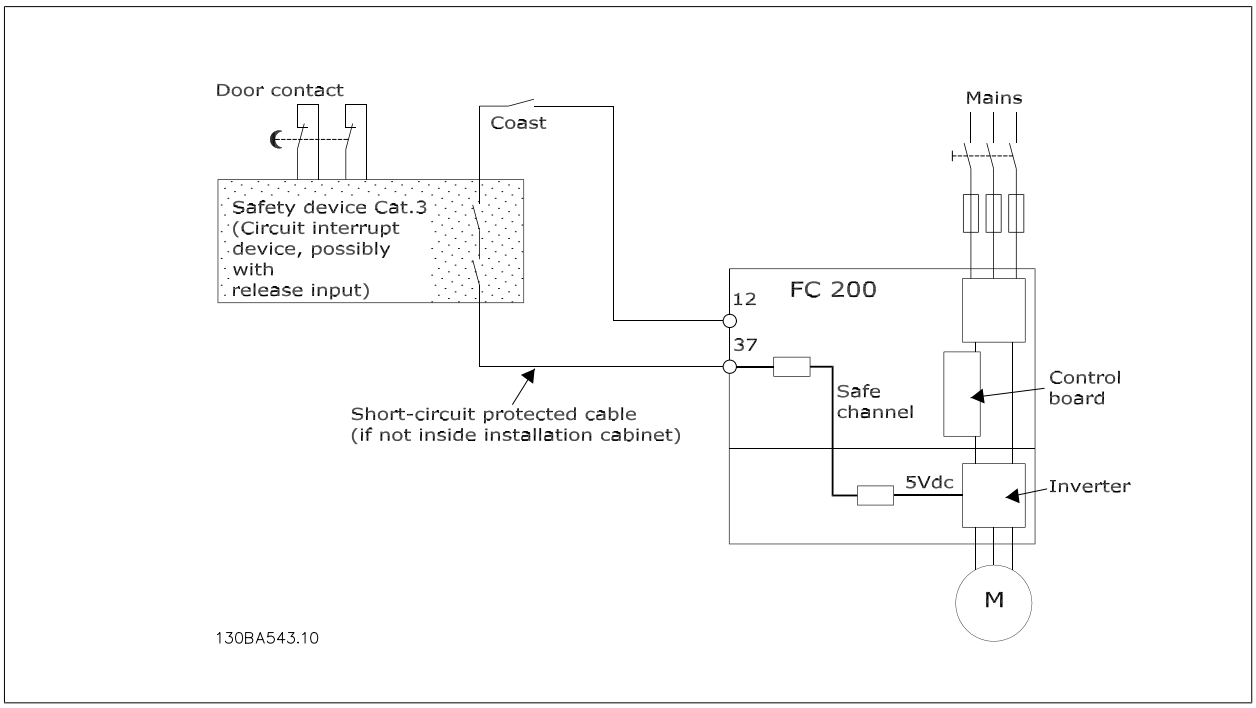



Illustration 5.12: Illustration of the essential aspects of an installation to achieve a Stopping Category 0 (EN 60204-1) with safety Cat. 3 (EN 954-1).

### 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 |
|---|---|

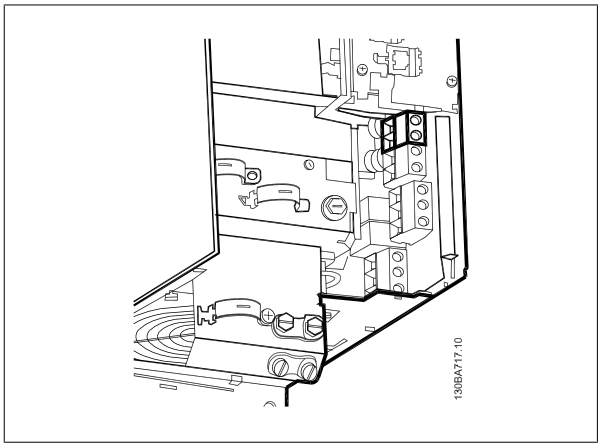



Illustration 5.13: DC bus connections for enclosure B3.

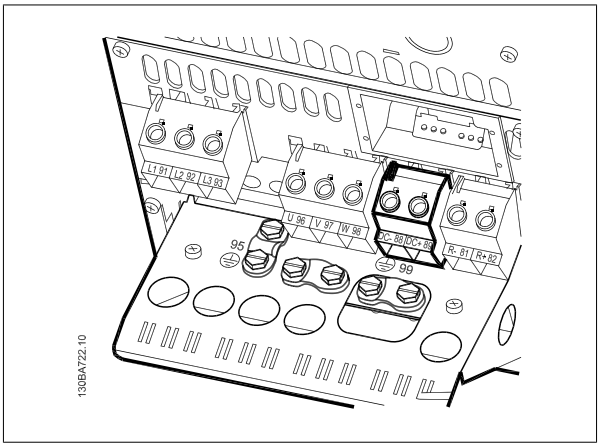



Illustration 5.14: DC bus connections for enclosure B4.

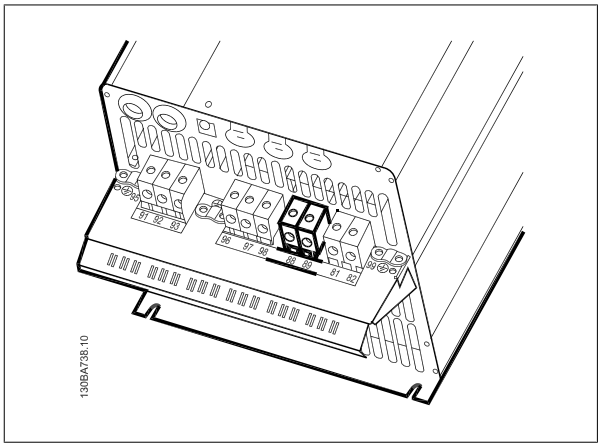



Illustration 5.15: DC bus connections for enclosure C3.

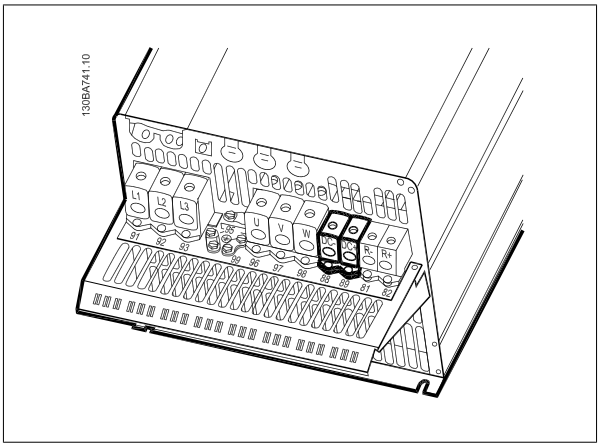



Illustration 5.16: DC bus connections for enclosure enclosure C4.

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.

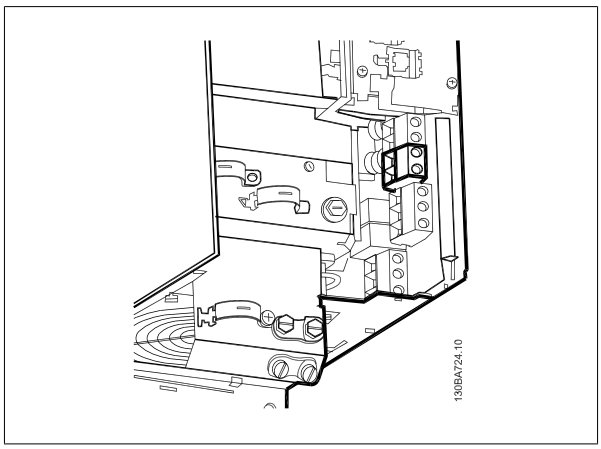



Illustration 5.17: Brake connection terminal for B3.

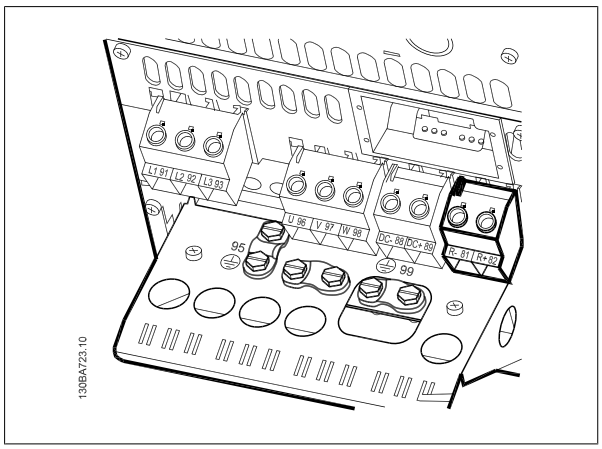



Illustration 5.18: Brake connection terminal for B4.

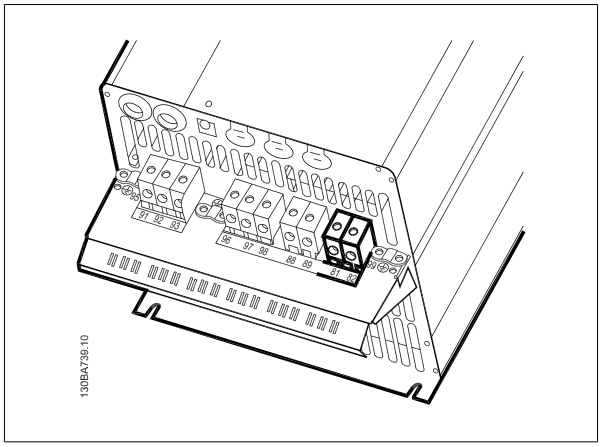



Illustration 5.19: Brake connection terminal for C3.

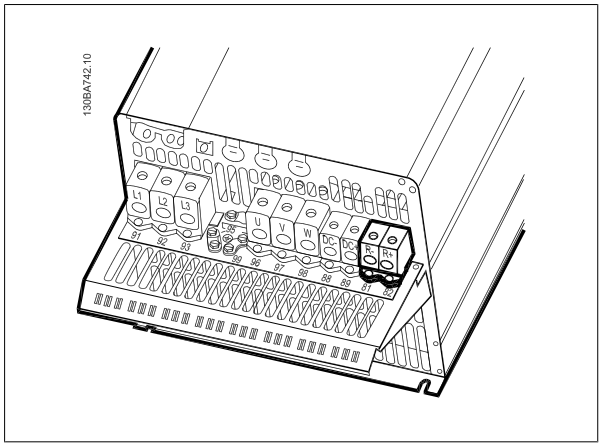



Illustration 5.20: Brake connection terminal for C4.

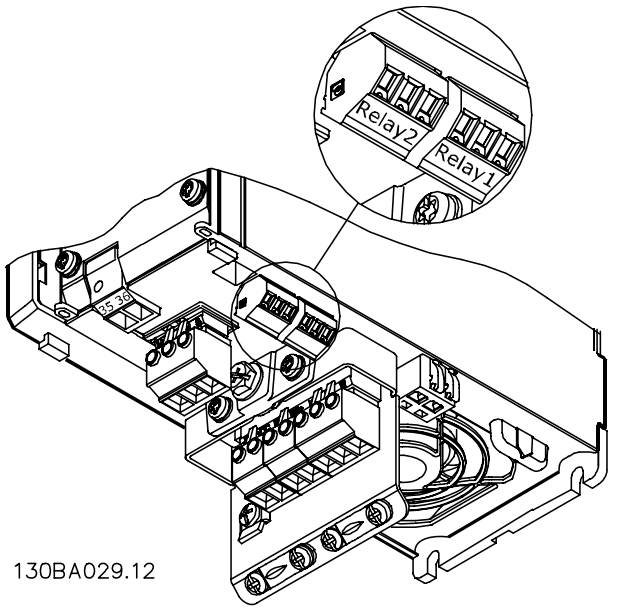
**NB!**

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.

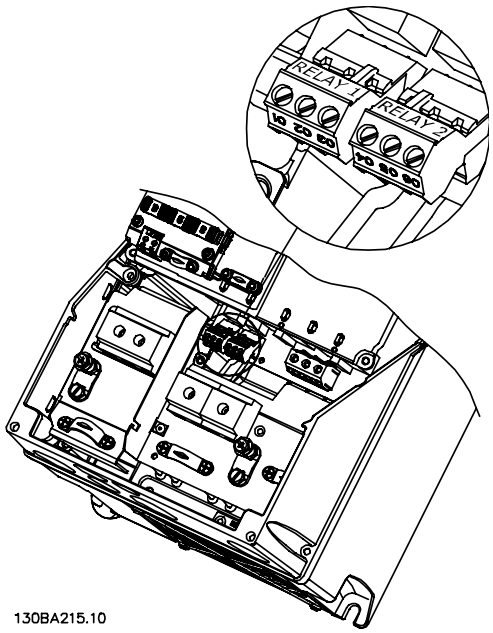
## 5.5.3. Relay Connection

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).

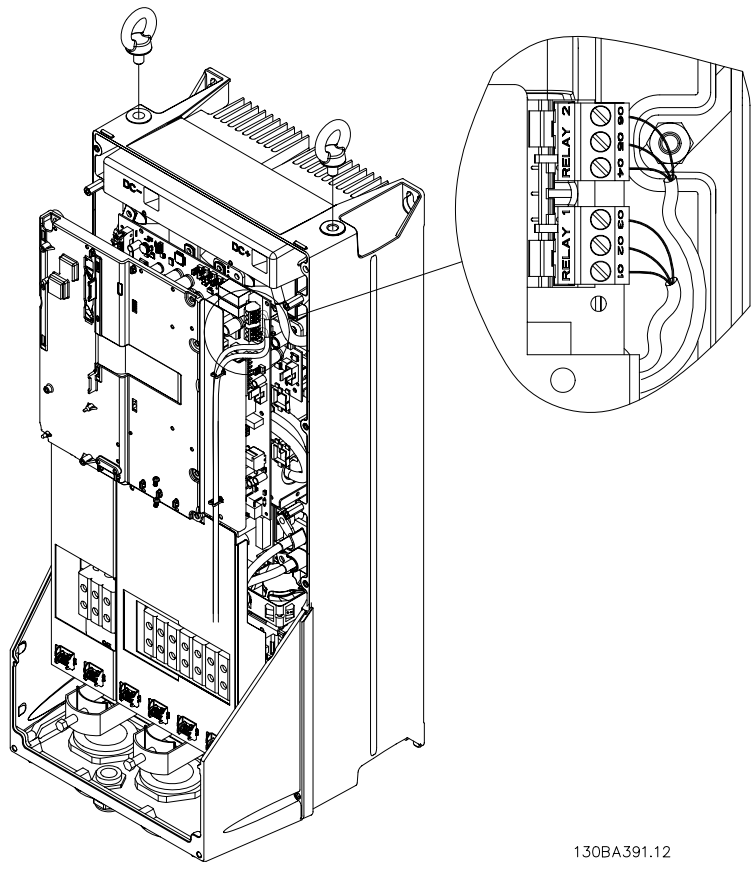



Illustration 5.21: Terminals for relay connection (C1 and C2 enclosures).

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

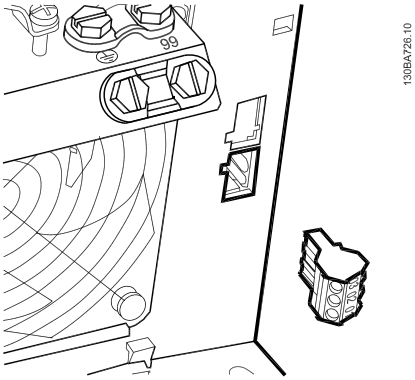



Illustration 5.22: Terminals for relay connections for B3. Only one knock-out is fitted from the factory.

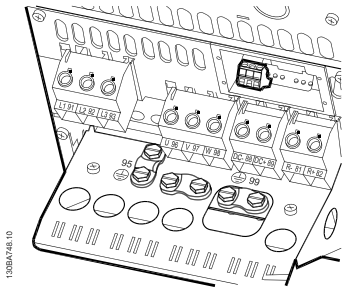



Illustration 5.23: Terminals for relay connections for B4.

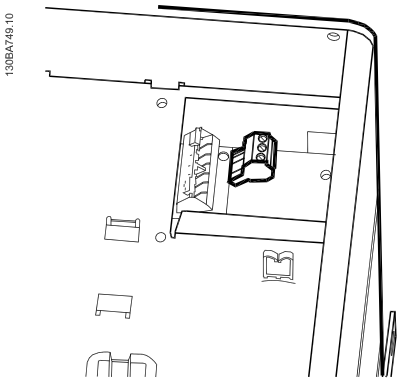



Illustration 5.24: Terminals for relay connections for C3 and C4. Located in the upper right corner of the frequency converter.

## 5.5.4. Relay Output

**Relay 1**

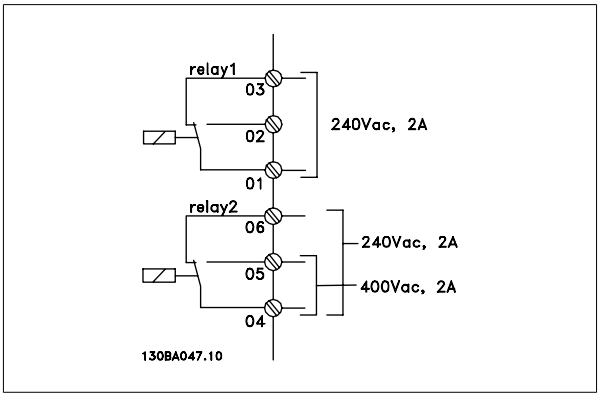
- Terminal 01: common
- Terminal 02: normal open 240 V AC
- Terminal 03: normal closed 240 V AC

**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.



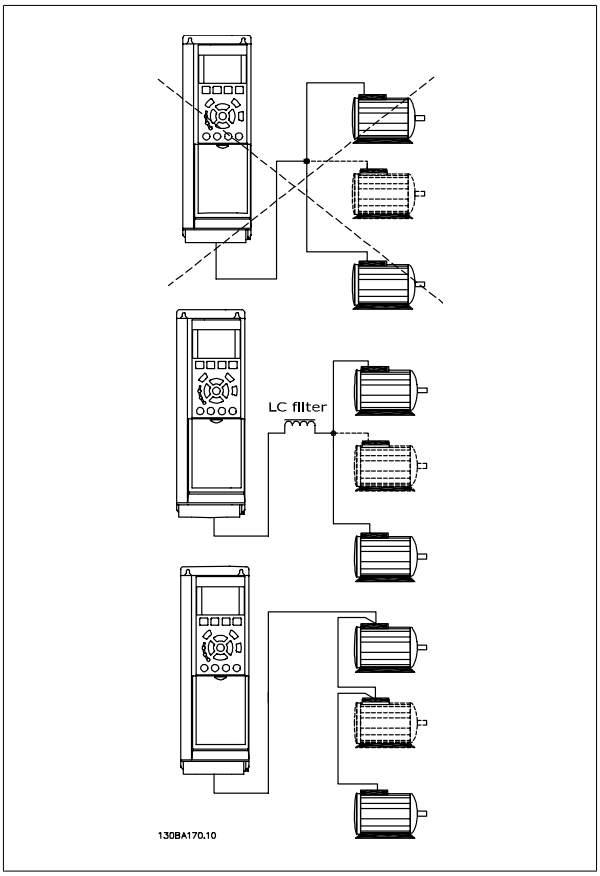

## 5.5.5. Parallel Connection of Motors

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).



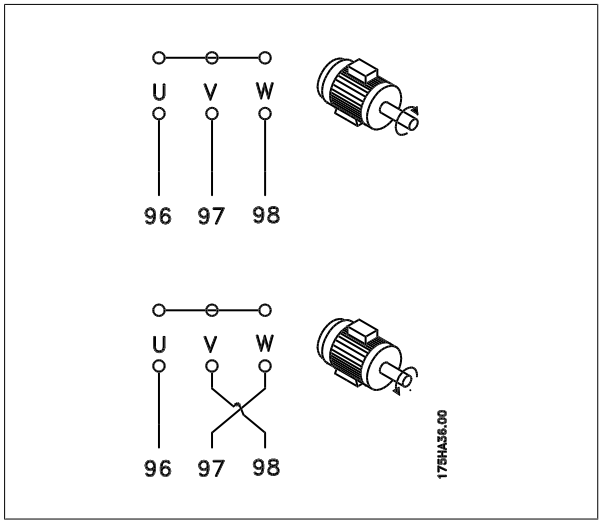
### 5.5.6. Direction of Motor Rotation

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

### 5.5.7. Motor Thermal Protection

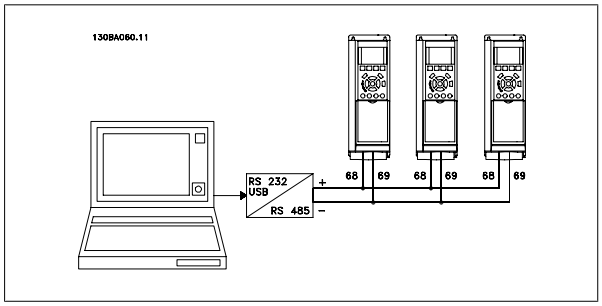
The electronic thermal relay in the frequency converter has received the UL-approval for single motor protection, when par. 1-90 Motor *Thermal Protection* is set for *ETR Trip* and par. 1-24 Motor *Current* is set to the rated motor current (see motor name plate).

## 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.

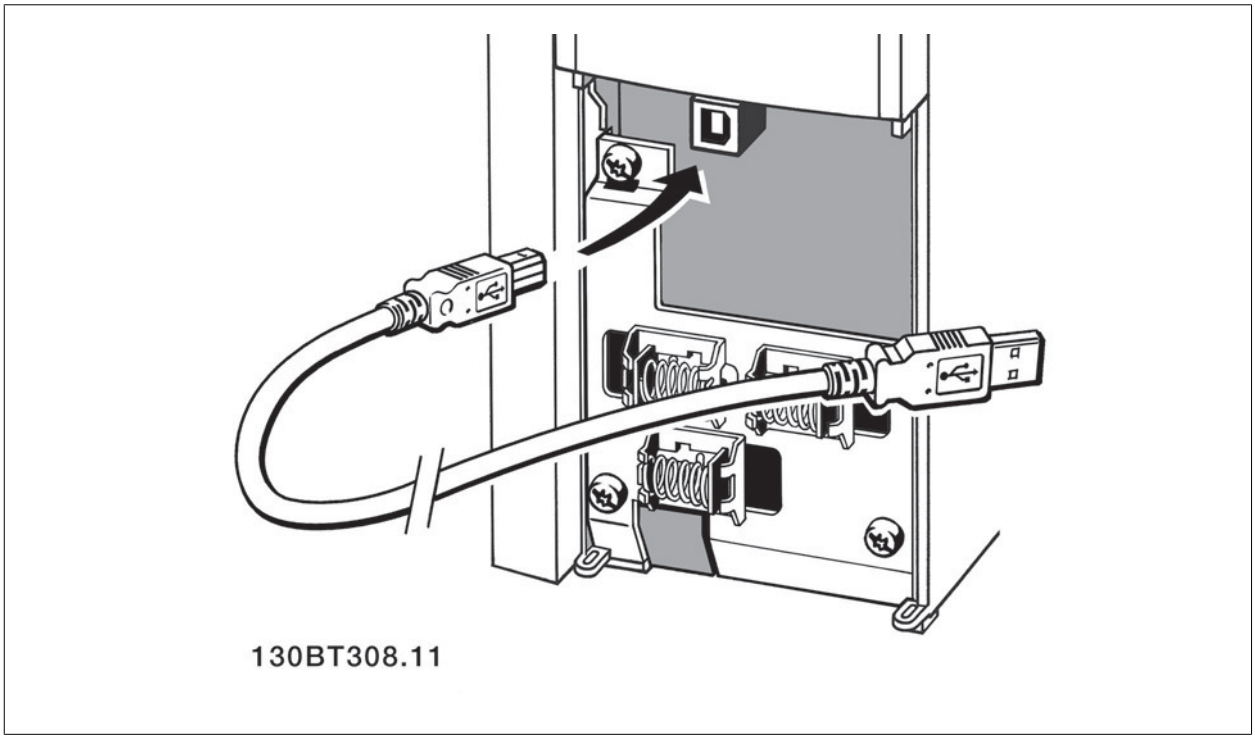
**Bus termination**
The RS485 bus must be terminated by a resistor network at both ends. For this purpose, set switch S801 on the control card for "ON".
For more information, see the paragraph *Switches S201, S202, and S801*.

**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.






**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.

5

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

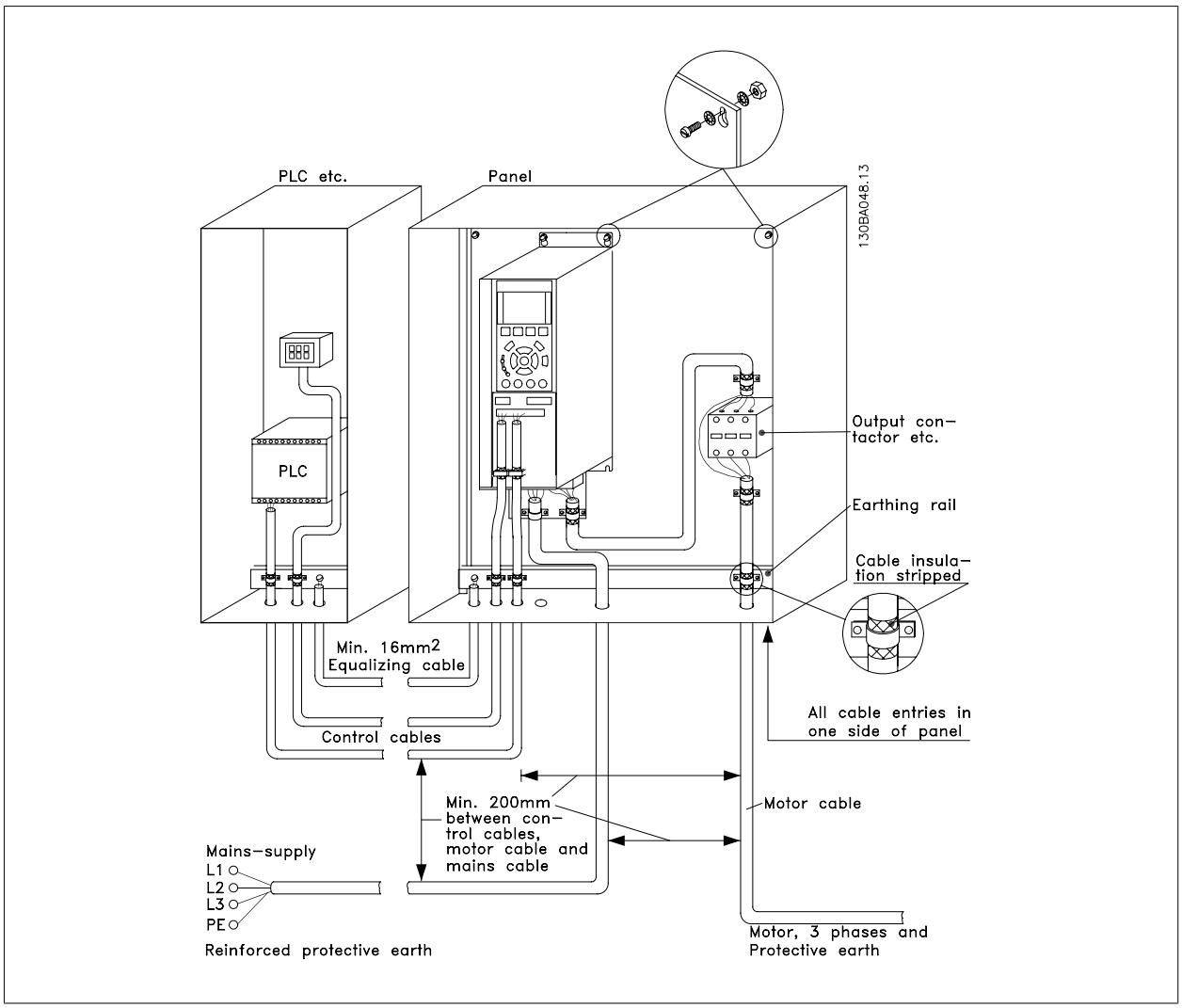



Illustration 5.25: EMC-correct electrical installation of a frequency converter in cabinet.

## 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.

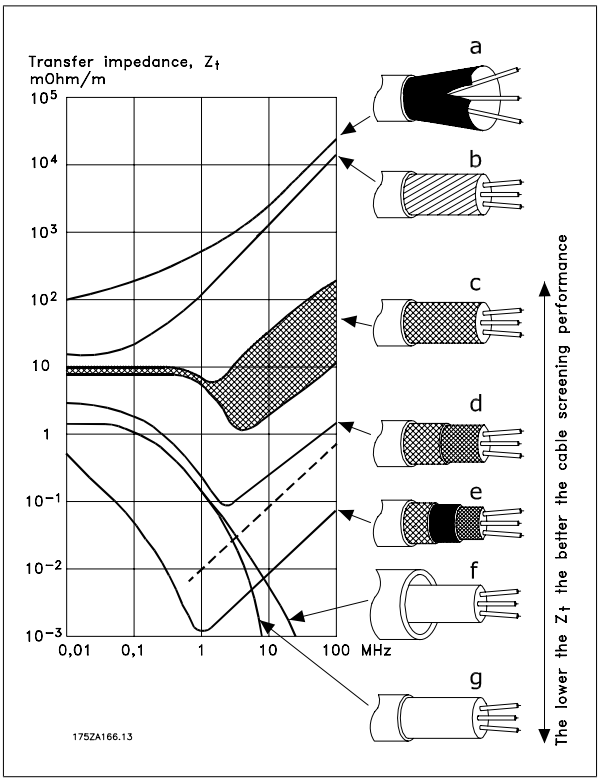
c. Single-layer braided copper wire with varying percentage screen coverage.
This is the typical reference cable.

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.

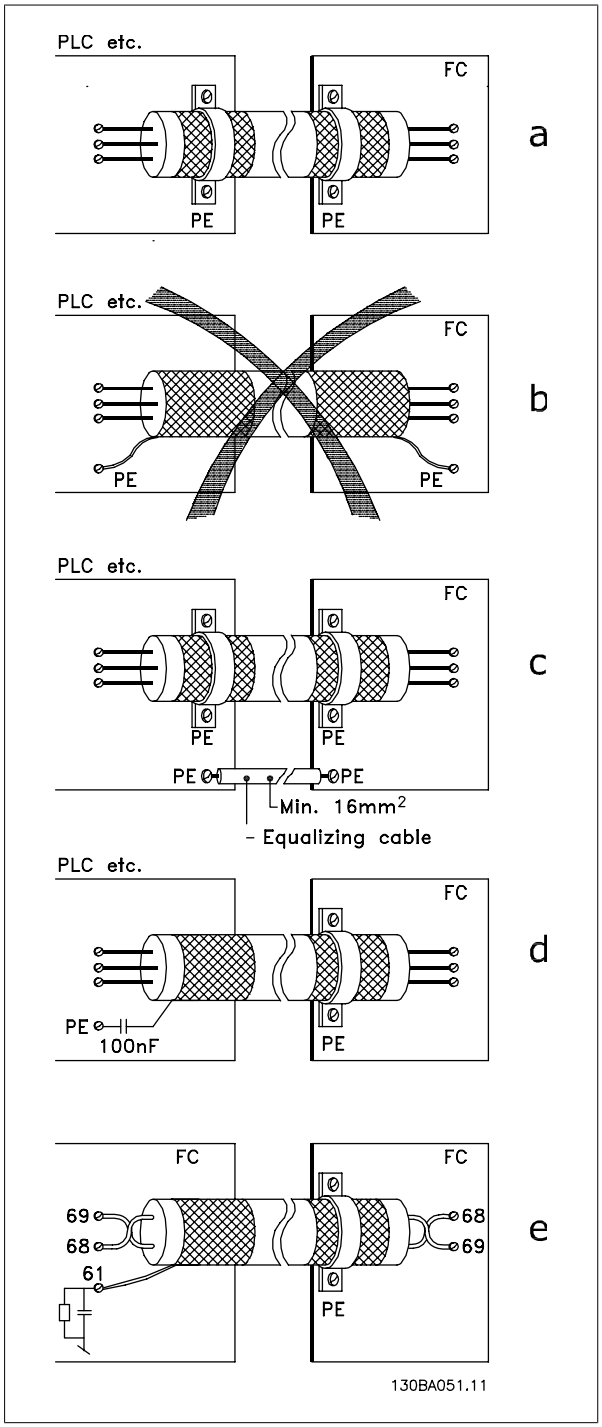
a. **Correct earthing**
Control cables and cables for serial communication must be fitted with cable clamps at both ends to ensure the best possible electrical contact.

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

# 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)

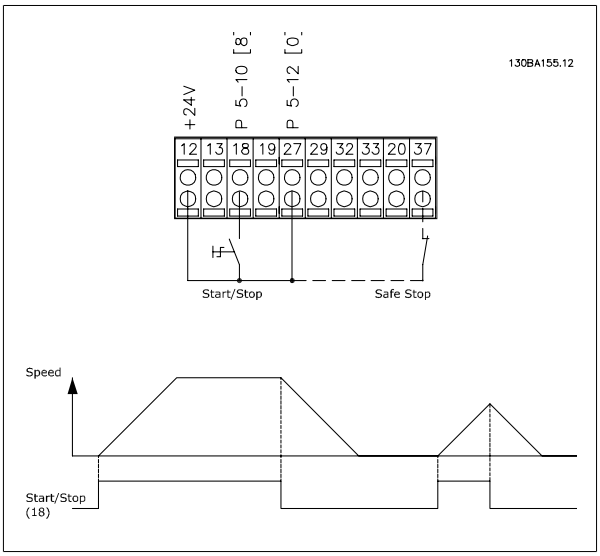



Illustration 6.1: Terminal 37: Available only with Safe Stop Function!

## 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*

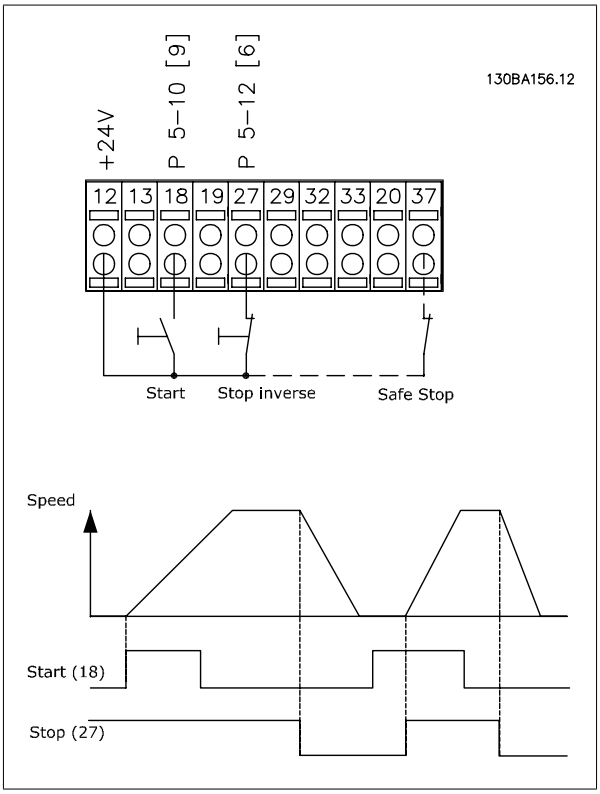



Illustration 6.2: Terminal 37: Available only with Safe Stop Function!

### 6.1.3. Potentiometer Reference

Voltage reference via a potentiometer.

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

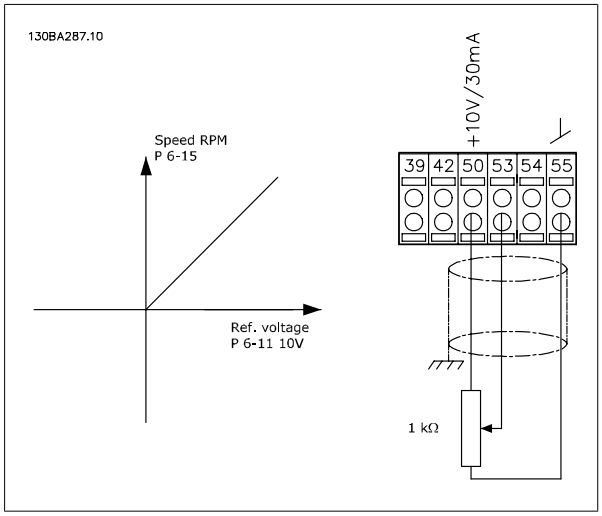
par. 6-10 Terminal *53 Low Voltage* = 0 Volt

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.

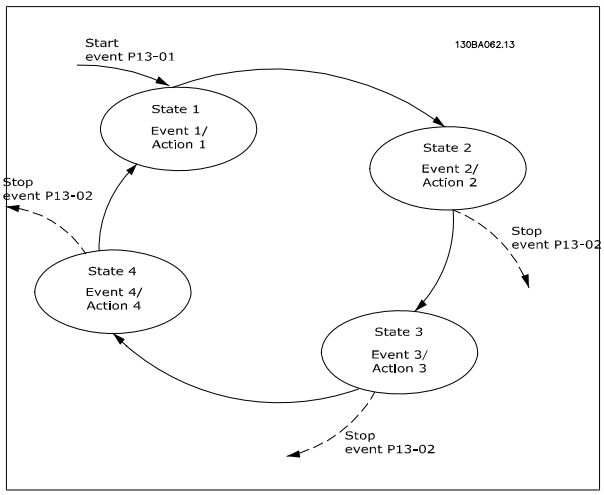
**Limitations and preconditions:**

- 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*:



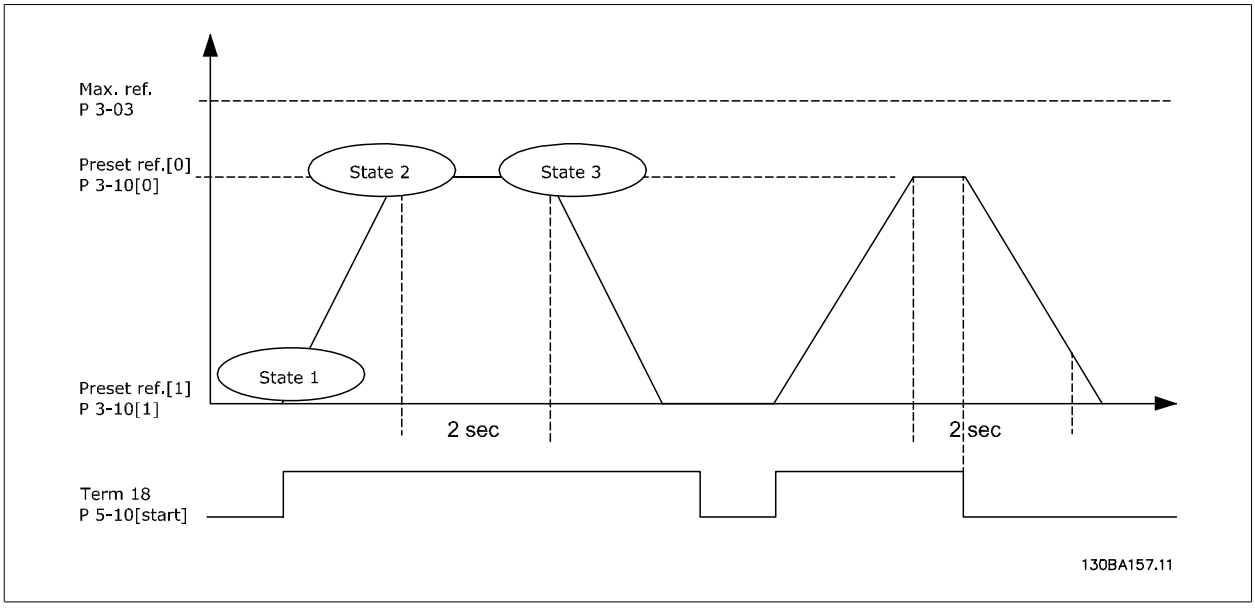

## 6.1.5. Smart Logic Control Programming

6

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.



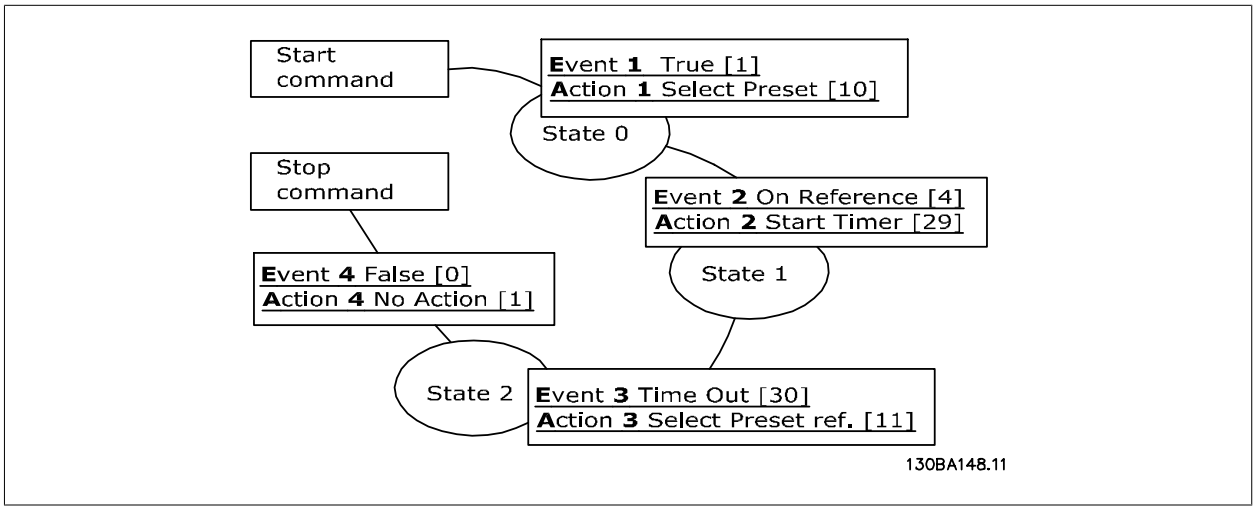

Set the ramping times in par. 3-41 Ramp *1 Ramp Up Time* and par. 3-42 Ramp *1 Ramp Down Time* to the wanted times

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

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]



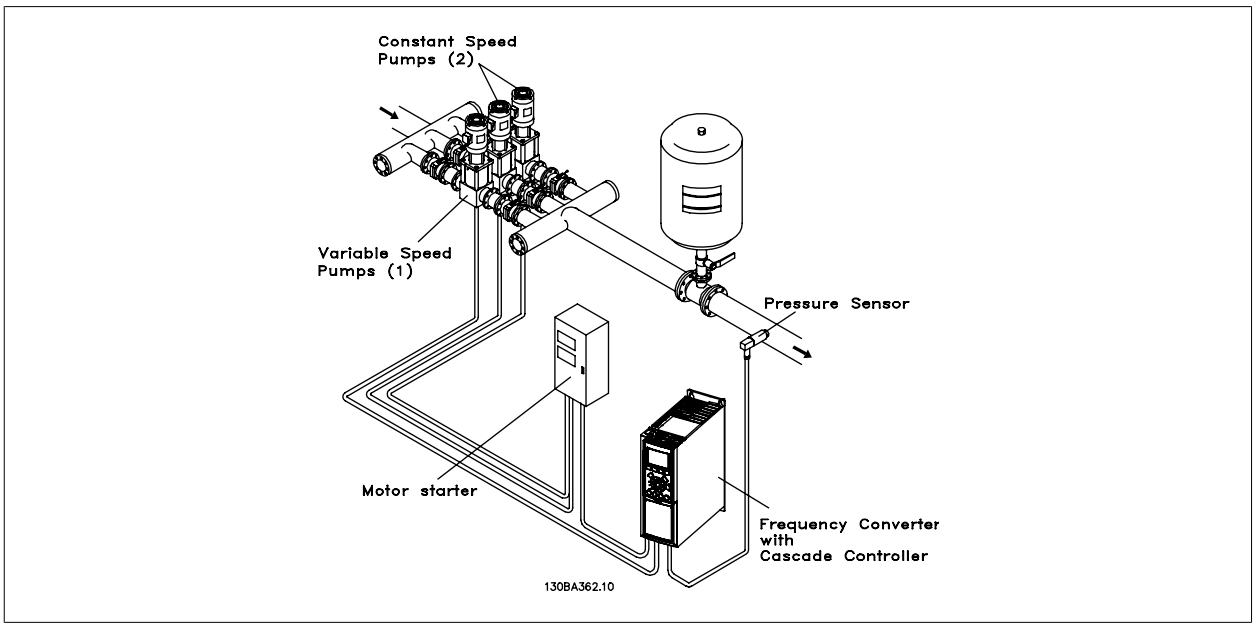

Set the Smart Logic Control in par. 13-00 SL *Controller Mode* to ON.

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.




6

**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.

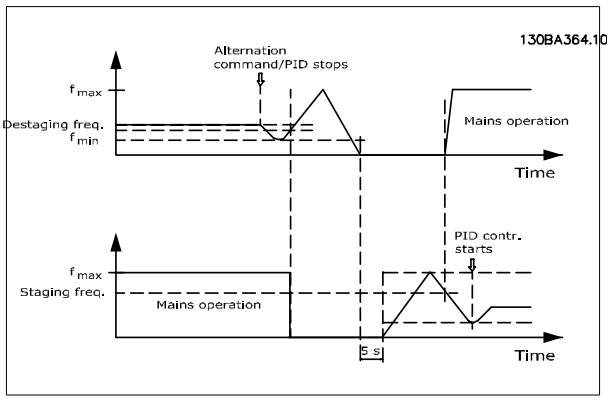
**Bandwidth Management**

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

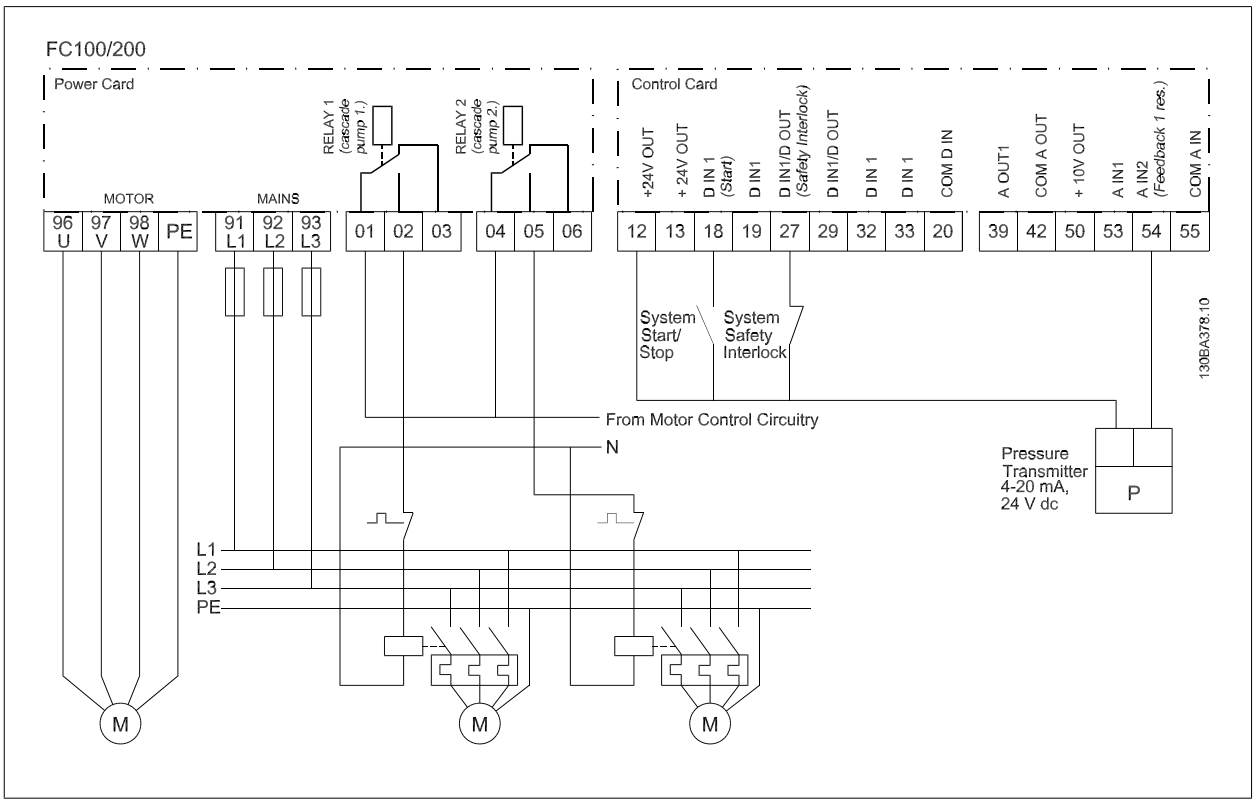
If the lead pump goes into Sleep Mode, the function is displayed on the Local Control Panel. It is possible to alternate the lead pump on a Sleep Mode condition.

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:

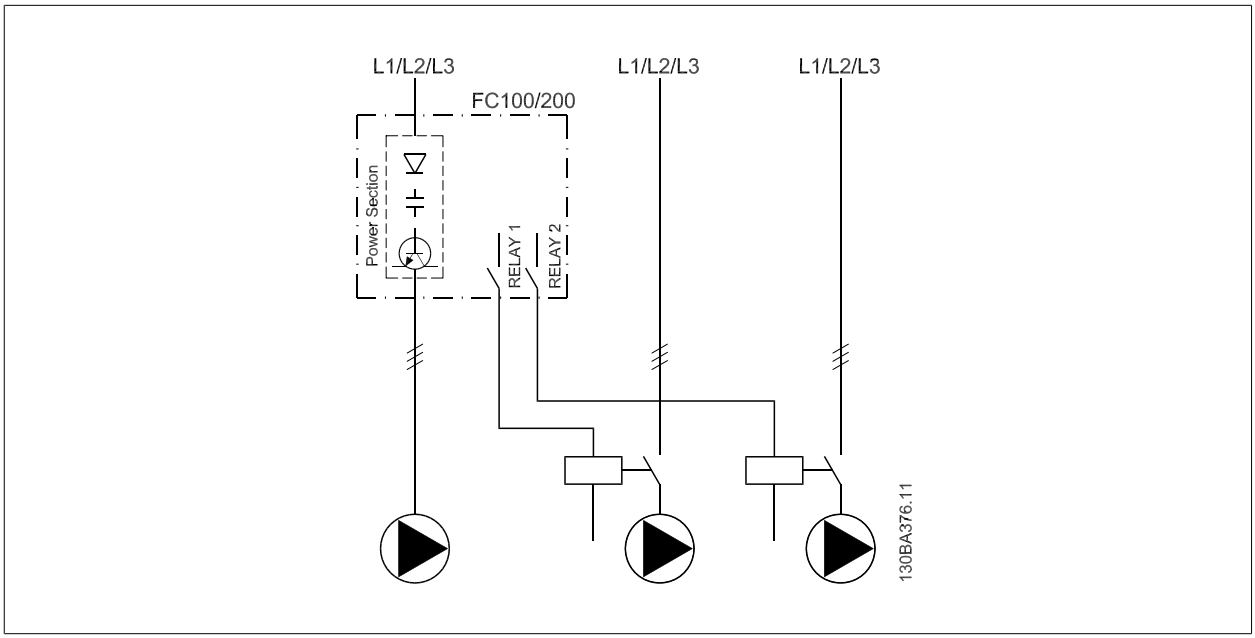
- Pumps Status, is a read out of the status for the relays assigned to each pump. The display shows pumps that are disabled, off, running on the frequency converter or running on the mains/motor starter.
- Cascade Status, is a read out of the status for the Cascade Controller. The display shows the Cascade 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

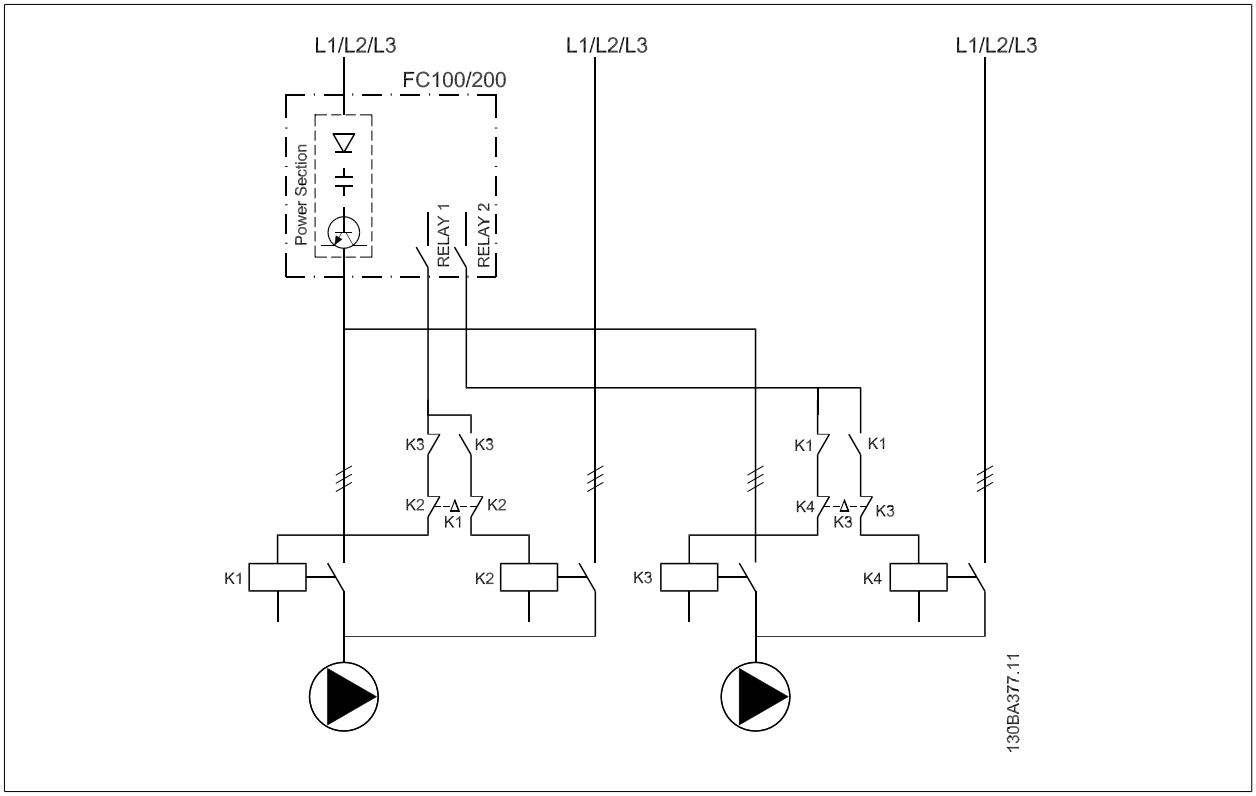
The wiring diagram shows an example with the built in BASIC cascade controller with one variable speed pump (lead) and two fixed speed pumps, a 4-20 mA transmitter and System Safety Interlock.




### 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.

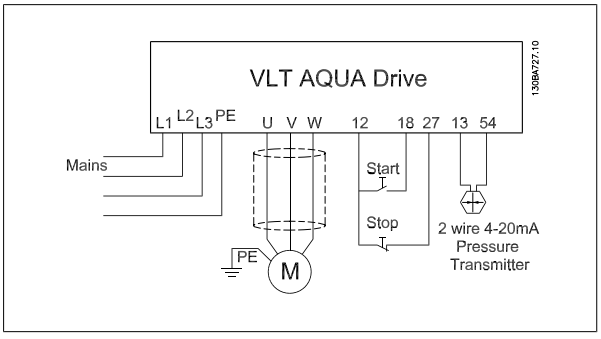
The special "can motor" is used due to the wet installation conditions. The drive needs to be designed for the system according to output current to be able to run the motor at nominal power.

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) | |

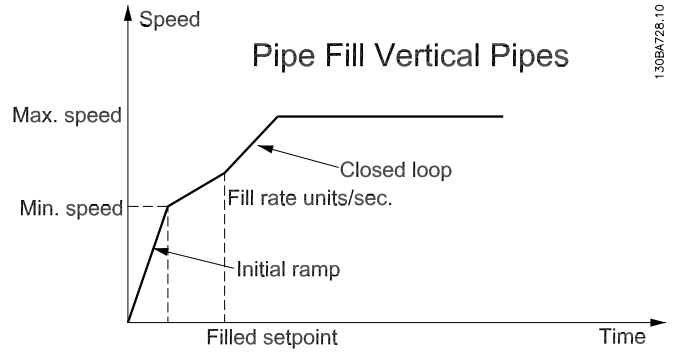



**NB!**
Note the analog input 2, (terminal (54) format must be set to mA. (switch 202).

| | | |
|---|---|---|
| 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) |




## 6.1.15. 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.

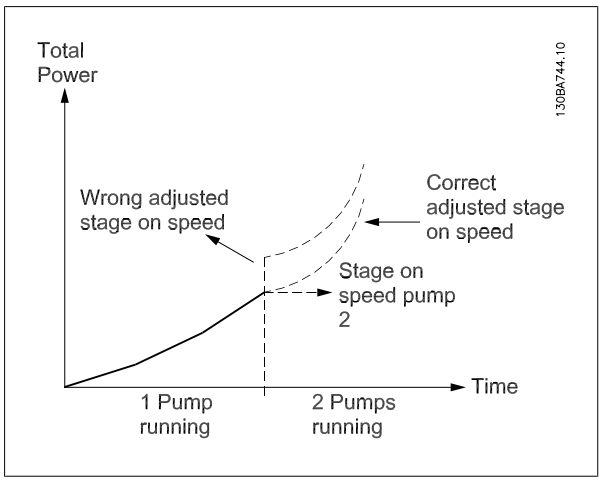



Illustration 6.3: Total power consumption.

6

| | 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**

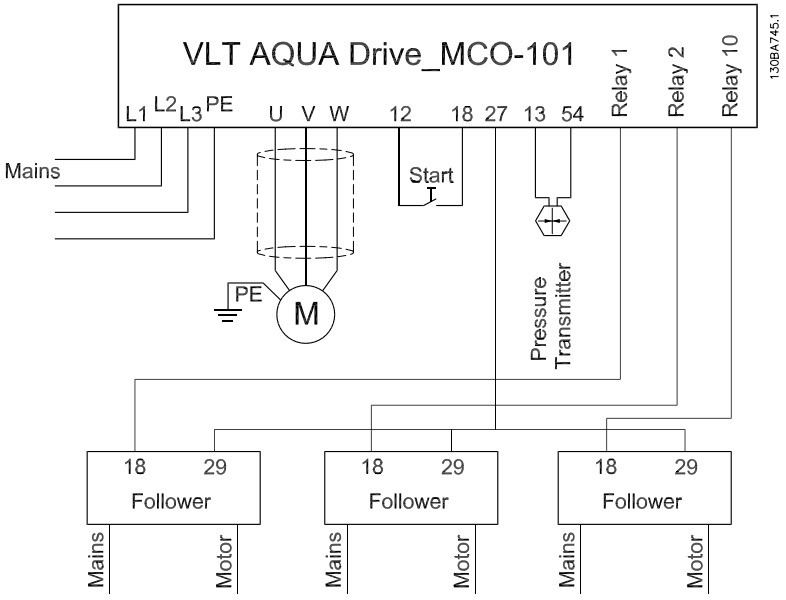



Illustration 6.4: Electrical wiring. Terminal 27 on master drive is used as pulse output reference. Terminal 29 on the follower drives is used as pulse input reference. All follower drives are connected to mains and motor the same way as the master drive symbolized with the text: *Mains* and *Motor*.

**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.



**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

### 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.

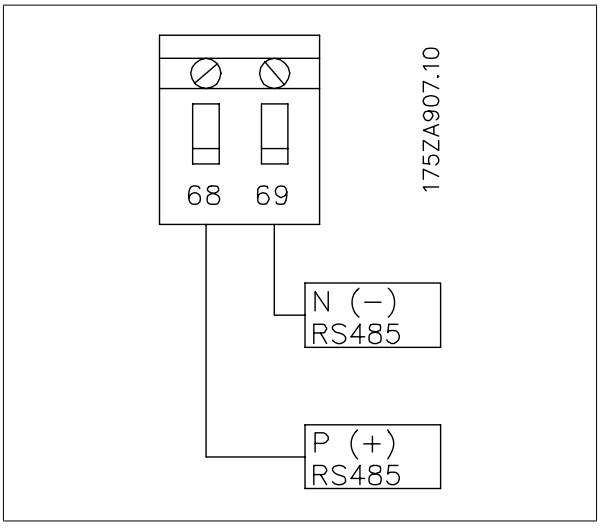
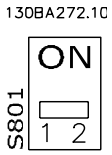



Illustration 7.1: Network Terminal Connection

### 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



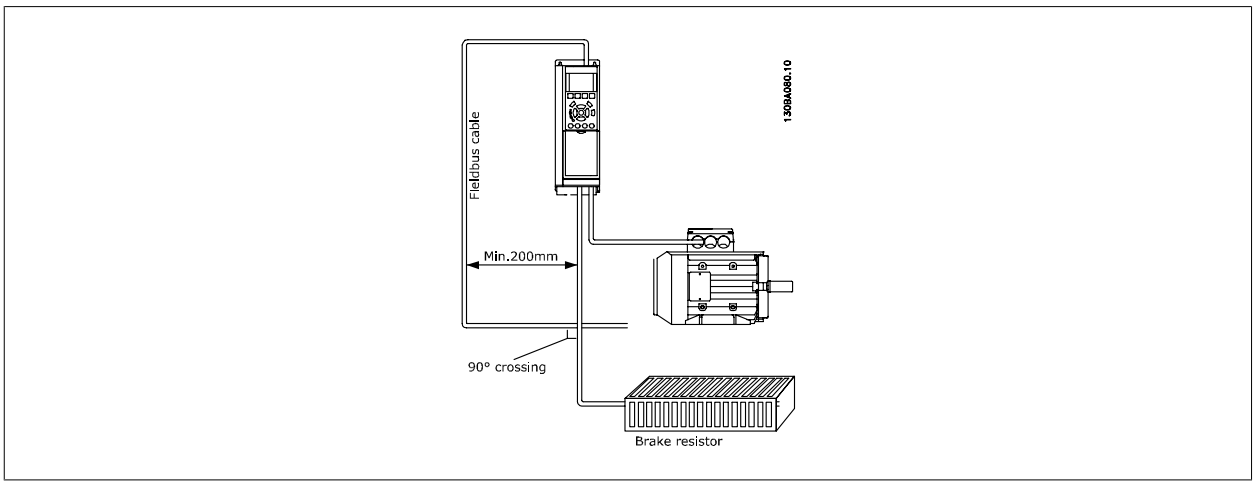
The following parameters apply to the RS-485 interface (FC-port):

| 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.

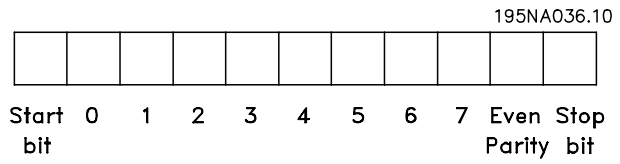
| Parameter Number | Parameter name | Setting |
|---|---|---|
| 8-30 | Protocol | FC |
| 8-31 | Address | 1 - 126 |
| 8-32 | Baud Rate | 2400 - 115200 |
| 8-33 | Parity/Stop bits | Even parity, 1 stop bit (default) |

# 7.4. FC Protocol Message Framing Structure

## 7.4.1. Content of a Character (byte)

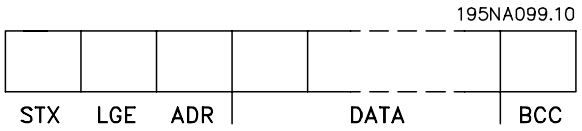
Each character transferred begins with a start bit. Then 8 data bits are transferred, corresponding to a byte. Each character is secured via a parity bit, which is set at "1" when it reaches parity (i.e. when there is an equal number of 1's in the 8 data bits and the parity bit in total). A character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






## 7.4.2. 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)

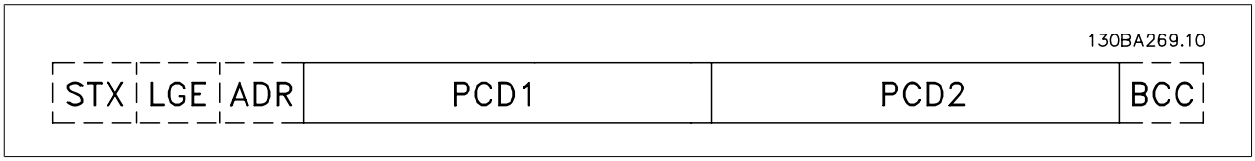
The checksum is calculated as an XOR-function. Before the first byte in the telegram is received, the Calculated Checksum is 0.

### 7.4.6. The Data Field

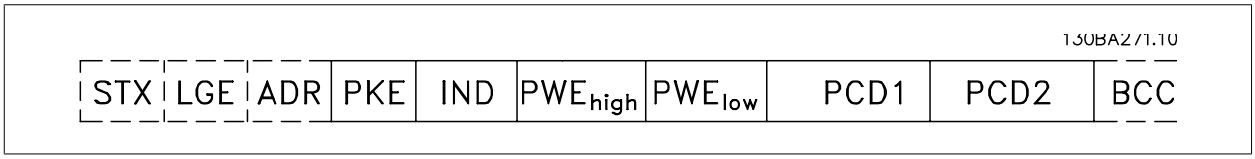
The structure of data blocks depends on the type of telegram. There are three telegram types, and the type applies for both control telegrams (master=>slave) and response telegrams (slave=>master).

The three types of telegram are:

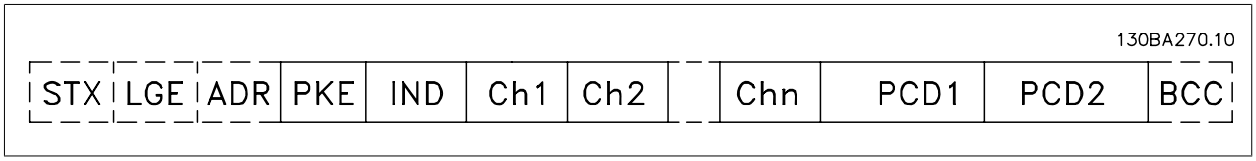
Process block (PCD):
The PCD is made up of a data block of four bytes (2 words) and contains:
- Control word and reference value (from master to slave)
- Status word and present output frequency (from slave to master).




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.

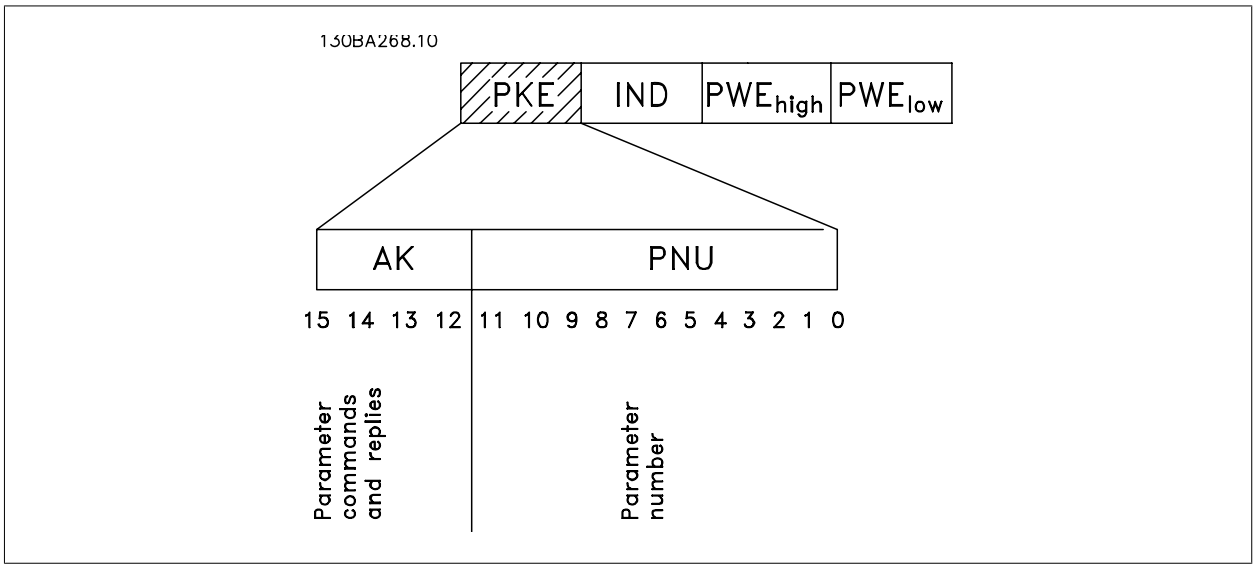


Text block:
The text block is used to read or write texts via the data block.




### 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.



## 7.4.9. 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)

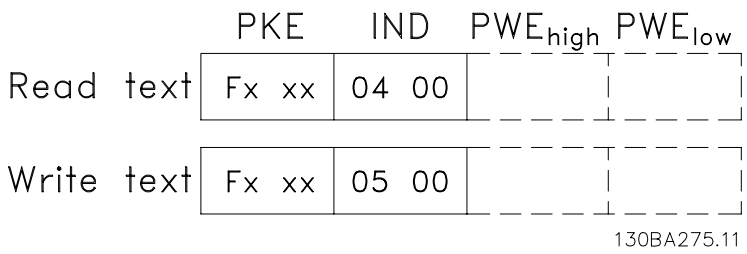
The parameter value block consists of 2 words (4 bytes), and the value depends on the defined command (AK). The master prompts for a parameter value when the PWE block contains no value. To change a parameter value (write), write the new value in the PWE block and send from the master to the slave.

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 |

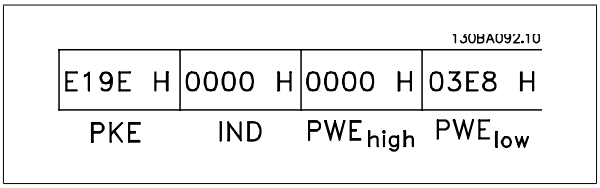
# 7.5. Examples

## 7.5.1. Writing a parameter value

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

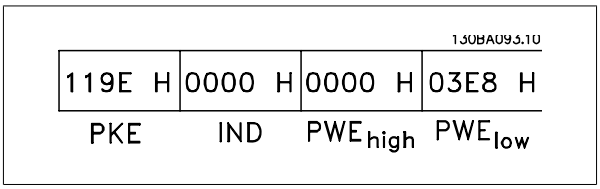
PKE = E19E Hex - Write single word in par. 4-14 Motor *Speed High Limit [Hz]*
IND = 0000 Hex
PWEHIGH = 0000 Hex
PWELOW = 03E8 Hex - Data value 1000, corresponding to 100 Hz, see Conversion.

The telegram will look like this:




Note: par. is a single word, and the parameter command for write in EEPROM is "E". Parameter number 4-14 is 19E in hexadecimal.

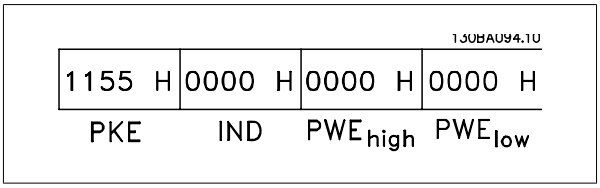
The response from the slave to the master will be:



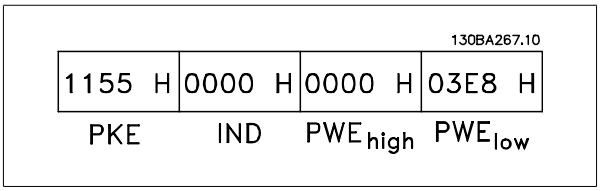

## 7.5.2. Reading a parameter value

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




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:




**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

# 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.

| Start bit | Data bit | | | | | | | | | Stop/ parity | Stop |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |

| | |
|---|---|
| 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<br>8 data bits, least significant bit sent first<br>1 bit for even/odd parity; no bit for no parity<br>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



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) | | Master to slave |
| | 0 = | Parameter changes are written to the RAM of the frequency converter | |
| | 1 = | Parameter changes are written to the RAM and EEPROM of the frequency converter. | |
| 66-65536 | Reserved | | |

| Coil | 0 | 1 |
|---|---|---|
| 01 | Preset reference LSB | |
| 02 | Preset reference MSB | |
| 03 | DC brake | No DC brake |
| 04 | Coast stop | No coast stop |
| 05 | Quick stop | No quick stop |
| 06 | Freeze freq. | No freeze freq. |
| 07 | Ramp stop | Start |
| 08 | No reset | Reset |
| 09 | No jog | Jog |
| 10 | Ramp 1 | Ramp 2 |
| 11 | Data not valid | Data valid |
| 12 | Relay 1 off | Relay 1 on |
| 13 | Relay 2 off | Relay 2 on |
| 14 | Set up LSB | |
| 15 | 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 |



## 7.8.11. 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) | - |



**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) | - |

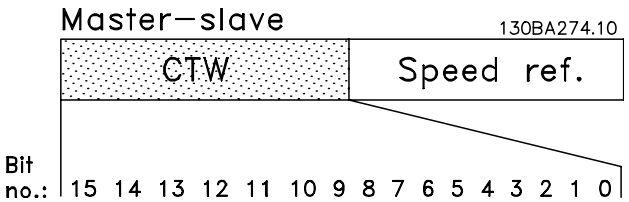
**Response**

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*.

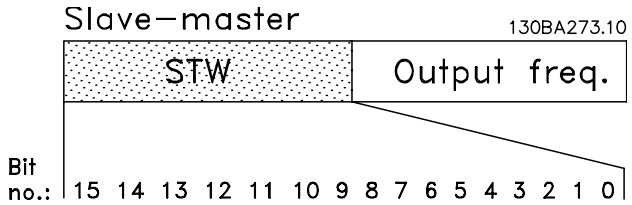
**NB!**

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.

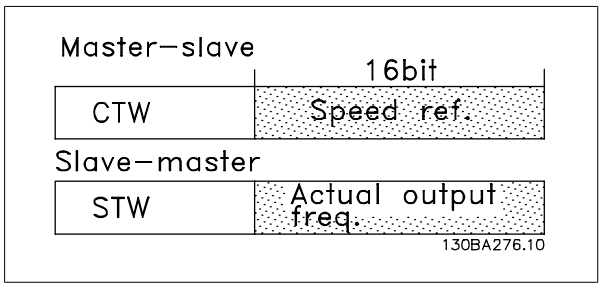
Bit 15, Timer OK/limit exceeded:
Bit 15 = '0': The timers for motor thermal protection and thermal protection are not exceeded 100%. Bit 15 = '1': One of the timers exceeds 100%.



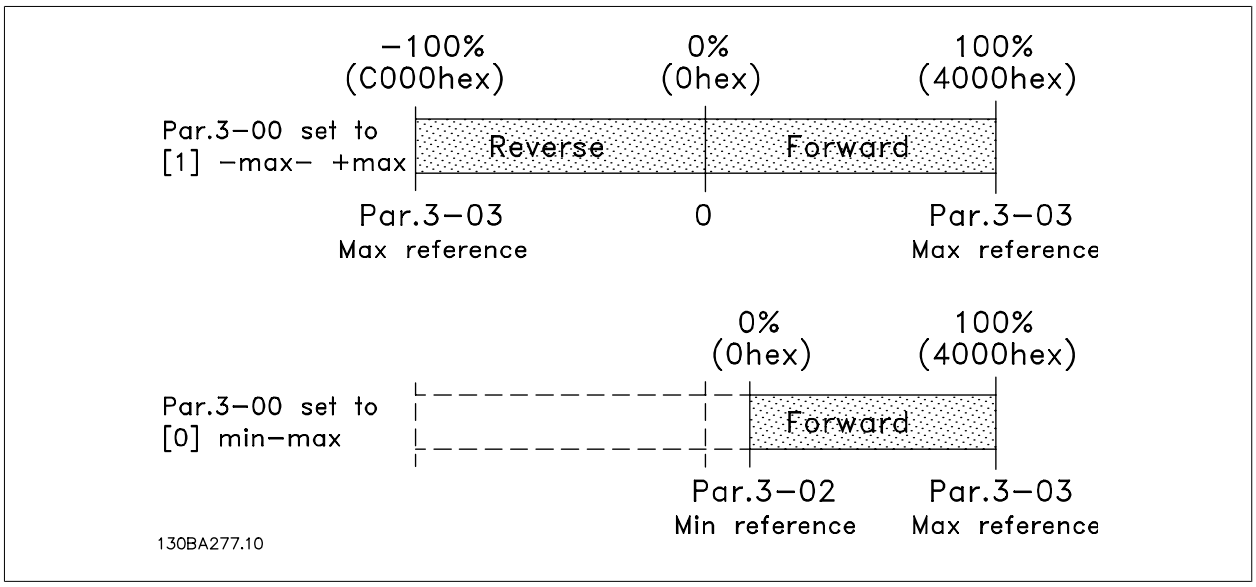
**NB!**
All bits in the STW are set to '0' if the connection between the Interbus option and the frequency converter is lost, or an internal communication problem has occurred.

### 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.

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 Word | Status |
|---|---|---|---|---|---|---|
| 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

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


## 0

0 - 10 Vdc 75
0-20 Ma 75

## 2

24 V Back-up Option Mcb 107 (option D) 73

## 4

4-20 Ma 75

## 6

60 Avm 63
6-wire Motor Terminal Block 105

## A

Abbreviations 5
Access To Control Terminals 111
Accessory Bag A2 85
Accessory Bag A3 85
Accessory Bag A5 85
Accessory Bag B1 85
Accessory Bag B2 85
Accessory Bag B3 86
Accessory Bag B4 86
Accessory Bag C1 86
Accessory Bag C2 86
Accessory Bag C3 86
Accessory Bag C4 86
Acoustic Noise 57
Aggressive Environments 15
Air Humidity 15
Aluminium Conductors 105
Ama 134, 142
Analog I/o Option Mcb 109 75
Analog I/o Selection 75
Analog Inputs 6
Analog Inputs 53
Analog Inputs 7
Analog Output 54
Analog Outputs - Terminal X30/5+8 71
Analog Voltage Inputs - Terminal X30/10-12 71
Analogue Input 145
Analogue Output Format Of 4-20ma 143
Automatic Adaptations To Ensure Performance 68
Automatic Motor Adaptation 134
Automatic Motor Adaptation (ama) 116
Available Literature For Vlt Aqua Drive 4
Awg 45

## B

Backplate 85
Basic Cascade Controller 77
Basic Settings 145
Basic Wiring Example 113
Battery Back-up Of Clock Function 75
Brake Connection Option 119
Brake Function 37
Brake Power 7, 38
Brake Resistor 37
Brake Resistor Cabling 38
Brake Resistors 80

Brake Resistors 80
Branch Circuit Protection 106
Building Management System 75

## C

Cable Clamp 130
Cable Clamps 127
Cable Length And Cross-section 105
Cable Lengths And Cross Sections 53
Can Motor 142
Ce Conformity And Labelling 12
Clockwise Rotation 124
Closed Loop (pid) Controller 22
Coasting 170
Coasting 5, 169
Conducted Emission. 33
Connection To Mains 102
Constant Pressure 143
Constant Pressure Water Systems 143
Constant Torque Applications (ct Mode) 67
Control Board Vlt Aqua Drive 85
Control Cable Length 114
Control Cables 127
Control Cables 115
Control Cables 114
Control Card Performance 56
Control Card, +10 V Dc Output 55
Control Card, 24 V Dc Output 55
Control Card, Rs-485 Serial Communication: 53
Control Card, Usb Serial Communication 56
Control Characteristics 56
Control Structure 20
Control Terminals 112
Control Word 168
Cooling 67
Copyright, Limitation Of Liability And Revision Rights 3
Cos Φ Compensation 19

## D

Data Types Supported By Vlt Aqua 154
Database Error Codes 160
Dc Brake 168
Dc Bus Connection 118
Dc Link Connector 85
Decoupling Plate 104
Definitions 5
Derating For Ambient Temperature 63
Derating For Installing Long Motor Cables Or Cables With Larger Cross-section 67
Derating For Low Air Pressure 66
Derating For Running At Low Speed 67
Devicenet 85
Digital Inputs - Terminal X30/1-4 71
Digital Inputs: 54
Digital Output 54
Digital Outputs - Terminal X30/5-7 71
Direction Of Motor Rotation 124
Display Settings - Follower Drives 145
Display Settings - Master Drive 145
Disposal Instruction 12
Drive Configurator 83
Du/dt Filters 81

## E

Earth Connection 102
Earth Leakage Current 127
Earth Leakage Current 36

Earthing 130
Earthing Of Screened/armoured Control Cables 130
Easy Installation 143
Efficiency 57
Electrical Installation 105, 114
Electrical Installation - Emc Precautions 127
Electrical Installation, Control Cable Terminals 112
Electrical Wiring 144
Electrical Wiring 142
Emc Directive 89/336/eec 14
Emc Test Results 33
Emission Requirements 32
Energy Saving 143
Energy Savings 17
Energy Savings 17
Equalising Cable, 130
Ethernet Ip 85
Etr 123
Example Of Closed Loop Pid Control 25
Extended Cascade Controller Option 77
External 24 V Dc Supply 74
Extreme Running Conditions 38

## F

Fan A2 85
Fan A3 85
Fan A5 85
Fan B1 85
Fan B2 85
Fan B3 85
Fan B4 85
Fan C1 85
Fan C2 85
Fan C3 85
Fan C4 85
Fc Profile 168
Feedback Sensor 144
Final Set-up And Test 116
Fixed Speed Pump 77
Follower Drive 77
Freeze Output 5
Function Codes Supported By Modbus Rtu 160
Fuses 106

## G

General Aspects Of Emc Emissions 31
General Aspects Of Harmonics Emission 33
General Warning 4
Gland/conduit Entry - Ip21 (nema 1) And Ip54 (nema12) 99

## H

Harmonic Filters 86
Harmonics Emission Requirements 34
High Power Terminal Block Connections 105
High Voltage Test 126
Hold Output Frequency 169
How To Connect A Pc To The Vlt Aqua Drive 125

## I

I/os For Set Point Inputs 75
Immunity Requirements 34
Index (ind) 153
Input Filters 81
Installation At High Altitudes 11
Intermediate Circuit 37, 38, 57, 58

Introduction To The Extended Cascade Controller 77
Ip 21/4x Top/type 1 Kit 85
Ip 21/ip 4x/ Type 1 Enclosure Kit 81
Ip 21/type 1 Enclosure Kit 81
Ip55 Or Even Ip66 143

## J

Jog 5
Jog 169

## L

Laws Of Proportionality 17
Lcp 5, 8, 20
Lcp 101 85
Lcp Cable 85
Lcp Kit 85
Lead Pump Alternation Wiring Diagram 140
Leakage Current 36
Load Drive Settings: 126
Local (hand On) And Remote (auto On) Control 20

## M

Mains Plug Connector 102
Mains Supply 9
Mains Supply 45, 51
Mains Supply (l1, L2, L3) 53
Mains Supply 1 X 200 - 240 Vac 44
Manual Pid Adjustment 27
Master Drive 143
Master Drive 77
Master/follower Operation Application 143
Mca 101 85
Mca 104 85
Mca 108 85
Mcb 101 85
Mcb 105 85
Mcb 105 Option 71
Mcb 107 85
Mcb 109 85
Mco 101 77, 85
Mco 102 85
Mct 10 125
Mct 10 Set-up Software 125
Mct 31 126
Mechanical Dimensions 95, 97
Mechanical Dimensions High Power 95
Mechanical Installation 93
Mechanical Mounting 98
Moment Of Inertia 38
Motor Cables 127
Motor Cables 105
Motor Connection 103
Motor Name Plate 116
Motor Output 53
Motor Parameters 134
Motor Phases 38
Motor Protection 53, 123
Motor Rotation 124
Motor Thermal Protection 171
Motor Thermal Protection 39, 124
Motor Voltage 58
Mounting Of Decoupling Plate. 104
Multi-zone Control 75
Musec 144

## N

Name Plate Data 116
Ni1000 Temperature Sensor 75
Non Ul Compliance 106

## O

Open Loop Mode 77
Optimise The Energy Consumption 146
Options And Accessories 68
Ordering Numbers 83
Ordering Numbers: Brake Resistors 90
Ordering Numbers: Du/dt Filters, 380-480 Vac 89
Ordering Numbers: Harmonic Filters 86
Ordering Numbers: Options And Accessories 85
Ordering Numbers: Sine Wave Filter Modules, 200-500 Vac 88
Output Filters 81
Output Performance (u, V, W) 53
Outputs For Actuators 75
Over-current Protection 106

## P

Parallel Connection Of Motors 123
Parameter Settings 145
Parameter Values 161
Pay Back Period 17
Pc Software Tools 125
Peak Voltage On Motor 58
Pelv - Protective Extra Low Voltage 35
Plc 130
Potentiometer Reference 134
Power Factor 9
Power Factor Correction 19
Pressure Transmitter 144
Principle Diagram 75
Prioritize The Pumps 146
Profibus 85
Profibus Dp-v1 125
Profibus D-sub 9 85
Profibus Top Entry Kit 85
Programming Order 26
Protection 15, 35, 36
Protection And Features 53
Protocol Overview 149
Pt1000 Temperature Sensor 75
Public Supply Network 34
Pulse Inputs 55
Pulse Start/stop 133
Pulse Width Modulation 63
Pump Staging With Lead Pump Alternation 137

## R

Radiated Emission 33
Rated Motor Speed 6
Rcd 8, 36
Real-time Clock (rtc) 76
Reference Handling 28
Relay Connection 120
Relay Option Mcb 105 71
Relay Output 122
Relay Outputs 55
Removal Of Knockouts For Extra Cables 99
Residual Current Device 36, 131
Rise Time 58
Rs 485 Bus Connection 124

Rs-485 147

## S

Safe Stop Commissioning Test 118
Safe Stop Installation 117
Safe Stop Operation (optional) 41
Safety Earth Connection 127
Safety Note 11
Safety Regulations 11
Safety Requirements Of Mechanical Installation 98
Save Drive Settings: 125
Screened/armoured 115
Screening Of Cables 105
Serial Communication 56, 130
Serial Communication Port 6
Set Speed Limit And Ramp Time 117
Settings For The Follower Drives 146
Settings For The Master Drive 145
Sfavm 63
Short Circuit Protection 106
Side-by-side Installation 98
Sine-wave Filter 104
Sine-wave Filter 142
Sine-wave Filters 81
Smart Logic Control 134
Soft-starter 19
Software Version 144
Software Version And Approvals 12
Software Versions 86
Speed Instead Of Feedback 143
Stage Off Speed [hz] 144
Stage On And Off Speed 144
Stage On And Stage Off 144
Stage On Speed [hz] 144
Star/delta Starter 19
Start/stop 133
Stator Frequency Asyncron Vector Modulation 63
Status Word 170
Submersible Pump 142
Successful Ama 117
Surroundings 56
Switch S201 145
Switches S201, S202, And S801 115
Switching Frequency 105
System Status And Operation 138

## T

Terminal 27 144
Terminal 29 144
Terminal 37 41
Terminal Blocks 85
The Clear Advantage - Energy Savings 16
The Emc Directive (89/336/eec) 13
The Low-voltage Directive (73/23/eec) 13
The Machinery Directive (98/37/eec) 12
Thermistor 9
Torque Characteristics 53
Transmitter/sensor Inputs 75
Tuning The Drive Closed Loop Controller 27
Type Code String 84

## U

Ul Fuses 200 - 240 V 109
Unsuccessful Ama 117
Usb Connection 112
Use Of Emc-correct Cables 129

## V

Variable (quadratic) Torque Applications (vt) 67
Variable Control Of Flow And Pressure 18
Variable Speed Pumps. 77
Varying Flow Over 1 Year 17
Vibration And Shock 15
Vlt Extended Cascade Controller Option Mcb-101 143
Voltage Level 54
Vvcplus 9

## W

Warning Against Unintended Start 11
Weak Pipe System 143
What Is Ce Conformity And Labelling? 12
What Is Covered 13

## Z

Ziegler Nichols Tuning Method 27