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## 1 How to Read this Design Guide

# 1

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

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

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Danfoss 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 DriveFC 200**

- VLT® AQUA Drive Instruction Manual MG.20.Mx.yy provides the necessary information for getting the drive up and running.
- VLT® AQUA Drive High Power Instruction Manual MG.20.Px.yy provides the necessary information for getting the HP drive up and running.
- VLT® AQUA Drive Design Guide MG.20.Nx.yy contains all the technical information about the drive and customer design and applications.
- VLT® AQUA Drive Programming Guide MN.20.Ox.yy provides information on how to program 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
- Output Filters Design Guide MG.90.Nx.yy
- VLT® AQUA Drive FC 200 Cascade Controller MI.38.Cx.yy
- Application Note MN20A102: Submersible Pump Application
- Application Note MN20B102: Master/Follower Operation Application
- Application Note MN20F102: Drive Closed-loop and Sleep Mode
- 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

Danfoss technical literature is also available online at

[www.danfoss.com/BusinessAreas/DrivesSolutions/Documentations/Technical+Documentation.htm](http://www.danfoss.com/BusinessAreas/DrivesSolutions/Documentations/Technical+Documentation.htm).

**1.1.3 Symbols**

Symbols used in this guide.

**NOTE!**

Indicates something to be noted by the reader.



Indicates a general warning.



Indicates a high-voltage warning.

\*

Indicates a default setting

### 1.1.4 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                          | Adjustable frequency drive |
| Gram                           | g                          |
| Hertz                          | Hz                         |
| Kilohertz                      | kHz                        |
| Local Control Panel            | LCP                        |
| Meter                          | m                          |
| Millihenry Inductance          | mH                         |
| Milliampere                    | mA                         |
| Millisecond                    | ms                         |
| Minute                         | min                        |
| Motion Control Tool            | MCT                        |
| Nanofarad                      | nF                         |
| Newton Meters                  | Nm                         |
| Nominal motor current          | $I_{M,N}$                  |
| Nominal motor frequency        | $f_{M,N}$                  |
| Nominal motor power            | $P_{M,N}$                  |
| Nominal motor voltage          | $U_{M,N}$                  |
| 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                   | $T_{LIM}$                  |
| Volt                           | V                          |

### 1.1.5 Definitions

#### Drive:

$I_{VLT,MAX}$

The maximum output current.

$I_{VLT,N}$

The rated output current supplied by the adjustable frequency drive.

$U_{VLT,MAX}$

The maximum output voltage.

1

Input:

|                                                                                                                                                                                                                                |                                                                                                |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|
| <u>Control command</u><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. |
| Group 2                                                                                                                                                                                                                        | Start, Pulse start, Reversing, Start reversing, Jog and Freeze output                          |

Motor:

f<sub>JOG</sub>  
The motor frequency when the jog function is activated (via digital terminals).

f<sub>M</sub>  
The motor frequency.

f<sub>MAX</sub>  
The maximum motor frequency.

f<sub>MIN</sub>  
The minimum motor frequency.

f<sub>M,N</sub>  
The rated motor frequency (nameplate data).

I<sub>M</sub>  
The motor current.

I<sub>M,N</sub>  
The rated motor current (nameplate data).

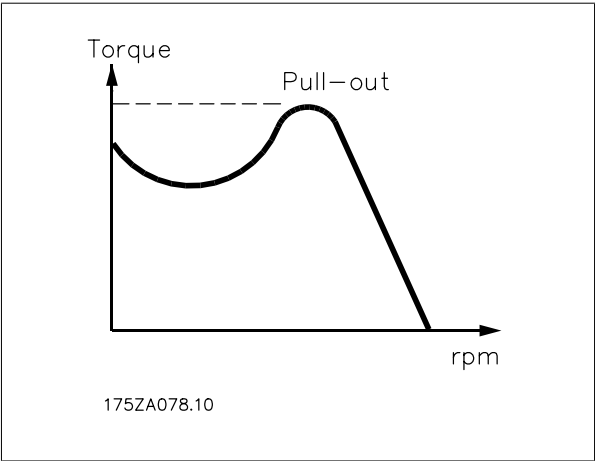
n<sub>M,N</sub>  
The rated motor speed (nameplate data).

P<sub>M,N</sub>  
The rated motor power (nameplate data).

T<sub>M,N</sub>  
The rated torque (motor).

U<sub>M</sub>  
The instantaneous motor voltage.

U<sub>M,N</sub>  
The rated motor voltage (nameplate data).



$\eta_{VLT}$ 

The efficiency of the adjustable frequency drive 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<sub>MAX</sub>

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

Ref<sub>MIN</sub>

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

**Miscellaneous:**Analog Inputs

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

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 braking energy generated in regenerative braking. This regenerative braking energy 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.

**1**Digital Inputs

The digital inputs can be used for controlling various adjustable frequency drive functions.

Digital Outputs

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

DSP

Digital Signal Processor.

Relay Outputs:

The adjustable frequency 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)

Initializing

If initializing is carried out (par. 14-22), the programmable parameters of the adjustable frequency drive 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 non-periodic duty.

**LCP**

The Local Control Panel (LCP) makes up a complete interface for control and programming of the adjustable frequency drive. The control panel is detachable and can be installed up to 9.8 ft [3 m] from the adjustable frequency drive, 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  $\equiv$  0.00079 in<sup>2</sup> (0.5067 mm<sup>2</sup>).

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 offline parameters are not activated until you enter [OK] on the LCP.

PID Controller

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

RCD

Residual Current Device.

Set-up

You can save parameter settings in four set-ups. Change between the four parameter set-ups, and edit one set-up, while another set-up is active.

SFAVM

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

Slip Compensation

The adjustable frequency drive 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 (adjustable frequency drive or motor).

Trip

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

Trip Locked

A state entered in fault situations when the adjustable frequency drive is protecting itself and requiring physical intervention, e.g., if the adjustable frequency drive is subject to a short circuit on the output. A locked trip can only be canceled by cutting off line power, removing the cause of the fault, and reconnecting the adjustable frequency drive. Restart is prevented until the trip state is canceled by activating reset or, in some cases, by being programmed to reset automatically. The trip-lock function may not be used as a personal safety measure.

VT Characteristics

Variable torque characteristics used for pumps and fans.

VVC<sup>plus</sup>

If compared with standard voltage/frequency ratio control, Voltage Vector Control (VVC<sup>plus</sup>) 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

**1.1.6 Power Factor**

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

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

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

The power factor for 3-phase control:

The power factor indicates to which extent the adjustable frequency drive imposes a load on the line power supply.

The lower the power factor, the higher the  $I_{RMS}$  for the same kW performance.

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

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

The built-in DC coils in the adjustable frequency drive produce a high power factor, which minimizes the imposed load on the line power supply.



## 2 Introduction to the VLT AQUA Drive

### 2.1 Safety

#### 2.1.1 Safety note



The voltage of the adjustable frequency drive is dangerous whenever connected to line power. Incorrect installation of the motor, adjustable frequency drive or serial communication bus 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 adjustable frequency drive must be disconnected from line power if repair work is to be carried out. Make sure that the line power supply has been disconnected and that the necessary time has passed before removing motor and line plugs.
2. The [STOP/RESET] key on the control panel of the adjustable frequency drive does not disconnect the equipment from line power and is thus not to be used as a safety switch.
3. Correct protective grounding 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 ground 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 initialized at 1.16 x rated motor current and rated motor frequency. For the North American market: The ETR functions provide class 20 motor overload protection in accordance with NEC.
6. Do not remove the plugs for the motor and line power supply while the adjustable frequency drive is connected to line power. Make sure that the line power supply has been disconnected and that the necessary time has passed before removing motor and line plugs.
7. Please note that the adjustable frequency drive 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. Make sure that all voltage inputs have been disconnected and that the necessary time has passed before commencing repair work.

#### Installation at High Altitudes



At altitudes higher than 6,600 feet [2 km], please contact Danfoss 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 adjustable frequency drive is connected to line power. 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 adjustable frequency drive, or if a temporary overload or a fault in the supply line power or the motor connection ceases.



Warning:  
Touching the electrical parts may be fatal - even after the equipment has been disconnected from line power.

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 Instruction Manual MG.20.MX.YY* for further safety guidelines.

2.1.2 Caution

2



The adjustable frequency drive DC link capacitors remain charged after power has been disconnected. To avoid an electrical shock hazard, disconnect the adjustable frequency drive from line power before carrying out maintenance. Wait at least as follows before doing service on the adjustable frequency drive:

| Voltage (V) | Min. Waiting Time (Minutes) |                       |                         |                           |                           |
|-------------|-----------------------------|-----------------------|-------------------------|---------------------------|---------------------------|
|             | 4                           | 15                    | 20                      | 30                        | 40                        |
| 200 - 240   | 0.34–5 hp [0.25–3.7 kW]     | 7.5–60 hp [5.5–45 kW] |                         |                           |                           |
| 380 - 480   | 0.5–10 hp [0.37–7.5 kW]     | 15–125 hp [11–90 kW]  | 150–350 hp [110–250 kW] | 450–1350 hp [315–1000 kW] |                           |
| 525-600     | 1–10 hp [0.75 kW–7.5 kW]    | 15–125 hp [11–90 kW]  |                         |                           | 450–1600 hp [315–1200 kW] |
| 525-690     |                             | 15–125 hp [11–90 kW]  | 60–550 hp [45–400 kW]   | 600–1600 hp [450–1200 kW] |                           |

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

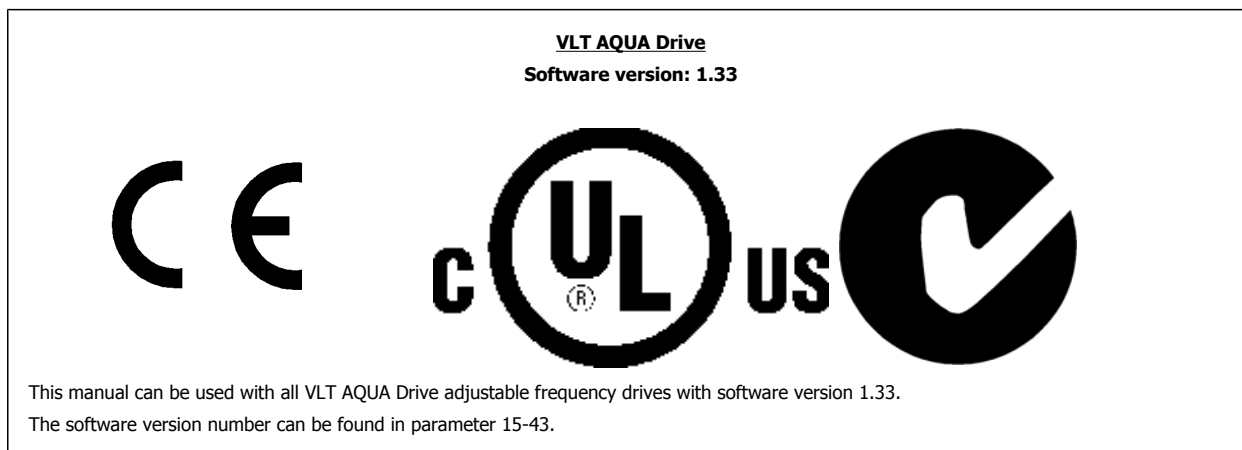
2.1.3 Disposal Instructions



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



2

## 2.3 CE labeling

### 2.3.1 CE Conformity and Labeling

#### What is CE Conformity and Labeling?

The purpose of CE labeling is to avoid technical trade obstacles within the 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. Adjustable frequency drives 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 an adjustable frequency drive is largely electrical, it does not fall under the Machinery Directive. However, if an adjustable frequency drive is supplied for use in a machine, we provide information on its safety aspects in the manufacturer's declaration.

#### The low-voltage directive (73/23/EEC)

Adjustable frequency drives must be CE-labeled in accordance with the Low-voltage Directive of January 1, 1997. The directive applies to all electrical equipment and appliances used in the 50–1,000 V AC and the 75 –1,500 V DC voltage ranges. Danfoss CE labels in accordance with the directive and issues a declaration of conformity upon request.

#### The EMC directive (89/336/EEC)

EMC is short for electromagnetic compatibility. The presence of electromagnetic compatibility means that the mutual interference between different components/appliances does not affect the way the appliances work.

The EMC directive came into effect on January 1, 1996. Danfoss CE labels in accordance with the directive and issues a declaration of conformity upon request. To carry out EMC-correct installation, see the instructions in this Design Guide. In addition, we specify the standards with which our products comply. We offer the filters presented in the specifications and provide other types of assistance to ensure the optimum EMC result.

The adjustable frequency drive 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 an adjustable frequency drive. See below for EMC coverage and CE labeling.

1. The adjustable frequency drive is sold directly to the end-consumer. For example, it may be sold to a DIY market. The end-consumer is a layman. He installs the adjustable frequency drive himself for use with a hobby machine, a kitchen appliance, etc. For such applications, the adjustable frequency drive must be CE-labeled in accordance with the EMC directive.
2. The adjustable frequency drive 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 adjustable frequency drive nor the finished plant must be CE-labeled under the EMC directive. However, the unit must comply with the basic EMC requirements of the directive. This is ensured by using components, appliances and systems that are CE-labeled under the EMC directive.
3. The adjustable frequency drive is sold as part of a complete system. The system is being marketed as complete and could, for example, be an air-conditioning system. The complete system must be CE-labeled in accordance with the EMC directive. The manufacturer can ensure CE-labeling under the EMC directive either by using CE-labeled components or by testing the EMC of the system. If he chooses to use only CE-labeled components, he does not have to test the entire system.

### 2.3.3 Danfoss Adjustable frequency drive and CE Labeling

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

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

The covered specifications can be very different and a CE label may therefore give the installer a false feeling of security when using an adjustable frequency drive as a component in a system or an appliance.

Danfoss CE labels the adjustable frequency drives in accordance with the low-voltage directive. This means that if the adjustable frequency drive is installed correctly, we guarantee compliance with the low-voltage directive. Danfoss issues a declaration of conformity that confirms our CE labeling in accordance with the low-voltage directive.

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

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

Danfoss 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 adjustable frequency drive is mostly used by professionals of the trade as a complex component forming part of a larger appliance, system or installation. It must be noted that the responsibility for the final EMC properties of the appliance, system or installation rests with the installer. As an aid to the installer, Danfoss has prepared EMC installation guidelines for the Power Drive system. The standards and test levels stated for power drive systems are complied with, provided that the EMC-correct instructions for installation are followed; see the section *EMC Immunity*.

The adjustable frequency drive has been designed to meet the IEC/EN 60068-2-3 standard, EN 50178 pkt. 9.4.2.2 at 122°F [50°C].

An adjustable frequency drive contains a large number of mechanical and electronic components. All are to some extent vulnerable to environmental effects.



The adjustable frequency drive 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 adjustable frequency drive.

Liquids can be carried through the air and condense in the adjustable frequency drive 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 printed circuit boards can be ordered as an option.

Airborne particles such as dust may cause mechanical, electrical or thermal failure in the adjustable frequency drive. A typical indicator of excessive levels of airborne particles is the presence of dust particles around the adjustable frequency drive fan. In very dusty environments, use equipment with enclosure rating IP 54/55 or a cabinet for IP 00/IP 20/TYP 1 equipment.

In environments with high temperatures and humidity, corrosive gases such as sulfur, nitrogen and chlorine compounds will cause chemical reactions on the adjustable frequency drive 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 adjustable frequency drive.

An extra protection in such areas is a coating of the printed circuit boards, which can be ordered as an option.



**NOTE!**

Mounting adjustable frequency drives in aggressive environments increases the risk of stoppages and considerably reduces the life of the drive.

Before installing the adjustable frequency drive, 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 the blackening of copper rails and cable ends on existing installations.

**NOTE!**

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

## 2.6 Vibration and shock

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

The adjustable frequency drive 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 an adjustable frequency drive for controlling fans and pumps?

An adjustable frequency drive 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 an adjustable frequency drive for controlling the speed of fans or pumps lies in the electricity savings. Compared to alternative control systems and technologies, an adjustable frequency drive is the optimum energy control system for controlling fan and pump systems.

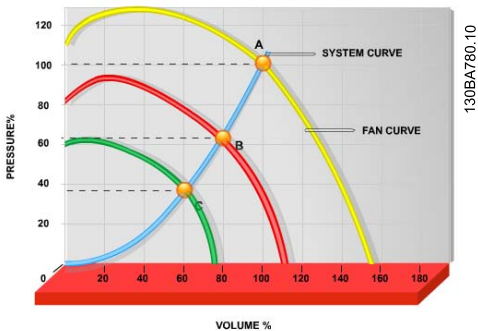


Figure 2.1: The graph is showing fan curves (A, B and C) for reduced fan volumes.

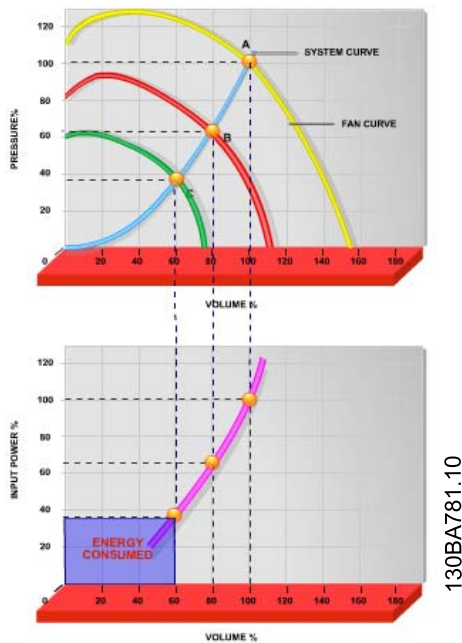


Figure 2.2: When using a adjustable frequency drive to reduce fan capacity to 60%, more than 50% energy savings may be obtained in typical applications.

### 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 rated speed by only 20%, 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 corresponding to 100% a few days each year, while the average is below 80% of the rated flow for the remainder of the year, the amount of energy saved is even greater 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<sub>1</sub> = Rated flow

P<sub>1</sub> = Rated power

Q<sub>2</sub> = Reduced flow

P<sub>2</sub> = Reduced power

H = Pressure

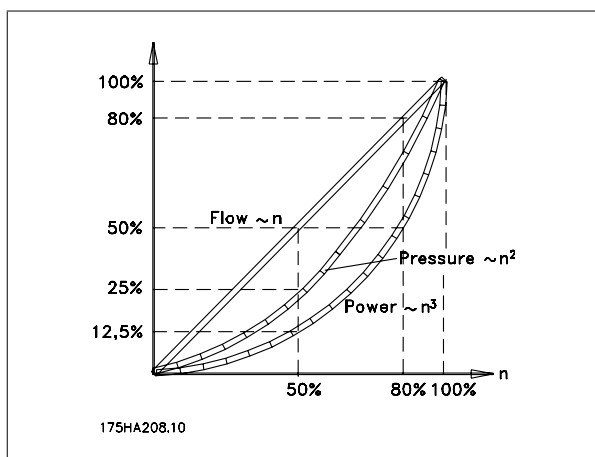
n = Speed regulation

H<sub>1</sub> = Rated pressure

n<sub>1</sub> = Rated speed

H<sub>2</sub> = Reduced pressure

n<sub>2</sub> = Reduced speed



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

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

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

### 2.7.4 Example with Varying Flow over 1 Year

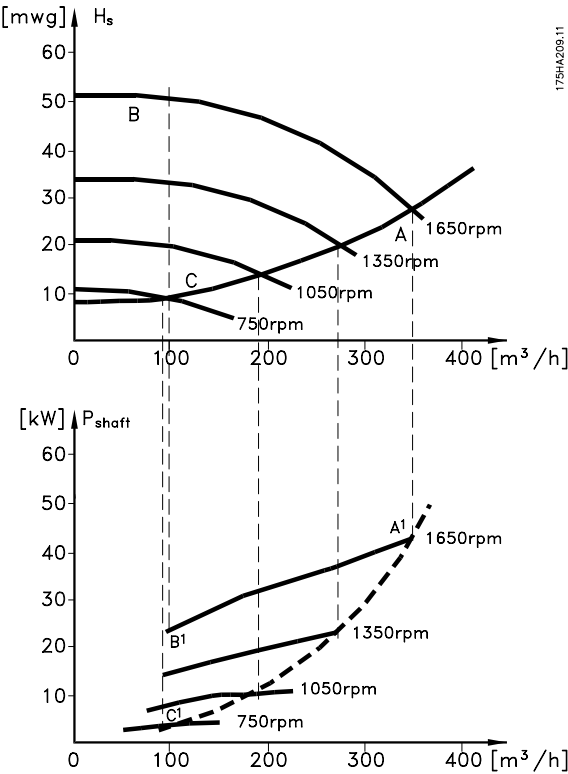
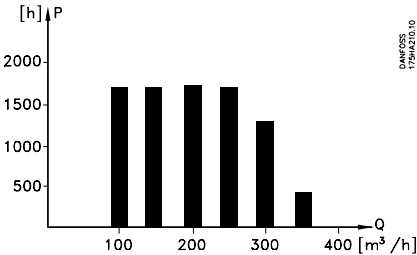
The example below is calculated on the basis of pump characteristics obtained from a pump datasheet.

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 the price of the adjustable frequency drive. In this example, it is less than a year when compared with valves and constant speed.

Energy savings

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

Flow distribution over 1 year





| m <sup>3</sup> /h | Distribution |       | Valve regulation                |             | Adjustable frequency drive control |             |
|-------------------|--------------|-------|---------------------------------|-------------|------------------------------------|-------------|
|                   | %            | Hours | Power                           | Consumption | Power                              | Consumption |
|                   |              |       | A <sub>1</sub> - B <sub>1</sub> | kWh         | A <sub>1</sub> - C <sub>1</sub>    | kWh         |
| 350               | 5            | 438   | 42.5                            | 18.615      | 42.5                               | 18.615      |
| 300               | 15           | 1314  | 38.5                            | 50.589      | 29.0                               | 38.106      |
| 250               | 20           | 1752  | 35.0                            | 61.320      | 18.5                               | 32.412      |
| 200               | 20           | 1752  | 31.5                            | 55.188      | 11.5                               | 20.148      |
| 150               | 20           | 1752  | 28.0                            | 49.056      | 6.5                                | 11.388      |
| 100               | 20           | 1752  | 23.0                            | 40.296      | 3.5                                | s           |
| <b>Σ</b>          | 100          | 8760  |                                 | 275.064     |                                    | 26.801      |

### 2.7.5 Better Control

If an adjustable frequency drive is used for controlling the flow or pressure of a system, improved control is obtained.

An adjustable frequency drive can vary the speed of the fan or pump, thereby obtaining variable control of flow and pressure.

Furthermore, an adjustable frequency drive 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 $\phi$ Compensation

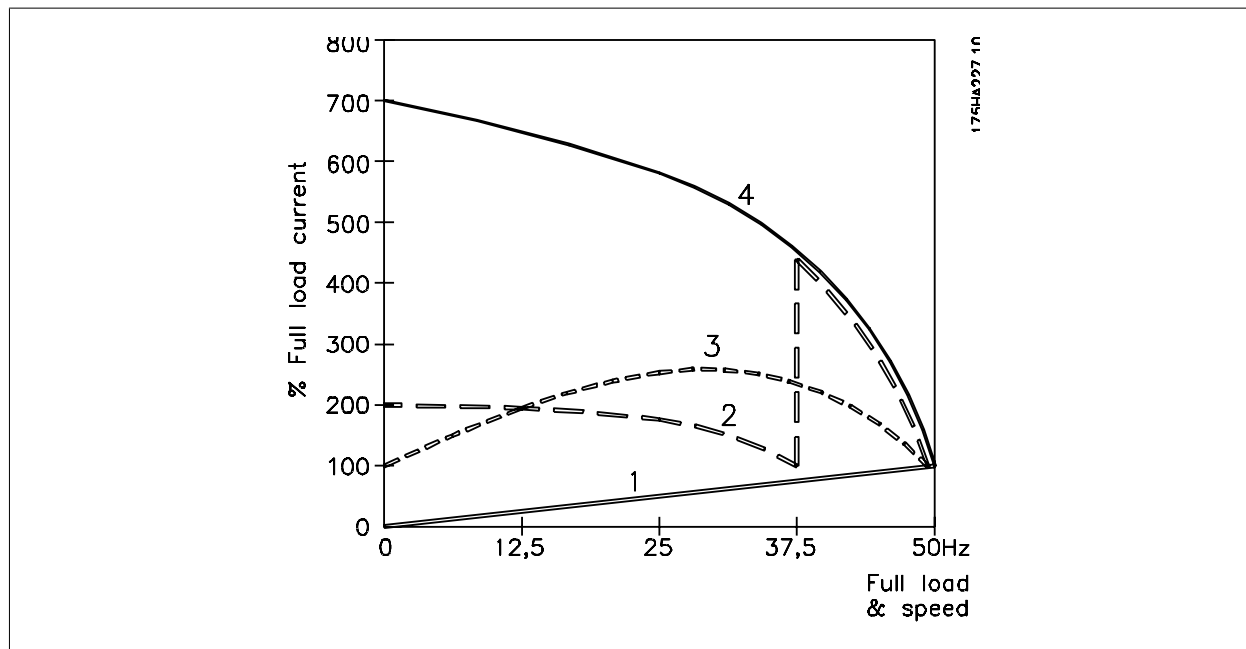
Generally speaking, an adjustable frequency drive with a cos  $\phi$  of 1 provides power factor correction for the cos  $\phi$  of the motor, which means that there is no need to make allowance for the cos  $\phi$  of the motor when sizing the power factor correction unit.

### 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 an adjustable frequency drive is used.

2

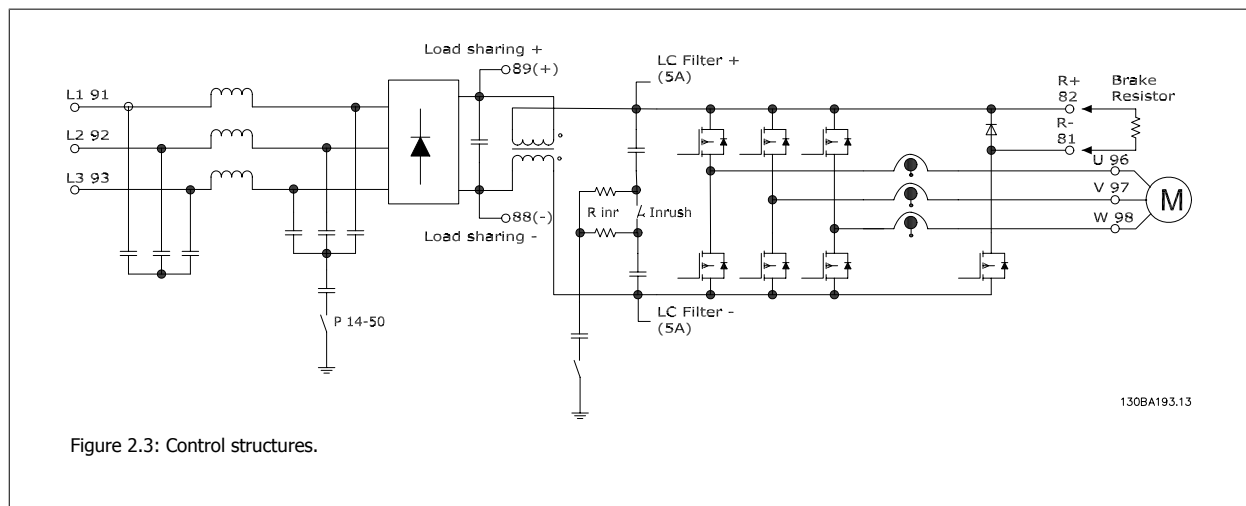
As illustrated in the figure below, an adjustable frequency drive does not consume more than rated current.



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

## 2.8 Control Structures

### 2.8.1 Control Principle

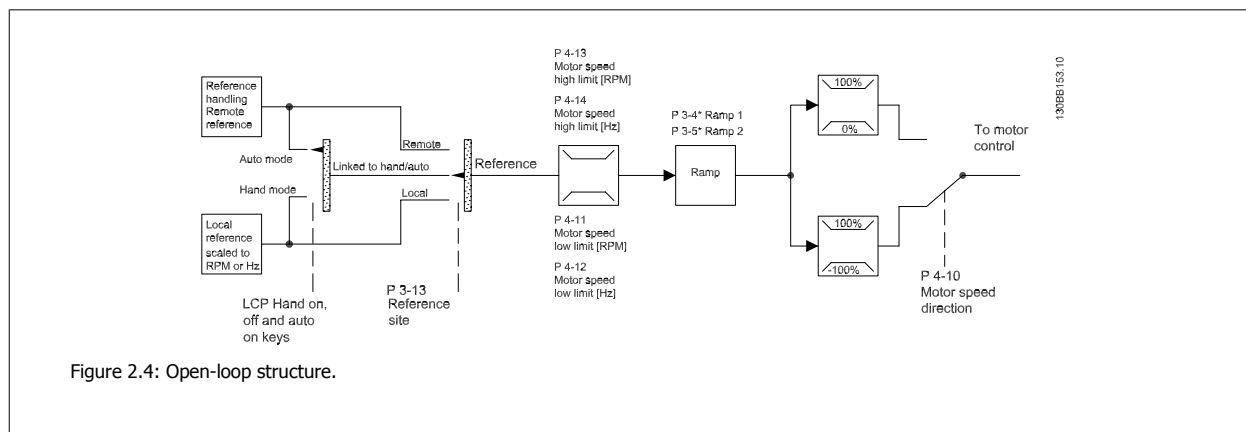


The adjustable frequency drive is a high performance unit for demanding applications. It can handle various kinds of motor control principles such as U/f special motor mode and VVC plus and can handle normal squirrel cage asynchronous motors.

Short circuit behavior on this adjustable frequency drive depends on the 3 current transducers in the motor phases.

In *par. 1-00 Configuration Mode*, it is possible to select whether either open-loop or closed-loop is to be used

### 2.8.2 Control Structure Open-loop



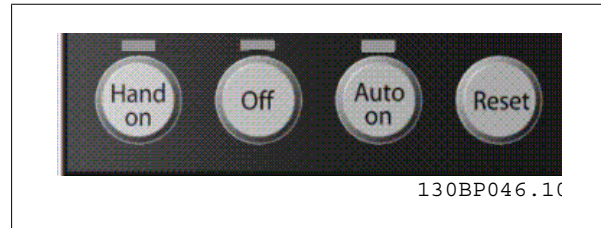
In the configuration shown in the illustration above, *par. 1-00 Configuration Mode* is set to Open-loop [0]. The resulting reference from the reference handling system or the local reference is received and fed through the ramp limitation and speed limitation before being sent to the motor control.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

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

The adjustable frequency drive can be operated manually via the local control panel (LCP) or remotely via analog/digital inputs or 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 adjustable frequency drive by LCP using the [Hand ON] and [Off] keys. Alarms can be reset via the [RESET] key. After pressing the [Hand On] key, the adjustable frequency drive goes into hand mode and follows (as default) the local reference set by using the LCP arrow keys up [▲] and down [▼].

After pressing the [Auto On] key, the adjustable frequency drive goes into auto mode and follows (as default) the remote reference. In this mode, it is possible to control the adjustable frequency drive via the digital inputs and various serial interfaces (RS-485, USB, or an optional serial communication bus). 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).



| Hand Off<br>Auto<br>LCP Keys | Reference Site<br>par. 3-13 <i>Reference Site</i> | 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.



#### NOTE!

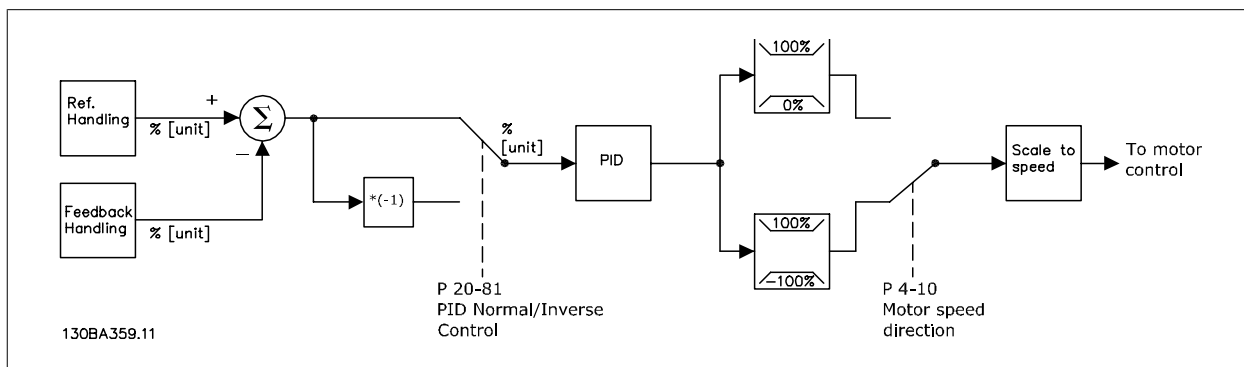
Local Reference will be restored at power-down.

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).

### 2.8.4 Control Structure Closed-loop

The 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.

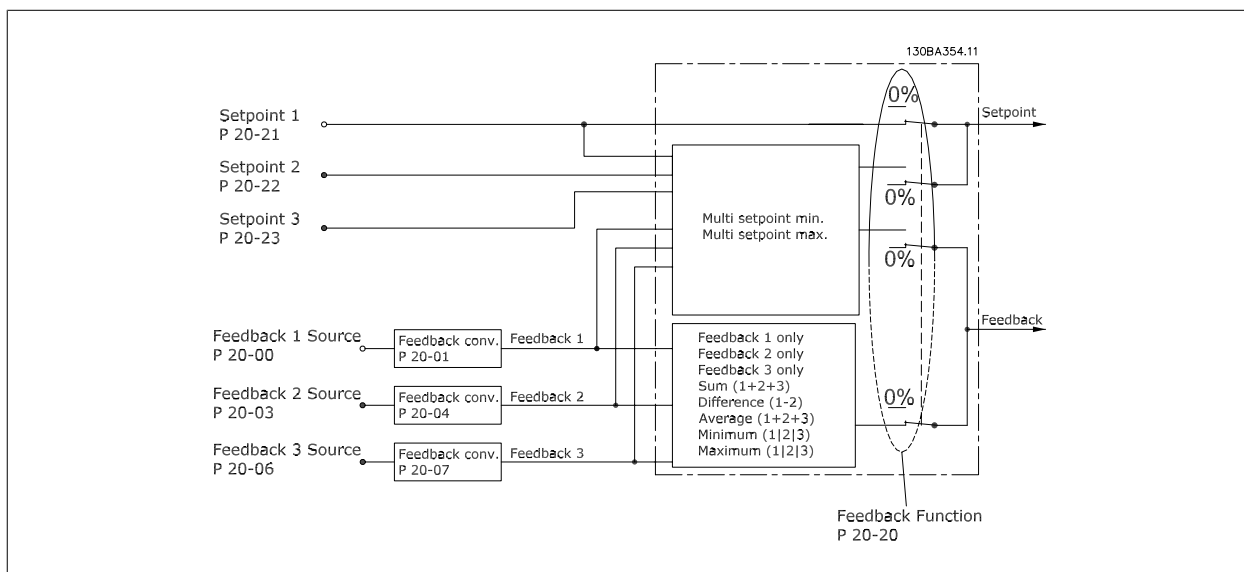
**NOTE!**

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.

## 2.8.5 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.

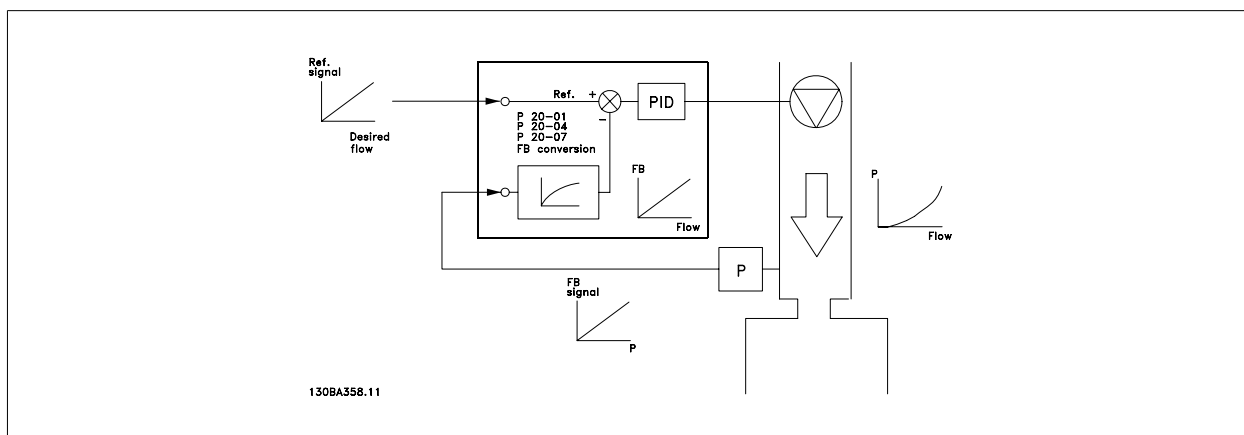
## 2

**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).

**2.8.6 Feedback Conversion**

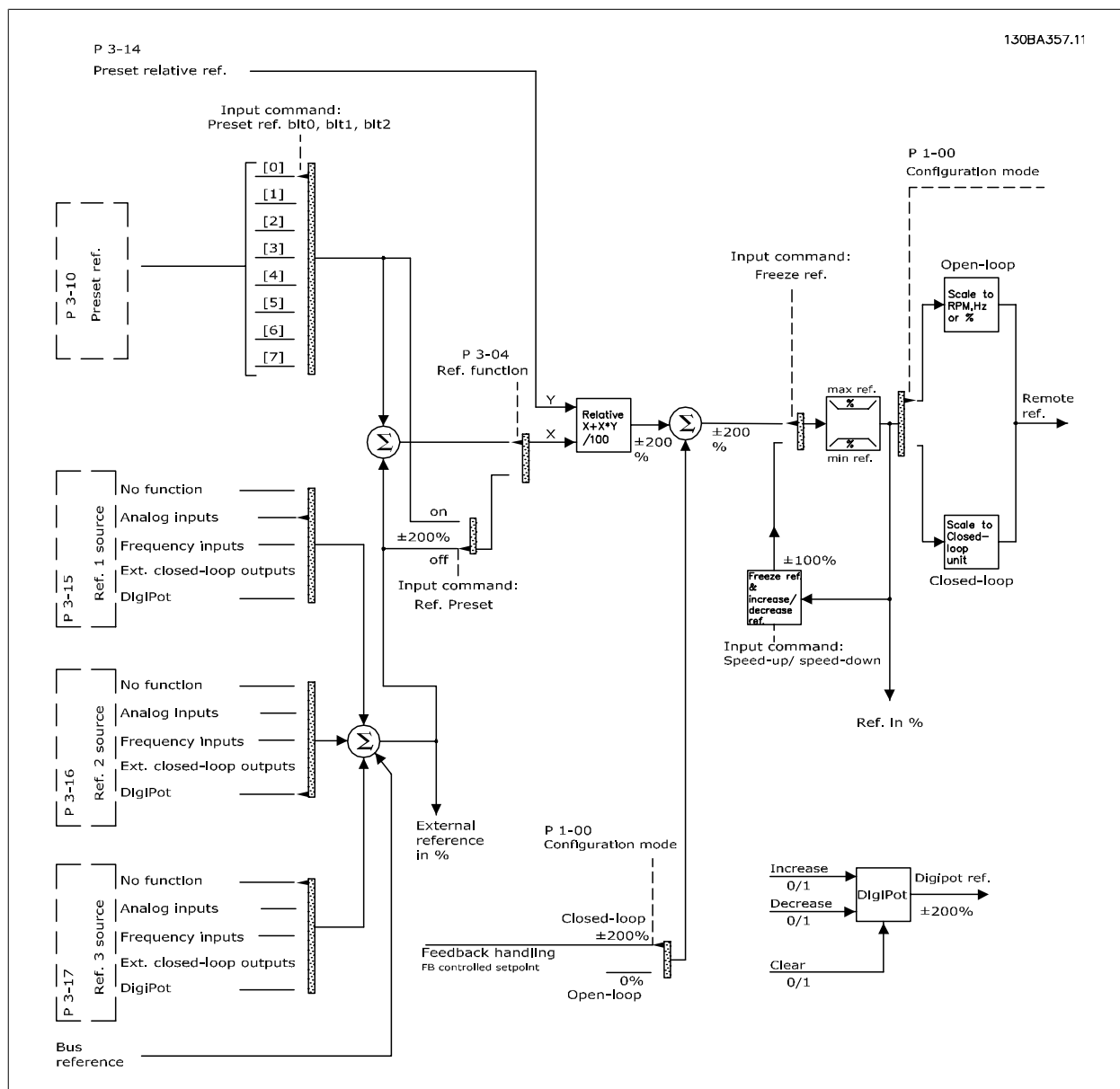
In some applications, it may be useful to convert the feedback signal. One example of this is using a pressure signal to provide flow feedback. Since the square root of pressure is proportional to flow, the square root of the pressure signal yields a value proportional to the flow. This is shown below.



## 2.8.7 Reference Handling

### Details for Open-loop and Closed-loop Operation

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 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 [%].

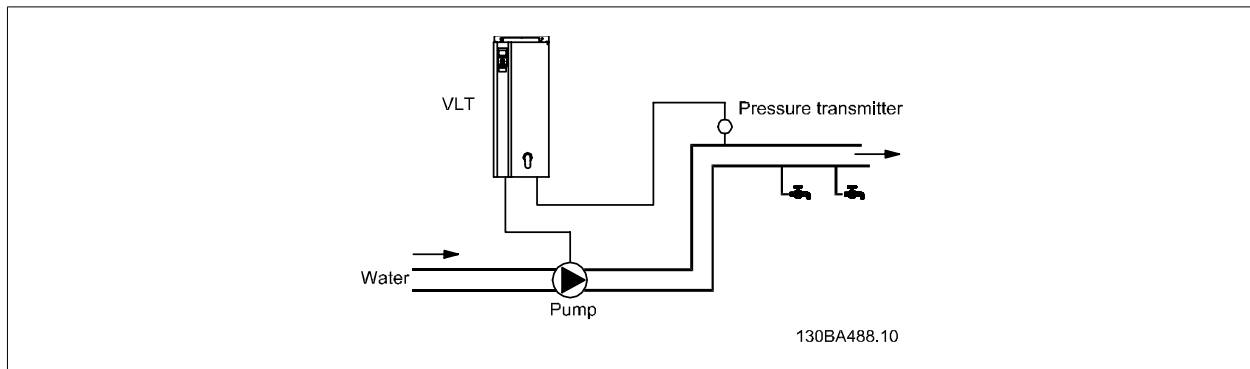


**NOTE!**

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

### 2.8.8 Example of Closed-loop PID Control

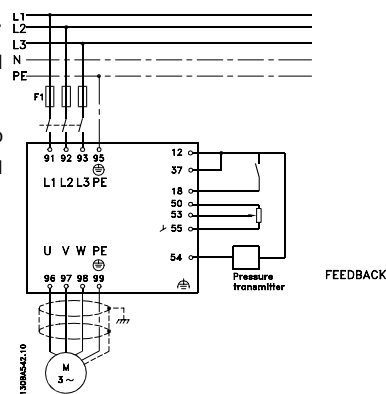
The following is an example of a closed-loop control for a booster pump application:



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 0–10 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).



NB. SHIELD FOR CONTROL WIRES TO BE CONNECTED TO TERMINAL 38 OR 61

NOTE: ALL ADJUSTMENTS ARE BASED ON FACTORY SETTINGS. ONLY THE FOLLOWING HAVE TO BE SELECTED;

MOTOR POWER PAR. 103  
 MOTOR VOLTAGE PAR. 104  
 MOTOR FREQUENCY PAR. 105  
 MOTOR CURRENT PAR. 107

## 2.8.9 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 nameplate                                                                         |
| 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. Make sure 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 adjustable frequency drive limits are set to safe values.                                                       |                |                                                                                                         |
| Make sure that the ramp settings are within the capabilities of the drive and the allowed application operating specifications.  | 3-41           | 60 sec.                                                                                                 |
|                                                                                                                                  | 3-42           | 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           | 10 Hz, Motor min speed                                                                                  |
|                                                                                                                                  | 4-14           | 50 Hz, Motor max speed                                                                                  |
|                                                                                                                                  | 4-19           | 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           | 0 Bar                                                                                                   |
|                                                                                                                                  | 3-03           | 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           | 0 V                                                                                                     |
|                                                                                                                                  | 6-11           | 10 V (default)                                                                                          |
|                                                                                                                                  | 6-14           | 0 Bar                                                                                                   |
|                                                                                                                                  | 6-15           | 10 Bar                                                                                                  |
| Scale Analog Input 54 for pressure sensor (0–10 Bar, 4–20 mA)                                                                    | 6-22           | 4 mA                                                                                                    |
|                                                                                                                                  | 6-23           | 20 mA (default)                                                                                         |
|                                                                                                                                  | 6-24           | 0 Bar                                                                                                   |
|                                                                                                                                  | 6-25           | 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 settings to the LCP for safekeeping.                                                                          | 0-50           | All to LCP [1]                                                                                          |

### 2.8.10 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.

### 2.8.11 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 the Integral Time by 15-50%.
4. Par. 20-95 (PID Differential Time) should only be used for very fast-acting systems. The typical value is 25% of the PID Integral Time (par. 20-94). The differential function 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 low-pass filter for the feedback signal (par 6 16, 6 26, 5 54 or 5 59, as required).

## 2.9 General aspects of EMC

### 2.9.1 General Aspects of EMC Emissions

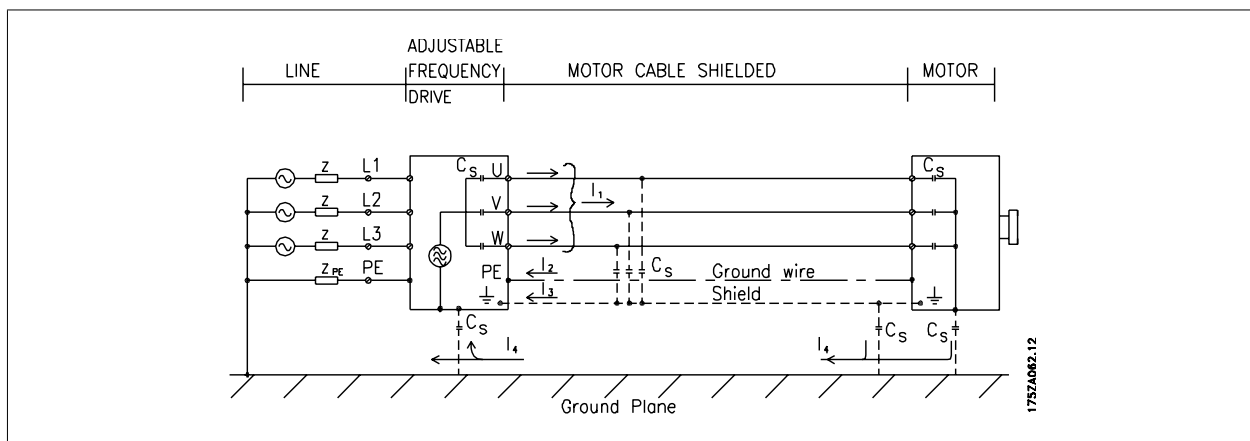
2

Electrical interference is usually conducted at frequencies in the range of 150 kHz to 30 MHz. Airborne interference from the drive system in the range of 30 MHz to 1 GHz is generated from the inverter, motor cable and 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 shielded motor cable increases the leakage current (see illustration below), because shielded cables have higher capacitance to ground than non-shielded cables. If the leakage current is not filtered, it will cause greater interference on the line power supply in the radio frequency range below approximately 5 MHz. Since the leakage current ( $I_1$ ) is carried back to the unit through the shield ( $I_3$ ), there will in principle only be a small electromagnetic field ( $I_4$ ) from the shielded motor cable according to the below figure.

The shield reduces the radiated interference, but increases the low-frequency interference in the line power supply. The motor cable screen must be connected to the adjustable frequency drive enclosure as well as on the motor enclosure. This is best done by using integrated shield clamps so as to avoid twisted shield ends (pigtails). These increase the shield impedance at higher frequencies, which reduces the shield effect and increases the leakage current ( $I_4$ ).

If a shielded cable is used for the serial communication bus, relay, control cable, signal interface and brake, the shield must be mounted on the enclosure at both ends. In some situations, however, it will be necessary to break the shield to avoid current loops.



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



#### NOTE!

When non-shielded 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.

## 2.9.2 Emission Requirements

According to the EMC product standard for adjustable speed adjustable frequency drives EN/IEC61800-3:2004, the EMC requirements depend on the intended use of the adjustable frequency drive. Four categories are defined in the EMC product standard. The definitions of the four categories together with the requirements for line power supply voltage-conducted emissions are given in the table below:

| Category | Definition                                                                                                                                                                                                                             | Conducted emission requirement according to the limits given in EN55011 |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| C1       | adjustable frequency drives installed in the first environment (home and office) with a supply voltage less than 1,000 V.                                                                                                              | Class B                                                                 |
| C2       | adjustable frequency drives installed in the first environment (home and office) with a supply voltage of 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       | adjustable frequency drives installed in the second environment (industrial) with a supply voltage lower than 1,000 V.                                                                                                                 | Class A Group 2                                                         |
| C4       | adjustable frequency drives installed in the second environment with a supply voltage above 1,000 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 adjustable frequency drives 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                                                         |

### 2.9.3 EMC Test Results (Emission)

The following test results were obtained using a system with an adjustable frequency drive (with options, if relevant), a shielded control cable, a control box with potentiometer, as well as a motor and motor-shielded cable.

| RFI filter type                     | Phase type   | Conducted emission.            |                                      |                        | Radiated emission                    |                  |
|-------------------------------------|--------------|--------------------------------|--------------------------------------|------------------------|--------------------------------------|------------------|
|                                     |              | Maximum shielded cable length. |                                      |                        |                                      |                  |
|                                     |              | Industrial environment         | Housing, trades and light industries | Industrial environment | Housing, trades and light industries |                  |
| Set-up:                             | <b>S / T</b> | EN 55011 Class A2              | EN 55011 Class A1                    | EN 55011 Class B       | EN 55011 Class A1                    | EN 55011 Class B |
| <b>H1</b>                           |              | meter                          | meter                                | meter                  |                                      |                  |
| 1.5–30 hp [1.1–22 kW] 220–240 V     | <b>S2</b>    | 150                            | 150                                  | 50                     | Yes                                  | No               |
| 0.34–60 hp [0.25–45 kW] 200–240 V   | <b>T2</b>    | 150                            | 150                                  | 50                     | Yes                                  | No               |
| 10–50 hp [7.5–37 kW] 380–480 V      | <b>S4</b>    | 150                            | 150                                  | 50                     | Yes                                  | No               |
| 0.5–125 hp [0.37–90 kW] 380–480 V   | <b>T4</b>    | 150                            | 150                                  | 50                     | Yes                                  | No               |
| <b>H2</b>                           |              |                                |                                      |                        |                                      |                  |
| 1.5–30 hp [1.1–22 kW] 220–240 V     | <b>S2</b>    | 25                             | No                                   | No                     | No                                   | No               |
| 0.34–5 hp [0.25–3.7 kW] 200–240 V   | <b>T2</b>    | 5                              | No                                   | No                     | No                                   | No               |
| 7.5–60 hp [5.5–45 kW] 200–240 V     | <b>T2</b>    | 25                             | No                                   | No                     | No                                   | No               |
| 0.5–10 hp [0.37–7.5 kW] 380–480 V   | <b>T4</b>    | 5                              | No                                   | No                     | No                                   | No               |
| 10–50 hp [7.5–37 kW] 380–480 V      | <b>S4</b>    | 25                             | No                                   | No                     | No                                   | No               |
| 15–125 hp [11–90 kW] 380–480 V      | <b>T4</b>    | 25                             | No                                   | No                     | No                                   | No               |
| 150–1350 hp [110–1000 kW] 380–480 V | <b>T4</b>    | 50                             | No                                   | No                     | No                                   | No               |
| 1–125 hp [0.75–90 kW] 525–600 V     | <b>T6</b>    | 150                            | No                                   | No                     | No                                   | No               |
| 15–125 hp [11–90 kW] 525–690 V      | <b>T7</b>    | Yes                            | No                                   | No                     | No                                   | No               |
| 60–1600 hp [45–1200 kW] 525–690 V   | <b>T7</b>    | 150                            | No                                   | No                     | No                                   | No               |
| <b>H3</b>                           |              |                                |                                      |                        |                                      |                  |
| 0.34–60 hp [0.25–45 kW] 200–240 V   | <b>T2</b>    | 75                             | 50                                   | 10                     | Yes                                  | No               |
| 0.5–125 hp [0.37–90 kW] 380–480 V   | <b>T4</b>    | 75                             | 50                                   | 10                     | Yes                                  | No               |
| <b>H4</b>                           |              |                                |                                      |                        |                                      |                  |
| 150–1350 hp [110–1000 kW] 380–480 V | <b>T4</b>    | 150                            | 150                                  | No                     | Yes                                  | No               |
| 15–125 hp [11–90 kW] 525–690 V      | <b>T7</b>    | No                             | Yes                                  | No                     | Yes                                  | No               |
| 60–550 hp [45–400 kW] 525–690 V     | <b>T7</b>    | 150                            | 30                                   | No                     | No                                   | No               |
| <b>Hx</b>                           |              |                                |                                      |                        |                                      |                  |
| 1–125 hp [0.75–90 kW] 525–600 V     | <b>T6</b>    | -                              | -                                    | -                      | -                                    | -                |

Table 2.1: EMC Test Results (Emission)

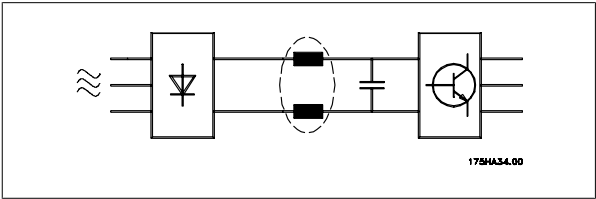
### 2.9.4 General Aspects of Harmonics Emission

An adjustable frequency drive takes up a non-sinusoidal current from the line power, 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 cur-

rents at a low level to prevent an overload of the transformer and high temperature in the cables.



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



**NOTE!**  
To ensure low harmonic currents, the adjustable frequency drive is standard-equipped with intermediate circuit coils. This normally reduces the input current  $I_{RMS}$  by 40%.

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

$$THD \% = \sqrt{U_{\frac{2}{5}}^2 + U_{\frac{2}{7}}^2 + \dots + U_{\frac{2}{N}}^2}$$

( $U_N$ % of  $U$ )

2.9.5 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 1.5 hp [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.                       |

## 2.9.6 Harmonics Test Results (Emission)

|                             | Individual Harmonic Current $I_n/I_1$ (%) |       |          |          | Harmonic current destination factor (%) |      |
|-----------------------------|-------------------------------------------|-------|----------|----------|-----------------------------------------|------|
|                             | $I_5$                                     | $I_7$ | $I_{11}$ | $I_{13}$ | THD                                     | PWHD |
| Actual (typical)            | 40                                        | 20    | 10       | 8        | 46                                      | 45   |
| Limit for $R_{sc} \geq 120$ | 40                                        | 25    | 15       | 10       | 48                                      | 46   |

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 P90K in T4 complies with IEC/EN 61000-3-12. Power sizes P110 - P450 in T4 also complies with IEC/EN 61000-3-12 even though not required because currents are above 75 A.

Table 4,  $R_{sc} \geq 120$ , THD  $\leq 48\%$  and PWHD  $\geq 46\%$  provided that the short-circuit power of the supply  $S_{sc}$  is greater than or equal to:

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

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.

## 2.10 Immunity Requirements

The immunity requirements for adjustable frequency drives depend on the environment where they are installed. The requirements for the industrial environment are higher than the requirements for the home and office environment. All Danfoss adjustable frequency drives 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 an adjustable frequency drive (with options if relevant), a shielded 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):** Electrical interference: 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<br>IEC 61000-4-4 | Surge<br>IEC 61000-4-5        | ESD<br>IEC<br>61000-4-2 | Radiated electromagnetic field<br>IEC 61000-4-3 | RF common<br>mode voltage<br>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 <sub>RMS</sub>                        |
| Motor                                        | 4 kV CM                | 4 kV/2 Ω <sup>1)</sup>        | —                       | —                                               | 10 V <sub>RMS</sub>                        |
| Brake                                        | 4 kV CM                | 4 kV/2 Ω <sup>1)</sup>        | —                       | —                                               | 10 V <sub>RMS</sub>                        |
| Load sharing                                 | 4 kV CM                | 4 kV/2 Ω <sup>1)</sup>        | —                       | —                                               | 10 V <sub>RMS</sub>                        |
| Control wires                                | 2 kV CM                | 2 kV/2 Ω <sup>1)</sup>        | —                       | —                                               | 10 V <sub>RMS</sub>                        |
| Standard bus                                 | 2 kV CM                | 2 kV/2 Ω <sup>1)</sup>        | —                       | —                                               | 10 V <sub>RMS</sub>                        |
| Relay wires                                  | 2 kV CM                | 2 kV/2 Ω <sup>1)</sup>        | —                       | —                                               | 10 V <sub>RMS</sub>                        |
| Application and serial communication options | 2 kV CM                | 2 kV/2 Ω <sup>1)</sup>        | —                       | —                                               | 10 V <sub>RMS</sub>                        |
| LCP cable                                    | 2 kV CM                | 2 kV/2 Ω <sup>1)</sup>        | —                       | —                                               | 10 V <sub>RMS</sub>                        |
| External 24 V DC                             | 2 kV CM                | 0.5 kV/2 Ω DM<br>1 kV/12 Ω CM | —                       | —                                               | 10 V <sub>RMS</sub>                        |
| 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 screen.

Table 2.2: Immunity

## 2.11 Galvanic isolation (PELV)

### 2.11.1 PELV - Protective Extra Low Voltage

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

All control terminals and relay terminals 01-03/04-06 comply with PELV (Protective Extra Low Voltage) (Does not apply to grounded Delta leg above 400 V).

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

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

The PELV galvanic isolation can be shown in six locations (see illustration):

In order to maintain PELV, all connections made to the control terminals must be PELV. For example, the 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 soft-charge, RFI and temperature measurement circuits.
6. Custom relays.

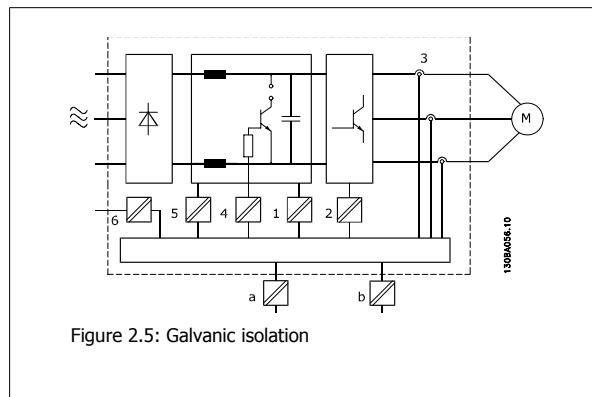


Figure 2.5: Galvanic isolation

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



#### Installation at high altitude:

380–500 V, enclosure A, B and C: At altitudes above 6,500 ft [2 km], please contact Danfoss regarding PELV.

380–500 V, enclosure D, E and F: At altitudes above 10,000 ft [3 km], please contact Danfoss regarding PELV.

525–690 V: At altitudes above 6,500 ft [2 km], please contact Danfoss regarding PELV.

## 2.12 Ground leakage current



#### Warning:

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

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 backup.

Before touching any electrical parts, wait at least the amount of time indicated in the *Safety Precautions* section.

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



#### Leakage Current

The ground leakage current from the adjustable frequency drive exceeds 3.5 mA. To ensure that the ground cable has a good mechanical connection to the ground connection (terminal 95), the cable cross-section must be at least 3.9 in<sup>2</sup> [10 mm<sup>2</sup>] or two rated ground wires terminated separately.

#### Residual Current Device

This product can cause DC current in the protective conductor. Where a residual current device (RCD) is used for protection in case of direct or indirect contact, only an RCD of Type B is allowed on the supply side of this product. Otherwise, another protective measure shall be applied, such as separation from the environment by double or reinforced insulation, or isolation from the supply system by a transformer. See also RCD Application Note MN.90.GX.02.

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

## 2.13 Control with brake function

### 2.13.1 Selection of Brake Resistor

In certain applications, for instance, in 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 adjustable frequency drive.

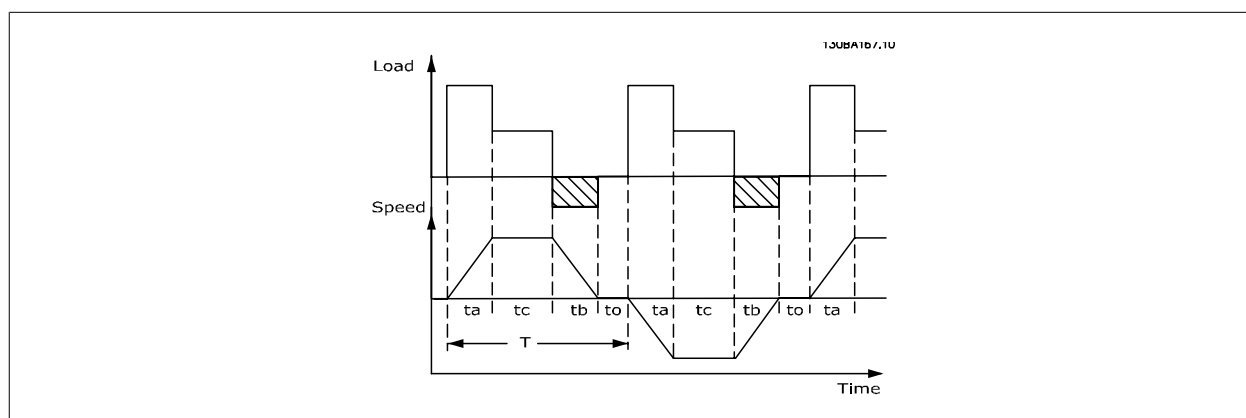
If the amount of kinetic energy transferred to the resistor in each braking period is not known, the average power can be calculated on the basis of the cycle time and braking time, also known as the intermitted duty cycle. The resistor intermittent duty cycle is an indication of the duty cycle at which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

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

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

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 a duty cycle of 5%, 10% and 40%, which are all suitable for use with the FC202 AQUA drive series. If a 10% duty cycle resistor is applied, it is capable of absorbing braking energy up to 10% of the cycle time, with the remaining 90% being used to dissipate heat from the resistor.

For further selection advice, please contact Danfoss.



#### NOTE!

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

### 2.13.2 Control with Brake Function

The brake is protected against short-circuiting of the brake resistor, and the brake transistor is monitored to ensure that short-circuiting of the transistor is detected. A relay/digital output can be used for protecting the brake resistor against overloading in connection with a fault in the adjustable frequency drive.

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)*.



**NOTE!**

Monitoring the braking energy is not a safety function; a thermal switch is required for that purpose. The brake resistor circuit is not protected against ground leakage.

*Overvoltage 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 if, for example, the ramp-down time is too short because tripping the adjustable frequency drive is avoided. In this situation, the ramp-down time is extended.

## 2.14 Mechanical brake control

### 2.14.1 Brake Resistor Cabling

EMC (twisted cables/shielding)

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

For enhanced EMC performance, a metal shield can be used.

## 2.15 Extreme running conditions

### Short Circuit (Motor Phase – Phase)

The adjustable frequency drive 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 adjustable frequency drive is fully permitted. You cannot damage the adjustable frequency drive 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 the following cases:

1. The load drives the motor, i.e., 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 adjustable frequency drive, the motor and the installation.
3. Incorrect slip compensation setting may cause higher DC link voltage.

The control unit may attempt to correct the ramp if possible (par. 2-17 *Overvoltage 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 adjustable frequency drive.

**Line Drop-out**

During a line drop-out, the adjustable frequency drive keeps running until the intermediate circuit voltage drops below the minimum stop level, which is typically 15% below the adjustable frequency drive's lowest rated supply voltage.

The AC line voltage before the drop-out and the motor load determine how long it takes for the inverter to coast.

**Static Overload in VVC<sup>plus</sup> mode**

When the adjustable frequency drive is overloaded (the torque limit in par. 4-16/4-17 is reached), the control reduces the output frequency to reduce the load.

If the overload is excessive, a current may occur that makes the adjustable frequency drive cut out after approximately 5-10 s.

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

### 2.15.1 Motor Thermal Protection

This is the way Danfoss 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:

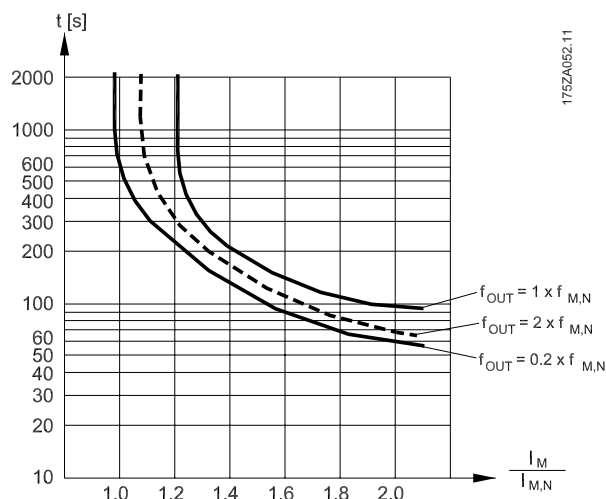


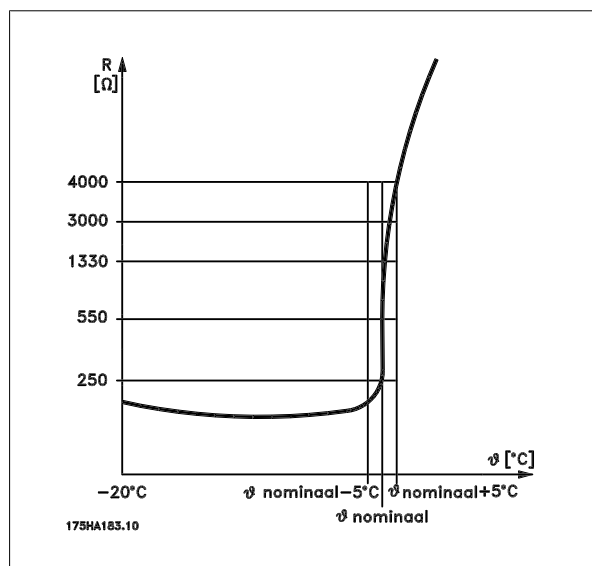
Figure 2.6: The X-axis show the ratio between  $I_{\text{motor}}$  and  $I_{\text{motor nominal}}$ . The Y-axis shows the time in seconds before the ETR cuts off and trips the drive. The curves show the characteristic nominal speed at twice the nominal speed and at 0.2x the nominal speed.

At lower speeds, the ETR cuts off at lower levels due to reduced cooling of the motor. In that way, the motors are protected from being overheated even at low speeds. The ETR feature calculates the motor temperature based on the actual current and speed. The calculated temperature is visible as a readout parameter in par. 16-18 *Motor Thermal* in the adjustable frequency drive.

The thermistor cut-out value is  $> 3 \text{ k}\Omega$ .

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).



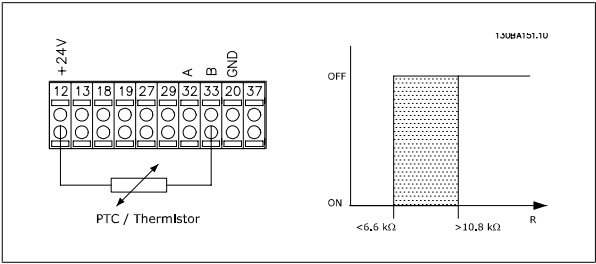
Using a digital input and 24 V as power supply:

Example: The adjustable frequency drive trips when the motor temperature is too high.

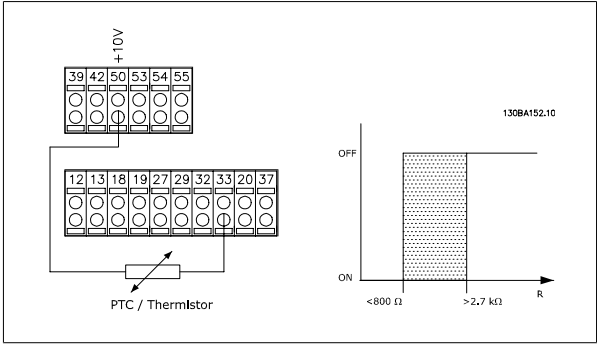
Parameter set-up:

Set par. 1-90 *Motor Thermal Protection* to *Thermistor Trip* [2]

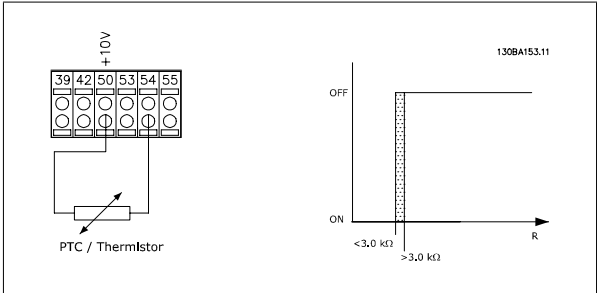
Set par. 1-93 *Thermistor Source* to *Digital Input 33* [6]



Using a digital input and 10 V as power supply:  
 Example: The adjustable frequency drive 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 adjustable frequency drive 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          | Supply Voltage | Threshold            |
|----------------|----------------|----------------------|
| Digital/analog | Volt           | 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  |

**NOTE!**  
 Ensure that the chosen supply voltage follows the specification of the thermistor element utilized.

**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 overheated and there is no need for any further motor protection. That means when the motor is heated up, the ETR timer controls how long the motor may run at that temperature before it is stopped in order to prevent overheating. If the motor is overloaded without reaching the temperature where the ETR shuts off the motor, the torque limit protects the motor and application for becoming overloaded.

**NOTE!**

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 adjustable frequency drive is set in par. 14-25 *Trip Delay at Torque Limit*.

## 2

**2.15.2 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 deemed suitable for the requirements of Safety Category 3 in EN 954-1. This function is called safe stop.

Prior to integration and use of the 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 the 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.

**NOTE!**

The safe stop function of the FC 202 can be used for asynchronous and synchronous motors. It may happen that two faults occur in the adjustable frequency drive's power semiconductor. When using synchronous motors, this may cause a residual rotation. The rotation can be calculated to  $\text{Angle} = 360 / (\text{Number of Poles})$ . 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.

**NOTE!**

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.

**NOTE!**

The adjustable frequency drive does not provide 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 organizational level. For more information - see section *Safe Stop Installation*.

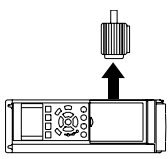


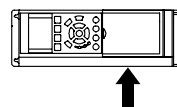
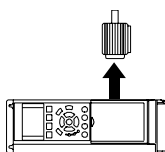
## 3 VLT AQUA Selection

### 3.1 General Specifications

### 3.1.1 Line Power Supply 1 x 200–240 V AC

**Line Power Supply 1 x 200–240 V AC - Normal overload 110% for 1 minute**

|                                                                                                                                                                                                                                                                                                                                                    |                |      |      |      |      |      |      |        |        |      |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|------|------|------|------|------|------|--------|--------|------|
| <div>Adjustable frequency drive</div> <div>Typical Shaft Output [kW]</div> <div>Typical Shaft Output [HP] at 240 V</div> <div>IP 20 / Chassis</div> <div>IP 21 / NEMA 1</div> <div>IP 55 / NEMA 12</div> <div>IP 66</div> <div>Output current</div> <div></div> | P1K1           | P1K5 | P2K2 | P3K0 | P3K7 | P5K5 | P7K5 | P15K0  | P22K0  |      |
|                                                                                                                                                                                                                                                                                                                                                    | 1.1            | 1.5  | 2.2  | 3.0  | 3.7  | 5.5  | 7.5  | 15     | 22     |      |
|                                                                                                                                                                                                                                                                                                                                                    | 1.5            | 2.0  | 2.9  | 4.0  | 4.9  | 7.5  | 10   | 20     | 30     |      |
|                                                                                                                                                                                                                                                                                                                                                    | A3             | -    | -    | -    | -    | -    | -    | -      | -      |      |
|                                                                                                                                                                                                                                                                                                                                                    | -              | B1   | B1   | B1   | B1   | B1   | B2   | C1     | C2     |      |
|                                                                                                                                                                                                                                                                                                                                                    | A5             | B1   | B1   | B1   | B1   | B1   | B2   | C1     | C2     |      |
|                                                                                                                                                                                                                                                                                                                                                    | A5             | B1   | B1   | B1   | B1   | B1   | B2   | C1     | C2     |      |
|                                                                                                                                                                                                                                                                                                                                                    | Continuous     | 6.6  | 7.5  | 10.6 | 12.5 | 16.7 | 24.2 | 30.8   | 59.4   | 88   |
|                                                                                                                                                                                                                                                                                                                                                    | Intermittent   | 7.3  | 8.3  | 11.7 | 13.8 | 18.4 | 26.6 | 33.4   | 65.3   | 96.8 |
|                                                                                                                                                                                                                                                                                                                                                    | Continuous kVA |      |      |      |      |      |      |        |        |      |
| (208 V AC) [kVA]                                                                                                                                                                                                                                                                                                                                   |                |      |      |      |      | 5.00 | 6.40 | 12.27  | 18.30  |      |
| Max. cable size:                                                                                                                                                                                                                                                                                                                                   |                |      |      |      |      |      |      |        |        |      |
| (line power, motor, brake)                                                                                                                                                                                                                                                                                                                         | 0.2-4 / 4-10   |      |      |      |      |      | 35/2 | 50/1/0 | 95/4/0 |      |
| [[mm <sup>2</sup> / AWG] <sup>2)</sup>                                                                                                                                                                                                                                                                                                             |                |      |      |      |      |      |      |        |        |      |
| Max. input current                                                                                                                                                                                                                                                                                                                                 |                |      |      |      |      |      |      |        |        |      |
| Continuous                                                                                                                                                                                                                                                                                                                                         | 12.5           | 15   | 20.5 | 24   | 32   | 46   | 59   | 111    | 172    |      |
| Intermittent                                                                                                                                                                                                                                                                                                                                       | 13.8           | 16.5 | 22.6 | 26.4 | 35.2 | 50.6 | 64.9 | 122.1  | 189.2  |      |
| Max. pre-fuses <sup>3)</sup> [A]                                                                                                                                                                                                                                                                                                                   | 20             | 30   | 40   | 40   | 60   | 80   | 100  | 150    | 200    |      |
| Environment                                                                                                                                                                                                                                                                                                                                        |                |      |      |      |      |      |      |        |        |      |
| Estimated power loss                                                                                                                                                                                                                                                                                                                               | 44             | 30   | 44   | 60   | 74   | 110  | 150  | 300    | 440    |      |
| at rated max. load [W] <sup>4)</sup>                                                                                                                                                                                                                                                                                                               |                |      |      |      |      |      |      |        |        |      |
| Weight enclosure IP 20 [kg]                                                                                                                                                                                                                                                                                                                        | 4.9            | -    | -    | -    | -    | -    | -    | -      | -      |      |
| Weight enclosure IP 21 [kg]                                                                                                                                                                                                                                                                                                                        | -              | 23   | 23   | 23   | 23   | 23   | 27   | 45     | 65     |      |
| Weight enclosure IP 55 [kg]                                                                                                                                                                                                                                                                                                                        | -              | 23   | 23   | 23   | 23   | 23   | 27   | 45     | 65     |      |
| Weight enclosure IP 66 [kg]                                                                                                                                                                                                                                                                                                                        | -              | 23   | 23   | 23   | 23   | 23   | 27   | 45     | 65     |      |
| Efficiency <sup>3)</sup>                                                                                                                                                                                                                                                                                                                           | 0.968          | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98   | 0.98   |      |

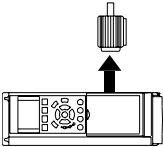
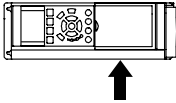


### 3.1.2 Line power Supply 3 x 200–240 V AC

### Normal overload 110% for 1 minute

|                                                                    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|--------------------------------------------------------------------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|
| IP 20 / NEMA Chassis                                               |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| IP 21 / NEMA 1                                                     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| IP 55 / NEMA 12                                                    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| IP 66                                                              |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| <b>Line power supply 200–240 V AC</b>                              |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Adjustable frequency drive                                         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Typical Shaft Output [kW]                                          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Typical Shaft Output [HP] at 208 V                                 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| <b>Output current</b>                                              |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|                                                                    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Continuous<br>(3 x 200–240 V) [A]                                  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Intermittent<br>(3 x 200–240 V) [A]                                |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Continuous<br>kVA (208 V AC) [KVA]                                 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Max. cable size:                                                   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| (line power, motor, brake)                                         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| [mm <sup>2</sup> /AWG] <sup> 2)</sup>                              |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 0.00031–0.0062 in <sup>2</sup> [0.2–4 mm <sup>2</sup> ] / 4–10 AWG |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| <b>Max. input current</b>                                          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|                                                                    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Continuous<br>(3 x 200–240 V) [A]                                  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Intermittent<br>(3 x 200–240 V) [A]                                |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Max. pre-fuses <sup>1)</sup> [A]                                   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Environment                                                        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Estimated power loss<br>at rated max. load [W] <sup> 4)</sup>      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Weight enclosure IP20 [kg]                                         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Weight enclosure IP21 [kg]                                         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Weight enclosure IP55 [kg]                                         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Weight enclosure IP66 [kg]                                         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Efficiency <sup> 3)</sup>                                          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

**Line power supply 3 x 200–240 V AC - 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))<br><br>IP 21 / NEMA 1<br><br>IP 55 / NEMA 12<br><br>IP 66                                                                                                                                                                                               |      |      |        |        |         |        |         |         |         |         |         |         |
|                                                                                                                                                                                                                                                                                                                                                                          | B3   | B3   | B3     | B4     | B4      | C3     | C3      | C3      | C4      | C4      | C4      | C4      |
|                                                                                                                                                                                                                                                                                                                                                                          | B1   | B1   | B1     | B2     | B2      | C1     | C1      | C1      | C2      | C2      | C2      | C2      |
|                                                                                                                                                                                                                                                                                                                                                                          | B1   | B1   | B1     | B2     | B2      | C1     | C1      | C1      | C2      | C2      | C2      | C2      |
| Adjustable frequency drive<br>Typical Shaft Output [kW]<br><br>Typical Shaft Output [HP] at 208 V                                                                                                                                                                                                                                                                        | P5K5 | P7K5 | P11K   | P15K   | P18K    | P22K   | P30K    | P37K    | P45K    | P55K    | P66K    | P75K    |
|                                                                                                                                                                                                                                                                                                                                                                          | 5.5  | 7.5  | 11     | 15     | 18.5    | 22     | 30      | 37      | 45      | 55      | 66      | 75      |
|                                                                                                                                                                                                                                                                                                                                                                          | 7.5  | 10   | 15     | 20     | 25      | 30     | 40      | 50      | 60      | 75      | 90      | 100     |
| <b>Output current</b>                                                                                                                                                                                                                                                                                                                                                    |      |      |        |        |         |        |         |         |         |         |         |         |
|  Continuous<br>(3 x 200–240 V) [A]<br><br>Intermittent<br>(3 x 200–240 V) [A]<br><br>Continuous<br>kVA (208 V AC) [kVA]<br><br>Max. cable size:<br>(line power, motor, brake)<br>[mm <sup>2</sup> / AWG] <sup>2)</sup>                                                                | 24.2 | 30.8 | 46.2   | 59.4   | 74.8    | 88.0   | 115     | 143     | 170     | 208     | 250     | 300     |
|                                                                                                                                                                                                                                                                                                                                                                          | 26.6 | 33.9 | 50.8   | 65.3   | 82.3    | 96.8   | 127     | 157     | 187     | 234     | 281     | 339     |
|                                                                                                                                                                                                                                                                                                                                                                          | 8.7  | 11.1 | 16.6   | 21.4   | 26.9    | 31.7   | 41.4    | 51.5    | 61.2    | 76.4    | 95.5    | 116.6   |
|                                                                                                                                                                                                                                                                                                                                                                          | 10/7 | 35/2 | 50/1/0 | 95/4/0 | 120/250 | 160/40 | 200/250 | 250/350 | 300/400 | 350/450 | 400/500 | 450/550 |
| <b>Max. input current</b>                                                                                                                                                                                                                                                                                                                                                |      |      |        |        |         |        |         |         |         |         |         |         |
| Continuous<br>(3 x 200–240 V) [A]<br><br>Intermittent<br>(3 x 200–240 V) [A]<br><br>Max. pre-fuses <sup>1)</sup> [A]<br><br>Environment:<br><br>Estimated power loss<br>at rated max. load [W] <sup>4)</sup><br><br>Weight enclosure IP20 [kg]<br>Weight enclosure IP21 [kg]<br>Weight enclosure IP55 [kg]<br>Weight enclosure IP66 [kg]<br><br>Efficiency <sup>3)</sup> | 22.0 | 28.0 | 42.0   | 54.0   | 68.0    | 80.0   | 104.0   | 130.0   | 154.0   | 190     | 220     | 270     |
|                                                                                                                                                                                                                                                                                                                                                                          | 24.2 | 30.8 | 46.2   | 59.4   | 74.8    | 88.0   | 114.0   | 143.0   | 169.0   | 211     | 250     | 300     |
|                                                                                                                                                                                                                                                                                                                                                                          | 63   | 63   | 63     | 80     | 125     | 125    | 160     | 200     | 250     | 300     | 350     | 400     |
|                                                                                                                                                                                                                                                                                                                                                                          | 269  | 310  | 447    | 602    | 737     | 845    | 1140    | 1353    | 1636    | 2045    | 2454    | 2963    |
|  Weight enclosure IP20 [kg]<br>Weight enclosure IP21 [kg]<br>Weight enclosure IP55 [kg]<br>Weight enclosure IP66 [kg]<br><br>Efficiency <sup>3)</sup>                                                                                                                                | 12   | 12   | 12     | 23.5   | 23.5    | 35     | 35      | 50      | 50      | 65      | 65      | 80      |
|                                                                                                                                                                                                                                                                                                                                                                          | 23   | 23   | 23     | 27     | 45      | 45     | 65      | 65      | 80      | 100     | 100     | 120     |
|                                                                                                                                                                                                                                                                                                                                                                          | 23   | 23   | 23     | 27     | 45      | 45     | 65      | 65      | 80      | 100     | 100     | 120     |
|                                                                                                                                                                                                                                                                                                                                                                          | 23   | 23   | 23     | 27     | 45      | 45     | 65      | 65      | 80      | 100     | 100     | 120     |
| Efficiency <sup>3)</sup>                                                                                                                                                                                                                                                                                                                                                 | 0.96 | 0.96 | 0.96   | 0.96   | 0.96    | 0.97   | 0.97    | 0.97    | 0.97    | 0.97    | 0.97    | 0.97    |
|                                                                                                                                                                                                                                                                                                                                                                          | 0.96 | 0.96 | 0.96   | 0.96   | 0.96    | 0.97   | 0.97    | 0.97    | 0.97    | 0.97    | 0.97    | 0.97    |
|                                                                                                                                                                                                                                                                                                                                                                          | 0.96 | 0.96 | 0.96   | 0.96   | 0.96    | 0.97   | 0.97    | 0.97    | 0.97    | 0.97    | 0.97    | 0.97    |
|                                                                                                                                                                                                                                                                                                                                                                          | 0.96 | 0.96 | 0.96   | 0.96   | 0.96    | 0.97   | 0.97    | 0.97    | 0.97    | 0.97    | 0.97    | 0.97    |

3.1.3 Line Power Supply 1 x 380–480 V AC

Line Power Supply 1x 380 V AC - Normal overload 110% for 1 minute

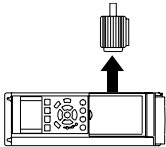
|                                    |      |      |      |      |
|------------------------------------|------|------|------|------|
| Adjustable frequency drive         | P7K5 | P11K | P18K | P37K |
| Typical Shaft Output [kW]          | 7.5  | 11   | 18.5 | 37   |
| Typical Shaft Output [HP] at 460 V | 10   | 15   | 25   | 50   |
| IP 21 / NEMA 1                     |      | B1   | B2   | C1   |
| IP 55 / NEMA 12                    |      | B1   | B2   | C2   |
| IP 66                              |      | B1   | B2   | C2   |

Output current

|                                  |      |      |      |      |
|----------------------------------|------|------|------|------|
| Continuous (3 x 380–440 V) [A]   | 16   | 24   | 37.5 | 73   |
| Intermittent (3 x 380–440 V) [A] | 17.6 | 26.4 | 41.2 | 80.3 |
| Continuous (3 x 441–480 V) [A]   | 14.5 | 21   | 34   | 65   |
| Intermittent (3 x 441–480 V) [A] | 15.4 | 23.1 | 37.4 | 71.5 |
| Continuous kVA (400 V AC) [kVA]  | 11.0 | 16.6 | 26   | 50.6 |
| Continuous kVA (460 V AC) [kVA]  | 11.6 | 16.7 | 27.1 | 51.8 |

Max. cable size:

(line power, motor, brake)  
[[mm<sup>2</sup>/ AWG] <sup>2</sup>]



Max. input current

|                                  |    |    |      |     |
|----------------------------------|----|----|------|-----|
| Continuous (1 x 380–440 V) [A]   | 33 | 48 | 78   | 151 |
| Intermittent (1 x 380–440 V) [A] | 36 | 53 | 85.8 | 166 |
| Continuous (1 x 441–480 V) [A]   | 30 | 41 | 72   | 135 |
| Intermittent (1 x 441–480 V) [A] | 33 | 46 | 79.2 | 148 |
| Max. pre-fuses <sup>1</sup> [A]  | 63 | 80 | 160  | 250 |

Environment

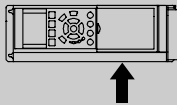
Estimated power loss  
at rated max. load [W] <sup>4)</sup>

Weight enclosure IP 21 [kg]

Weight enclosure IP 55 [kg]

Weight enclosure IP 66 [kg]

Efficiency <sup>3)</sup>



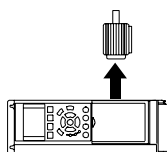
### 3.1.4 Line Power Supply 3 x 380–480 V AC

**Line Power Supply 3 x 380–480 V AC - Normal overload 110% for 1 minute**

|                                    |      |      |      |      |      |      |      |      |      |      |
|------------------------------------|------|------|------|------|------|------|------|------|------|------|
| Adjustable frequency drive         | 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:

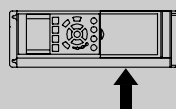
(line power, motor, brake)

[[mm<sup>2</sup>/ AWG] <sup>2)</sup>

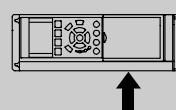
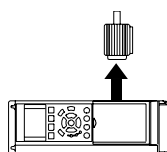
4/10

#### 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 <sup>1)</sup> [A]                          | 10   | 10   | 10   | 10   | 10   | 20   | 20   | 20   | 30   | 30   |
| Environment                                               |      |      |      |      |      |      |      |      |      |      |
| Estimated power loss at rated max. load [W] <sup>4)</sup> | 35   | 42   | 46   | 58   | 62   | 88   | 116  | 124  | 187  | 255  |
| Weight enclosure IP 20 [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 <sup>3)</sup>                                  | 0.93 | 0.95 | 0.96 | 0.96 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 |



| Line Power Supply 3 x 380–480 V AC - Normal overload 110% for 1 minute                                           |      |      |      |      |      |      |        |      |      |         |  |
|------------------------------------------------------------------------------------------------------------------|------|------|------|------|------|------|--------|------|------|---------|--|
| Adjustable frequency drive                                                                                       | P11K | P15K | P18K | P22K | P30K | P37K | P45K   | P55K | P75K | P90K    |  |
| Typical Shaft Output [kW]                                                                                        | 11   | 15   | 18.5 | 22   | 30   | 37   | 45     | 55   | 75   | 90      |  |
| Typical Shaft Output [HP] at 460 V                                                                               | 15   | 20   | 25   | 30   | 40   | 50   | 60     | 75   | 100  | 125     |  |
| IP 20 / NEMA Chassis<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   | C2      |  |
| IP 66                                                                                                            | B1   | B1   | B1   | B2   | B2   | C1   | C1     | C1   | C2   | C2      |  |
| Output current                                                                                                   |      |      |      |      |      |      |        |      |      |         |  |
| Continuous (3 x 380–440 V) [A]                                                                                   | 24   | 32   | 37.5 | 44   | 61   | 73   | 90     | 106  | 147  | 177     |  |
| Intermittent (3 x 380–440 V) [A]                                                                                 | 26.4 | 35.2 | 41.3 | 48.4 | 67.1 | 80.3 | 99     | 117  | 162  | 195     |  |
| Continuous (3 x 441–480 V) [A]                                                                                   | 21   | 27   | 34   | 40   | 52   | 65   | 80     | 105  | 130  | 160     |  |
| Intermittent (3 x 441–480 V) [A]                                                                                 | 23.1 | 29.7 | 37.4 | 44   | 61.6 | 71.5 | 88     | 116  | 143  | 176     |  |
| Continuous kVA (400 V AC) [kVA]                                                                                  | 16.6 | 22.2 | 26   | 30.5 | 42.3 | 50.6 | 62.4   | 73.4 | 102  | 123     |  |
| Continuous kVA (460 V AC) [kVA]                                                                                  | 16.7 | 21.5 | 27.1 | 31.9 | 41.4 | 51.8 | 63.7   | 83.7 | 104  | 128     |  |
| Max. cable size:                                                                                                 |      |      |      |      |      |      |        |      |      |         |  |
| (line power, motor, brake)                                                                                       | 10/7 |      |      | 35/2 |      |      | 50/1/0 |      |      | 120/4/0 |  |
| [[mm <sup>2</sup> / AWG] <sup>2)</sup>                                                                           |      |      |      |      |      |      |        |      |      |         |  |
| Max. input current                                                                                               |      |      |      |      |      |      |        |      |      |         |  |
| Continuous (3 x 380–440 V) [A]                                                                                   | 22   | 29   | 34   | 40   | 55   | 66   | 82     | 96   | 133  | 161     |  |
| Intermittent (3 x 380–440 V) [A]                                                                                 | 24.2 | 31.9 | 37.4 | 44   | 60.5 | 72.6 | 90.2   | 106  | 146  | 177     |  |
| Continuous (3 x 441–480 V) [A]                                                                                   | 19   | 25   | 31   | 36   | 47   | 59   | 73     | 95   | 118  | 145     |  |
| Intermittent (3 x 441–480 V) [A]                                                                                 | 20.9 | 27.5 | 34.1 | 39.6 | 51.7 | 64.9 | 80.3   | 105  | 130  | 160     |  |
| Max. pre-fuses <sup>1)</sup> [A]                                                                                 | 63   | 63   | 63   | 63   | 80   | 100  | 125    | 160  | 250  | 250     |  |
| Environment                                                                                                      |      |      |      |      |      |      |        |      |      |         |  |
| Estimated power loss at rated max. load [W] <sup>4)</sup>                                                        | 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   | 27   | 45     | 45   | 65   | 65      |  |
| Weight enclosure IP 55 [kg]                                                                                      | 23   | 23   | 23   | 27   | 27   | 27   | 45     | 45   | 65   | 65      |  |
| Weight enclosure IP 66 [kg]                                                                                      | 23   | 23   | 23   | 27   | 27   | 27   | 45     | 45   | 65   | 65      |  |
| Efficiency <sup>3)</sup>                                                                                         | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98   | 0.98 | 0.98 | 0.99    |  |



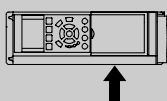
## Output current

Max. cable size:

|                                                     |               |                    |                    |                    |                      |
|-----------------------------------------------------|---------------|--------------------|--------------------|--------------------|----------------------|
| (motor), [mm <sup>2</sup> / AWG <sup>3</sup> ]      | 2x70<br>2x2/0 | 2x185<br>2x300 mcm | 4x240<br>4x500 mcm | 8x150<br>8x300 mcm | 12x150<br>12x300 mcm |
| (line power) [mm <sup>2</sup> / AWG <sup>2</sup> ]  | 2x70<br>2x2/0 | 2x185<br>2x300 mcm | 4x240<br>4x500 mcm | 8x240<br>8x500 mcm |                      |
| (loadsharing) [mm <sup>2</sup> / AWG <sup>2</sup> ] | 2x70<br>2x2/0 | 2x185<br>2x300 mcm | 4x240<br>4x500 mcm | 4x120<br>4x250 mcm |                      |
| (brake) [mm <sup>2</sup> / AWG <sup>2</sup> ]       | 2x70<br>2x2/0 | 2x185<br>2x300 mcm | 2x185<br>2x350 mcm | 4x185<br>4x350 mcm | 6x185<br>6x350 mcm   |



| <b>Normal overload 110% for 1 minute</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |      |      |      |      |      |      |      |      |       |       |       |       |       |       |  |  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|------|------|------|------|------|------|-------|-------|-------|-------|-------|-------|--|--|
| Adjustable frequency drive                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | P110 | P132 | P160 | P200 | P250 |      | P400 | P450 | P500  | P560  | P630  | P710  | P800  | P1M0  |  |  |
| Typical Shaft Output [kW] at 400 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 110  | 132  | 160  | 200  | 250  | 315  | 400  | 450  | 500   | 560   | 630   | 710   | 800   | 1000  |  |  |
| Typical Shaft Output [HP] at 460V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 150  | 200  | 250  | 300  | 350  | 450  | 550  | 600  | 650   | 750   | 900   | 1000  | 1200  | 1350  |  |  |
| IP 00                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | D3   | D3   | D4   | D4   | D4   | E2   | E2   | E2   | F1/F3 | F1/F3 | F1/F3 | F1/F3 | F2/F4 | F2/F4 |  |  |
| IP 21 / Nema 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | D1   | D1   | D2   | D2   | D2   | E1   | E1   | E1   | F1/F3 | F1/F3 | F1/F3 | F1/F3 | F2/F4 | F2/F4 |  |  |
| IP 54 / Nema 12                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | D1   | D1   | D2   | D2   | D2   | E1   | E1   | E1   | F1/F3 | F1/F3 | F1/F3 | F1/F3 | F2/F4 | F2/F4 |  |  |
| <b>Max. input current</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |      |      |      |      |      |      |      |      |       |       |       |       |       |       |  |  |
| Continuous (3 x 380–440 V) [A]                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 204  | 251  | 304  | 381  | 463  | 590  | 733  | 787  | 857   | 964   | 1090  | 1227  | 1422  | 1675  |  |  |
| Continuous (3 x 441–480 V) [A]                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 183  | 231  | 291  | 348  | 427  | 531  | 667  | 718  | 759   | 867   | 1022  | 1129  | 1344  | 1490  |  |  |
| Max. pre-fuses <sup>1)</sup> [A]                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 300  | 350  | 400  | 500  | 630  | 700  | 900  | 900  | 1600  | 1600  | 2000  | 2000  | 2500  | 2500  |  |  |
| Environment:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |  |  |
| Estimated power loss at 400 V AC at rated max. load [W] <sup>4)</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 3234 | 3782 | 4213 | 5119 | 5893 | 6790 | 8879 | 9670 | 10647 | 12338 | 13201 | 15436 | 18084 | 20358 |  |  |
| Estimated power loss at 460 V AC at rated max. load [W] <sup>4)</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2947 | 3665 | 4063 | 4652 | 5634 | 6082 | 8089 | 8803 | 9414  | 11006 | 12353 | 14041 | 17137 | 17752 |  |  |
| Weight enclosure IP00 [kg]                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 82   | 91   | 112  | 123  | 138  | 221  | 236  | 277  | -     | -     | -     | -     | -     | -     |  |  |
| Weight enclosure IP 21 [kg]                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 96   | 104  | 125  | 136  | 151  | 263  | 272  | 313  | 1004  | 1004  | 1004  | 1004  | 1246  | 1246  |  |  |
| Weight enclosure IP 54 [kg]                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 96   | 104  | 125  | 136  | 151  | 263  | 272  | 313  | 1299  | 1299  | 1299  | 1299  | 1541  | 1541  |  |  |
| Efficiency <sup>3)</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 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  |  |  |
| <sup>1)</sup> For type of fuse see section <i>Fuses</i><br><sup>2)</sup> American Wire Gauge<br><sup>3)</sup> Measured using 16 ft [5 m] shielded motor cables at rated load and rated frequency<br><sup>4)</sup> 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 adjustable frequency drive and vice versa.<br>If the switching frequency is raised from nominal, the power losses may rise significantly.<br>LCP and typical control card power consumptions are included. Further options and customer load may add up to 30 W to the losses. (Though typically only 4 W extra for a fully loaded control card or options for slot A or slot B, each).<br>Although measurements are made with state-of-the-art equipment, some measurement inaccuracy must be allowed for (+/-5%). |      |      |      |      |      |      |      |      |       |       |       |       |       |       |  |  |



### 3.1.5 Line Power Supply 3 x 525–600 V AC

Normal overload 110% for 1 minute

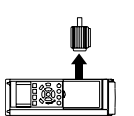
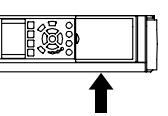
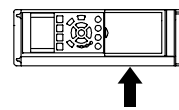
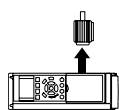
| Size:                                                                                 | PK75                                                         | P1K1 | P1K5 | P2K2 | P3K0 | P4K0 | P5K5 | P7K5 | P11K    | P15K    | P18K                                   | P22K | P30K | P37K | P45K | P55K | P75K | P90K       |  |
|---------------------------------------------------------------------------------------|--------------------------------------------------------------|------|------|------|------|------|------|------|---------|---------|----------------------------------------|------|------|------|------|------|------|------------|--|
| Typical Shaft Output [kW]                                                             | 0.75                                                         | 1.1  | 1.5  | 2.2  | 3    | 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   | A3   | A3   | B3      | B3      | B3                                     | B4   | B4   | B4   | C3   | C3   | C4   | C4         |  |
| IP 21 / NEMA 1                                                                        | 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   | B1      | B1      | B1                                     | B2   | B2   | B2   | C1   | C1   | C2   | C2         |  |
| IP 66                                                                                 | A5                                                           | A5   | A5   | A5   | A5   | A5   | A5   | A5   | B1      | B1      | B1                                     | B2   | B2   | B2   | C1   | C1   | C2   | C2         |  |
| Output current                                                                        |                                                              |      |      |      |      |      |      |      |         |         |                                        |      |      |      |      |      |      |            |  |
|    | Continuous<br>(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<br>(3 x 525–550 V) [A]                          | 2.9  | 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<br>(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<br>(3 x 525–600 V) [A]                          | 2.6  | 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)<br>[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)<br>[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<br>(line power, motor, brake)<br>[AWG] <sup>2)</sup> [mm²]            | 24 - 10 AWG<br>0.2 - 4                                       |      |      |      |      |      |      |      | 6<br>16 | 2<br>35 | 1<br>50<br><br>3/0<br>95 <sup>5)</sup> |      |      |      |      |      |      |            |  |
| Max. input current                                                                    |                                                              |      |      |      |      |      |      |      |         |         |                                        |      |      |      |      |      |      |            |  |
|  | Continuous<br>(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<br>(3 x 525–600 V) [A]                          | 2.7  | 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 <sup>1)</sup> [A]                             | 10   | 10   | 10   | 20   | 20   | 20   | 32   | 32      | 40      | 40                                     | 50   | 60   | 80   | 100  | 150  | 160  | 225 250    |  |
|                                                                                       | Environment:                                                 |      |      |      |      |      |      |      |         |         |                                        |      |      |      |      |      |      |            |  |
|                                                                                       | Estimated power loss<br>at rated max. load [W] <sup>4)</sup> | 35   | 50   | 65   | 92   | 122  | 145  | 195  | 261     | 225     | 285                                    | 329  | 460  | 560  | 740  | 860  | 890  | 1020 1130  |  |
| Weight [kg]:                                                                          |                                                              |      |      |      |      |      |      |      |         |         |                                        |      |      |      |      |      |      |            |  |
| Enclosure IP20                                                                        | 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 <sup>4)</sup>                                                              | 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: <sup>5)</sup> Motor and line cable: 300MCM/150mm<sup>2</sup>



### 3.1.6 Line Power Supply 3 x 525–690 V AC

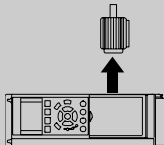
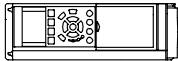
| Normal overload 110% for 1 minute                                                   |                                                                                       |                                   |      |      |      |      |           |      |      |      |       |
|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-----------------------------------|------|------|------|------|-----------|------|------|------|-------|
| Size:                                                                               | P11K                                                                                  | P15K                              | P18K | P22K | P30K | P37K | P45K      | P55K | P75K | P90K |       |
| Typical Shaft Output [kW]                                                           | 11                                                                                    | 15                                | 18.5 | 22   | 30   | 37   | 45        | 55   | 75   | 90   |       |
| Typical Shaft Output [HP] at 575 V                                                  | 10                                                                                    | 16.4                              | 20.1 | 24   | 33   | 40   | 50        | 60   | 75   | 100  |       |
| IP 21 / NEMA 1                                                                      | B2                                                                                    | B2                                | B2   | B2   | B2   | C2   | C2        | C2   | C2   | C2   |       |
| IP 55 / NEMA 12                                                                     | B2                                                                                    | B2                                | B2   | B2   | B2   | C2   | C2        | C2   | C2   | C2   |       |
| Output current                                                                      |                                                                                       |                                   |      |      |      |      |           |      |      |      |       |
|  | Continuous<br>(3 x 525–550 V) [A]                                                     | 14                                | 19   | 23   | 28   | 36   | 43        | 54   | 65   | 87   | 105   |
|                                                                                     | Intermittent<br>(3 x 525–550 V) [A]                                                   | 15.4                              | 20.9 | 25.3 | 30.8 | 39.6 | 47.3      | 59.4 | 71.5 | 95.7 | 115.5 |
|                                                                                     | Continuous<br>(3 x 551–690 V) [A]                                                     | 13                                | 18   | 22   | 27   | 34   | 41        | 52   | 62   | 83   | 100   |
|                                                                                     | Intermittent<br>(3 x 551–690 V) [A]                                                   | 14.3                              | 19.8 | 24.2 | 29.7 | 37.4 | 45.1      | 57.2 | 68.2 | 91.3 | 110   |
|                                                                                     | Continuous kVA (550 V AC) [kVA]                                                       | 13.3                              | 18.1 | 21.9 | 26.7 | 34.3 | 41        | 51.4 | 61.9 | 82.9 | 100   |
|                                                                                     | Continuous kVA (575 V AC) [kVA]                                                       | 12.9                              | 17.9 | 21.9 | 26.9 | 33.8 | 40.8      | 51.8 | 61.7 | 82.7 | 99.6  |
|                                                                                     | Continuous kVA (690 V AC) [kVA]                                                       | 15.5                              | 21.5 | 26.3 | 32.3 | 40.6 | 49        | 62.1 | 74.1 | 99.2 | 119.5 |
|                                                                                     | Max. cable size<br>(line power, motor, brake)<br>[mm²]/[AWG] <sup>2)</sup>            | 35<br>1/0                         |      |      |      |      | 95<br>4/0 |      |      |      |       |
|                                                                                     | Max. input current                                                                    |                                   |      |      |      |      |           |      |      |      |       |
|                                                                                     |  | Continuous<br>(3 x 525–690 V) [A] | 15   | 19.5 | 24   | 29   | 36        | 49   | 59   | 71   | 87    |
| Intermittent<br>(3 x 525–690 V) [A]                                                 |                                                                                       | 16.5                              | 21.5 | 26.4 | 31.9 | 39.6 | 53.9      | 64.9 | 78.1 | 95.7 | 108.9 |
| Max. pre-fuses <sup>1)</sup> [A]                                                    |                                                                                       | 60                                | 60   | 60   | 60   | 60   | 150       | 150  | 150  | 150  | 150   |
| Environment:                                                                        |                                                                                       |                                   |      |      |      |      |           |      |      |      |       |
| Estimated power loss<br>at rated max. load [W] <sup>4)</sup>                        |                                                                                       | 201                               | 285  | 335  | 375  | 430  | 592       | 720  | 880  | 1200 | 1440  |
| Weight:                                                                             |                                                                                       |                                   |      |      |      |      |           |      |      |      |       |
| IP21 [kg]                                                                           |                                                                                       | 27                                | 27   | 27   | 27   | 27   | 65        | 65   | 65   | 65   | 65    |
| IP55 [kg]                                                                           | 27                                                                                    | 27                                | 27   | 27   | 27   | 65   | 65        | 65   | 65   | 65   |       |
| Efficiency <sup>4)</sup>                                                            | 0.98                                                                                  | 0.98                              | 0.98 | 0.98 | 0.98 | 0.98 | 0.98      | 0.98 | 0.98 | 0.98 |       |

Table 3.2: <sup>5)</sup> Motor and line cable: 300MCM/150mm<sup>2</sup>

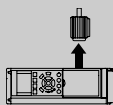
### 3.1.7 Line Power Supply 3 x 525–690 V AC

Normal overload 110% for 1 minute

| Adjustable frequency drive         | P45K |    |    | P55K |     |     | P75K |     |     | P90K |     |     | P110 |     |     | P132 |       |       | P160  |       |       | P200 |  |  | P250 |  |  | P315 |  |  | P400 |  |  | P450 |  |  | P500 |  |  | P560 |  |  | P630 |  |  | P710 |  |  | P800 |  |  | P900 |  |  | P1M0 |  |  | P1M2 |  |  |
|------------------------------------|------|----|----|------|-----|-----|------|-----|-----|------|-----|-----|------|-----|-----|------|-------|-------|-------|-------|-------|------|--|--|------|--|--|------|--|--|------|--|--|------|--|--|------|--|--|------|--|--|------|--|--|------|--|--|------|--|--|------|--|--|------|--|--|------|--|--|
|                                    | 45   | 55 | 75 | 90   | 110 | 132 | 160  | 200 | 250 | 300  | 350 | 400 | 450  | 500 | 560 | 630  | 710   | 800   | 900   | 1000  | 1200  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |
| Typical Shaft Output [kW]          | 50   | 60 | 75 | 100  | 125 | 150 | 200  | 250 | 300 | 350  | 400 | 450 | 500  | 560 | 630 | 710  | 800   | 900   | 1000  | 1200  |       |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |
| Typical Shaft Output [HP] at 575 V | D3   | D3 | D3 | D3   | D3  | D3  | D3   | D4  | D4  | D4   | D4  | D4  | E2   | E2  | E2  | E2   | F1/   | F1/   | F1/   | F2/   | F2/   |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |
| IP 00                              | D1   | D1 | D1 | D1   | D1  | D1  | D1   | D2  | D2  | D2   | D2  | D2  | E1   | E1  | E1  | E1   | F3(6) | F3(6) | F3(6) | F4(6) | F4(6) |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |
| IP 21 / Nema 1                     | D1   | D1 | D1 | D1   | D1  | D1  | D1   | D2  | D2  | D2   | D2  | D2  | E1   | E1  | E1  | E1   | F1/   | F1/   | F1/   | F2/   | F2/   |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |      |  |  |
| IP 54 / Nema 12                    | D1   | D1 | D1 | D1   | D1  | D1  | D1   | D2  | D2  | D2   | D2  | D2  | E1   | E1  | E1  | E1   | F3(6) | F3(6) | F3(6) | F4(6) | F4(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 690 V) [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 V AC) [kVA] | 53 | 72 | 86  | 108 | 131 | 154 | 191 | 241 | 289 | 343 | 398 | 448 | 498 | 568 | 600 | 727 | 847  | 941  | 1056 | 1255 |
| Continuous kVA (575 V AC) [kVA] | 54 | 73 | 86  | 108 | 130 | 154 | 191 | 241 | 289 | 343 | 398 | 448 | 498 | 568 | 627 | 727 | 847  | 941  | 1056 | 1255 |
| Continuous kVA (690 V AC) [kVA] | 65 | 87 | 103 | 129 | 157 | 185 | 229 | 289 | 347 | 411 | 478 | 538 | 598 | 681 | 753 | 872 | 1016 | 1129 | 1267 | 1506 |



Max. cable size:

|                                                    |      |       |           |       |       |           |       |           |            |
|----------------------------------------------------|------|-------|-----------|-------|-------|-----------|-------|-----------|------------|
| (line power) [mm <sup>2</sup> / AWG] <sup>2)</sup> | 2x70 | 2x185 | 2x300 mcm | 4x240 | 8x240 | 8x500 mcm | 8x240 | 8x500 mcm | 8x240      |
| (Motor) [mm <sup>2</sup> / AWG] <sup>2)</sup>      | 2x70 | 2x185 | 2x300 mcm | 4x240 | 8x150 | 12x150    | 8x150 | 8x300 mcm | 12x300 mcm |
| (Brake) [mm <sup>2</sup> / AWG] <sup>2)</sup>      | 2x70 | 2x185 | 2x300 mcm | 2x185 | 4x185 | 6x185     | 4x185 | 4x350 mcm | 6x350 mcm  |

| <b>Normal overload 110% for 1 minute</b>                             |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |                         |                         |                         |                         |
|----------------------------------------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|-------------------------|-------------------------|-------------------------|-------------------------|
| Adjustable frequency drive                                           | P45K | P55K | P75K | P90K | P110 | P132 | P160 | P200 | P250 | P315 | P400 | P450 | P500 | P560 | P630 | P710                    | P800                    | P900                    | 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/<br>F3 <sup>6)</sup> | F1/<br>F3 <sup>6)</sup> | F1/<br>F3 <sup>6)</sup> | F2/<br>F4 <sup>6)</sup> |
| IP 54 / Nema 12                                                      | D1   | D1   | D1   | D1   | D1   | D1   | D1   | D2   | D2   | D2   | D2   | E1   | E1   | E1   | E1   | F1/<br>F3 <sup>6)</sup> | F1/<br>F3 <sup>6)</sup> | F1/<br>F3 <sup>6)</sup> | F1/<br>F3 <sup>6)</sup> |
| <b>Max. input current</b>                                            |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |                         |                         |                         |                         |
| Continuous (3 x 550 V) [A]                                           | 60   | 77   | 89   | 110  | 130  | 158  | 198  | 245  | 299  | 355  | 408  | 453  | 504  | 574  | 607  | 743                     | 866                     | 962                     | 1079 1282               |
| Continuous (3 x 575 V) [A]                                           | 58   | 74   | 85   | 106  | 124  | 151  | 189  | 224  | 286  | 339  | 390  | 434  | 482  | 549  | 607  | 711                     | 828                     | 920                     | 1032 1227               |
| Continuous (3 x 690 V) [A]                                           | 58   | 77   | 87   | 109  | 128  | 155  | 197  | 240  | 296  | 352  | 400  | 434  | 482  | 549  | 607  | 711                     | 828                     | 920                     | 1032 1227               |
| Max. line power pre-fuses <sup>1)</sup> [A]                          | 125  | 160  | 200  | 200  | 250  | 315  | 350  | 350  | 400  | 500  | 550  | 700  | 700  | 900  | 900  | 2000                    | 2000                    | 2000                    | 2000 2000               |
| <b>Environment:</b>                                                  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |                         |                         |                         |                         |
| Estimated power loss at 690 VAC at rated max. load [W] <sup>4)</sup> | 1458 | 1717 | 1913 | 2262 | 2662 | 3430 | 3612 | 4292 | 5156 | 5821 | 6149 | 6440 | 7249 | 8727 | 9673 | 11315                   | 1290                    | 14533                   | 1637                    |
| Estimated power loss at 575 VAC at rated max. load [W] <sup>4)</sup> | 1398 | 1645 | 1827 | 2157 | 2533 | 2963 | 3430 | 4051 | 4867 | 5493 | 5852 | 6132 | 6903 | 8343 | 9244 | 10771                   | 1227                    | 13835                   | 1559                    |
| Weight enclosure IP00 [kg]                                           | 82   | 82   | 82   | 82   | 82   | 82   | 91   | 112  | 123  | 138  | 151  | 221  | 221  | 236  | 277  | -                       | -                       | -                       | -                       |
| Weight enclosure IP21 [kg] 6)                                        | 96   | 96   | 96   | 96   | 96   | 96   | 104  | 125  | 136  | 151  | 165  | 263  | 263  | 272  | 313  | 1004                    | 1004                    | 1004                    | 1246                    |
| Weight enclosure IP54 [kg] 6)                                        | 96   | 96   | 96   | 96   | 96   | 96   | 104  | 125  | 136  | 151  | 165  | 263  | 263  | 272  | 313  | 1004                    | 1004                    | 1004                    | 1246                    |
| Efficiency <sup>3)</sup>                                             | 0.97 | 0.97 | 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                    |

<sup>1)</sup> For type of fuse see section *Fuses*

<sup>2)</sup> American Wire Gauge

<sup>3)</sup> Measured using 16 ft [5 m] shielded motor cables at rated load and rated frequency

<sup>4)</sup> 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 adjustable frequency drive and vice versa.

If the switching frequency is raised from nominal the power losses may rise significantly. LCP and typical control card power consumptions are included. Further options and customer load may add up to 30 [W] to the losses. (Though typically only 4 [W] 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%).

<sup>6)</sup> Adding the F-enclosure option cabinet (resulting in the F3 and F4 enclosure sizes) adds 650 lbs [295 kg] to the estimated weight.

## Protection and Features:

- Electronic thermal motor protection against overload.
- Temperature monitoring of the heatsink ensures that the adjustable frequency drive trips if the temperature reaches 203°F ± 41°F [95°C ± 5°C]. An overload temperature cannot be reset until the temperature of the heatsink is below 158°F ± 9°F [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 its heatsink reaching 203°F [95°C].
- The adjustable frequency drive is protected against short-circuits on motor terminals U, V, W.
- If a line phase is missing, the adjustable frequency drive trips or issues a warning (depending on the load).
- Monitoring of the intermediate circuit voltage ensures that the adjustable frequency drive trips if the intermediate circuit voltage is too low or too high.
- The adjustable frequency drive is protected against ground faults on motor terminals U, V, W.

## Line power supply (L1, L2, L3):

|                |                |
|----------------|----------------|
| Supply voltage | 200–240 V ±10% |
| Supply voltage | 380–480 V ±10% |
| Supply voltage | 525–600 V ±10% |
| Supply voltage | 525–690 V ±10% |

*AC line voltage low / line drop-out:*

*During low AC line voltage or a line drop-out, the adjustable frequency drive continues until the intermediate circuit voltage drops below the minimum stop level, which corresponds typically to 15% below the adjustable frequency drive's lowest rated supply voltage. Power-up and full torque cannot be expected at AC line voltage lower than 10% below the adjustable frequency drive's lowest rated supply voltage.*

|                  |                 |
|------------------|-----------------|
| Supply frequency | 50/60 Hz +4/-6% |
|------------------|-----------------|

*The adjustable frequency drive power supply is tested in accordance with IEC61000-4-28, 50 Hz +4/-6%.*

|                                                                           |                                             |
|---------------------------------------------------------------------------|---------------------------------------------|
| Max. imbalance temporary between line phases                              | 3.0% of rated supply voltage                |
| True Power Factor ( $\lambda$ )                                           | ≥ 0.9 nominal at rated load                 |
| Displacement Power Factor ( $\cos\phi$ ) 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.                         |
| Switching on input supply L1, L2, L3 (power-ups) ≥ enclosure type D, E, F | maximum 1 time/2 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.              |

\* Dependent on power size.

## 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, shielded/armored                            | VLT AQUA Drive: 492 ft [150 m]                                                                             |
| Max. motor cable length, unshielded/unarmored                        | VLT AQUA Drive: 984 ft [300 m]                                                                             |
| Max. cross-section to motor, line power, load sharing and brake *    |                                                                                                            |
| Maximum cross-section to control terminals, rigid wire               | 0.0023 in <sup>2</sup> [1.5 mm <sup>2</sup> ]/16 AWG (2 x 0.00112 in <sup>2</sup> [0.75 mm <sup>2</sup> ]) |
| Maximum cross-section to control terminals, flexible cable           | 0.0016 in <sup>2</sup> [1 mm <sup>2</sup> ]/18 AWG                                                         |
| Maximum cross-section to control terminals, cable with enclosed core | 0.0008 in <sup>2</sup> [0.5 mm <sup>2</sup> ]/20 AWG                                                       |
| Minimum cross-section to control terminals                           | 0.25 mm <sup>2</sup>                                                                                       |

\* See Line Power Supply tables for more information!

## Control card, RS-485 serial communication:

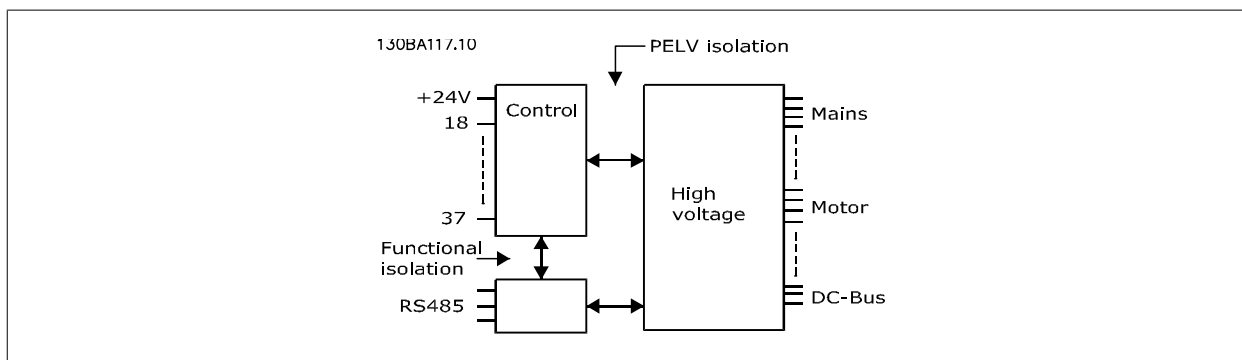
|                    |                                  |
|--------------------|----------------------------------|
| Terminal number    | 68 (P,TX+, RX+), 69 (N,TX-, RX-) |
| Terminal number 61 | Common for terminals 68 and 69   |

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

## 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 <sub>i</sub> | 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 <sub>i</sub> | 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 <sup>1)</sup> , 29 <sup>1)</sup> , 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 <sub>i</sub> | approx. 4 k                                           |

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 <sup>1)</sup>           |
| 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 <sub>i</sub>   | 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                       |
| <b>Relay 01 Terminal number</b>                                                      | 1-3 (break), 1-2 (make) |
| Max. terminal load (AC-1) <sup>1)</sup> on 1-3 (NC), 1-2 (NO) (Resistive load)       | 240 V AC, 2 A           |
| Max. terminal load (AC-15) <sup>1)</sup> (Inductive load @ cosφ 0.4)                 | 240 V AC, 0.2 A         |
| Max. terminal load (DC-1) <sup>1)</sup> on 1-2 (NO), 1-3 (NC) (Resistive load)       | 60 V DC, 1A             |
| Max. terminal load (DC-13) <sup>1)</sup> (Inductive load)                            | 24 V DC, 0.1A           |
| <b>Relay 02 Terminal number</b>                                                      | 4-6 (break), 4-5 (make) |
| Max. terminal load (AC-1) <sup>1)</sup> on 4-5 (NO) (Resistive load) <sup>2)3)</sup> | 400 V AC, 2 A           |
| Max. terminal load (AC-15) <sup>1)</sup> on 4-5 (NO) (Inductive load @ cosφ 0.4)     | 240 V AC, 0.2 A         |



|                                                                                  |                                             |
|----------------------------------------------------------------------------------|---------------------------------------------|
| Max. terminal load (DC-1) <sup>1)</sup> on 4-5 (NO) (Resistive load)             | 80 V DC, 2 A                                |
| Max. terminal load (DC-13) <sup>1)</sup> on 4-5 (NO) (Inductive load)            | 24 V DC, 0.1A                               |
| Max. terminal load (AC-1) <sup>1)</sup> on 4-6 (NC) (Resistive load)             | 240 V AC, 2 A                               |
| Max. terminal load (AC-15) <sup>1)</sup> on 4-6 (NC) (Inductive load @ cosφ 0.4) | 240 V AC, 0.2 A                             |
| Max. terminal load (DC-1) <sup>1)</sup> on 4-6 (NC) (Resistive load)             | 50 V DC, 2 A                                |
| Max. terminal load (DC-13) <sup>1)</sup> 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 enclosure A/B/C                        | 1.0 g                                                           |
| Vibration test enclosure D/E/F                        | 0.7 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. 122°F [50°C]                                               |

Derating for high ambient temperature, see section on special conditions

|                                                         |                                   |
|---------------------------------------------------------|-----------------------------------|
| Minimum ambient temperature during full-scale operation | 32°F [0°C]                        |
| Minimum ambient temperature at reduced performance      | 14°F [-10°C]                      |
| Temperature during storage/transport                    | -13°–+149°/158°F [-25°–+65°/70°C] |
| Maximum altitude above sea level without derating       | 3280 ft [1000 m]                  |
| Maximum altitude above sea level with derating          | 9842 ft [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                    |
|                         | EN 61800-3, EN 61000-6-1/2,                                          |
| EMC standards, Immunity | 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 |

3



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 ground. Only use an isolated laptop/PC as the connection to the USB connector on an VLT AQUA Drive or an isolated USB cable/drive.

## 3.2 Efficiency

### Efficiency of VLT AQUA ( $\eta_{VLT}$ )

The load on the adjustable frequency drive 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 partial loads.

This also means that the efficiency of the adjustable frequency drive 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 greater than 5 kHz. The efficiency will also be slightly reduced if the AC line voltage is 480 V, or if the motor cable is longer than 98.43 ft [30 m].

### Efficiency of the motor ( $\eta_{MOTOR}$ )

The efficiency of a motor connected to the adjustable frequency drive depends on magnetizing level. In general, the efficiency is just as good as with line 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 adjustable frequency drive, and when it runs directly on line power.

In small motors, the influence from the U/f characteristic on efficiency is marginal. However, in motors from 15 hp [11 kW] and up, the advantages are significant.

In general, the switching frequency does not affect the efficiency of small motors. The efficiency of motors from 15 hp [11 kW] and up improves by 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 ( $\eta_{MOTOR}$ ):

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

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

### 3.3 Acoustic noise

The acoustic noise from the adjustable frequency drive comes from three sources:

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

Typical values are measured at a distance of 3.28 ft. [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          | 59.4                                 | 70.5                 |
| B4          | 53                                   | 62.8                 |
| C1          | 52                                   | 62                   |
| C2          | 55                                   | 65                   |
| C3          | 56.4                                 | 67.3                 |
| C4          | -                                    | -                    |
| D1+D3       | 74                                   | 76                   |
| D2+D4       | 73                                   | 74                   |
| E1/E2 *     | 73                                   | 74                   |
| E1/E2 **    | 82                                   | 83                   |
| F1/F2/F3/F4 | 78                                   | 80                   |

\* 450 hp [315 kW], 380–480 V AC and 600/675 hp [450/500 kW], 525–690 V AC only!

\*\* Remaining E1+E2 power sizes.

\*\*\* For D, E and F 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  $du/dt$  ratio depending on:

- the motor cable (type, cross-section, length, shielded or unshielded)
- 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, motors without phase coil insulation are especially affected. If the motor cable is short (by a few yards), the rise time and peak voltage are lower.

If the motor cable is long (328 ft [100 m]), the rise time and peak voltage increase.

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

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.  $U_{PEAK} = \text{DC-link voltage} \times 1.9$   
(DC-link voltage = AC line voltage  $\times 1.35$ ).

3. 
$$\left. \frac{dU}{dt} \right| = \frac{0.8 \times U_{PEAK}}{\text{Risetime}}$$

Data are measured according to IEC 60034-17.

Cable lengths are in meters.

3

#### FC 202, P7K5T2

| Cable length [m] | AC line voltage [V] | Rise time [ $\mu\text{sec}$ ] | Vpeak [kV] | dU/dt [kV/ $\mu\text{sec}$ ] |
|------------------|---------------------|-------------------------------|------------|------------------------------|
| 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] | AC line voltage [V] | Rise time [ $\mu\text{sec}$ ] | Vpeak [kV] | dU/dt [kV/ $\mu\text{sec}$ ] |
|------------------|---------------------|-------------------------------|------------|------------------------------|
| 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] | AC line voltage [V] | Rise time [ $\mu\text{sec}$ ] | Vpeak [kV] | dU/dt [kV/ $\mu\text{sec}$ ] |
|------------------|---------------------|-------------------------------|------------|------------------------------|
| 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] | AC line voltage [V] | Rise time [ $\mu\text{sec}$ ] | Vpeak [kV] | dU/dt [kV/ $\mu\text{sec}$ ] |
|------------------|---------------------|-------------------------------|------------|------------------------------|
| 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] | AC line voltage [V] | Rise time [ $\mu\text{sec}$ ] | Vpeak [kV] | dU/dt [kV/ $\mu\text{sec}$ ] |
|------------------|---------------------|-------------------------------|------------|------------------------------|
| 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] | AC line voltage [V] | Rise time [ $\mu\text{sec}$ ] | Vpeak [kV] | dU/dt [kV/ $\mu\text{sec}$ ] |
|------------------|---------------------|-------------------------------|------------|------------------------------|
| 15               | 240                 | 0.194                         | 0.626      | 2.581                        |
| 50               | 240                 | 0.252                         | 0.574      | 1.822                        |
| 150              | 240                 | 0.488                         | 0.538      | 0.882                        |

**FC 202, P37KT2**

| Cable length [m] | AC line 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] | AC line 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] | AC line 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] | AC line 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] | AC line 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] | AC line 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] | AC line 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] | AC line 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] | AC line 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] | AC line 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] | AC line 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, P45KT4**

| Cable length [m] | AC line 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] | AC line 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] | AC line 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] | AC line 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] | AC line voltage [V] | Rise time [μsec] | Vpeak [kV] | dU/dt [kV/μsec] |
|------------------|---------------------|------------------|------------|-----------------|
| 30               | 400                 | 0.34             | 1.040      | 2.447           |

**FC 202, P315 - P1M0, T4**

| Cable length [m] | AC line voltage [V] | Rise time [ $\mu$ sec] | Vpeak [kV] | dU/dt [kV/ $\mu$ sec] |
|------------------|---------------------|------------------------|------------|-----------------------|
| 30               | 500                 | 0.71                   | 1.165      | 1.389                 |
| 30               | 400                 | 0.61                   | 0.942      | 1.233                 |

**FC 202, P110 - P400, T7**

| Cable length [m] | AC line voltage [V] | Rise time [ $\mu$ sec] | Vpeak [kV] | dU/dt [kV/ $\mu$ sec] |
|------------------|---------------------|------------------------|------------|-----------------------|
| 30               | 690                 | 0.38                   | 1.513      | 3.304                 |
| 30               | 575                 | 0.23                   | 1.313      | 2.750                 |
| 30               | 690 <sup>1)</sup>   | 1.72                   | 1.329      | 0.640                 |

1) With Danfoss dU/dt filter.

**FC 202, P450 - P1M2, T7**

| Cable length [m] | AC line voltage [V] | Rise time [ $\mu$ sec] | Vpeak [kV] | dU/dt [kV/ $\mu$ sec] |
|------------------|---------------------|------------------------|------------|-----------------------|
| 30               | 690                 | 0.57                   | 1.611      | 2.261                 |
| 30               | 575                 | 0.25                   |            | 2.510                 |
| 30               | 690 <sup>1)</sup>   | 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 adjustable frequency drive at low air pressure (high elevations), 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

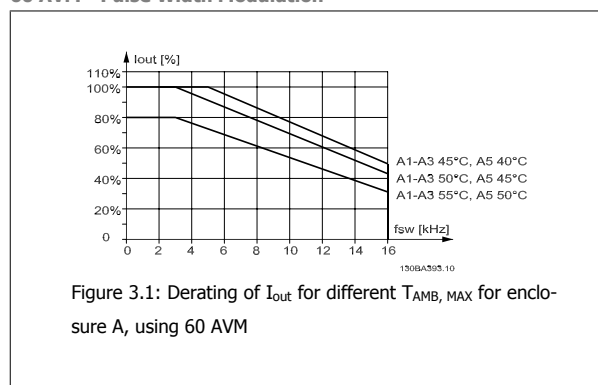
The average temperature ( $T_{AMB, AVG}$ ) measured over 24 hours must be at least 9°F [5°C] lower than the maximum allowed ambient temperature ( $T_{AMB, MAX}$ ).

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

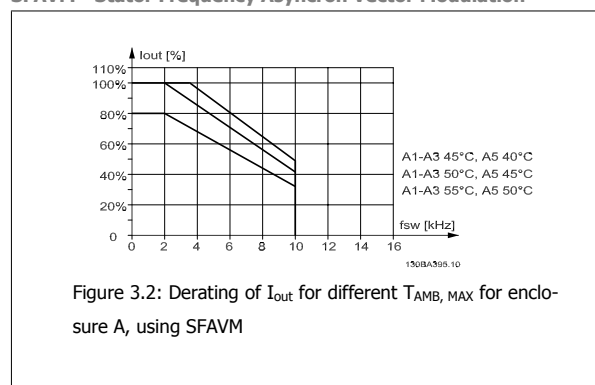
The derating depends on the switching pattern, which can be set to 60 AVM or SFAVM in parameter 14-00.

#### A enclosures

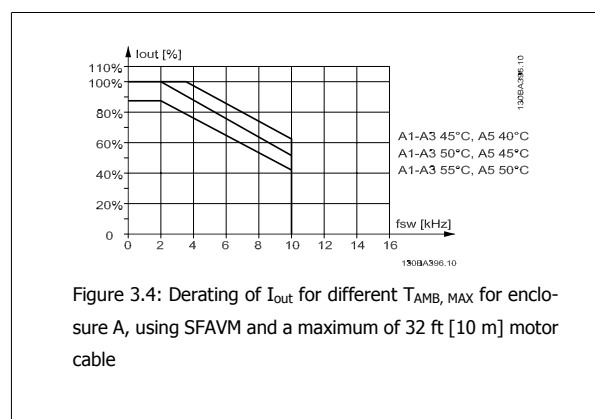
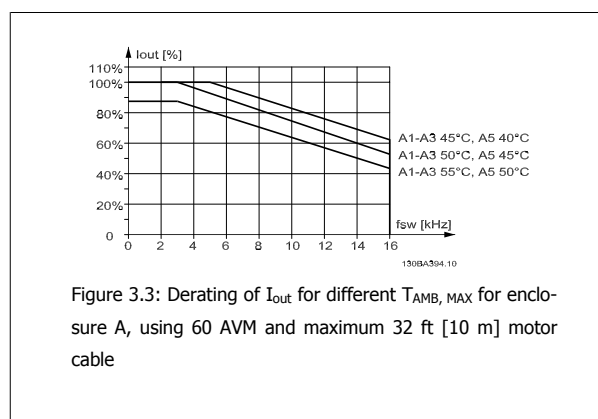
##### 60 AVM - Pulse Width Modulation



##### SFAVM - Stator Frequency Asynchron Vector Modulation



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. 32 ft [10 m] motor cable is also shown.



3

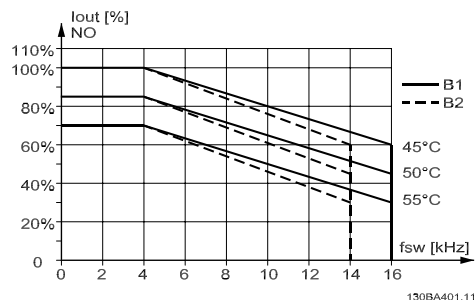
**B enclosures****60 AVM - Pulse Width Modulation**

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

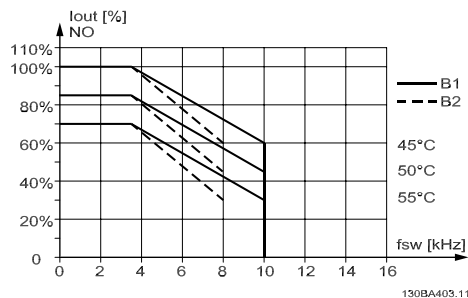
**SFAVM - Stator Frequency Asynchron Vector Modulation**

Figure 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 125 hp [90 kW] in IP55 and IP66, the max. ambient temperature is 9°F [5°C] lower.

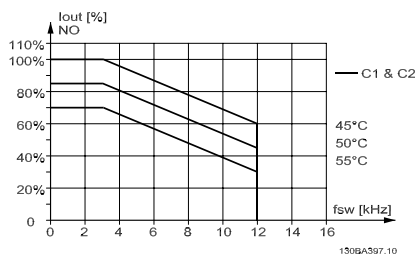
**60 AVM - Pulse Width Modulation**

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

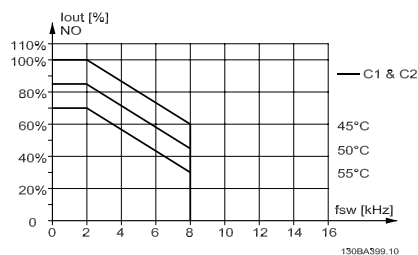
**SFAVM - Stator Frequency Asynchron Vector Modulation**

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

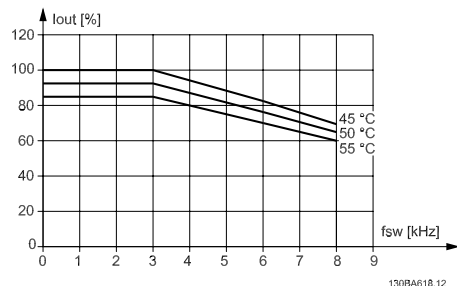
**D enclosures****60 AVM - Pulse Width Modulation, 380–480 V**

Figure 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)

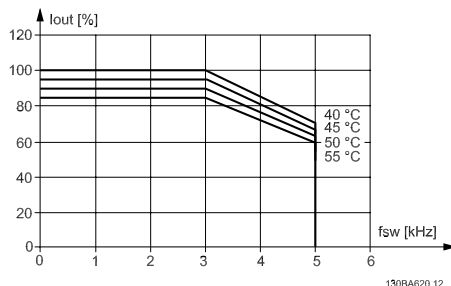
**SFAVM - Stator Frequency Asynchron Vector Modulation**

Figure 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)

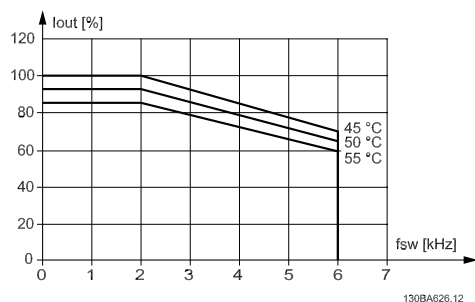
**60 AVM - Pulse Width Modulation, 525–690 V (except P400)**

Figure 3.11: Derating of  $I_{out}$  for different  $T_{AMB, MAX}$  for enclosure D at 690 V, using 60 AVM in Normal torque mode (110% over torque). Note: *not* valid for P400.

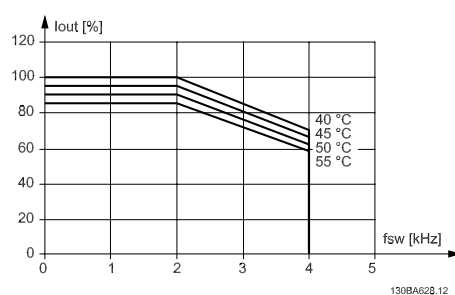
**SFAVM - Stator Frequency Asyncon Vector Modulation**

Figure 3.12: Derating of  $I_{out}$  for different  $T_{AMB, MAX}$  for enclosure D at 690 V, using SFAVM in normal torque mode (110% over torque). Note: *not* valid for P400.

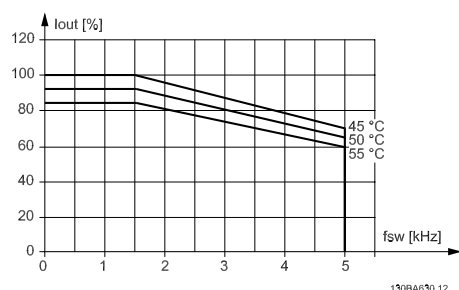
**60 AVM - Pulse Width Modulation, 525–690 V, P400**

Figure 3.13: Derating of  $I_{out}$  for different  $T_{AMB, MAX}$  for enclosure D at 690 V, using 60 AVM in Normal torque mode (110% over torque). Note: P400 *only*.

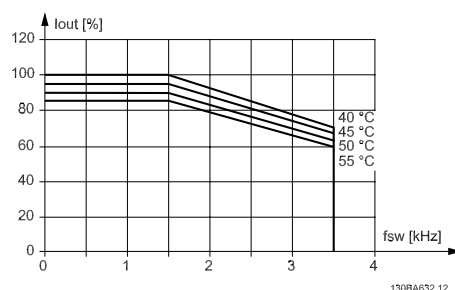
**SFAVM - Stator Frequency Asyncon Vector Modulation**

Figure 3.14: Derating of  $I_{out}$  for different  $T_{AMB, MAX}$  for enclosure D at 690 V, using SFAVM in normal torque mode (110% over torque). Note: P400 *only*.

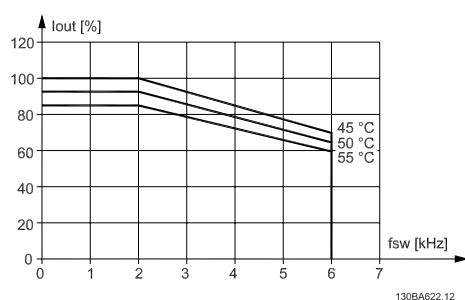
**E and F enclosures****60 AVM - Pulse Width Modulation, 380–480 V**

Figure 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)

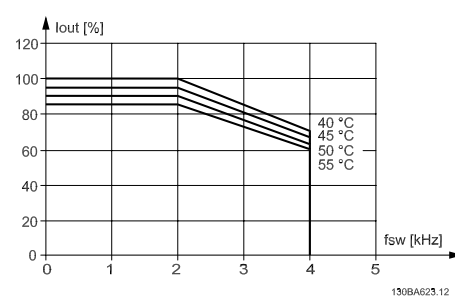
**SFAVM - Stator Frequency Asyncon Vector Modulation**

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

60 AVM - Pulse Width Modulation, 525–690 V

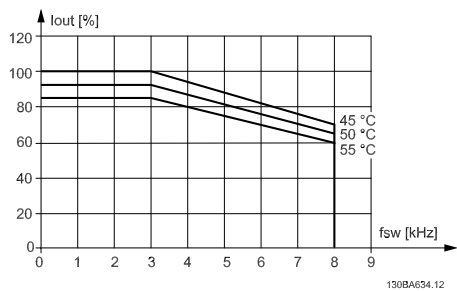


Figure 3.17: Derating of  $I_{out}$  for different  $T_{AMB, MAX}$  for enclosure E and F at 690 V, using 60 AVM in Normal torque mode (110% over torque).

SFAVM - Stator Frequency Asynchron Vector Modulation

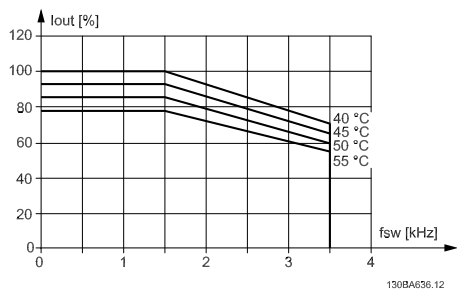


Figure 3.18: Derating of  $I_{out}$  for different  $T_{AMB, MAX}$  for enclosure E and F at 690 V, using SFAVM in Normal torque mode (110% over torque).

3.5.3 Derating for Low Air Pressure

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

At an altitude lower than 3,280 ft [1,000 m], no derating is necessary, but above 3,280 ft [1,000 m], the ambient temperature ( $T_{AMB}$ ) or max. output current ( $I_{out}$ ) should be derated in accordance with the diagram shown.

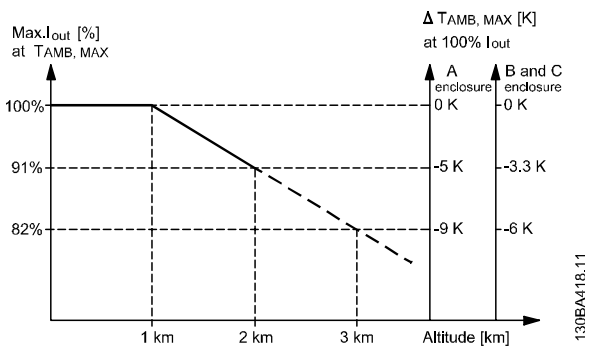
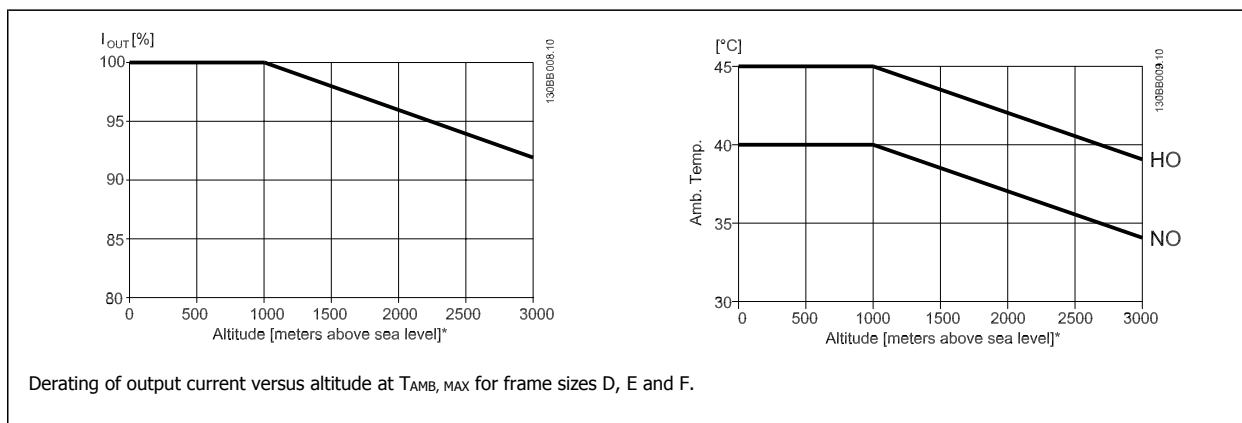


Figure 3.19: Derating of output current versus altitude at  $T_{AMB, MAX}$  for frame sizes A, B and C. At altitudes above 6,600 ft [2 km], please contact Danfoss Drives regarding PELV.

An alternative is to lower the ambient temperature at high altitudes and thereby ensure 100% output current at high altitudes. As an example of how to read the graph, the situation at 6,600 ft [2 km] is elaborated. At a temperature of 113°F [45°C] ( $T_{AMB, MAX} - 3.3$  K), 91% of the rated output current is available. At a temperature of 107°F [41.7°C], 100% of the rated output current is available.



### 3.5.4 Derating for Running at Low Speed

When a motor is connected to an adjustable frequency drive, it is necessary to check that the cooling of the motor is adequate. The level of heating depends on the load on the motor as well as the operating speed and time.

#### Constant torque applications (CT mode)

A problem may occur at low RPM values in constant torque applications. In a constant torque application, a motor may overheat at low speeds due to less cooling air from the motor integral fan.

Therefore, if the motor 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).

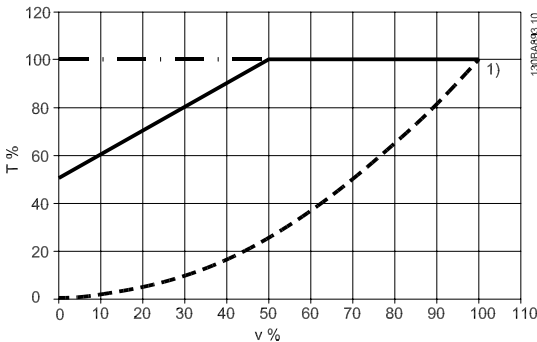
An alternative is to reduce the load level of the motor by choosing a larger motor. However, the design of the adjustable frequency drive limits the motor size.

#### 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 104°F [40°C] driven by an adjustable frequency drive type VLT FCxxx



**Legend:** --- Typical torque at VT load -.-.- Max torque with forced cooling — Max torque  
Note 1) Oversynchronous speed operation will result in the available motor torque decreasing inversely proportional to the increase in speed. This must be considered during the design phase to avoid overloading the motor.

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

**NOTE!**  
Applicable for drives up to 125 hp [90 kW] only.

The maximum cable length for this adjustable frequency drive is 984 ft [300 m] for unshielded cable, and 492 ft [150 m] for shielded cable.

The adjustable frequency drive 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 ground, and thus an increased ground leakage current).

3.5.6 Automatic Adaptations to Ensure Performance

The adjustable frequency drive 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 adjustable frequency drive can adjust the switching frequency and / or change the switching pattern in order to ensure the performance of the adjustable frequency drive. The capability to automatically reduce the output current extends the acceptable operating conditions even further.

## 3.6 Options and Accessories

Danfoss offers a wide range of options and accessories for adjustable frequency drives.

### 3.6.1 Mounting Option Modules in Slot B

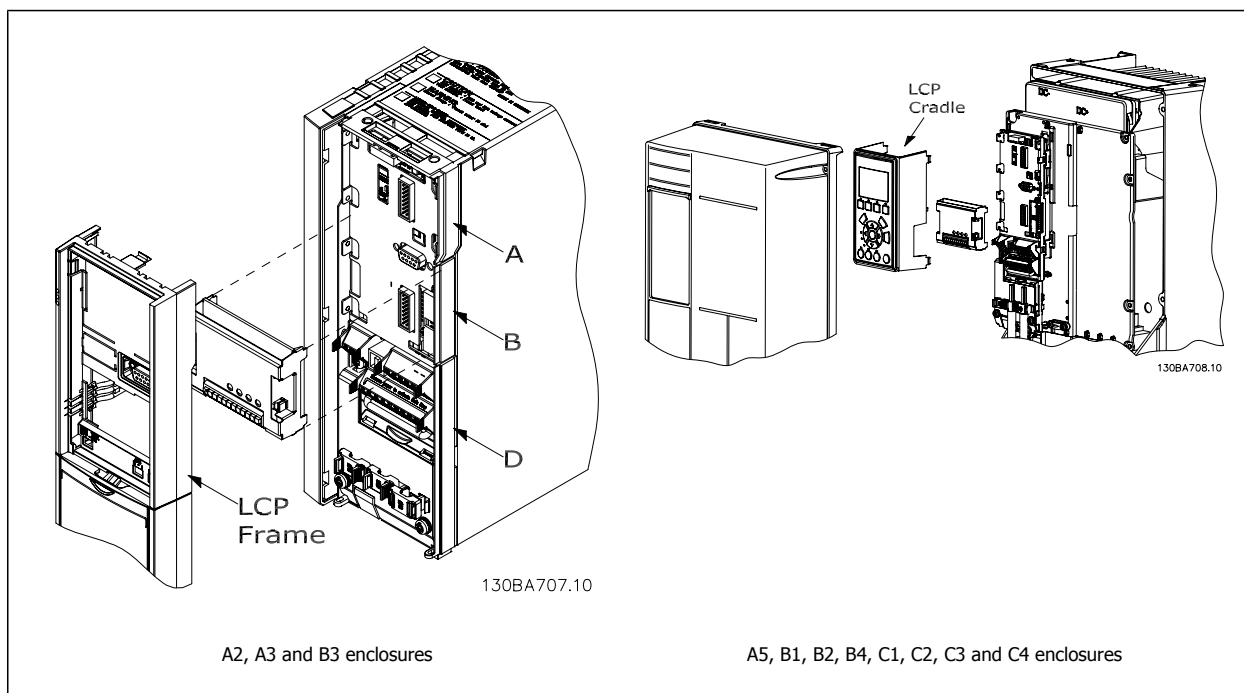
The power to the adjustable frequency drive must be disconnected.

For A2 and A3 enclosures:

- Remove the LCP (Local Control Panel), the terminal cover, and the LCP frame from the adjustable frequency drive.
- Insert the MCB10x option card into slot B.
- Connect the control cables and fasten the cables with the enclosed cable strips.  
Remove the knock-out in the extended LCP frame delivered in the option set so that the option will fit under the extended LCP frame.
- Fit the extended LCP frame and terminal cover.
- Fit the LCP or blind cover in the extended LCP frame.
- Connect power to the adjustable frequency drive.
- 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 LCP and the LCP 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 LCP



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: the MCB 101 must be inserted into slot B in the VLT AQUA Drive.**

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

130BA208.10

MCB 101

General Purpose I/O

FC Series

B slot

SW. ver. XX.XX

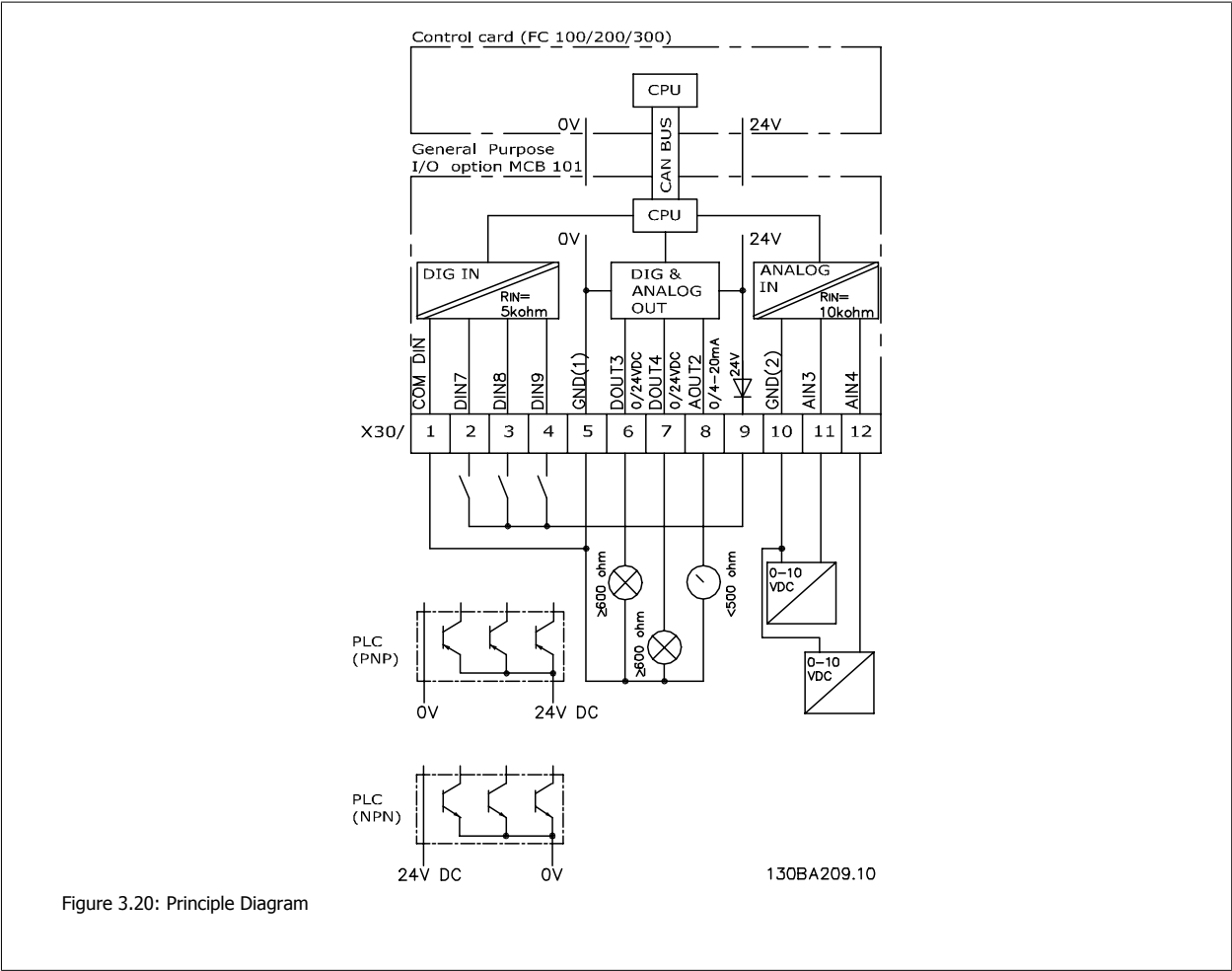
Code No. 130BXXXX

| COM  | DIN7 | DIN8 | DIN9 | GND(1) | DOUT3 | DOUT4 | AOUT2 | 24V | GND(2) | AIN3 | AIN4 |    |
|------|------|------|------|--------|-------|-------|-------|-----|--------|------|------|----|
| X30/ | 1    | 2    | 3    | 4      | 5     | 6     | 7     | 8   | 9      | 10   | 11   | 12 |

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 the ones on the control card of the drive.

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





### 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

### 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    | Approximately 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.

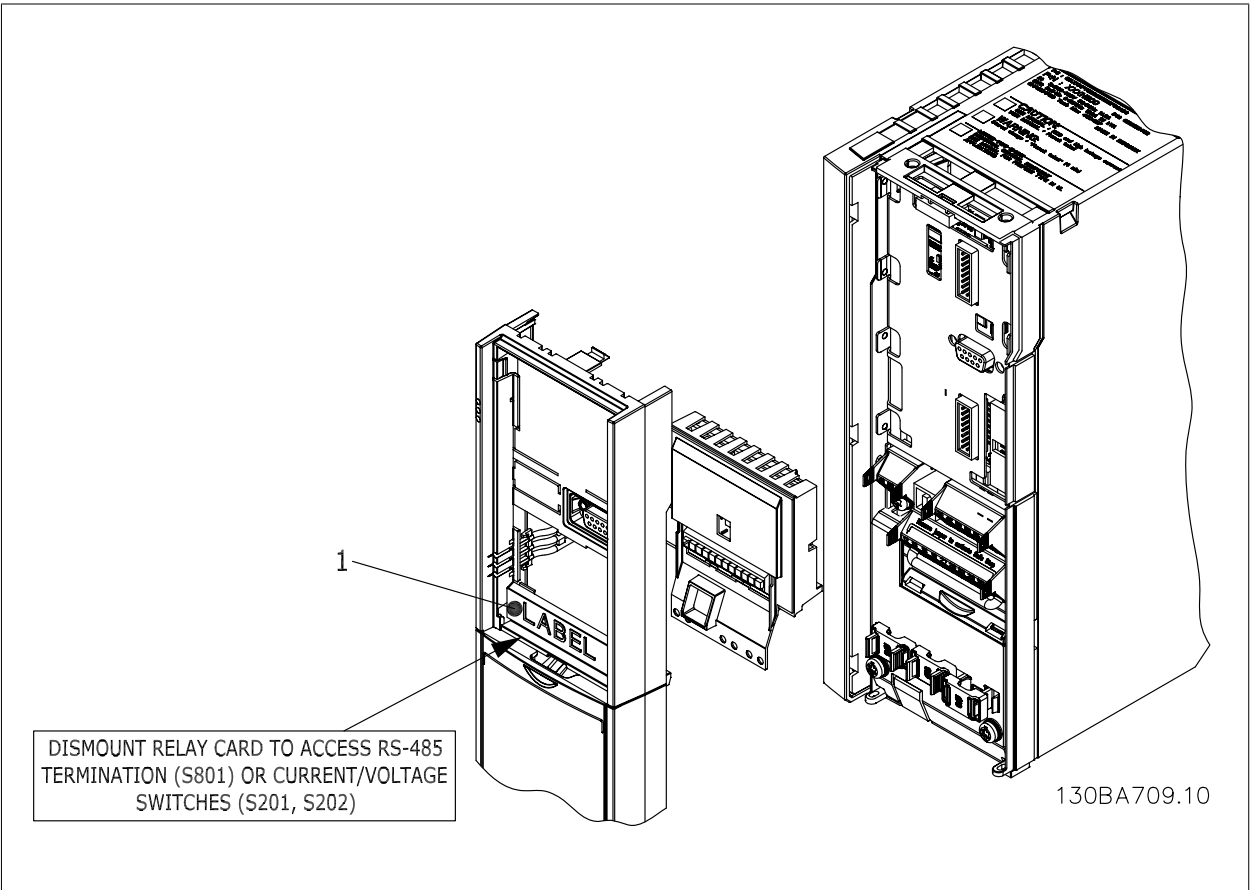
Electrical Data:

|                                                                     |                                           |
|---------------------------------------------------------------------|-------------------------------------------|
| Max terminal load (AC-1) <sup>1)</sup> (Resistive load)             | 240 V AC 2A                               |
| Max terminal load (AC-15) <sup>1)</sup> (Inductive load @ cosφ 0.4) | 240 V AC 0.2 A                            |
| Max terminal load (DC-1) <sup>1)</sup> (Resistive load)             | 24 V DC 1 A                               |
| Max terminal load (DC-13) <sup>1)</sup> (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 <sup>-1</sup> /20 sec <sup>-1</sup> |

1) IEC 947 part 4 and 5

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

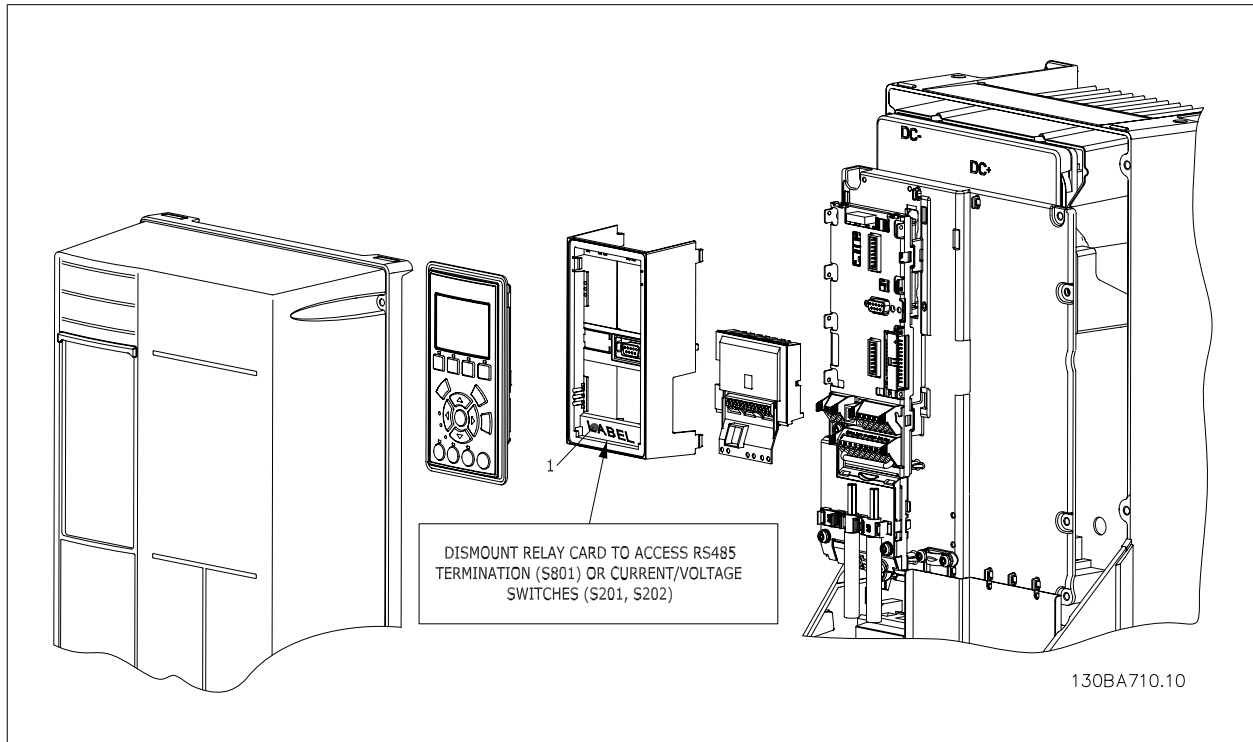
- Relay Module MCB 105
- Extended LCP frame and enlarged terminal cover
- Label for covering access to switches S201, S202 and S801
- Cable strips for fastening cables to relay module



A2-A3-B3

A5-B1-B2-B4-C1-C2-C3-C4

<sup>1)</sup> **IMPORTANT!** The label MUST be placed on the LCP frame as shown (UL approved).

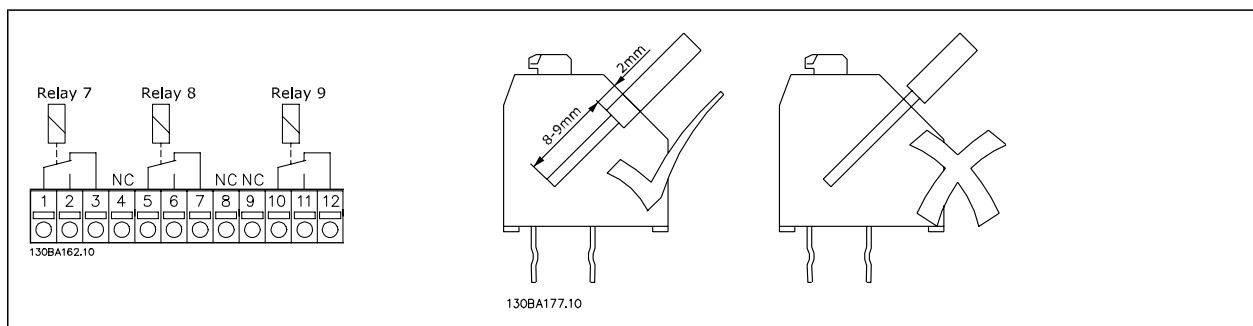


Warning Dual supply

How to add the MCB 105 option:

- See the mounting instructions at the beginning of the 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)



130BA1/6.10

2

3

4

5

6

7

8

9

10

11

12

NC

NC

NC

NC

NC

NC

NC

NC

NC

NC

NC

NC

LIVE PART

LIVE PART

PELV

1

2

3

4

5

6

7

8

9

10

11

12

NC

NC

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NC

NC

NC

NC

NC

NC

NC

PELV

PELV

PELV

1

2

3

4

5

6

7

8

9

10

11

12

NC

NC

NC

NC

NC

NC

NC

NC

NC

NC

NC

NC

LIVE PART

LIVE PART

LIVE PART

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 LCP (including the parameter setting) and serial communication buses without line power 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 adjustable frequency drive | 0.9 A                            |
| Max cable length                                         | 246 ft [75 m]                    |
| Input capacitance load                                   | < 10 uF                          |
| Power-up delay                                           | < 0.6 s                          |

The inputs are protected.

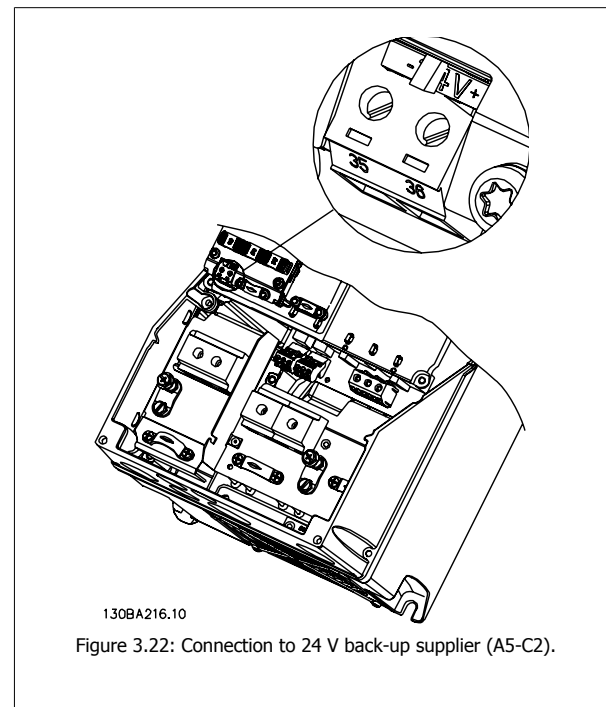
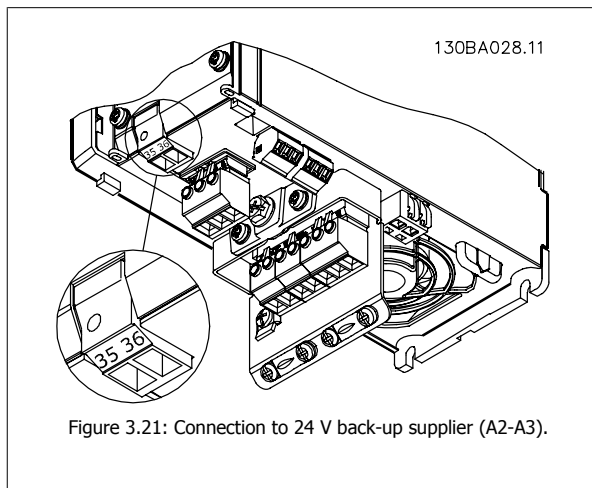
Terminal numbers:

- Terminal 35: - external 24 V DC supply.
- Terminal 36: + external 24 V DC supply.

Follow these steps:

1. Remove the LCP or blind cover
2. Remove the Terminal Cover
3. Remove the cable de-coupling 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 de-coupling plate
6. Attach the terminal cover and the LCP or blind cover.

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



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### 3.6.9 Analog I/O option MCB 109OPCAIO Analog I/O Option Module

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 the adjustable frequency drive into a de-central I/O block supporting a Building Management System with inputs for sensors and outputs for operating dampers and valve servos
- Support extended PID controllers with I/Os for setpoint inputs, transmitter/sensor inputs and outputs for switches.

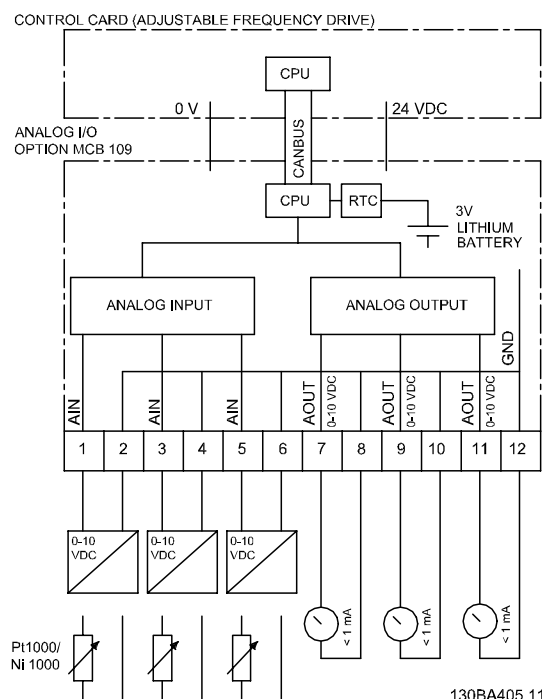


Figure 3.23: Principle diagram for analog I/O mounted in the adjustable frequency drive.

#### Analog I/O configuration

3 x analog inputs, capable of handling following:

- 0–10 VDC

OR

- 0–20 mA (voltage input 0–10 V) by mounting a 510Ω resistor across terminals (see NB!)
- 4–20 mA (voltage input 2–10 V) 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 32°F [°C]. Specifications according to IEC 60751

3 x analog outputs supplying 0–10 V DC.



#### NOTE!

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 8.997 V.

E24: Closest standard value is 510Ω, creating an input of 486.4Ω and 9.728 V.

E48: Closest standard value is 511Ω, creating an input of 487.3Ω and 9.746 V.

E96: Closest standard value is 523Ω, creating an input of 498.2Ω and 9.964 V.

#### Analog inputs - terminal X42/1-6

Parameter group for readout: 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                   | Resolution | Accuracy                                                  | Sampling | Max load              | Impedance          |
|----------------------------------|-----------------------------------|------------|-----------------------------------------------------------|----------|-----------------------|--------------------|
| Used as temperature sensor input | -58°F to +302°F [-50°C to +150°C] | 11 bits    | -58°F [-50°C]<br>±1 Kelvin<br>302°F [+150°C]<br>±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, the maximum cable length to connect sensors is 262 ft [80 m] with non-shielded/non-twisted wires.

#### Analog outputs - terminal X42/7-12

Parameter group for readout 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 has the same options as for analog outputs on the 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 77°F [25°C].

The built-in lithium back-up battery lasts on average for minimum 0 years, when adjustable frequency drive is operating at 104°F [40°C] ambient temperature. If the battery back-up pack fails, the analog I/O option must be replaced.

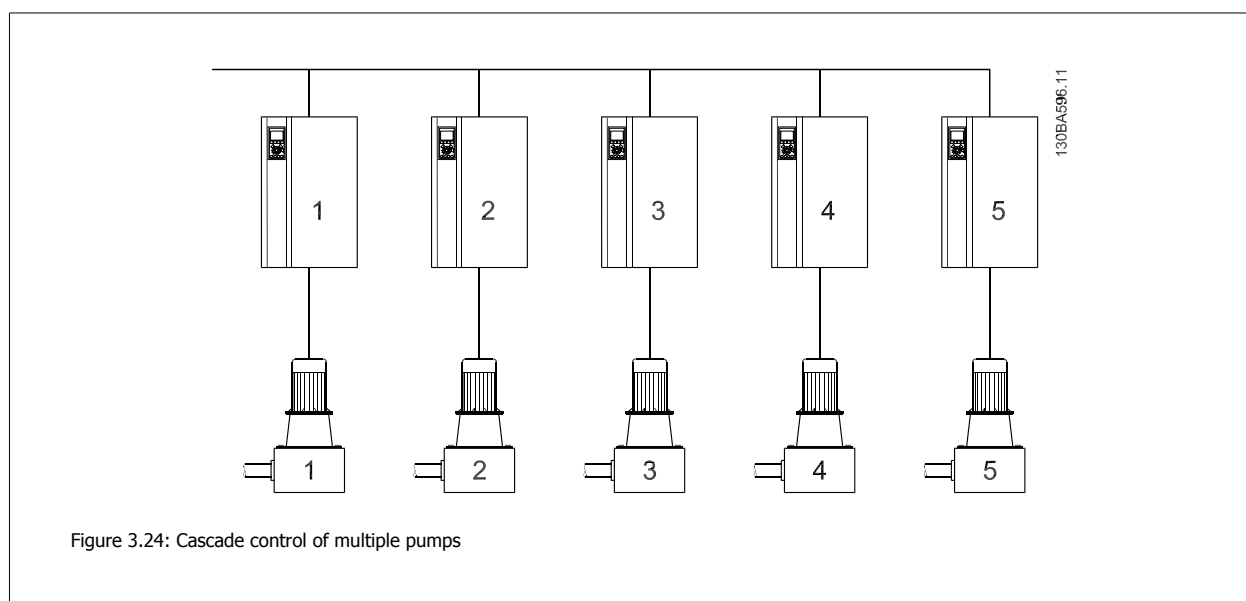
### 3.6.10 Extended Cascade Controller, MCO 101, and Advanced Cascade Controller, MCO 102

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

The 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.

3

When using cascade controllers, 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 the pumps connected to VLT AQUA Drives is also controlled to provide a continuous range of system output.



Cascade controllers are optional hardware and software components that can be added to the VLT AQUA Drive. It consists of an option board containing three relays that are installed in option slot B on the drive. Once options are installed, the parameters needed to support the 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 three relays and even up to eight relays with the Advanced Cascade Control card installed.

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 cascade controllers for any application requiring multiple motors configured in parallel.

### 3.6.11 General Description

The cascade controller software runs from a single VLT AQUA Drive with the Cascade Controller option card installed. This adjustable frequency drive is referred to as the master drive. It controls a set of pumps each controlled by an adjustable frequency drive or connected directly to line power through a contactor or through a soft starter.

Each additional adjustable frequency drive in the system is referred to as a Follower Drive. These adjustable frequency drives do not need the 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 adjustable frequency drives are referred to as Variable Speed Pumps.

Each additional pump connected to line power 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 adjustable frequency drive with the cascade controller option card installed has five relays available for controlling pumps. Two (2) relays are standard in the adjustable frequency drive and additional three relays are found on the option card MCO 101 or 8 relays and 7 digital inputs on option card MCO 102.

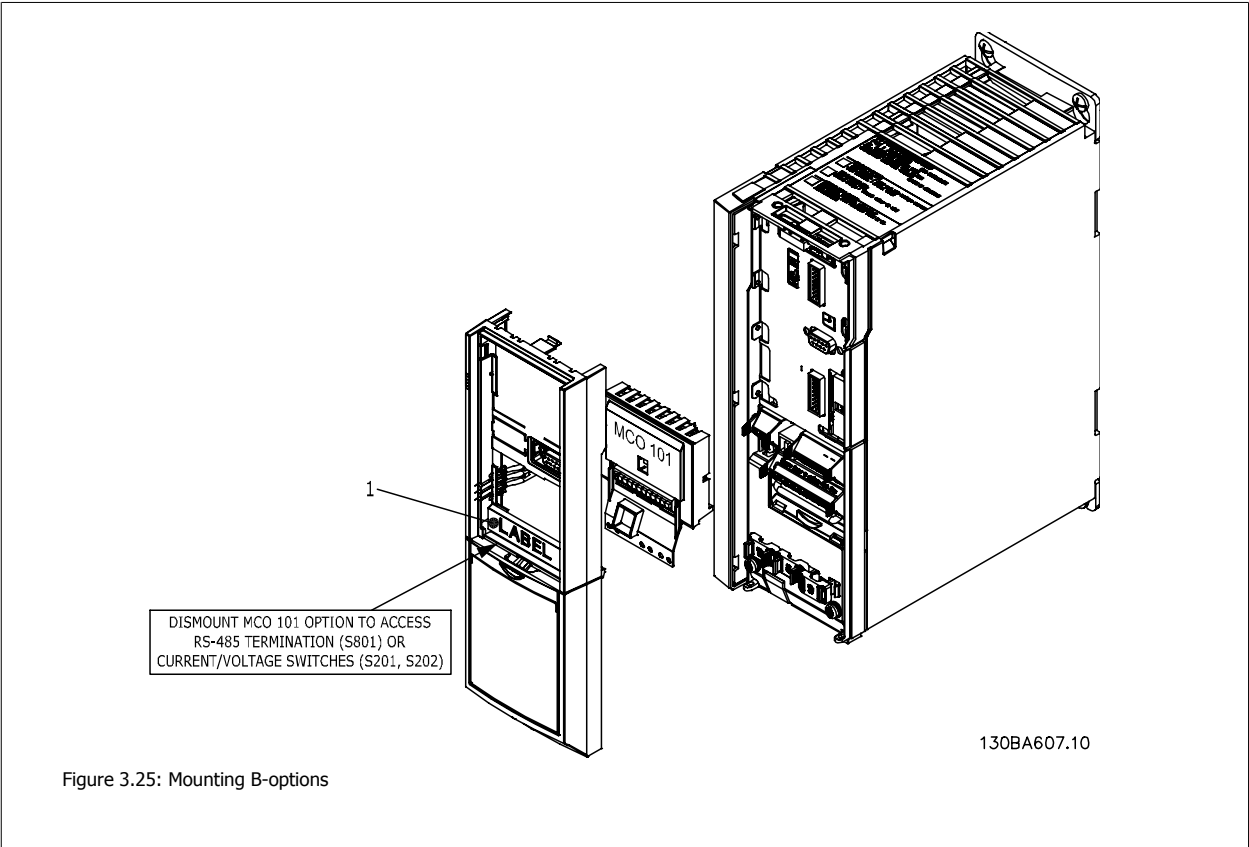
The difference between the MCO 101 and the MCO 102 is mainly the number of optional relays available to the adjustable frequency drive. When the MCO 102 is installed, the relays option card MCB 105 may be mounted in option slot B.

The 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 three change-over contacts and can be inserted 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 <sup>-1</sup> /20 sec <sup>-1</sup> |



Warning Dual supply

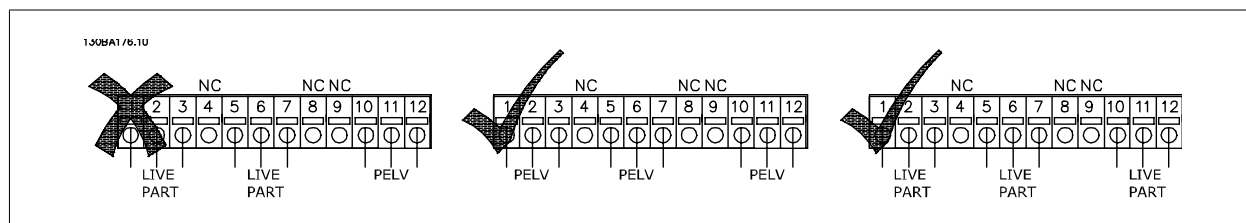
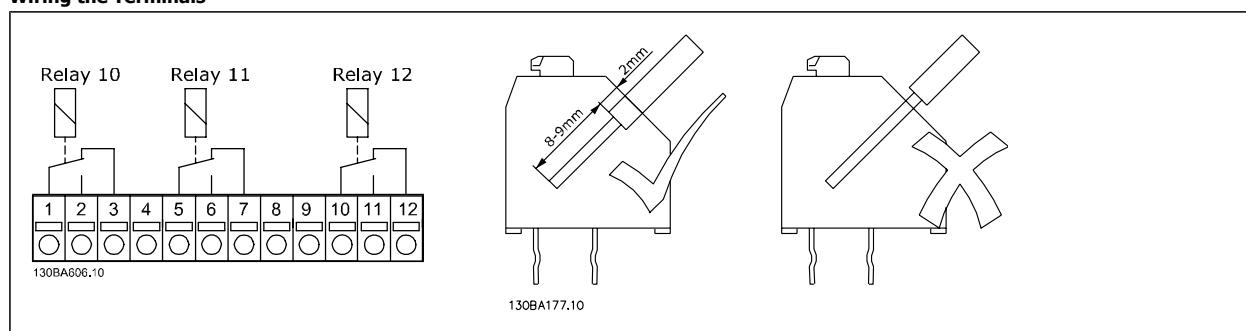
**NOTE!**

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

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How to add the MCO 101 option:

- The power to the adjustable frequency drive 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 fasten the cables by the enclosed cable strips.
- Different systems must not be mixed.
- Fit the extended cradle and terminal cover.
- Replace the LCP.
- Connect power to the adjustable frequency drive.

**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 sent back into the adjustable frequency drive. If the energy cannot be transported back to the motor, it will increase the voltage in the drive DC line. In applications with frequent braking and/or high inertia loads, this increase may lead to an overvoltage trip in the drive, and ultimately, 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. Danfoss offers a wide variety of different resistors that are specially designed to our adjustable frequency drives. See the section *Control with brake function* for the dimensioning of brake resistors. Code numbers can be found in the section *How to order*.

3.6.14 Remote Mounting Kit for

The local control panel can be moved to the front of a cabinet by using the remote built-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: | 9.8 ft [3 m] |
| Communication std:                  | RS 485       |

**Ordering no. 130B1113**

130BA138.10

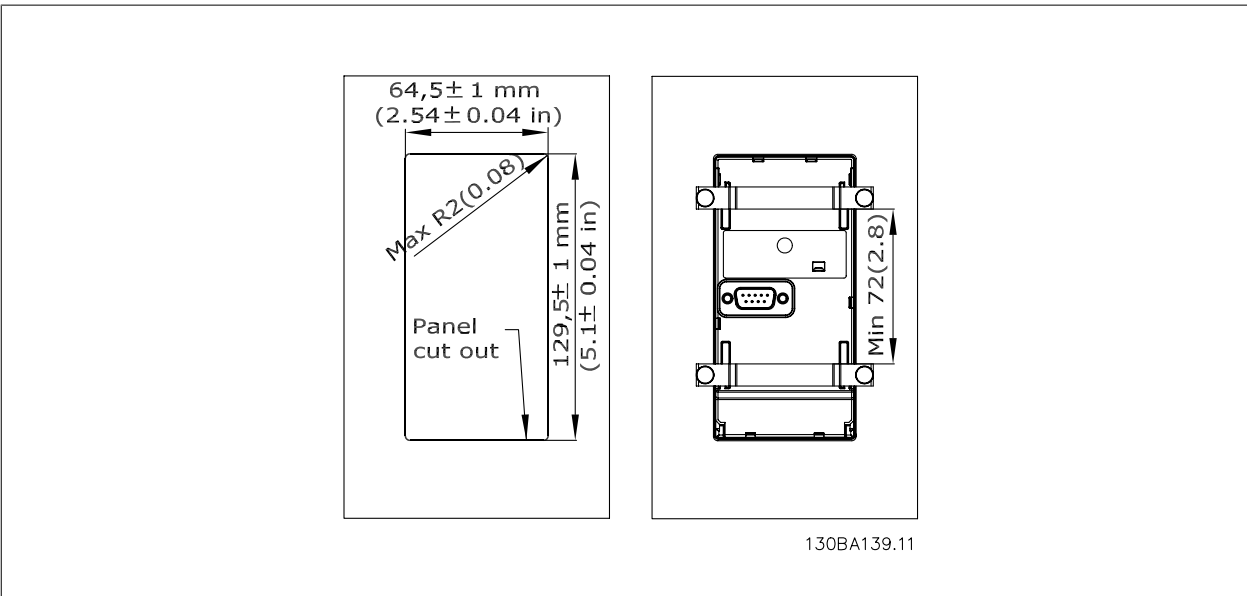
Figure 3.26: LCP kit with graphical LCP, fasteners, 9.8 ft [3 m] cable and gasket.

**Ordering no. 130B1114**

130BA200.10

Figure 3.27: LCP kit with numerical LCP, fasteners and gasket.

LCP kit without an LCP is also available. Ordering number: 130B1117  
For IP55 units, the ordering number is 130B1129.



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

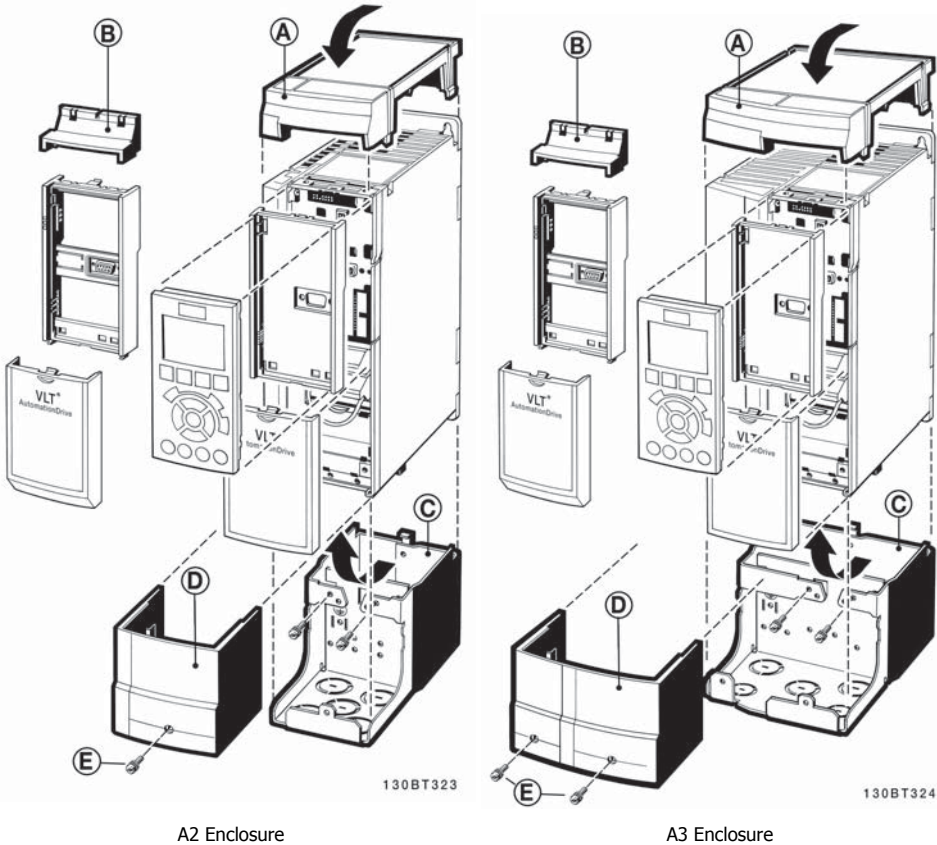
IP 20/IP 4X top/ TYPE 1 is an optional enclosure element available for IP 20 compact units, enclosure size A2-A3 up to 10 hp [7.5 kW].  
If the enclosure kit is used, an IP 20 unit is upgraded to comply with enclosure IP 21/ 4X top/TYPE 1.

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

3

- A – Top cover
- B – Brim
- C – Base part
- D – Base cover
- E – Screw(s)

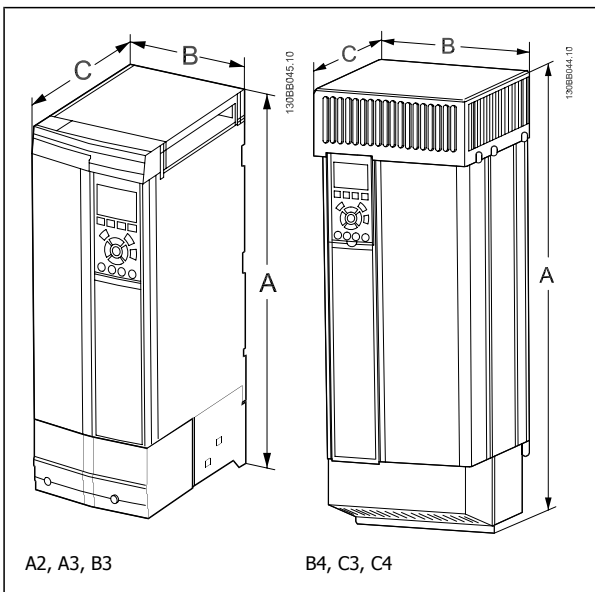
Place the top cover as shown. If an A or B option is used, the brim must be fitted to cover the top inlet. Place the base part C at the bottom of the drive and use the clamps from the accessory bag to correctly fasten the cables. Holes for cable connectors:  
Size A2: 2x M25 and 3xM32  
Size A3: 3xM25 and 3xM32



Dimensions

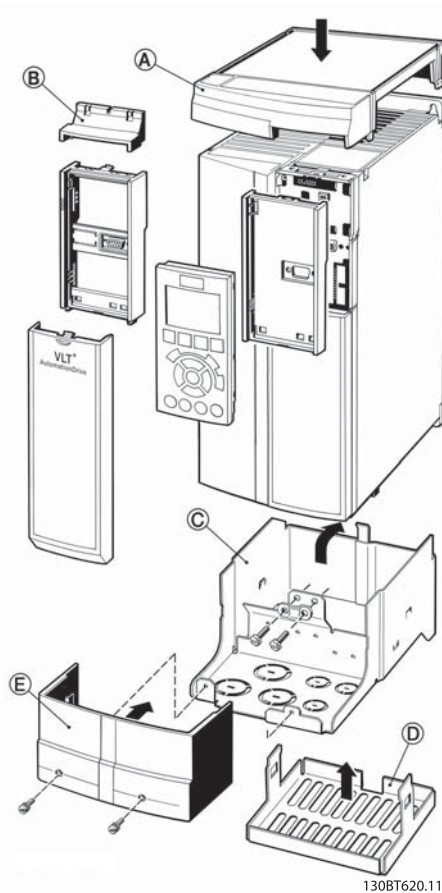
| Enclosure type | Height (mm)<br>A | Width (mm)<br>B | Depth (mm)<br>C* |
|----------------|------------------|-----------------|------------------|
| A2             | 372              | 90              | 205              |
| A3             | 372              | 130             | 205              |
| B3             | 475              | 165             | 249              |
| B4             | 670              | 255             | 246              |
| C3             | 755              | 329             | 337              |
| C4             | 950              | 391             | 337              |

\* If option A/B is used, the depth will increase (see section Mechanical Dimensions for details)

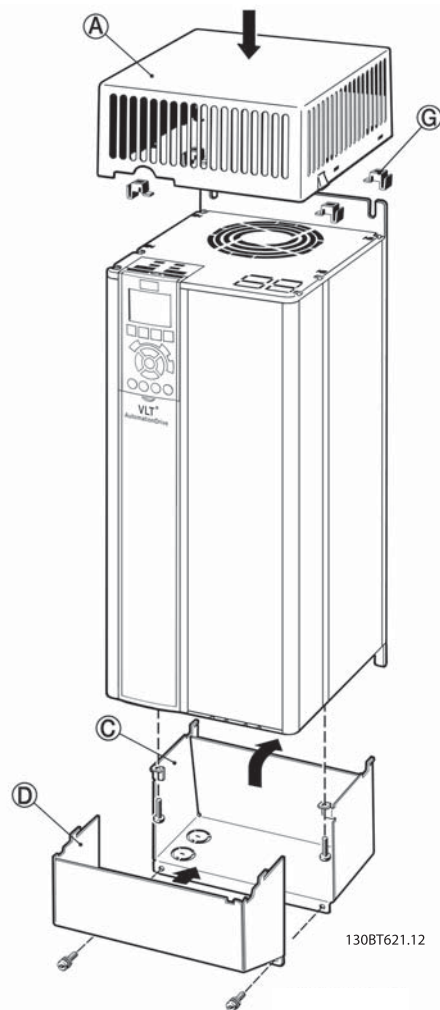


- A – Top cover
- B – Brim
- C – Base part
- D – Base cover
- E – Screw(s)
- F – Fan cover
- G – Top clip

When option module A and/or option module B is/are used, the brim (B) must be fitted to the top cover (A).



B3 Enclosure



B4 - C3 - C4 Enclosure

3

### 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 adjustable frequency drives.

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 adjustable frequency drive 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, it prevents premature aging and flashover in the motor insulation. The 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 allow only low frequencies to 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 adjustable frequency drive 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 service. 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.

## 3.7 High Power Options

### 3.7.1 Installation of Duct Cooling Kit in Rittal Enclosures

This section deals with the installation of IP00 / chassis enclosed adjustable frequency drives with duct work cooling kits in Rittal enclosures. In addition to the enclosure an 8 in [200 mm] base/plinth is required.

3

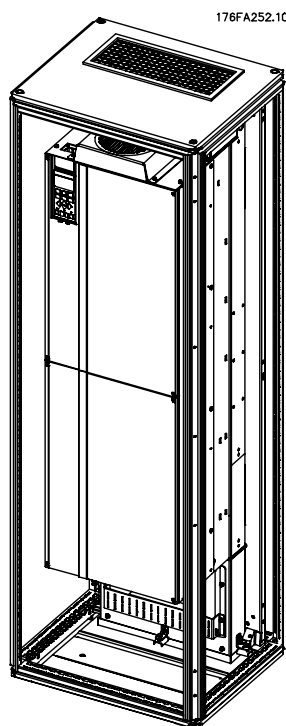


Figure 3.28: Installation of IP00 in Rittal TS8 enclosure.

**The minimum enclosure dimension is:**

- D3 and D4 frame: Depth 19.7 in [500 mm] and width 23.6 in [600 mm].
- E2 frame: Depth 23.6 in [600 mm] and width 31.5 in [800 mm].

The maximum depth and width are as required for the installation. When using multiple adjustable frequency drives in one enclosure it is recommended that each drive is mounted on its own back panel and supported along the mid-section of the panel. These duct work kits do not support the "in frame" mounting of the panel (see Rittal TS8 catalog for details). The duct work cooling kits listed in the table below are suitable for use only with IP 00 / Chassis adjustable frequency drives in Rittal TS8 IP 20 and UL and NEMA 1 and IP 54 and UL and NEMA 12 enclosures.



For the E2 frames, it is important to mount the plate at the absolute rear of the Rittal enclosure due to the weight of the adjustable frequency drive.



**NOTE!**  
A door fan or fans are required on the Rittal cabinet to remove the losses not contained in the backchannel of the drive. The minimum door fan airflow required at the drive maximum ambient for the D3 and D4 is 391 m<sup>3</sup>/h (230 cfm). The minimum door fan airflow required at the drive maximum ambient for the E2 is 782 m<sup>3</sup>/h (460 cfm). If the ambient is below maximum or if additional components and heat loss are added within the enclosure, a calculation must be made to ensure the proper airflow is provided to cool the inside of the Rittal enclosure.

3

Ordering Information

| Rittal TS-8 Enclosure | Frame D3 Kit Part No. | Frame D4Kit Part No. | Frame E2 Part No. |
|-----------------------|-----------------------|----------------------|-------------------|
| 5.9 ft [1800 mm]      | 176F1824              | 176F1823             | Not possible      |
| 6.5 ft [2000 mm]      | 176F1826              | 176F1825             | 176F1850          |
| 7.2 ft [2200 mm]      |                       |                      | 176F0299          |

Kit Contents

- Ductwork components
- Mounting hardware
- Gasket material
- Delivered with D3 and D4 frame kits:
  - 175R5639 - Mounting templates and top/bottom cut out for Rittal enclosure.
- Delivered with E2 frame kits:
  - 175R1036 - Mounting templates and top/bottom cut out for Rittal enclosure.

All fasteners are either:

- 0.39 in [10 mm], M5 Nuts torque to 2.3 Nm (20 in-lbs)
- T25 Torx screws torque to 2.3 Nm (20 in-lbs)



**NOTE!**  
Please see the *Duct Kit Instruction Manual, 175R5640*, for further information

External ducts

If additional duct work is added externally to the Rittal cabinet, the pressure drop in the ducting must be calculated. Use the charts below to derate the adjustable frequency drive according to the pressure drop.

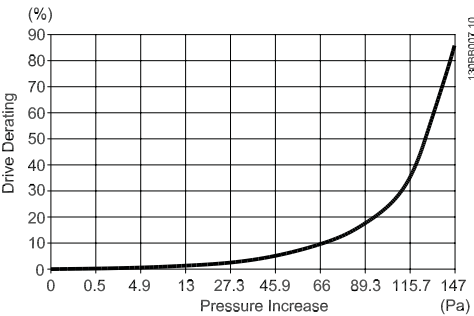


Figure 3.29: D Frame Derating vs. Pressure Change  
Drive air flow: 450 cfm (765 m3/h)



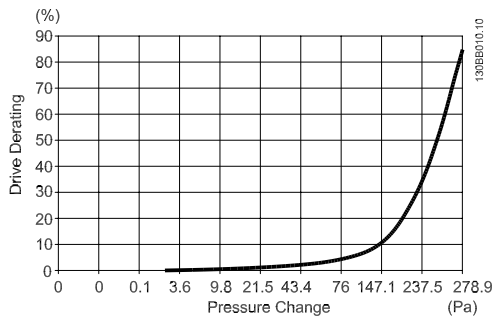


Figure 3.30: E Frame Derating vs. Pressure Change (Small Fan), P250T5 and P355T7-P400T7  
Drive air flow: 650 cfm (1105 m<sup>3</sup>/h)

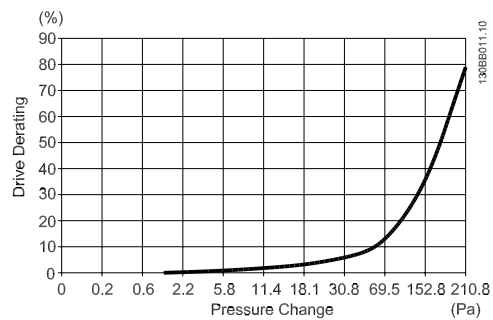


Figure 3.31: E Frame Derating vs. Pressure Change (Large Fan), P315T5-P400T5 and P500T7-P560T7  
Drive air flow: 850 cfm (1445 m<sup>3</sup>/h)

### 3.7.2 Outside Installation/ NEMA 3R Kit for Rittal enclosures



This section is for the installation of NEMA 3R kits available for the adjustable frequency drive frames D3, D4 and E2. These kits are designed and tested to be used with IP00/ Chassis versions of these frames in Rittal TS8 NEMA 3R or NEMA 4 enclosures. The NEMA-3R enclosure is an outdoor enclosure

that provides a degree of protection against rain and ice. The NEMA-4 enclosure is an outdoor enclosure that provides a greater degree of protection against weather and hosed water.

The minimum enclosure depth is 19.7 in [500 mm] 23.6 in [600 mm] for E2 frame) and the kit is designed for a 23.6 in [600 mm] 31.5 in [800 mm] for E2 frame) wide enclosure. Other enclosure widths are possible, however additional Rittal hardware is required. The maximum depth and width are as required for the installation.

## 3

**NOTE!**

The current rating of drives in D3 and D4 frames are de-rated by 3%, when adding the NEMA 3R kit. Drives in E2 frames require no derating

**NOTE!**

A door fan or fans are required on the Rittal cabinet to remove the losses not contained in the backchannel of the drive. The minimum door fan airflow required at the drive maximum ambient for the D3 and D4 is 391 m<sup>3</sup>/h (230 cfm). The minimum door fan airflow required at the drive maximum ambient for the E2 is 782 m<sup>3</sup>/h (460 cfm). If the ambient is below maximum or if additional components and heat loss are added within the enclosure, a calculation must be made to ensure the proper airflow is provided to cool the inside of the Rittal enclosure.

**Ordering information**

Frame size D3: 176F4600

Frame size D4: 176F4601

Frame size E2: 176F1852

**Kit contents:**

- Ductwork components
- Mounting hardware
- 0.63 in [16 mm], M5 torx screws for top vent cover
- 0.39 in [10 mm], M5 for attaching drive mounting plate to enclosure
- M10 nuts to attach drive to mounting plate
- Gasket material

**Torque requirements:**

1. M5 screws/ nuts torque to 20 in-lbs (2.3 N-M)
2. M6 screws/ nuts torque to 35 in-lbs (3.9 N-M)
3. M10 nuts torque to 170 in-lbs (20 N-M)
4. T25 Torx screws torque to 20 in-lbs (2.3 N-M)

**NOTE!**

Please see the instructions 175R5922 for further information

### 3.7.3 Installation on Pedestal

This section describes the installation of a pedestal unit available for the adjustable frequency drives frames D1 and D2. This is an 8 in [200 mm] high pedestal that allows these frames to be floor mounted. The front of the pedestal has openings for input air to the power components.

The adjustable frequency drive connector plate must be installed to provide adequate cooling air to the control components of the adjustable frequency drive via the door fan and to maintain the IP21/NEMA 1 or IP54/NEMA 12 degrees of enclosure protections.



Figure 3.32: Drive on pedestal

There is one pedestal that fits both frames D1 and D2. Its ordering number is 176F1827. The pedestal is standard for E1 frame.

#### Required Tools:

- Socket wrench with 0.28–0.67 in [7–17 mm] sockets
- T30 Torx Driver

#### Torques:

- M6 - 4.0 Nm (35 in-lbs)
- M8 - 9.8 Nm (85 in-lbs)
- M10 - 19.6 Nm (170 in-lbs)

#### Kit Contents:

- Pedestal parts
- Instruction Manual

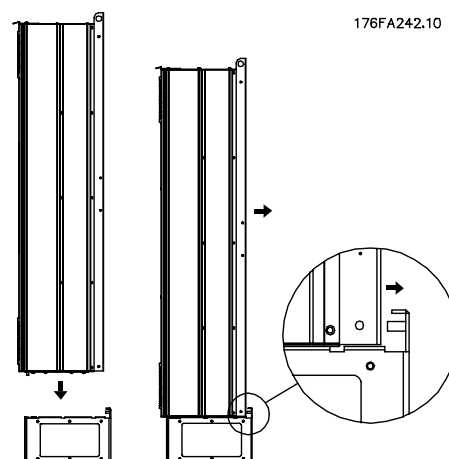
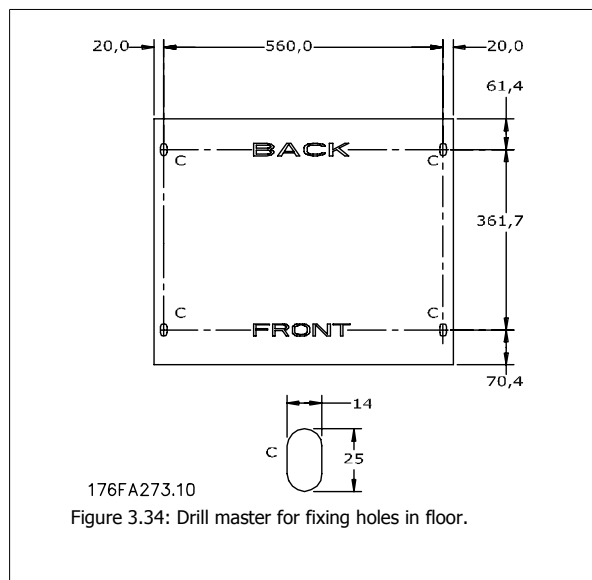


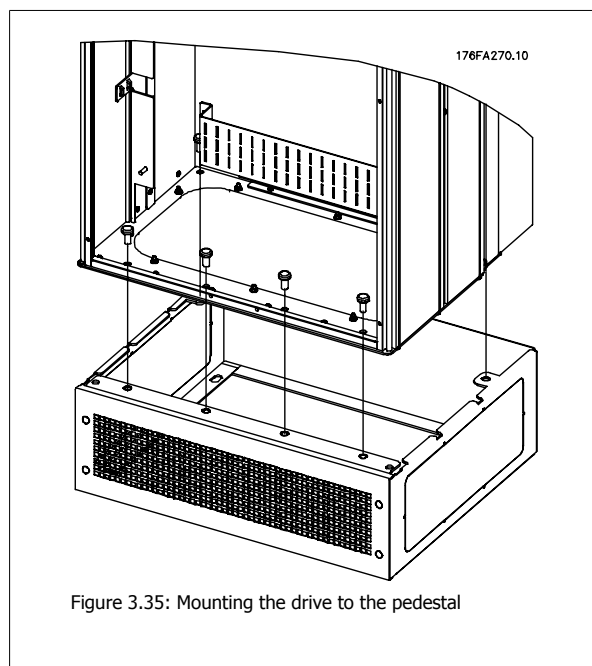
Figure 3.33: Mount the drive onto pedestal.

### 3.7.4 Floor Mounting - Pedestal Installation IP21 (NEMA1) and IP54 (NEMA12)

Install the pedestal on the floor. Fixing holes are to be drilled according to this figure:



Mount the drive on the pedestal and using the enclosed bolts, attach it to the pedestal, as shown in the illustration.



**NOTE!**

Please see the *Pedestal Kit Instruction Manual, 175R5642*, for further information.

### 3.7.5 Input Plate Option

This section is for the field installation of input option kits available for adjustable frequency drives in all D and E frames.

Do not attempt to remove RFI filters from input plates. Damage may occur to RFI filters if they are removed from the input plate.


**NOTE!**

Where RFI filters are available, there are two different types of RFI filters depending on the input plate combination and the RFI filters interchangeable. Field installable kits in certain cases are the same for all voltages.

**3**

|    | 380–480 V<br>380–500 V                                                 | Fuses    | Disconnect Fuses | RFI      | RFI Fuses | RFI Disconnect<br>Fuses |
|----|------------------------------------------------------------------------|----------|------------------|----------|-----------|-------------------------|
| D1 | All D1 power sizes                                                     | 176F8442 | 176F8450         | 176F8444 | 176F8448  | 176F8446                |
| D2 | All D2 power sizes                                                     | 176F8443 | 176F8441         | 176F8445 | 176F8449  | 176F8447                |
| E1 | FC102/ 202: 450 hp [315<br>kW]<br>: 350 hp [250 kW]                    | 176F0253 | 176F0255         | 176F0257 | 176F0258  | 176F0260                |
|    | FC102/ 202: 500–600 HP<br>[355–450 kW]<br>: 450–550 HP [315–400<br>kW] | 176F0254 | 176F0256         | 176F0257 | 176F0259  | 176F0262                |

|    | 525–690 V                                                                  | Fuses    | Disconnect Fuses | RFI      | RFI Fuses | RFI Disconnect<br>Fuses |
|----|----------------------------------------------------------------------------|----------|------------------|----------|-----------|-------------------------|
| D1 | FC102/ 202: 60–125 HP<br>[45–90 kW]<br>FC302: 50–100 HP [37–<br>75 kW]     | 175L8829 | 175L8828         | 175L8777 | NA        | NA                      |
|    | FC102/202: 150–250 HP<br>[110–160 kW]<br>FC302: 125–175 HP [90–<br>132 kW] | 175L8442 | 175L8445         | 175L8777 | NA        | NA                      |
| D2 | All D2 power sizes                                                         | 175L8827 | 175L8826         | 175L8825 | NA        | NA                      |
| E1 | FC102/202: 600–675 HP<br>[450–500 kW]<br>FC302: 500–550 HP<br>[355–400 kW] | 176F0253 | 176F0255         | NA       | NA        | NA                      |
|    | FC102/202: 750–850 HP<br>[560–630 kW]<br>FC302: 675–750 HP<br>[500–560 kW] | 176F0254 | 176F0258         | NA       | NA        | NA                      |

**Kit contents**

- Input plate assembled
- Instruction sheet 175R5795
- Modification Label
- Disconnect handle template (units w/ line power disconnect)

**Cautions**

- The adjustable frequency drive contains dangerous voltages when connected to line voltage. The adjustable frequency drive contains dangerous voltages when connected to line voltage.
- Electrical parts on the adjustable frequency drive may contain dangerous voltages even after line power has been disconnected. Wait the minimum time listed on the drive label after disconnecting line power before touching any internal components to ensure that capacitors have fully discharged
- The input plates contain metal parts with sharp edges. Use hand protection when removing and reinstalling.
- E frames input plates are heavy 44–77 lbs [20–35 kg] depending on configuration). It is recommended that the disconnect switch be removed from the input plate for easier installation and then be reinstalled on the input plate after the input plate has been installed on the drive.

**NOTE!**

For further information, please see the Instruction Sheet, *175R5795*

### 3.7.6 Installation of Line Power Shield for Adjustable Frequency Drives

This section is for the installation of a line power shield for the adjustable frequency drive series with D1, D2 and E1 frames. It is not possible to install in the IP00/ Chassis versions as these have included as standard a metal cover. These shields satisfy VBG-4 requirements.

**Ordering numbers:**

Frames D1 and D2: 176F0799

Frame E1: 176F1851

**Torque requirements**

M6 - 35 in-lbs (4.0 N-M)

M8 - 85 in-lbs (9.8 N-M)

M10 - 170 in-lbs (19.6 N-M)

**NOTE!**

For further information, please see the Instruction Sheet, *175R5923*

### 3.7.7 Frame size F Panel Options

#### Space Heaters and Thermostat

Mounted on the cabinet interior of frame size F adjustable frequency drives, space heaters controlled via automatic thermostat help control humidity inside the enclosure, extending the lifetime of drive components in damp environments.

#### Cabinet Light with Power Outlet

A light mounted on the cabinet interior of frame size F adjustable frequency drives increase visibility during servicing and maintenance. The housing light includes a power outlet for temporarily powering tools or other devices, available in two voltages:

- 230 V, 50 Hz, 2.5 A, CE/ENEC
- 120 V, 60 Hz, 5 A, UL/cUL

#### Transformer Tap Set-up

If the Cabinet Light & Outlet and/or the Space Heaters & Thermostat are installed Transformer T1 requires it taps to be set to the proper input voltage. A 380–480/500 V 380–480 V drive will initially be set to the 525 V tap and a 525–690 V drive will be set to the 690 V tap to insure no overvoltage of secondary equipment occurs if the tap is not changed prior to power being applied. See the table below to set the proper tap at terminal T1 located in the rectifier cabinet. For location in the drive, see illustration of rectifier in the *Power Connections* section.

| Input Voltage Range | Tap to Select |
|---------------------|---------------|
| 380–440 V           | 400 V         |
| 441–490 V           | 460 V         |
| 491–550 V           | 525 V         |
| 551–625 V           | 575 V         |
| 626–660 V           | 660 V         |
| 661–690 V           | 690 V         |

#### NAMUR Terminals

This requires the MCB 112 PTC thermistor card and MCB 113 extended relay card. Selection of this option provides terminals organized and labeled to the specifications of the NAMUR standard for drive input and output terminals. This requires MCB 112 PTC Thermistor Card and MCB 113 Extended Relay Card.

#### RCD (Residual Current Device)

Uses the core balance method to monitor ground fault currents in grounded and high-resistance grounded systems (TN and TT systems in IEC terminology). There is a pre-warning (50% of main alarm setpoint) and a main alarm setpoint. Associated with each setpoint is an SPDT alarm relay for external use. Requires an external “window-type” current transformer (supplied and installed by customer).

- Integrated into the drive’s safe-stop circuit
- IEC 60755 Type B device monitors AC, pulsed DC, and pure DC ground fault currents
- LED bar graph indicator of the ground fault current level from 10–100% of the setpoint
- Fault memory
- TEST / RESET button

#### Insulation Resistance Monitor (IRM)

Monitors the insulation resistance in ungrounded systems (IT systems in IEC terminology) between the system phase conductors and ground. There is an ohmic pre-warning and a main alarm setpoint for the insulation level. Associated with each setpoint is an SPDT alarm relay for external use. Note: only one insulation resistance monitor can be connected to each ungrounded (IT) system.

- Integrated into the drive’s safe-stop circuit
- LCD display of the ohmic value of the insulation resistance
- Fault Memory
- INFO, TEST, and RESET buttons

#### IEC Emergency Stop with Pilz Safety Relay

Includes a redundant 4-wire emergency stop pushbutton mounted on the front of the enclosure and a Pilz relay that monitors it in conjunction with the drive’s safe stop circuit and the line power contactor located in the options cabinet.

### Manual Motor Starters

Provide 3-phase power for electric blowers often required for larger motors. Power for the starters is provided from the load side of any supplied contactor, circuit breaker, or disconnect switch. Power is fused before each motor starter, and is off when the incoming power to the drive is off. Up to two starters are allowed (one if a 30 A, fuse-protected circuit is ordered). Integrated into the drive's safe-stop circuit.

Unit features include:

- Operation switch (on/off)
- Short-circuit and overload protection with test function
- Manual reset function

### 30 Ampere, Fuse-protected Terminals

- 3-phase power matching incoming AC line voltage for powering auxiliary customer equipment
- Not available if two manual motor starters are selected
- Terminals are off when the incoming power to the drive is off
- Power for the fused protected terminals will be provided from the load side of any supplied contactor, circuit breaker, or disconnect switch.

### 24 VDC Power Supply

- 5 amp, 120 W, 24 VDC
- Protected against output overcurrent, overload, short circuits, and overtemperature
- For powering customer-supplied accessory devices such as sensors, PLC I/O, contactors, temperature probes, LEDs, and/or other electronic hardware
- Diagnostics include a dry DC-ok contact, a green DC-ok LED, and a red overload LED

### External Temperature Monitoring

Designed for monitoring temperatures of external system components, such as the motor windings and/or bearings. Includes eight universal input modules plus two dedicated thermistor input modules. All ten modules are integrated into the drive's safe-stop circuit and can be monitored via a serial communication bus network (requires the purchase of a separate module/bus coupler).

#### Universal inputs (8)

Signal types:

- RTD inputs (including Pt100), 3-wire or 4-wire
- Thermocouple
- Analog current or analog voltage

Additional features:

- One universal output, configurable for analog voltage or analog current
- Two output relays (N.O.)
- Dual-line LC display and LED diagnostics
- Sensor lead wire break, short-circuit, and incorrect polarity detection
- Interface set-up software

#### Dedicated thermistor inputs (2)

Features:

- Each module is capable of monitoring up to six thermistors in a series
- Fault diagnostics for wire breakage or short-circuits of sensor leads
- ATEX/UL/CSA certification
- A third thermistor input can be provided by the PTC thermistor option card MCB 112, if necessary.



## 4 How to Order

### 4.1 Ordering form

#### 4.1.1 Drive Configurator

It is possible to design a VLT AQUA adjustable frequency drive 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 to the Danfoss sales office, for example.:

FC-202P18KT4E21H1XGCXXSXXXXAGBKXXXXDX

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*.

Use the Internet-based drive configurator to 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](http://www.danfoss.com/drives).

### 4.1.2 Type Code String

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39

FC-202P T H XXSXXXA B C D

130BA484.10

4

| Description                | Pos.: | Possible choice                                                                                                                                                                                                                                                                                                                                               |
|----------------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Product group & VLT Series | 1-6   | FC 202                                                                                                                                                                                                                                                                                                                                                        |
| Power rating               | 7-10  | 0.34–1600 hp [0.25–1200 kW]                                                                                                                                                                                                                                                                                                                                   |
| Number of phases           | 11    | Three phases (T)                                                                                                                                                                                                                                                                                                                                              |
| AC line voltage            | 11-12 | S2: 220–240 V AC single phase<br>S4: 380–480 V AC single phase<br>T 2: 200–240 V AC<br>T 4: 380–480 V AC<br>T 6: 525–600 V AC<br>T 7: 525–690 V AC                                                                                                                                                                                                            |
| 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/ line power shield<br>E5M: IP 55/NEMA Type 12 w/ line power 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                                                                                                                                                                                                                                                 |

Table 4.1: Type code description.

| Description                                                        | Pos.: | Possible choice                                                                                                                                              |
|--------------------------------------------------------------------|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Coating PCB                                                        | 20    | X: No coated PCB<br>C: Coated PCB                                                                                                                            |
| Line power option                                                  | 21    | D: Loadsharing<br>X: No line power disconnect switch<br>8: Line Power Disconnect + Loadsharing                                                               |
| Cable entries                                                      | 22    | X: Standard cable entries<br>O: European metric thread in cable entries                                                                                      |
|                                                                    | 23    | Reserved                                                                                                                                                     |
| Software release                                                   | 24-27 | Current software version                                                                                                                                     |
| Software language                                                  | 28    |                                                                                                                                                              |
| A options                                                          | 29-30 | AX: No options<br>A0: MCA 101 Profibus DP V1<br>A4: MCA 104 DeviceNet<br>AN: MCA 121 Ethernet IP                                                             |
| 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<br>BY: MCO 101 Extended Cascade Control |
| C <sub>0</sub> options                                             | 33-34 | CX: No options                                                                                                                                               |
| C <sub>1</sub> options                                             | 35    | X: No options<br>5: MCO 102 Advanced Cascade Control                                                                                                         |
| C option software                                                  | 36-37 | XX: Standard software                                                                                                                                        |
| D options                                                          | 38-39 | DX: No option<br>D0: DC backup                                                                                                                               |
| The various options are described further on in this Design Guide. |       |                                                                                                                                                              |

Table 4.2: Type code description.

### 4.1.3 Type Code String High Power

4

| Description                | Pos.: | Possible choice                                                                                                                                                                                                                                                                                                                                               |
|----------------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Product group & VLT Series | 1-6   | FC 202                                                                                                                                                                                                                                                                                                                                                        |
| Power rating               | 7-10  | 0.34–1600 hp [0.25–1200 kW]                                                                                                                                                                                                                                                                                                                                   |
| Number of phases           | 11    | Three phases (T)                                                                                                                                                                                                                                                                                                                                              |
| AC line voltage            | 11-12 | S2: 220–240 V AC single phase<br>S4: 380–480 V AC single phase<br>T 2: 200–240 V AC<br>T 4: 380–480 V AC<br>T 6: 525–600 V AC<br>T 7: 525–690 V AC                                                                                                                                                                                                            |
| 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/ line power shield<br>E5M: IP 55/NEMA Type 12 w/ line power 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                                                                                                                                                                                                                                                                                                                             |
| Line power option          | 21    | D: Loadsharing<br>X: No line power disconnect switch<br>8: Line Power Disconnect + Loadsharing                                                                                                                                                                                                                                                                |
| Cable entries              | 22    | X: Standard cable entries<br>O: European metric thread in cable entries                                                                                                                                                                                                                                                                                       |
|                            | 23    | Reserved                                                                                                                                                                                                                                                                                                                                                      |
| Software release           | 24-27 | Current software version                                                                                                                                                                                                                                                                                                                                      |
| Software language          | 28    |                                                                                                                                                                                                                                                                                                                                                               |

Table 4.3: Type code description.

**Ordering type code frame size F**

| Description            | Pos   | Possible choice                                                                                                                                              |
|------------------------|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A options              | 29-30 | AX: No options<br>A0: MCA 101 Profibus DP V1<br>A4: MCA 104 DeviceNet<br>AN: MCA 121 Ethernet IP                                                             |
| 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<br>BY: MCO 101 Extended Cascade Control |
| C <sub>0</sub> options | 33-34 | CX: No options                                                                                                                                               |
| C <sub>1</sub> options | 35    | X: No options<br>5: MCO 102 Advanced Cascade Control                                                                                                         |
| C option software      | 36-37 | XX: Standard software                                                                                                                                        |
| D options              | 38-39 | DX: No option<br>D0: DC backup                                                                                                                               |

The various options are described further in this Design Guide.

## 4.2 Ordering Numbers

### 4.2.1 Ordering Numbers: Options and Accessories

4

| Type                          | Description                                                                                                          | Ordering no.           |
|-------------------------------|----------------------------------------------------------------------------------------------------------------------|------------------------|
| <b>Miscellaneous hardware</b> |                                                                                                                      |                        |
| DC link connector             | Terminal block for DC link connection, 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               |
| IP21/TYPE 1 Kit               | Top and bottom, frame size B3                                                                                        | 130B1187               |
| IP21/TYPE 1 Kit               | Top and bottom, frame size B4                                                                                        | 130B1189               |
| IP21/TYPE 1 Kit               | Top and bottom, frame size C3                                                                                        | 130B1191               |
| IP21/TYPE 1 Kit               | Top and bottom, frame size C4                                                                                        | 130B1193               |
| IP21/TYPE 1 Kit               | Top, frame size B3                                                                                                   | 130B1188               |
| IP21/TYPE 1 Kit               | Top, frame size B4                                                                                                   | 130B1190               |
| IP21/TYPE 1 Kit               | Top, frame size C3                                                                                                   | 130B1192               |
| IP21/TYPE 1 Kit               | Top, frame size C4                                                                                                   | 130B1194               |
| MCF 110 panel                 | Panel Through Mounting Kit, frame size A5                                                                            | 130B1028               |
| MCF 110 panel                 | Panel Through Mounting Kit, frame size B1                                                                            | 130B1046               |
| MCF 110 panel                 | Panel Through Mounting Kit, frame size B2                                                                            | 130B1047               |
| MCF 110 panel                 | Panel Through Mounting Kit, frame size C1                                                                            | 130B1048               |
| MCF 110 panel                 | Panel Through Mounting Kit, frame size C2                                                                            | 130B1049               |
| Profibus D-Sub 9              | Connector kit for IP 20                                                                                              | 130B1112               |
| MCF 103                       | USB Cable 14 in [350 mm], IP55/66                                                                                    | 130B1155               |
| MCF 103                       | USB Cable 26 in [650 mm], IP55/66                                                                                    | 130B1156               |
| Profibus top entry kit        | Top entry kit for Profibus connection - only A enclosures                                                            | 130B0524 <sup>1)</sup> |
| Terminal blocks               | Screw terminal blocks for replacing spring loaded terminals<br>1 x 10-pin, 1 x 6-pin and 1 x 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               |
| <b>LCP</b>                    |                                                                                                                      |                        |
| LCP 101                       | Numerical Local Control Panel (NLCP)                                                                                 | 130B1124               |
| LCP 102                       | Graphical Local Control Panel (GLCP)                                                                                 | 130B1107               |
| LCP cable                     | Separate LCP cable, 9.8 ft. [3 m]                                                                                    | 175Z0929               |
| LCP kit                       | Panel mounting kit including graphical LCP, fasteners, 9.8 ft. [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, 9.8 ft. [3 m] cable and gasket                                  | 130B1117               |
| LCP kit                       | Panel mounting kit for all LCPs including fasteners and gasket - without cable                                       | 130B1170               |
| LCP kit                       | Panel mounting kit for all LCPs including fasteners, 26 ft [8 m] cable, connectors and gasket for IP55/66 enclosures | 130B1129               |

| Type                                                                       | Description                         | Ordering no. |          |
|----------------------------------------------------------------------------|-------------------------------------|--------------|----------|
| 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     | 130B1212 |
| MCB 105                                                                    | Relay option                        | 130B1110     | 130B1210 |
| MCB 109                                                                    | Analog I/O option                   | 130B1143     | 130B1243 |
| MCB 114                                                                    | PT 100 / PT 1000 sensor input       | 130B1172     | 10B1272  |
| MCO 101                                                                    | Extended Cascade Control            | 130B1118     | 130B1218 |
| Options for C0                                                             |                                     |              |          |
| Mounting kit for frame size A2 and A3 (1.57 in [40 mm] for one C option)   |                                     | 130B7530     |          |
| Mounting kit for frame size A2 and A3 (2.36 in [60 mm] for C0 + C1 option) |                                     | 130B7531     |          |
| Mounting kit for frame size A5                                             |                                     | 130B7532     |          |
| Mounting kit for frame size B, C, D, E and F2 and 3 (except B3)            |                                     | 130B7533     |          |
| Mounting kit for frame size B3 (1.57 in [40 mm] for one C option)          |                                     | 130B1413     |          |
| Mounting kit for frame size B3 (2.36 in [60 mm] for C0 + C1 option)        |                                     | 130B1414     |          |
| Option for Slot C                                                          |                                     |              |          |
| MCO 102                                                                    | Advanced Cascade Control            | 130B1154     | 130B1254 |
| Option for Slot D                                                          |                                     |              |          |
| MCB 107                                                                    | 24 V DC back-up                     | 130B1108     | 130B1208 |

| Type                            | Description                  | Ordering no. |          |
|---------------------------------|------------------------------|--------------|----------|
| External Options                |                              |              |          |
| Ethernet IP                     | Ethernet                     | 130B1119     | 130B1219 |
| Spare Parts                     |                              |              |          |
| Control board VLT AQUA Drive    | With Safe Stop Function      |              | 130B1167 |
| Control board VLT AQUA Drive    | Without Safe Stop Function   |              | 130B1168 |
| Accessory Bag Control Terminals |                              | 130B0295     |          |
| 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     |          |
| 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      |

1) Only IP 21 / > 14.75 HP [11 kW]

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

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



## 4.2.2 Ordering Numbers: Harmonic Filters

Harmonic filters are used to reduce line harmonics.

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

| <b>380–415 V, 50Hz</b> |                         |                         |                        |                                 |
|------------------------|-------------------------|-------------------------|------------------------|---------------------------------|
| I <sub>AHF,N</sub>     | Typical Motor Used [kW] | Danfoss ordering number |                        | Adjustable frequency drive 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<br>+ 175G6610  | 175G6631<br>+ 175G6632 | P250                            |
| 578 A                  | 315                     | 2x 175G6610             | 2x 175G6632            | P315                            |
| 648 A                  | 400                     | 2x175G6611              | 2x175G6633             | P400                            |

| <b>380–415 V, 60 Hz</b> |                         |                         |                        |                                 |
|-------------------------|-------------------------|-------------------------|------------------------|---------------------------------|
| I <sub>AHF,N</sub>      | Typical Motor Used [HP] | Danfoss ordering number |                        | Adjustable frequency drive 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<br>+ 130B2469  | 130B2480<br>+ 130B2481 | P250                            |
| 578 A                   | 500                     | 2x 130B2469             | 2x 130B2481            | P315                            |
| 648 A                   | 500                     | 2x130B2470              | 2x130B2482             | P355                            |

**440–480 V, 60 Hz**

| I <sub>AHF,N</sub> | Typical Motor Used [HP] | Danfoss ordering number |                     | Adjustable frequency drive 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 adjustable frequency drive and filter is pre-calculated based on 400 V/480 V, a typical motor load (4-pole) and 110% torque.

**500–525 V, 50 Hz**

| I <sub>AHF,N</sub> | Typical Motor Used [kW] | Danfoss ordering number |             | Adjustable frequency drive 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                     |

| <b>690 V, 50 Hz</b> |                         |                         |          |                                 |
|---------------------|-------------------------|-------------------------|----------|---------------------------------|
| $I_{AHF,N}$         | Typical Motor Used [kW] | Danfoss ordering number |          | Adjustable frequency drive 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 V AC

#### Line power supply 3 x 200–500 V

| Adjustable frequency drive size |           |           | Minimum switching frequency | Maximum output frequency | Part No. IP20 | Part No. IP00 | Rated filter current at 50 Hz |
|---------------------------------|-----------|-----------|-----------------------------|--------------------------|---------------|---------------|-------------------------------|
| 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                        |


**NOTE!**

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

#### 4.2.4 Ordering Numbers: Sine Wave Filters, 525–600/690 V AC

| Adjustable frequency drive size [kW] |           |                         |                                           | Part No. Danfoss |          |
|--------------------------------------|-----------|-------------------------|-------------------------------------------|------------------|----------|
| 525–600 V                            | 525–690 V | Current at 50 Hz<br>[A] | Minimum switch-<br>ing frequency<br>[kHz] | IP00             | IP20     |
| 0.75                                 | -         | 13                      | 2                                         | 130B2321         | 130B2341 |
| 1.1                                  | -         |                         |                                           |                  |          |
| 1.5                                  | -         |                         |                                           |                  |          |
| 2.2                                  | -         |                         |                                           |                  |          |
| 3.0                                  | -         |                         |                                           |                  |          |
| 4.0                                  | -         |                         |                                           |                  |          |
| 5.5                                  | -         |                         |                                           |                  |          |
| 7.5                                  | -         |                         |                                           |                  |          |
| -                                    | 11        | 28                      | 2                                         | 130B2322         | 130B2342 |
| 11                                   | 15        |                         |                                           |                  |          |
| 15                                   | 18.5      |                         |                                           |                  |          |
| 18.5                                 | 22        |                         |                                           |                  |          |
| 22                                   | 30        | 45                      | 2                                         | 130B2323         | 130B2343 |
| 30                                   | 37        |                         |                                           |                  |          |
| 37                                   | 45        | 76                      | 2                                         | 130B2324         | 130B2344 |
| 45                                   | 55        |                         |                                           |                  |          |
| 55                                   | 75        | 115                     | 2                                         | 130B2325         | 130B2345 |
| 75                                   | 90        |                         |                                           |                  |          |
| 90                                   | 110       | 165                     | 2                                         | 130B2326         | 130B2346 |
| 110                                  | 132       |                         |                                           |                  |          |
| 150                                  | 160       | 260                     | 2                                         | 130B2327         | 130B2347 |
| 180                                  | 200       |                         |                                           |                  |          |
| 220                                  | 250       | 303                     | 2                                         | 130B2329         | 130B2348 |
| 260                                  | 315       |                         |                                           |                  |          |
| 300                                  | 400       | 430                     | 1.5                                       | 130B2241         | 130B2270 |
| 375                                  | 500       |                         |                                           |                  |          |
| 450                                  | 560       | 660                     | 1.5                                       | 130B2337         | 130B2381 |
| 480                                  | 630       |                         |                                           |                  |          |
| 560                                  | 710       | 765                     | 1.5                                       | 130B2338         | 130B2382 |
| 670                                  | 800       |                         |                                           |                  |          |
| -                                    | 900       | 940                     | 1.5                                       | 130B2339         | 130B2383 |
| 820                                  | 1000      |                         |                                           |                  |          |
| 970                                  | 1200      | 1320                    | 1.5                                       | 130B2340         | 130B2384 |

Table 4.4: Line power supply 3x525–690 V

## 4.2.5 Ordering Numbers: du/dt Filters, 380–480 VAC

### Line power supply 3x380 to 3x480 V

| Adjustable frequency drive size |                   | Minimum switching frequency | Maximum output frequency | Part No. IP20 | Part No. IP00 | Rated filter current at 50 Hz |
|---------------------------------|-------------------|-----------------------------|--------------------------|---------------|---------------|-------------------------------|
| 380–440 V                       | 441–480 V         |                             |                          |               |               |                               |
| 15 hp [11 kW]                   | 15 hp [11 kW]     | 4 kHz                       | 60 Hz                    | 130B2396      | 130B2385      | 24 A                          |
| 20 hp [15 kW]                   | 20 hp [15 kW]     | 4 kHz                       | 60 Hz                    | 130B2397      | 130B2386      | 45 A                          |
| 25 hp [18.5 kW]                 | 25 hp [18.5 kW]   | 4 kHz                       | 60 Hz                    | 130B2397      | 130B2386      | 45 A                          |
| 30 hp [22 kW]                   | 30 hp [22 kW]     | 4 kHz                       | 60 Hz                    | 130B2397      | 130B2386      | 45 A                          |
| 40 hp [30 kW]                   | 40 hp [30 kW]     | 3 kHz                       | 60 Hz                    | 130B2398      | 130B2387      | 75 A                          |
| 50 hp [37 kW]                   | 50 hp [37 kW]     | 3 kHz                       | 60 Hz                    | 130B2398      | 130B2387      | 75 A                          |
| 60 hp [45 kW]                   | 75 hp [55 kW]     | 3 kHz                       | 60 Hz                    | 130B2399      | 130B2388      | 110 A                         |
| 75 hp [55 kW]                   | 100 hp [75 kW]    | 3 kHz                       | 60 Hz                    | 130B2399      | 130B2388      | 110 A                         |
| 100 hp [75 kW]                  | 125 hp [90 kW]    | 3 kHz                       | 60 Hz                    | 130B2400      | 130B2389      | 182 A                         |
| 125 hp [90 kW]                  | 150 hp [110 kW]   | 3 kHz                       | 60 Hz                    | 130B2400      | 130B2389      | 182 A                         |
| 150 hp [110 kW]                 | 175 hp [132 kW]   | 3 kHz                       | 60 Hz                    | 130B2401      | 130B2390      | 280 A                         |
| 175 hp [132 kW]                 | 250 hp [160 kW]   | 3 kHz                       | 60 Hz                    | 130B2401      | 130B2390      | 280 A                         |
| 250 hp [160 kW]                 | 300 hp [200 kW]   | 3 kHz                       | 60 Hz                    | 130B2402      | 130B2391      | 400 A                         |
| 300 hp [200 kW]                 | 350 hp [250 kW]   | 3 kHz                       | 60 Hz                    | 130B2402      | 130B2391      | 400 A                         |
| 350 hp [250 kW]                 | 450 hp [315 kW]   | 3 kHz                       | 60 Hz                    | 130B2277      | 130B2275      | 500 A                         |
| 450 hp [315 kW]                 | 500 hp [355 kW]   | 2 kHz                       | 60 Hz                    | 130B2278      | 130B2276      | 750 A                         |
| 500 hp [355 kW]                 | 550 hp [400 kW]   | 2 kHz                       | 60 Hz                    | 130B2278      | 130B2276      | 750 A                         |
| 550 hp [400 kW]                 | 600 hp [450 kW]   | 2 kHz                       | 60 Hz                    | 130B2278      | 130B2276      | 750 A                         |
| 600 hp [450 kW]                 | 675 hp [500 kW]   | 2 kHz                       | 60 Hz                    | 130B2405      | 130B2393      | 910 A                         |
| 675 hp [500 kW]                 | 750 hp [560 kW]   | 2 kHz                       | 60 Hz                    | 130B2405      | 130B2393      | 910 A                         |
| 750 hp [560 kW]                 | 850 hp [630 kW]   | 2 kHz                       | 60 Hz                    | 130B2407      | 130B2394      | 1500 A                        |
| 850 hp [630 kW]                 | 950 hp [710 kW]   | 2 kHz                       | 60 Hz                    | 130B2407      | 130B2394      | 1500 A                        |
| 950 hp [710 kW]                 | 1075 hp [800 kW]  | 2 kHz                       | 60 Hz                    | 130B2407      | 130B2394      | 1500 A                        |
| 1075 hp [800 kW]                | 1350 hp [1000 kW] | 2 kHz                       | 60 Hz                    | 130B2407      | 130B2394      | 1500 A                        |
| 1350 hp [1000 kW]               | 1475 hp [1100 kW] | 2 kHz                       | 60 Hz                    | 130B2410      | 130B2395      | 2300 A                        |

#### 4.2.6 Ordering Numbers: du/dt Filters, 525–600/690 V AC

| Adjustable frequency drive size [kW] |           |             |                                  | Part No. Danfoss |          |
|--------------------------------------|-----------|-------------|----------------------------------|------------------|----------|
| 525–600 V                            | 525–690 V | Current [A] | Minimum switching frequency [Hz] | IP00             | IP20     |
| -                                    | 11        | 28          | 4                                | 130B2414         | 130B2423 |
| 11                                   | 15        |             |                                  |                  |          |
| 15                                   | 18.5      |             |                                  |                  |          |
| 18.5                                 | 22        |             |                                  |                  |          |
| 22                                   | 30        | 45          | 4                                | 130B2415         | 130B2424 |
| 30                                   | 37        |             |                                  |                  |          |
| 37                                   | 45        | 75          | 3                                | 130B2416         | 130B2425 |
| 45                                   | 55        |             |                                  |                  |          |
| 55                                   | 75        | 115         | 3                                | 130B2417         | 130B2426 |
| 75                                   | 90        |             |                                  |                  |          |
| 90                                   | 110       | 165         | 3                                | 130B2418         | 130B2427 |
| 110                                  | 132       |             |                                  |                  |          |
| 150                                  | 160       | 260         | 3                                | 130B2419         | 130B2428 |
| 180                                  | 200       |             |                                  |                  |          |
| 220                                  | 250       | 310         | 3                                | 130B2420         | 130B2429 |
| 260                                  | 315       | 430         | 3                                | 130B2235         | 130B2238 |
| 300                                  | 400       |             |                                  |                  |          |
| 375                                  | 500       | 530         | 2                                | 130B2236         | 130B2239 |
| 450                                  | 560       | 630         | 2                                | 130B2280         | 130B2274 |
| 480                                  | 630       |             |                                  |                  |          |
| 560                                  | 710       | 765         | 2                                | 130B2421         | 130B2430 |
| -                                    | -         |             |                                  |                  |          |
| 670                                  | 800       | 1350        | 2                                | 130B2422         | 130B2431 |
| -                                    | 900       |             |                                  |                  |          |
| 820                                  | 1000      |             |                                  |                  |          |
| 970                                  | 1200      |             |                                  |                  |          |

Table 4.5: Line power supply 3x525–690 V

## 4.2.7 Ordering Numbers: Brake Resistors

**NOTE!**

When/where two resistors are listed in the tables - order two resistors.

4

| Ordering Numbers: Brake Resistors  |                    |                  |                     |                  |                     |           |        |                  |                     |           |        |                  |                     |
|------------------------------------|--------------------|------------------|---------------------|------------------|---------------------|-----------|--------|------------------|---------------------|-----------|--------|------------------|---------------------|
| Line power 200–240 V AC (T2-LP+MP) |                    |                  |                     |                  |                     |           |        |                  |                     |           |        |                  |                     |
| VLT AQUA Drive                     |                    |                  |                     |                  |                     |           |        |                  |                     |           |        |                  |                     |
| Selected resistor                  |                    |                  |                     |                  |                     |           |        |                  |                     |           |        |                  |                     |
| Standard IP 20                     |                    |                  |                     |                  |                     |           |        |                  |                     |           |        |                  |                     |
| Duty Cycle 10%                     |                    |                  |                     |                  |                     |           |        |                  |                     |           |        |                  |                     |
| Size:                              | P <sub>motor</sub> | R <sub>min</sub> | R <sub>br,nom</sub> | R <sub>rec</sub> | P <sub>br avg</sub> | Order no. | Period | R <sub>rec</sub> | P <sub>br avg</sub> | Order no. | Period | R <sub>rec</sub> | P <sub>br avg</sub> |
|                                    | [kW]               | [Ω]              | [Ω]                 | [Ω]              | [kW]                | 175Uxxxx  | [s]    | [Ω]              | [kW]                | 175Uxxxx  | [s]    | [Ω]              | [kW]                |
| PK25                               | 0.25               | 380              | 679                 | 425              | 0.095               | 1841      | 120    | 425              | 0.43                | 1941      | 120    | 430/100          | 0.43                |
| PK37                               | 0.37               | 380              | 459                 | 425              | 0.095               | 1841      | 120    | 425              | 0.43                | 1941      | 120    | 430/100          | 0.43                |
| PK55                               | 0.55               | 275              | 307                 | 310              | 0.25                | 1842      | 120    | 310              | 0.80                | 1942      | 120    | 330/100          | 0.80                |
| PK55                               | 0.55               | 275              | 307                 | 310              | 0.25                | 1842      | 120    | 310              | 0.80                | 1942      | 120    | 310/200          | 0.80                |
| PK75                               | 0.75               | 188              | 224                 | 210              | 0.285               | 1843      | 120    | 210              | 1.35                | 1943      | 120    | 220/100          | 1.35                |
| PK75                               | 0.75               | 188              | 224                 | 210              | 0.285               | 1843      | 120    | 210              | 1.35                | 1943      | 120    | 210/200          | 1.35                |
| PIK1                               | 1.1                | 130              | 152                 | 145              | 0.065               | 1820      | 120    | 145              | 0.26                | 1920      | 120    | 150/100          | 0.26                |
| PIK1                               | 1.1                | 130              | 152                 | 145              | 0.065               | 1820      | 120    | 145              | 0.26                | 1920      | 120    | 150/200          | 0.26                |
| PIK5                               | 1.5                | 81               | 110                 | 90               | 0.095               | 1821      | 120    | 90               | 0.43                | 1921      | 120    | 100/100          | 0.43                |
| PIK5                               | 1.5                | 81               | 110                 | 90               | 0.095               | 1821      | 120    | 90               | 0.43                | 1921      | 120    | 100/200          | 0.43                |
| P2K2                               | 2.2                | 58               | 74.2                | 65               | 0.25                | 1822      | 120    | 65               | 0.80                | 1922      | 120    | 72/200           | 0.80                |
| P3K0                               | 3                  | 45               | 53.8                | 50               | 0.285               | 1823      | 120    | 50               | 1.0                 | 1923      | 120    | 50/200           | 1.0                 |
| P3K7                               | 3.7                | 31.5             | 43.1                | 35               | 0.43                | 1824      | 120    | 35               | 1.35                | 1924      | 120    | 35/200           | 1.35                |
| P3K7                               | 3.7                | 31.5             | 43.1                | 35               | 0.43                | 1824      | 120    | 35               | 1.35                | 1924      | 120    | 72/200           | 1.35                |
| P5K5                               | 5.5                | 22.5             | 28.7                | 25               | 0.8                 | 1825      | 120    | 25               | 3.0                 | 1925      | 120    | 60/200           | 3.0                 |
| P7K5                               | 7.5                | 18               | 20.8                | 20               | 2.0                 | 1826      | 120    | 20               | -                   | -         | -      | -                | -                   |
| P11K                               | 11                 | 12.6             | 14.0                | 15               | 2.0                 | 1827      | 120    | 15               | -                   | -         | -      | -                | -                   |
| P15K                               | 15                 | 9                | 10.2                | 10               | 2.8                 | 1828      | 120    | 10               | -                   | -         | -      | -                | -                   |
| P18K                               | 18.5               | 6.3              | 8.2                 | 7                | 4                   | 1829      | 120    | 7                | -                   | -         | -      | -                | -                   |
| P22K                               | 22                 | 5.4              | 6.9                 | 6                | 4.8                 | 1830      | 120    | 6                | -                   | -         | -      | -                | -                   |
| P30K                               | 30                 | 4.2              | 5.0                 | 4.7              | 6                   | 1954      | 300    | 4.7              | -                   | -         | -      | -                | -                   |
| P37K                               | 37                 | 2.9              | 4.0                 | 3.3              | 8                   | 1955      | 300    | 3.3              | -                   | -         | -      | -                | -                   |
| P45K                               | 45                 | 2.4              | 3.3                 | 2.7              | 10                  | 1956      | 300    | 2.7              | -                   | -         | -      | -                | -                   |



## Ordering Numbers: Brake Resistors

**Line power 380–480 V  
AC (T4-LP+MP+HP)**

VLT AQUA Drive

Selected resistor

|       |                          |                  |                          | Standard IP 20   |                     |              |        |                  |                     |              |        | Flatpack IP65<br>for horizontal conveyors |                 |                 | Max. brake torque<br>with R <sub>rec</sub> |
|-------|--------------------------|------------------|--------------------------|------------------|---------------------|--------------|--------|------------------|---------------------|--------------|--------|-------------------------------------------|-----------------|-----------------|--------------------------------------------|
|       |                          |                  |                          | Duty Cycle 10%   |                     |              |        | Duty Cycle 40%   |                     |              |        | R <sub>rec</sub> per<br>item              |                 | Duty cy-<br>cle |                                            |
| Size: | P <sub>mo-<br/>tor</sub> | R <sub>min</sub> | R <sub>br,no<br/>m</sub> | R <sub>rec</sub> | P <sub>br avg</sub> | Order<br>no. | Period | R <sub>rec</sub> | P <sub>br avg</sub> | Order<br>no. | Period | R <sub>rec</sub> per<br>item              | Duty cy-<br>cle | Order<br>no.    |                                            |
|       | [kW]                     | [Ω]              | [Ω]                      | [Ω]              | [kW]                | 175U<br>xxxx | [s]    | [Ω]              | [kW]                | 175Ux<br>xxx | [s]    | [Ω/W]                                     | %               | 175Ux<br>xxx    | %                                          |
| PK37  | 0.37                     | 620              | 1825                     | 620              | 0.065               | 1840         | 120    | 620              | 0.26                | 1940         | 120    | 830/100                                   | 30              | 1000            | 110 (110)                                  |
| PK55  | 0.55                     | 620              | 1228                     | 620              | 0.065               | 1840         | 120    | 620              | 0.26                | 1940         | 120    | 830/100                                   | 20              | 1000            | 110 (110)                                  |
| PK75  | 0.75                     | 485              | 896                      | 620              | 0.065               | 1840         | 120    | 620              | 0.26                | 1940         | 120    | 830/100                                   | 20              | 1000            | 110 (110)                                  |
| P1K1  | 1.1                      | 329              | 608                      | 620              | 0.065               | 1840         | 120    | 620              | 0.26                | 1940         | 120    | 630                                       | -               | -               | 110 (110)                                  |
| P1K5  | 1.5                      | 240              | 443                      | 425              | 0.095               | 1841         | 120    | 425              | 1.0                 | 1941         | 120    | 430/100                                   | 10              | 1002            | 110 (110)                                  |
| P1K5  | 1.5                      | 240              | 443                      | 425              | 0.095               | 1841         | 120    | 425              | 1.0                 | 1941         | 120    | 430/200                                   | 20              | 0983            | 110 (110)                                  |
| P2K2  | 2.2                      | 161              | 299                      | 310              | 0.25                | 1842         | 120    | 310              | 1.6                 | 1942         | 120    | 320/200                                   | 14              | 0984            | 110 (110)                                  |
| P3K0  | 3                        | 117              | 217                      | 210              | 0.285               | 1843         | 120    | 210              | 2.5                 | 1943         | 120    | 215/200                                   | 10              | 0987            | 110 (110)                                  |
| P4K0  | 4                        | 86.9             | 161                      | 150              | 0.43                | 1844         | 120    | 150              | 3.7                 | 1944         | 120    | 150/200                                   | 14              | 0989            | 110 (110)                                  |
| P4K0  | 4                        | 86.9             | 161                      | 150              | 0.43                | 1844         | 120    | 150              | 3.7                 | 1944         | 120    | 300/200                                   | 7               | 2X098<br>5      | 110 (110)                                  |
| P5K5  | 5.5                      | 62.5             | 115                      | 110              | 0.6                 | 1845         | 120    | 110              | 4.7                 | 1945         | 120    | 120/200                                   | 6               | 2X099<br>0      | 110 (110)                                  |
| P7K5  | 7.5                      | 45.3             | 83.7                     | 80               | 0.85                | 1846         | 120    | 80               | 6.1                 | 1946         | 120    | 82/240                                    | 5               | 2X009<br>0      | 110 (110)                                  |
| P11K  | 11                       | 34.9             | 56.4                     | 40               | 2                   | 1848         | 120    | 40               | 11                  | 1948         | 120    | -                                         | -               | -               | 110 (110)                                  |
| P15K  | 15                       | 25.3             | 40.9                     | 40               | 2                   | 1848         | 120    | 40               | 11                  | 1948         | 120    | -                                         | -               | -               | 110 (110)                                  |
| P18K  | 18.5                     | 20.3             | 32.8                     | 30               | 2.8                 | 1849         | 120    | 30               | 18                  | 1949         | 120    | -                                         | -               | -               | 110 (110)                                  |
| P22K  | 22                       | 16.9             | 27.3                     | 25               | 3.5                 | 1850         | 120    | 25               | 23                  | 1950         | 120    | -                                         | -               | -               | 110 (110)                                  |
| P30K  | 30                       | 13.2             | 20                       | 20               | 4                   | 1851         | 120    | 20               | 25                  | 1951         | 120    | -                                         | -               | -               | 110 (110)                                  |
| P37K  | 37                       | 10.6             | 16.1                     | 15               | 4.8                 | 1852         | 120    | 15               | 32                  | 1952         | 120    | -                                         | -               | -               | 110 (110)                                  |
| P45K  | 45                       | 8.7              | 13.2                     | 12               | 5.5                 | 1853         | 120    | 12               | 40                  | 1953         | 120    | -                                         | -               | -               | 110 (110)                                  |
| P55K  | 55                       | 6.6              | 10.8                     | 10               | 15                  | 2008         | 120    | 10               | 62                  | 2007         | 120    | -                                         | -               | -               | 110 (110)                                  |
| P75K  | 75                       | 6.6              | 8                        | 7                | 13                  | 0069         | 120    | 7                | 72                  | 0068         | 120    | -                                         | -               | -               | 110 (110)                                  |
| P90K  | 90                       | 3.6              | 7                        | 5                | 18                  | 1959         | 300    | -                | -                   | -            | -      | -                                         | -               | -               | 110 (110)                                  |
| P110  | 110                      | 3                | 5                        | 5                | 18                  | 1959         | 300    | -                | -                   | -            | -      | -                                         | -               | -               | 110 (110)                                  |
| P132  | 132                      | 2.5              | 5                        | 4                | 22                  | 1960         | 300    | -                | -                   | -            | -      | -                                         | -               | -               | 110 (110)                                  |
| P160  | 160                      | 2                | 4                        | 3.8              | 22                  | 1960         | 300    | -                | -                   | -            | -      | -                                         | -               | -               | 106 (110)                                  |
| P200  | 200                      | 1.6              | 2.9                      | 2.6              | 32                  | 1962         | 300    | -                | -                   | -            | -      | -                                         | -               | -               | 110 (110)                                  |
| P250  | 250                      | 1.2              | 2.4                      | 2.1              | 39                  | 1963         | 300    | -                | -                   | -            | -      | -                                         | -               | -               | 110 (110)                                  |
| P315  | 315                      | 1.2              | 1.9                      | 2.1              | 39                  | 1963         | 300    | -                | -                   | -            | -      | -                                         | -               | -               | 98 (110)                                   |
| P355  | 355                      | 1.2              | 1.7                      | -                | -                   | -            | -      | -                | -                   | -            | -      | -                                         | -               | -               | (110)                                      |
| P400  | 400                      | 1.2              | 1.5                      | -                | -                   | -            | -      | -                | -                   | -            | -      | -                                         | -               | -               | (110)                                      |
| P450  | 450                      | 1.2              | 1.3                      | -                | -                   | -            | -      | -                | -                   | -            | -      | -                                         | -               | -               | (110)                                      |
| P500  | 500                      | 1.2              | 1.3                      | -                | -                   | -            | -      | -                | -                   | -            | -      | -                                         | -               | -               | (100)                                      |
| P560  | 560                      | 1.2              | 1.3                      | -                | -                   | -            | -      | -                | -                   | -            | -      | -                                         | -               | -               | (89)                                       |
| P630  | 630                      | 1.2              | 1.3                      | -                | -                   | -            | -      | -                | -                   | -            | -      | -                                         | -               | -               | (79)                                       |
| P710  | 710                      | 1.2              | 1.3                      | -                | -                   | -            | -      | -                | -                   | -            | -      | -                                         | -               | -               | (70)                                       |
| P800  | 800                      | 1.2              | 1.3                      | -                | -                   | -            | -      | -                | -                   | -            | -      | -                                         | -               | -               | (62)                                       |
| P1M0  | 1000                     | 1.2              | 1.3                      | -                | -                   | -            | -      | -                | -                   | -            | -      | -                                         | -               | -               | (50)                                       |

## Ordering Numbers: Brake Resistors

## Line power 525–690 V AC (T7-HP)

## VLT AQUA Drive

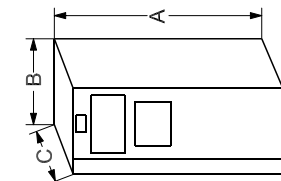
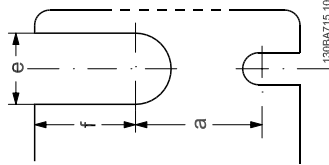
| Selected resistor |                            |                         |                            |                         |                             |           |               |                         |                             |           |               |                                              |
|-------------------|----------------------------|-------------------------|----------------------------|-------------------------|-----------------------------|-----------|---------------|-------------------------|-----------------------------|-----------|---------------|----------------------------------------------|
| Standard IP 20    |                            |                         |                            |                         |                             |           |               |                         |                             |           |               |                                              |
| Size:             | P <sub>motor</sub><br>[kW] | R <sub>min</sub><br>[Ω] | R <sub>br,nom</sub><br>[Ω] | Duty Cycle 10%          |                             |           |               | Duty Cycle 40%          |                             |           |               | Max. brake torque with R <sub>rec</sub><br>% |
|                   |                            |                         |                            | R <sub>rec</sub><br>[Ω] | P <sub>br,avg</sub><br>[kW] | Order no. | Period<br>[s] | R <sub>rec</sub><br>[Ω] | P <sub>br,avg</sub><br>[kW] | Order no. | Period<br>[s] |                                              |
| P37K              | 37                         | 22.5                    | 32.1                       | 20                      | 52                          | 2118      | 600           | 20                      | 32                          | 2118      | 600           | 110 (110)                                    |
| P45K              | 45                         | 22.5                    | 26.4                       | 15                      | 64                          | 2119      | 600           | 15                      | 39                          | 2119      | 600           | 110 (110)                                    |
| P55K              | 55                         | 18                      | 21.6                       | 15                      | 76                          | 2120      | 600           | 15                      | 47                          | 2120      | 600           | 110 (110)                                    |
| P75K              | 75                         | 13.5                    | 15.6                       | 9.8                     | 104                         | 2121      | 600           | 9.8                     | 64                          | 2121      | 600           | 110 (110)                                    |
| P90K              | 90                         | 8.8                     | 13                         | 9.8                     | 126                         | 2122      | 600           | 9.8                     | 77                          | 2122      | 600           | 110 (110)                                    |
| P110              | 110                        | 8.8                     | 10.7                       | 7.3                     | 153                         | 2123      | 600           | 7.3                     | 93                          | 2123      | 600           | 110 (110)                                    |
| P132              | 132                        | 6.6                     | 8.9                        | 4.7                     | 185                         | 2124      | 600           | 4.7                     | 113                         | 2124      | 600           | 110 (110)                                    |
| P160              | 160                        | 6.6                     | 7.3                        | 4.7                     | 224                         | 2125      | 600           | 4.7                     | 137                         | 2125      | 600           | 110 (110)                                    |
| P200              | 200                        | 4.2                     | 5.9                        | 3.8                     | 147                         | 2X2126    | 600           | 3.8                     | 90                          | 2X2126    | 600           | 110 (110)                                    |
| P250              | 250                        | 4.2                     | 4.7                        | 2.6                     | 173                         | 2X2127    | 600           | 2.6                     | 106                         | 2X2127    | 600           | 110 (110)                                    |
| P315              | 315                        | 3.4                     | 3.7                        | 2.6                     | 212                         | 2X2128    | 600           | 2.6                     | 130                         | 2X2128    | 600           | 108 (110)                                    |
| P400              | 355                        | 2.3                     | 3.3                        | 2.6                     | 72                          | 2x1062    | 300           | -                       | -                           | -         | -             | 110 (110)                                    |
| P450              | 400                        | 2.3                     | 2.9                        | 2.6                     | 72                          | 2x1062    | 300           | -                       | -                           | -         | -             | 110 (110)                                    |
| P500              | 500                        | 2.1                     | 2.3                        | 2.3                     | 90                          | 2x1063    | 300           | -                       | -                           | -         | -             | 110 (110)                                    |
| P560              | 560                        | 1.9                     | 2.1                        | 2.1                     | 100                         | 2x1064    | 300           | -                       | -                           | -         | -             | 110 (110)                                    |
| P630              | 630                        | 1.7                     | 1.9                        | -                       | -                           | -         | -             | -                       | -                           | -         | -             | -                                            |
| P710              | 710                        | 1.5                     | 1.7                        | -                       | -                           | -         | -             | -                       | -                           | -         | -             | -                                            |
| P800              | 800                        | 1.3                     | 1.5                        | -                       | -                           | -         | -             | -                       | -                           | -         | -             | -                                            |
| P900              | 900                        | 1.2                     | 1.3                        | -                       | -                           | -         | -             | -                       | -                           | -         | -             | -                                            |
| P1M0              | 1000                       | 1.2                     | 1.3                        | -                       | -                           | -         | -             | -                       | -                           | -         | -             | -                                            |

## 5 How to Install

### 5.1 Mechanical Installation

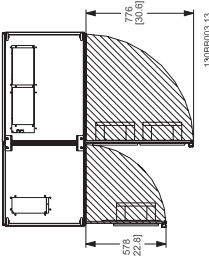
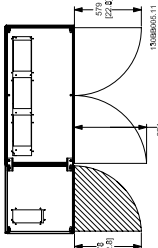
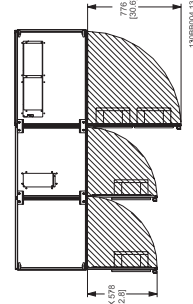
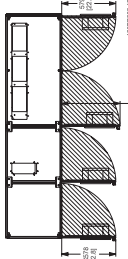
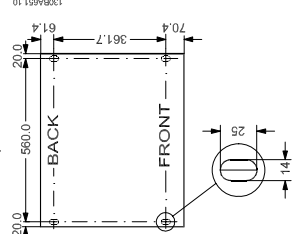
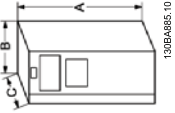
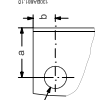
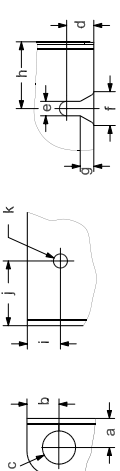
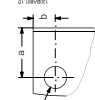
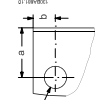
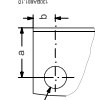
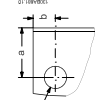
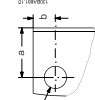
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5.1.1 Mechanical Front Views

|                                                                                                                 |                                                                                     |         |         |    |                                                                                     |         |    |                                                                                     |            |    |                                                                                     |                                                                                   |    |                                                                                     |      |    |                                                                                     |      |    |                                                                                   |            |    |                                                                                   |            |    |                                                                                   |      |    |                                                                                   |      |
|-----------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|---------|---------|----|-------------------------------------------------------------------------------------|---------|----|-------------------------------------------------------------------------------------|------------|----|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|----|-------------------------------------------------------------------------------------|------|----|-------------------------------------------------------------------------------------|------|----|-----------------------------------------------------------------------------------|------------|----|-----------------------------------------------------------------------------------|------------|----|-----------------------------------------------------------------------------------|------|----|-----------------------------------------------------------------------------------|------|
| A2                                                                                                              |  | IP20/21 | IP20/21 | A5 |  | IP55/66 | B1 |  | IP21/55/66 | B2 |  | IP21/55/66                                                                        | B3 |  | IP20 | B4 |  | IP20 | C1 |  | IP21/55/66 | C2 |  | IP21/55/66 | C3 |  | IP20 | C4 |  | IP20 |
|                              |                                                                                     |         |         |    |                                                                                     |         |    |                                                                                     |            |    |                                                                                     |  |    |                                                                                     |      |    |                                                                                     |      |    |                                                                                   |            |    |                                                                                   |            |    |                                                                                   |      |    |                                                                                   |      |
| Figure 5.1: Top and bottom mounting holes.                                                                      |                                                                                     |         |         |    |                                                                                     |         |    |                                                                                     |            |    |                                                                                     | Figure 5.2: Top and bottom mounting holes. (B4+C3+C4 only)                        |    |                                                                                     |      |    |                                                                                     |      |    |                                                                                   |            |    |                                                                                   |            |    |                                                                                   |      |    |                                                                                   |      |
| Accessory bags containing necessary brackets, screws and connectors are included with the drives upon delivery. |                                                                                     |         |         |    |                                                                                     |         |    |                                                                                     |            |    |                                                                                     |                                                                                   |    |                                                                                     |      |    |                                                                                     |      |    |                                                                                   |            |    |                                                                                   |            |    |                                                                                   |      |    |                                                                                   |      |
| All measurements in mm.                                                                                         |                                                                                     |         |         |    |                                                                                     |         |    |                                                                                     |            |    |                                                                                     |                                                                                   |    |                                                                                     |      |    |                                                                                     |      |    |                                                                                   |            |    |                                                                                   |            |    |                                                                                   |      |    |                                                                                   |      |

### 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<br>0.37-4.0<br>-<br>- | 3.7<br>5.5-7.5<br>0.75-7.5<br>- | 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                                                                                                                              |                                |                                 | 0.37-7.5 | 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 | 11-18.5   | 22-30     | 11-18.5 | 22-37   | 37-55     | 75-90     | 45-55   | 75-90   |
| 525–690 V                                                                                                                              | -                              | -                               | -        | -         | 11-30     | -       | -       | -         | 37-90     | -       | -       |
| IP                                                                                                                                     | 20                             | 21                              | 55/66    | 21/ 55/66 | 21/55/66  | 20      | 20      | 21/55/66  | 21/55/66  | 20      | 20      |
| NEMA                                                                                                                                   | Chassis                        | Type 1                          | Type 1   | Type 1/12 | Type 1/12 | Chassis | Chassis | Type 1/12 | Type 1/12 | Chassis | Chassis |
| Height (mm)                                                                                                                            |                                |                                 |          |           |           |         |         |           |           |         |         |
| Enclosure                                                                                                                              | A**                            | 246                             | 372      | 246       | 372       | 350     | 460     | 680       | 770       | 490     | 600     |
| .with de-coupling plate                                                                                                                | A2                             | 374                             | -        | 374       | -         | 419     | 595     | -         | -         | 630     | 800     |
| Backplate                                                                                                                              | A1                             | 268                             | 375      | 268       | 375       | 399     | 520     | 680       | 770       | 550     | 660     |
| Distance between mount. holes                                                                                                          | a                              | 257                             | 350      | 257       | 350       | 380     | 495     | 648       | 739       | 521     | 631     |
| Width (mm)                                                                                                                             |                                |                                 |          |           |           |         |         |           |           |         |         |
| Enclosure                                                                                                                              | B                              | 90                              | 90       | 130       | 242       | 165     | 231     | 308       | 370       | 308     | 370     |
| With one C option                                                                                                                      | B                              | 130                             | 130      | 170       | 242       | 205     | 231     | 308       | 370       | 308     | 370     |
| Backplate                                                                                                                              | B                              | 90                              | 90       | 130       | 242       | 165     | 231     | 308       | 370       | 308     | 370     |
| Distance between mount. holes                                                                                                          | b                              | 70                              | 70       | 110       | 210       | 140     | 200     | 272       | 334       | 270     | 330     |
| Depth (mm)                                                                                                                             |                                |                                 |          |           |           |         |         |           |           |         |         |
| Without option A/B                                                                                                                     | C                              | 205                             | 205      | 205       | 260       | 248     | 242     | 310       | 335       | 333     | 333     |
| With option A/B                                                                                                                        | C*                             | 220                             | 220      | 220       | 260       | 262     | 242     | 310       | 335       | 333     | 333     |
| Screw holes (mm)                                                                                                                       |                                |                                 |          |           |           |         |         |           |           |         |         |
|                                                                                                                                        | c                              | 8.0                             | 8.0      | 8.0       | 12        | 8       | -       | 12        | 12        | -       | -       |
| Diameter ø                                                                                                                             | d                              | 11                              | 11       | 11        | 19        | 12      | -       | 19        | 19        | -       | -       |
| Diameter ø                                                                                                                             | e                              | 5.5                             | 5.5      | 5.5       | 9         | 6.8     | 8.5     | 9.0       | 9.0       | 8.5     | 8.5     |
|                                                                                                                                        | f                              | 9                               | 9        | 9         | 9         | 7.9     | 15      | 9.8       | 9.8       | 17      | 17      |
| Max weight (kg)                                                                                                                        |                                | 4.9                             | 5.3      | 6.6       | 7.0       | 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. |                                |                                 |          |           |           |         |         |           |           |         |         |

|                                                                                     |                                                                                     |                                                                                      |           |                                                                                     |                |                                                                                     |                                                                                      |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                       |  |
|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|-----------|-------------------------------------------------------------------------------------|----------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|--|
|                                                                                     |                                                                                     |                                                                                      |           |                                                                                     | <b>F2/F4</b>   |                                                                                     |     |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                       |  |
|                                                                                     |                                                                                     |                                                                                      |           |                                                                                     | <b>F1/F3</b>   |                                                                                     |    |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                       |  |
|                                                                                     |                                                                                     |                                                                                      |           |                                                                                     | <b>IP21/54</b> |                                                                                     |   |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                       |  |
|                                                                                     |                                                                                     |                                                                                      |           |                                                                                     | <b>IP21/54</b> |                                                                                     |    |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                       |  |
|                                                                                     |                                                                                     |                                                                                      |           |                                                                                     | <b>IP21/54</b> |                                                                                     |  |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                       |  |
|                                                                                     |                                                                                     |                                                                                      |           |                                                                                     | <b>IP21/54</b> |                                                                                     |   |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                       |  |
| <b>D1</b>                                                                           |  | IP21/54                                                                              | <b>D2</b> |  | IP21/54        | <b>D3</b>                                                                           |   | <b>D4</b>                                                                           |  | <b>E1</b>                                                                           |  | <b>E2</b>                                                                           |  |  |  |
|  |                                                                                     |                                                                                      |           |                                                                                     |                |                                                                                     |                                                                                      |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                       |  |
|                                                                                     |                                                                                     |                                                                                      |           |                                                                                     |                |                                                                                     |                                                                                      |                                                                                     |                                                                                     | <b>Bottom mounting hole:</b>                                                        |                                                                                     |  |                                                                                     |                                                                                       |  |
|                                                                                     |                                                                                     |                                                                                      |           |                                                                                     |                |                                                                                     |                                                                                      |                                                                                     |                                                                                     | <b>Lifting eye:</b>                                                                 |                                                                                     |  |                                                                                     |                                                                                       |  |
| <b>Lifting eye and mounting holes:</b>                                              |                                                                                     |  |           |  |                |  |                                                                                      |  |                                                                                     |  |                                                                                     |  |                                                                                     |                                                                                       |  |
| <b>All measurements in mm</b>                                                       |                                                                                     |                                                                                      |           |                                                                                     |                |                                                                                     |                                                                                      |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                       |  |

All measurements in mm

| Mechanical dimensions                                                                                 |           |           |         |         |           |         |           |           |           |           |           |
|-------------------------------------------------------------------------------------------------------|-----------|-----------|---------|---------|-----------|---------|-----------|-----------|-----------|-----------|-----------|
| Enclosure size (kW)                                                                                   | D1        | D2        | D3      | D4      | E1        | E2      | F1        | F2        | F3        | F4        |           |
| 380-480 V AC                                                                                          | 110-132   | 160-250   | 110-132 | 160-250 | 315-450   | 315-450 | 500-710   | 800-1000  | 500-710   | 800-1000  |           |
| 525-690 V AC                                                                                          | 45-160    | 200-400   | 45-160  | 200-400 | 450-630   | 450-630 | 710-900   | 1000-1200 | 710-900   | 1000-1200 |           |
| IP                                                                                                    | 21/54     | 21/54     | 00      | 00      | 21/54     | 00      | 21/54     | 21/54     | 21/54     | 21/54     | Type 1/12 |
| NEMA                                                                                                  | Type 1/12 | Type 1/12 | Chassis | Chassis | Type 1/12 | Chassis | Type 1/12 | Type 1/12 | Type 1/12 | Type 1/12 | Type 1/12 |
| Shipping dimensions (mm):                                                                             |           |           |         |         |           |         |           |           |           |           |           |
| Width                                                                                                 | 1730      | 1730      | 1220    | 1490    | 2197      | 1705    | 2324      | 2324      | 2324      | 2324      | 2324      |
| Height                                                                                                | 650       | 650       | 650     | 650     | 840       | 831     | 1569      | 1962      | 2159      | 2559      | 2559      |
| Depth                                                                                                 | 570       | 570       | 570     | 570     | 736       | 736     | 927       | 927       | 927       | 927       | 927       |
| Adj. Freq. Drive dimensions: (mm)                                                                     |           |           |         |         |           |         |           |           |           |           |           |
| Height                                                                                                |           |           |         |         |           |         |           |           |           |           |           |
| Backplate                                                                                             | A         | 1209      | 1589    | 1046    | 1327      | 1547    | 2281      | 2281      | 2281      | 2281      | 2281      |
| Width                                                                                                 |           |           |         |         |           |         |           |           |           |           |           |
| Backplate                                                                                             | B         | 420       | 408     | 408     | 600       | 585     | 1400      | 1800      | 2000      | 2400      | 2400      |
| Depth                                                                                                 |           |           |         |         |           |         |           |           |           |           |           |
|                                                                                                       | C         | 380       | 375     | 375     | 494       | 494     | 607       | 607       | 607       | 607       | 607       |
| Dimensions brackets (mm/inch)                                                                         |           |           |         |         |           |         |           |           |           |           |           |
| Center hole to edge                                                                                   | a         | 22/0.9    | 22/0.9  | 22/0.9  | 56/2.2    | 23/0.9  |           |           |           |           |           |
| Center hole to edge                                                                                   | b         | 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  |           |           |           |           |           |
|                                                                                                       | 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      | 1246      | 1299      | 1541      |           |
| Please contact Danfoss for more detailed information and CAD drawings for your own planning purposes. |           |           |         |         |           |         |           |           |           |           |           |

### 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 adjustable frequency drive. Retighten all four screws.

The adjustable frequency drive 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            |
| D1/D2/D3/D4 | 225            |
| E1/E2       | 225            |
| F1/F2/F3/F4 | 225            |

Table 5.1: Required free air space above and below adjustable frequency drive

### 5.1.4 Safety Requirements for Mechanical Installation



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

The adjustable frequency drive is cooled by 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 adjustable frequency drive*, 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 113°–131°F [45°–55°C], derating of the adjustable frequency drive will become relevant, see *Derating for Ambient Temperature*.

The service life of the adjustable frequency drive 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 Pre-installation

### 5.2.1 Planning the Installation Site

**NOTE!**

Before performing the installation, it is important to plan the installation of the adjustable frequency drive. Neglecting this may result in extra work during and after installation.

**Select the best possible operation site by considering the following (see details on the following pages and in the respective Design Guides):**

- Ambient operating temperature
- Installation method
- How to cool the unit
- Position of the adjustable frequency drive.
- Cable routing
- Ensure the power source supplies the correct voltage and necessary current.
- Ensure that the motor current rating is within the maximum current from the adjustable frequency drive.
- If the adjustable frequency drive is without built-in fuses, ensure that the external fuses are rated correctly.

**5**

### 5.2.2 Receiving the Adjustable Frequency Drive

When receiving the adjustable frequency drive, make sure that the packaging is intact, and look for any damage that might have occurred to the unit during transport. If damage has occurred, immediately contact the shipping company to make a damage claim.

### 5.2.3 Transportation and Unpacking

Before unpacking the adjustable frequency drive, it is recommended to unload it as close as possible to the final installation site. Remove the box and handle the adjustable frequency drive on the pallet, as long as possible.

**NOTE!**

The card box cover contains a drilling master for the mounting holes in the D frames. For the E size, please refer to section *Mechanical Dimensions* later in this chapter.

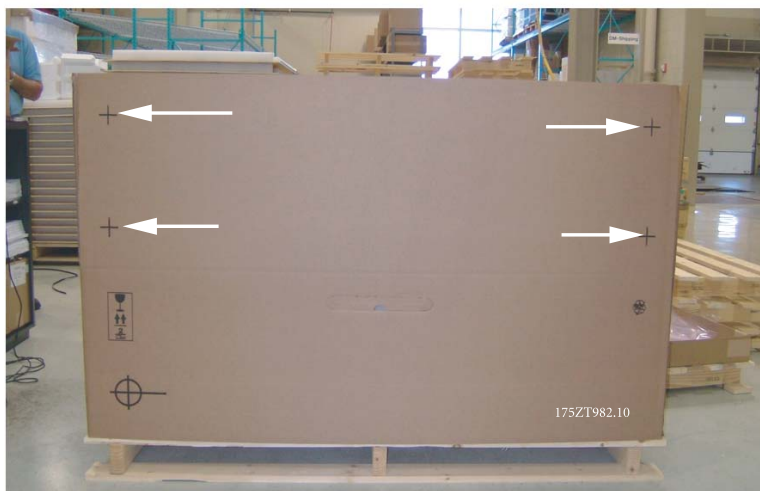


Figure 5.3: Mounting Template

### 5.2.4 Lifting

Always lift the adjustable frequency drive using the dedicated lifting holes. For all D and E2 (IP00) frames, use a bar to avoid bending the lifting holes of the adjustable frequency drive.

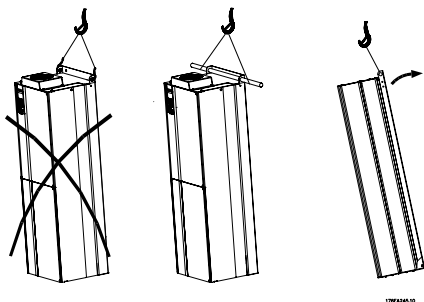


Figure 5.4: Recommended lifting method, frame sizes D and E .



#### NOTE!

The lifting bar must be able to handle the weight of the adjustable frequency drive. See *Mechanical Dimensions* for the weight of the different frame sizes. Maximum diameter for bar is 1 in [25 cm]. The angle from the top of the drive to the lifting cable should be 60 degrees or greater.

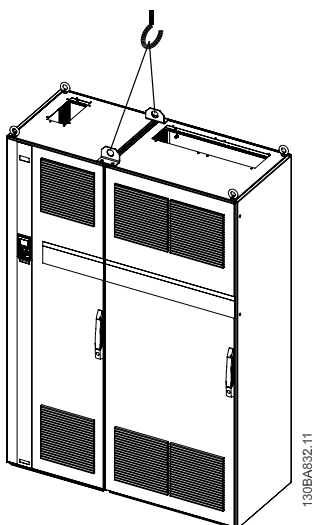


Figure 5.5: Recommended lifting method, frame size F1.

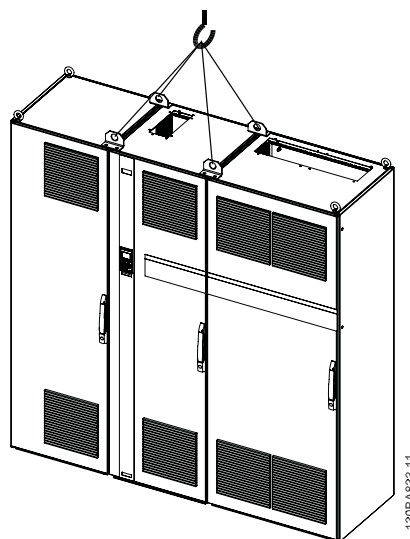


Figure 5.7: Recommended lifting method, frame size F3.

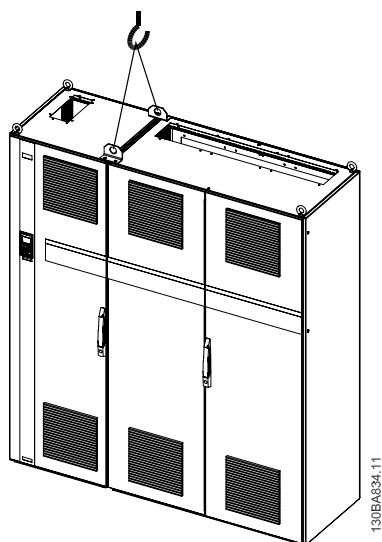


Figure 5.6: Recommended lifting method, frame size F2.

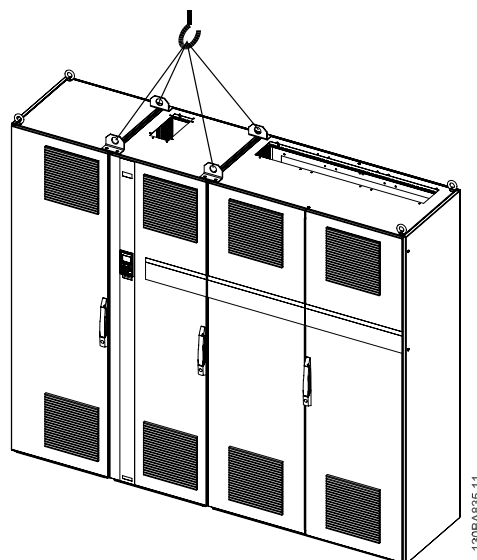


Figure 5.8: Recommended lifting method, frame size F4.

**NOTE!**

Note the plinth is provided in the same packaging as the adjustable frequency drive but is not attached to Unit Sizes F1-F461-64 frames during shipment. The plinth is required to allow airflow to the drive to provide proper cooling. The Unit Sizes F6 frames should be positioned on top of the plinth in the final installation location. The angle from the top of the drive to the lifting cable should be 60 degrees or greater.

## 5.2.5 Tools Needed

To perform the mechanical installation, the following tools are needed:

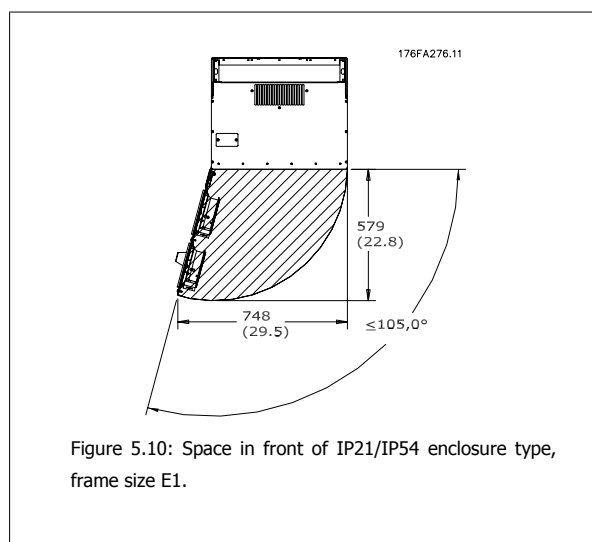
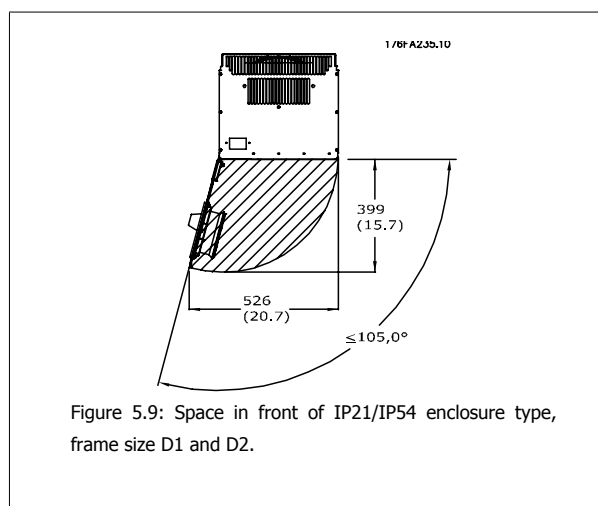
- Drill with 0.39 or 0.47 in [10 or 12 mm] drill.
- Tape measure
- Wrench with relevant metric sockets (0.28-0.67 in (7-17 mm))
- Extensions to wrench
- Sheet metal punch for conduits or cable connectors in IP 21/Nema 1 and IP 54 units
- Lifting bar to lift the unit (rod or tube max. Ø1 in [25 mm], able to lift minimum 880 lbs [400 kg].
- Crane or other lifting aid to place the adjustable frequency drive in position
- A Torx T50 tool is needed to install the E1 in IP21 and IP54 enclosure types.

# 5

## 5.2.6 General Considerations

### Space

Ensure proper space above and below the adjustable frequency drive to allow airflow and cable access. In addition, space in front of the unit must be considered to allow the panel door to be opened.



### NOTE!

For frame size F, please see section *Mechanical Installation High Power*.

### Wire access

Ensure that proper cable access is present including the necessary bending allowance. As the IP00 enclosure is open to the bottom cables must be fixed to the back panel of the enclosure where the adjustable frequency drive is mounted, i.e., by using cable clamps.



### NOTE!

All cable lugs/shoes must mount within the width of the terminal bus bar.

## 5.2.7 Cooling and Airflow

### Cooling

Cooling can be obtained in different ways, by using the cooling ducts in the bottom and the top of the unit, by taking air in and out the back of the unit or by combining the cooling possibilities.

### Duct cooling

A dedicated option has been developed to optimize installation of IP00/chassis frame adjustable frequency drives in Rittal TS8 enclosures utilizing the fan of the adjustable frequency drive for forced air cooling of the backchannel. The air out the top of the enclosure could but ducted outside a facility so the heat losses from the backchannel are not dissipated within the control room reducing air-conditioning requirements of the facility.

Please see *Installation of Duct Cooling Kit in Rittal enclosures*, for further information.

### Back cooling

The backchannel air can also be ventilated in and out the back of a Rittal TS8 enclosure. This offers a solution where the backchannel could take air from outside the facility and return the heat losses outside the facility thus reducing air-conditioning requirements.



#### NOTE!

A door fan or fans are required on the Rittal cabinet to remove the losses not contained in the backchannel of the drive. The minimum door fan airflow required at the drive maximum ambient for the D3 and D4 is 391 m<sup>3</sup>/h (230 cfm). The minimum door fan airflow required at the drive maximum ambient for the E2 is 782 m<sup>3</sup>/h (460 cfm). If the ambient is below maximum or if additional components and heat loss are added within the enclosure, a calculation must be made to ensure the proper airflow is provided to cool the inside of the Rittal enclosure.

5

### Airflow

The necessary airflow over the heatsink must be ensured. The flow rate is shown below.

| Enclosure protection                                   | Frame size        | Door fan/Top fan airflow                                     | Airflow over heatsink                                         |
|--------------------------------------------------------|-------------------|--------------------------------------------------------------|---------------------------------------------------------------|
| IP21 / NEMA 1                                          | D1 and D2         | 6,003 ft <sup>3</sup> /h [170 m <sup>3</sup> /h] (100 cfm)   | 27,015 ft <sup>3</sup> [765 m <sup>3</sup> /h] (450 cfm)      |
| IP54 / NEMA 12                                         | E1                | 12,006 ft <sup>3</sup> /h [340 m <sup>3</sup> /h] (200 cfm)  | 50,994 ft <sup>3</sup> /h [1,444 m <sup>3</sup> /h] (850 cfm) |
| IP21 / NEMA 1                                          | F1, F2, F3 and F4 | 24,720 ft <sup>3</sup> /h [700 m <sup>3</sup> /h] (412 cfm)* | 34,784 ft <sup>3</sup> /h [985 m <sup>3</sup> /h] (580 cfm)   |
| IP54 / NEMA 12                                         | F1, F2, F3 and F4 | 18,540 ft <sup>3</sup> /h [525 m <sup>3</sup> /h] (309 cfm)* | 34,784 ft <sup>3</sup> /h [985 m <sup>3</sup> /h] (580 cfm)   |
| IP00 / Chassis                                         | D3 and D4         | 9,005 ft <sup>3</sup> /h [255 m <sup>3</sup> /h] (150 cfm)   | 27,015 ft <sup>3</sup> [765 m <sup>3</sup> /h] (450 cfm)      |
|                                                        | E2                | 9,005 ft <sup>3</sup> /h [255 m <sup>3</sup> /h] (150 cfm)   | 50,994 ft <sup>3</sup> /h [1,444 m <sup>3</sup> /h] (850 cfm) |
| * Airflow per fan. Frame size F contain multiple fans. |                   |                                                              |                                                               |

Table 5.2: Heatsink Air Flow



#### NOTE!

The fan runs for the following reasons:

1. AMAAuto-tune
2. DC Hold
3. Pre-Mag
4. DC Brake
5. 60% of nominal current is exceeded
6. Specific heatsink temperature exceeded (power-size dependent).

Once the fan is started, it will run for a minimum of 10 minutes.

## 5.2.8 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.



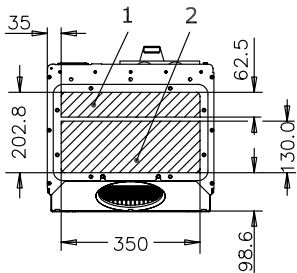
**NOTE!**  
The gland plate must be fitted to the adjustable frequency drive to ensure the specified protection degree, as well as ensuring proper cooling of the unit. If the gland plate is not mounted, the adjustable frequency drive may trip on Alarm 69, Pwr. Card Temp



130BB073.10

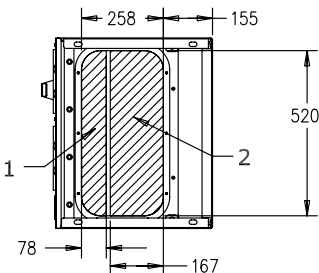
Figure 5.11: Example of proper installation of the gland plate.

**Frame size D1 + D2**



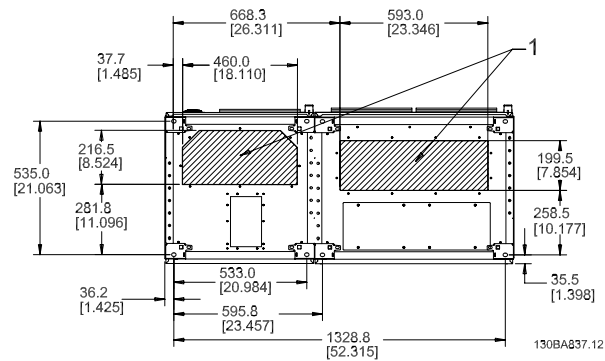
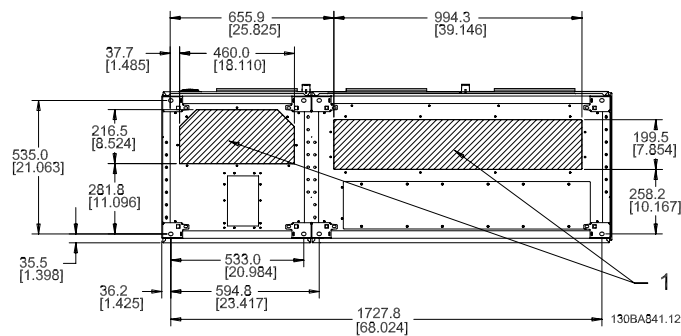
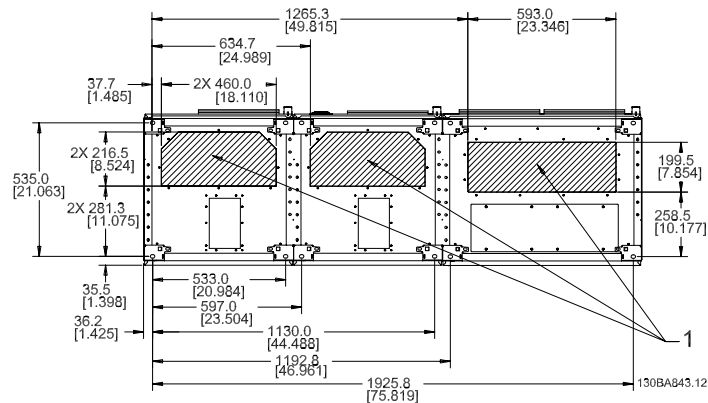
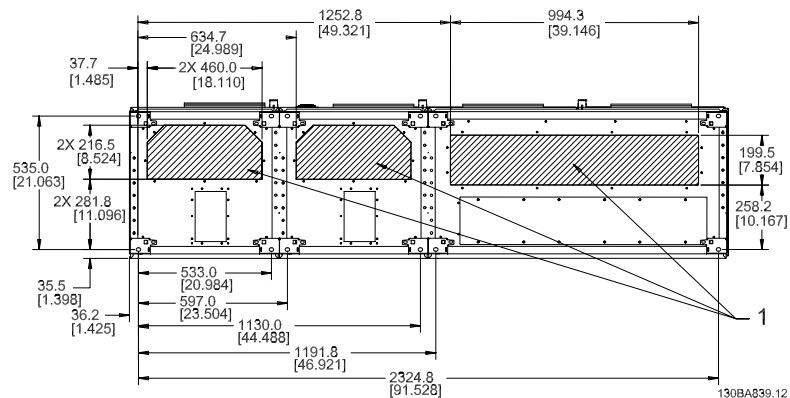
176FA289.11

**Frame size E1**



176FA290.11

Cable entries viewed from the bottom of the adjustable frequency drive - 1) Line power side 2) Motor side

**Frame size F1****Frame size F2****Frame size F3****Frame size F4**

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

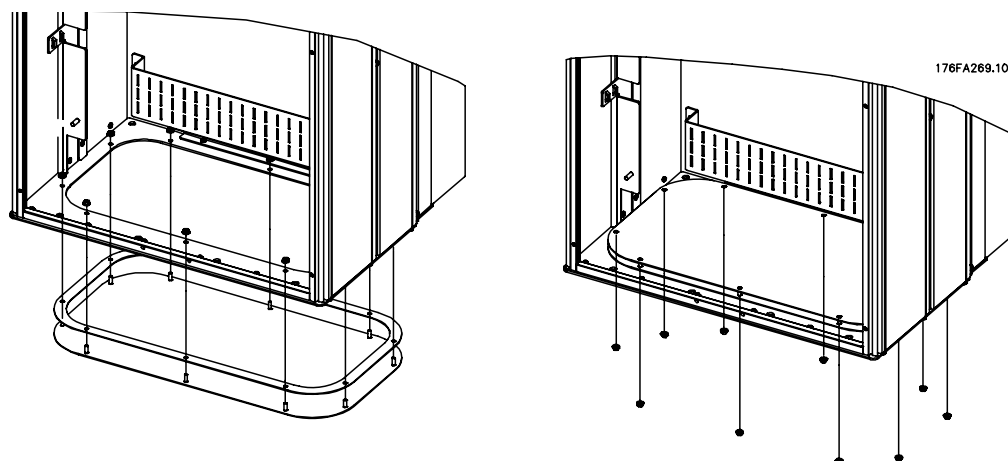


Figure 5.12: Mounting of bottom plate, Frame size E1.

The bottom plate of the E1 frame can be mounted from either inside 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 adjustable frequency drive is placed on the pedestal.

### 5.2.9 IP21 Drip Shield Installation (frame size D1 and D2 )

**To comply with the IP21 rating, a separate drip shield is to be installed as explained below:**

- Remove the two front screws.
- Insert the drip shield and replace the screws.
- Torque the screws to 5.6 Nm (50 in-lbs).

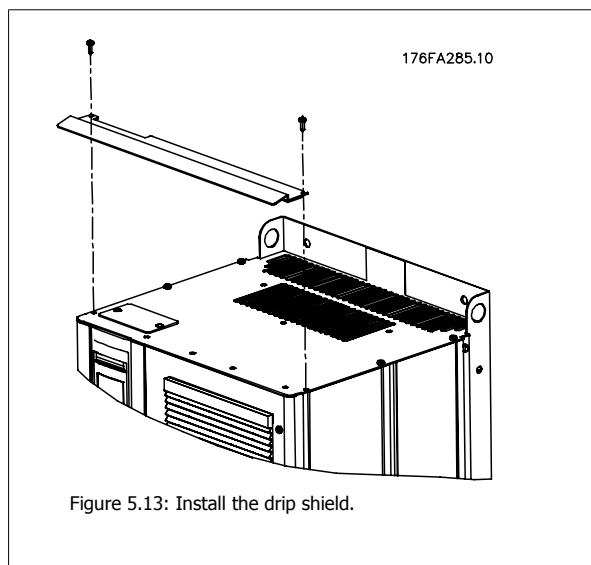


Figure 5.13: Install the drip shield.



## 5.3 Electrical Installation

### 5.3.1 Cables General


**NOTE!**

Cables General

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

**Details of terminal tightening torques.**

| Enclosure | Power (kW) |            | Torque (Nm) |       |               |       |        |       |
|-----------|------------|------------|-------------|-------|---------------|-------|--------|-------|
|           | 200-240 V  | 380-480 V  | Line        | Motor | DC connection | Brake | Ground | Relay |
| A2        | 0.25 - 3.0 | 0.37 - 4.0 | 1.8         | 1.8   | 1.8           | 1.8   | 3      | 0.6   |
| A3        | 3.7        | 5.5 - 7.5  | 1.8         | 1.8   | 1.8           | 1.8   | 3      | 0.6   |
| A5        | 0.25 - 3.7 | 0.37 - 7.5 | 1.8         | 1.8   | 1.8           | 1.8   | 3      | 0.6   |
| B1        | 5.5 - 7.5  | 11 - 18    | 1.8         | 1.8   | 1.5           | 1.5   | 3      | 0.6   |
| B2        | 11 - 15    | 22         | 2.5         | 2.5   | 3.7           | 3.7   | 3      | 0.6   |
|           |            | 30         | 4.5         | 4.5   | 3.7           | 3.7   | 3      | 0.6   |
| C1        | 18 - 22    | 37 - 55    | 10          | 10    | 10            | 10    | 3      | 0.6   |
| C2        | 30 - 45    | 75         | 14          | 14    | 14            | 14    | 3      | 0.6   |
|           |            | 90         | 24          | 24    | 14            | 14    | 3      | 0.6   |

Table 5.3: Tightening of terminals.

### 5.3.2 Removal of Knockouts for Extra Cables

1. Remove the cable entry from the adjustable frequency drive (this prevents foreign parts from falling into the adjustable frequency drive when removing knockouts)
2. The cable entry must 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 adjustable frequency drive.

### 5.3.3 Connection to Line Power and Grounding


**NOTE!**

The plug connector for power can be removed.

1. Make sure the adjustable frequency drive is properly grounded. Connect to ground connection (terminal 95). Use screw from the accessory bag.
2. Place plug connector 91, 92, 93 from the accessory bag onto the terminals labeled LINE at the bottom of the adjustable frequency drive.
3. Connect line power wires to the line plug connector.

**5**


The ground connection cable cross-section must be at least 0.016 in<sup>2</sup> [10 mm<sup>2</sup>] or have 2 rated line power supply wires terminated separately according to EN 50178.

The AC line input connection is fitted to the line power supply switch, if one is included.


**NOTE!**

Make sure that the AC line voltage corresponds to the AC line voltage of the adjustable frequency drive nameplate.


**IT Line Power**

Do not connect 400 V adjustable frequency drives with RFI filters to line power supplies with a voltage between phase and ground of more than 440 V.

For IT line power and delta ground (grounded leg), AC line voltage may exceed 440 V between phase and ground.

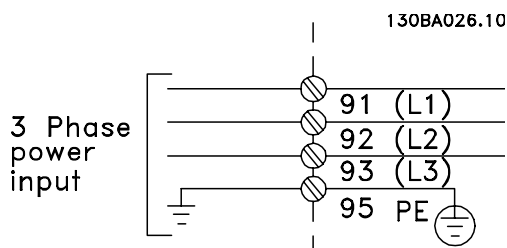


Figure 5.14: Terminals for line power and grounding.

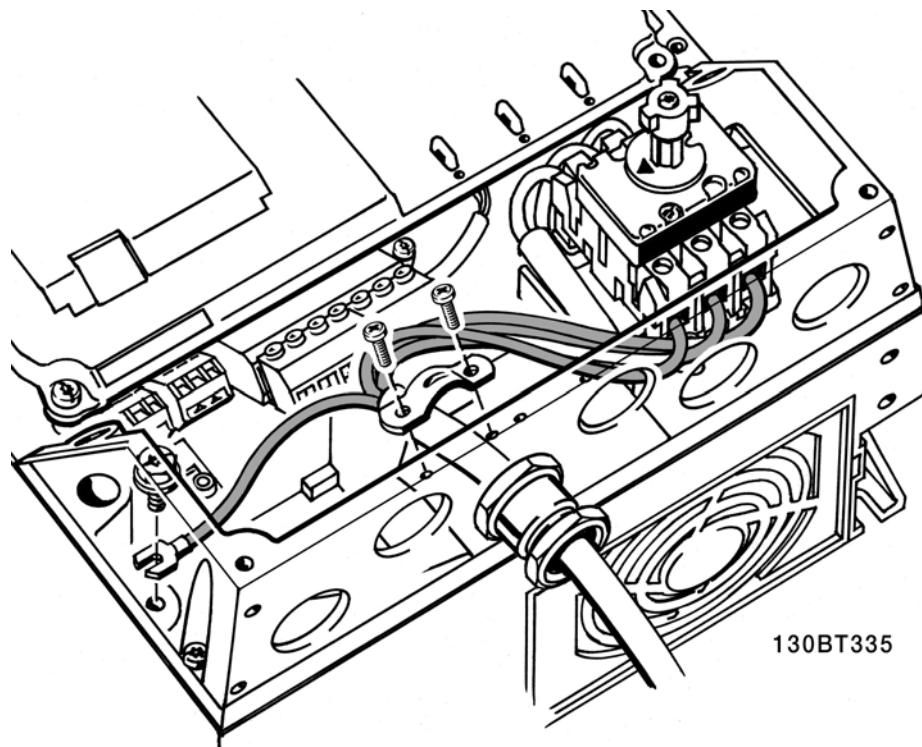


Figure 5.15: How to connect to the line power supply and grounding with disconnect (A5 enclosure).

### 5.3.4 Motor Cable Connection


**NOTE!**

Motor cable must be shielded/armored. If an unshielded / unarmored cable is used, some EMC requirements are not complied with. For more information, see *EMC specifications*.

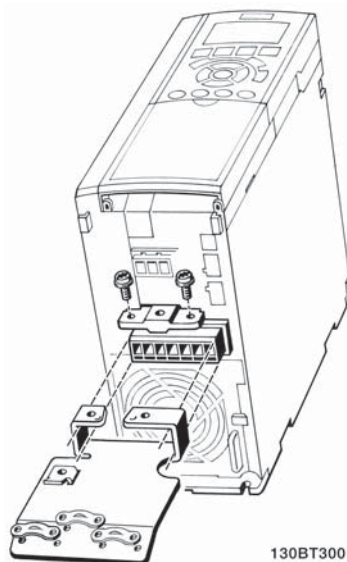
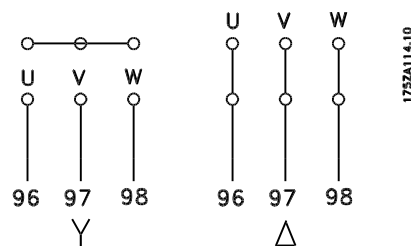


Figure 5.16: Mounting of decoupling plate.

1. Fasten a decoupling plate to the bottom of the adjustable frequency drive with screws and washers from the accessory bag.
2. Attach motor cable to terminals 96 (U), 97 (V), 98 (W).
3. Connect to ground 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 labeled MOTOR.
5. Fasten shielded cable to the decoupling plate with screws and washers from the accessory bag.

All types of three-phase asynchronous standard motors can be connected to the adjustable frequency drive. Normally, small motors are star-connected (230/400 V, D/Y). Large motors are delta-connected (400/6090 V, D/Y). Refer to the motor nameplate for correct connection mode and voltage.


**NOTE!**

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

| No. | 96       | 97       | 98       | Motor voltage 0–100% of AC line voltage                                            |
|-----|----------|----------|----------|------------------------------------------------------------------------------------|
|     | U        | V        | W        | 3 wires out of motor                                                               |
|     | U1<br>W2 | V1<br>U2 | W1<br>V2 | 6 wires out of motor, Delta-connected                                              |
|     | U1       | V1       | W1       | 6 wires out of motor, Star-connected<br>U2, V2, W2 to be interconnected separately |
| No. | 99       |          |          | Ground connection                                                                  |
|     | PE       |          |          |                                                                                    |

### 5.3.5 Motor Cables

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

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

#### F frame Requirements

**F1/F3 requirements:** Motor phase cable quantities must be 2, 4, 6, or 8 (multiples of 2, 1 cable is not allowed) to obtain equal amount of wires attached to both inverter module terminals. The cables are required to be equal length within 10% between the inverter module terminals and the first common point of a phase. The recommended common point is the motor terminals.

**F2/F4 requirements:** Motor phase cable quantities must be 3, 6, 9, or 12 (multiples of 3, 2 cables are not allowed) to obtain equal amount of wires attached to each inverter module terminal. The wires are required to be equal length within 10% between the inverter module terminals and the first common point of a phase. The recommended common point is the motor terminals.

**Output junction box requirements:** The length, minimum 8 ft [2.5 m], and quantity of cables must be equal from each inverter module to the common terminal in the junction box.



#### NOTE!

If a retrofit application requires unequal amount of wires per phase, please consult the factory for requirements.

### 5.3.6 Electrical Installation of Motor Cables

#### Shielding of cables

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

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

#### Cable length and cross-section

The adjustable frequency drive 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, thereby requiring that the cable length is reduced accordingly.

**Switching frequency**

When adjustable frequency drives 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 instructions in par. 14-01 *Switching Frequency*.

**Aluminum conductors**

Aluminum conductors are not recommended. Terminals can accept aluminum conductors, but the conductor surface has to be clean, oxidation must be removed, and the area must be 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 aluminum. It is crucial to keep the connection a gas-tight joint, otherwise the aluminum surface will oxidize again.

**5.3.7 Fuses****5****NOTE!**

All fuses mentioned are max. fuse sizes.

**Branch circuit protection:**

In order to protect the installation against electrical and fire hazards, all branch circuits in an installation - the switch gear, machines, etc. - must be protected from both short circuit and overcurrent in accordance with national/international regulations.

**Short circuit protection:**

The adjustable frequency drive must be protected against short circuit in order to prevent 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 adjustable frequency drive provides full short circuit protection in case of a short circuit in the motor output.

**Overcurrent protection:**

Provide overload protection to avoid fire hazard due to overheating of the cables in the installation. Overcurrent protection must always be provided in accordance with national regulations. The adjustable frequency drive is equipped with internal overcurrent 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<sub>rms</sub> (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 adjustable frequency drive.

| Adjustable frequency drive: | Max. fuse size:   | Voltage:  | Type:   |
|-----------------------------|-------------------|-----------|---------|
| <b>200–240 V</b>            |                   |           |         |
| K25-K75                     | 10A <sup>1</sup>  | 200–240 V | type gG |
| 1K1-2K2                     | 20A <sup>1</sup>  | 200–240 V | type gG |
| 3K0                         | 30A <sup>1</sup>  | 200–240 V | type gG |
| 3K7                         | 30A <sup>1</sup>  | 200–240 V | type gG |
| 5K5                         | 50A <sup>1</sup>  | 200–240 V | type gG |
| 7K5                         | 63A <sup>1</sup>  | 200–240 V | type gG |
| 11K                         | 63A <sup>1</sup>  | 200–240 V | type gG |
| 15K                         | 80A <sup>1</sup>  | 200–240 V | type gG |
| 18K5                        | 125A <sup>1</sup> | 200–240 V | type gG |
| 22K                         | 125A <sup>1</sup> | 200–240 V | type gG |
| 30K                         | 160A <sup>1</sup> | 200–240 V | type gG |
| 37K                         | 200A <sup>1</sup> | 200–240 V | type aR |
| 45K                         | 250A <sup>1</sup> | 200–240 V | type aR |
| <b>380–480 V</b>            |                   |           |         |
| K37-1K5                     | 10A <sup>1</sup>  | 380–480 V | type gG |
| 2K2-4K0                     | 20A <sup>1</sup>  | 380–480 V | type gG |
| 5K5-7K5                     | 30A <sup>1</sup>  | 380–480 V | type gG |
| 11K                         | 63A <sup>1</sup>  | 380–480 V | type gG |
| 15K                         | 63A <sup>1</sup>  | 380–480 V | type gG |
| 18K                         | 63A <sup>1</sup>  | 380–480 V | type gG |
| 22K                         | 63A <sup>1</sup>  | 380–480 V | type gG |
| 30K                         | 80A <sup>1</sup>  | 380–480 V | type gG |
| 37K                         | 100A <sup>1</sup> | 380–480 V | type gG |
| 45K                         | 125A <sup>1</sup> | 380–480 V | type gG |
| 55K                         | 160A <sup>1</sup> | 380–480 V | type gG |
| 75K                         | 250A <sup>1</sup> | 380–480 V | type aR |
| 90K                         | 250A <sup>1</sup> | 380–480 V | type aR |

Table 5.4: Non-UL fuses 200 V to 480 V

1) Max. fuses - see national/international regulations to select an appropriate fuse size.

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

Table 5.5: Additional Fuses for Non-UL Applications, E enclosures, 380–480 V

## UL Compliance

| VLT AQUA         | Bussmann | Bussmann | Bussmann | SIBA        | Littel fuse | Ferraz-Shawmut | Ferraz-Shawmut |
|------------------|----------|----------|----------|-------------|-------------|----------------|----------------|
| <b>200–240 V</b> |          |          |          |             |             |                |                |
| 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 5.6: UL fuses 200–240 V

| VLT AQUA                  | Bussmann | Bussmann | Bussmann | SIBA        | Littel fuse | Ferraz-Shawmut | Ferraz-Shawmut |
|---------------------------|----------|----------|----------|-------------|-------------|----------------|----------------|
| <b>380–500 V, 525–600</b> |          |          |          |             |             |                |                |
| 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 5.7: UL fuses 380–600 V

KTS fuses from Bussmann may substitute for KTN for 240 V adjustable frequency drives.

FWH fuses from Bussmann may substitute for FWX for 240 V adjustable frequency drives.

KLSR fuses from LITTEL FUSE may substitute for KLSR fuses for 240 V adjustable frequency drives.

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

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

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



| Adjustable frequency drive       | Bussmann | Bussmann | Bussmann | SIBA        | Littel fuse | Ferraz-Shawmut | Ferraz-Shawmut |
|----------------------------------|----------|----------|----------|-------------|-------------|----------------|----------------|
| <b>UL Compliance - 200-240 V</b> |          |          |          |             |             |                |                |
| 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 5.8: **UL fuses 200–240 V**

| Adjustable frequency drive                | Bussmann | Bussmann | Bussmann | SIBA        | Littel fuse | Ferraz-Shawmut | Ferraz-Shawmut |
|-------------------------------------------|----------|----------|----------|-------------|-------------|----------------|----------------|
| <b>UL Compliance - 380–480 V, 525–600</b> |          |          |          |             |             |                |                |
| 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 5.9: **UL fuses 380–600 V**

KTS fuses from Bussmann may substitute for KTN for 240 V adjustable frequency drives.

FWH fuses from Bussmann may substitute for FWX for 240 V adjustable frequency drives.

KLSR fuses from LITTEL FUSE may substitute for KLSR fuses for 240 V adjustable frequency drives.

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

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

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

### 380–500 V, frame sizes D, E and F

The fuses below are suitable for use on a circuit capable of delivering 100,000 Arms (symmetrical), 240 V, or 480 V, or 500 V, or 600 V depending on the drive voltage rating. With the proper fusing, the drive Short Circuit Current Rating (SCCR) is 100,000 Arms.

| Size/<br>Type | Bussmann<br>E1958<br>JFHR2** | Bussmann<br>E4273<br>T/JDDZ** | SIBA<br>E180276<br>RKI/JDDZ | LittellFuse<br>E71611<br>JFHR2** | Ferraz-<br>Shawmut<br>E60314<br>JFHR2** | Bussmann<br>E4274<br>H/JDDZ** | Bussmann<br>E125085<br>JFHR2* | Internal<br>Option<br>Bussmann |
|---------------|------------------------------|-------------------------------|-----------------------------|----------------------------------|-----------------------------------------|-------------------------------|-------------------------------|--------------------------------|
| P90K          | FWH-<br>300                  | JJS-<br>300                   | 2028220-<br>315             | L50S-300                         | A50-P300                                | NOS-<br>300                   | 170M3017                      | 170M3018                       |
| P110          | FWH-<br>350                  | JJS-<br>350                   | 2028220-<br>315             | L50S-350                         | A50-P350                                | NOS-<br>350                   | 170M3018                      | 170M3018                       |
| P132          | FWH-<br>400                  | JJS-<br>400                   | 206xx32-<br>400             | L50S-400                         | A50-P400                                | NOS-<br>400                   | 170M4012                      | 170M4016                       |
| P160          | FWH-<br>500                  | JJS-<br>500                   | 206xx32-<br>500             | L50S-500                         | A50-P500                                | NOS-<br>500                   | 170M4014                      | 170M4016                       |
| P200          | FWH-<br>600                  | JJS-<br>600                   | 206xx32-<br>600             | L50S-600                         | A50-P600                                | NOS-<br>600                   | 170M4016                      | 170M4016                       |

Table 5.10: Frame size D, Line fuses, 380–500 V

| 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 5.11: Frame size E, Line fuses, 380–500 V

| Size/Type | Bussmann PN* | Rating        | Siba           | Internal Bussmann Option |
|-----------|--------------|---------------|----------------|--------------------------|
| P450      | 170M7081     | 1600 A, 700 V | 20 695 32.1600 | 170M7082                 |
| P500      | 170M7081     | 1600 A, 700 V | 20 695 32.1600 | 170M7082                 |
| P560      | 170M7082     | 2000 A, 700 V | 20 695 32.2000 | 170M7082                 |
| P630      | 170M7082     | 2000 A, 700 V | 20 695 32.2000 | 170M7082                 |
| P710      | 170M7083     | 2500 A, 700 V | 20 695 32.2500 | 170M7083                 |
| P800      | 170M7083     | 2500 A, 700 V | 20 695 32.2500 | 170M7083                 |

Table 5.12: Frame size F, Line fuses, 380–500 V

| Size/Type | Bussmann PN* | Rating         | Siba           |
|-----------|--------------|----------------|----------------|
| P450      | 170M8611     | 1100 A, 1000 V | 20 781 32.1000 |
| P500      | 170M8611     | 1100 A, 1000 V | 20 781 32.1000 |
| P560      | 170M6467     | 1400 A, 700 V  | 20 681 32.1400 |
| P630      | 170M6467     | 1400 A, 700 V  | 20 681 32.1400 |
| P710      | 170M8611     | 1100 A, 1000 V | 20 781 32.1000 |
| P800      | 170M6467     | 1400 A, 700 V  | 20 681 32.1400 |

Table 5.13: Frame size F, Inverter module DC Link Fuses, 380–500 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

\*\*Any minimum 500 V UL listed fuse with associated current rating may be used to meet UL requirements.

**525–690 V, frame sizes D, E and F**

| <b>Size/Type</b> | Bussmann<br>E125085<br>JFHR2 | Amps | SIBA<br>E180276<br>JFHR2 | Ferraz-Shawmut<br>E76491<br>JFHR2 | Internal<br>Option<br>Bussmann |
|------------------|------------------------------|------|--------------------------|-----------------------------------|--------------------------------|
| P37K             | 170M3013                     | 125  | 2061032.125              | 6.6URD30D08A0125                  | 170M3015                       |
| P45K             | 170M3014                     | 160  | 2061032.16               | 6.6URD30D08A0160                  | 170M3015                       |
| P55K             | 170M3015                     | 200  | 2061032.2                | 6.6URD30D08A0200                  | 170M3015                       |
| P75K             | 170M3015                     | 200  | 2061032.2                | 6.6URD30D08A0200                  | 170M3015                       |
| P90K             | 170M3016                     | 250  | 2061032.25               | 6.6URD30D08A0250                  | 170M3018                       |
| P110             | 170M3017                     | 315  | 2061032.315              | 6.6URD30D08A0315                  | 170M3018                       |
| P132             | 170M3018                     | 350  | 2061032.35               | 6.6URD30D08A0350                  | 170M3018                       |
| P160             | 170M4011                     | 350  | 2061032.35               | 6.6URD30D08A0350                  | 170M5011                       |
| P200             | 170M4012                     | 400  | 2061032.4                | 6.6URD30D08A0400                  | 170M5011                       |
| P250             | 170M4014                     | 500  | 2061032.5                | 6.6URD30D08A0500                  | 170M5011                       |
| P315             | 170M5011                     | 550  | 2062032.55               | 6.6URD32D08A550                   | 170M5011                       |

Table 5.14: Frame size D, 525–690 V

| <b>Size/Type</b> | Bussmann PN* | Rating       | Ferraz           | Siba          |
|------------------|--------------|--------------|------------------|---------------|
| P355             | 170M4017     | 700 A, 700 V | 6.9URD31D08A0700 | 20 610 32.700 |
| P400             | 170M4017     | 700 A, 700 V | 6.9URD31D08A0700 | 20 610 32.700 |
| P500             | 170M6013     | 900 A, 700 V | 6.9URD33D08A0900 | 20 630 32.900 |
| P560             | 170M6013     | 900 A, 700 V | 6.9URD33D08A0900 | 20 630 32.900 |

Table 5.15: Frame size E, 525–690 V

| <b>Size/Type</b> | Bussmann PN* | Rating        | Siba           | Internal Bussmann Option |
|------------------|--------------|---------------|----------------|--------------------------|
| P630             | 170M7081     | 1600 A, 700 V | 20 695 32.1600 | 170M7082                 |
| P710             | 170M7081     | 1600 A, 700 V | 20 695 32.1600 | 170M7082                 |
| P800             | 170M7081     | 1600 A, 700 V | 20 695 32.1600 | 170M7082                 |
| P900             | 170M7081     | 1600 A, 700 V | 20 695 32.1600 | 170M7082                 |
| P1M0             | 170M7082     | 2000 A, 700 V | 20 695 32.2000 | 170M7082                 |

Table 5.16: Frame size F, Line fuses, 525–690 V

| <b>Size/Type</b> | Bussmann PN* | Rating         | Siba            |
|------------------|--------------|----------------|-----------------|
| P630             | 170M8611     | 1100 A, 1000 V | 20 781 32. 1000 |
| P710             | 170M8611     | 1100 A, 1000 V | 20 781 32. 1000 |
| P800             | 170M8611     | 1100 A, 1000 V | 20 781 32. 1000 |
| P900             | 170M8611     | 1100 A, 1000 V | 20 781 32. 1000 |
| P1M0             | 170M8611     | 1100 A, 1000 V | 20 781 32. 1000 |

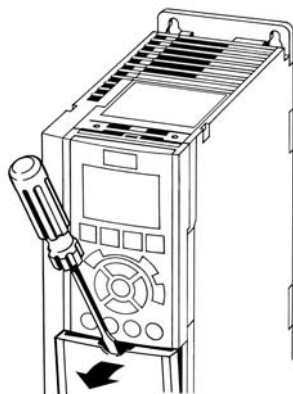
Table 5.17: Frame size F, Inverter module DC Link Fuses, 525–690 V

\*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.

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.

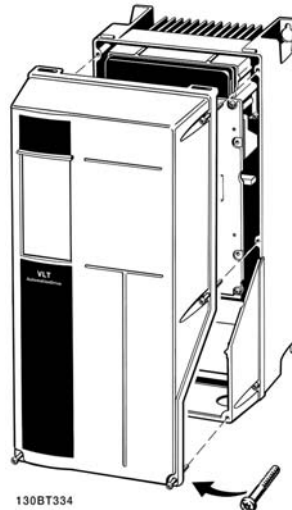
### 5.3.8 Access to Control Terminals

All terminals to the control cables are located underneath the terminal cover on the front of the adjustable frequency drive. Remove the terminal cover using a screwdriver (see illustration).



130BT304

Figure 5.17: Frame sizes A1, A2, A3,B3, B4, C3 and C4



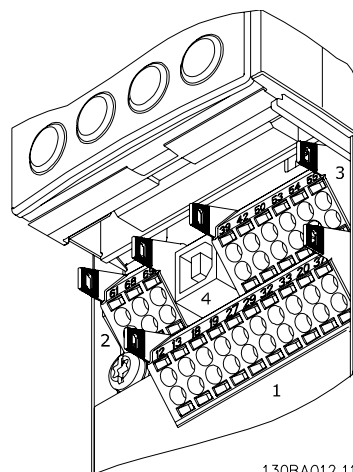
130BT334

Figure 5.18: Frame sizes A5, B1, B2, C1 and C2

### 5.3.9 Control Terminals

Drawing reference numbers:

1. 10-pole plug, digital I/O.
2. 3-pole plug, RS-485 bus.
3. 6-pole, analog I/O.
4. USB Connection.



130BA012.11

Figure 5.19: Control terminals (all enclosures)

### 5.3.10 Control Cable Terminals

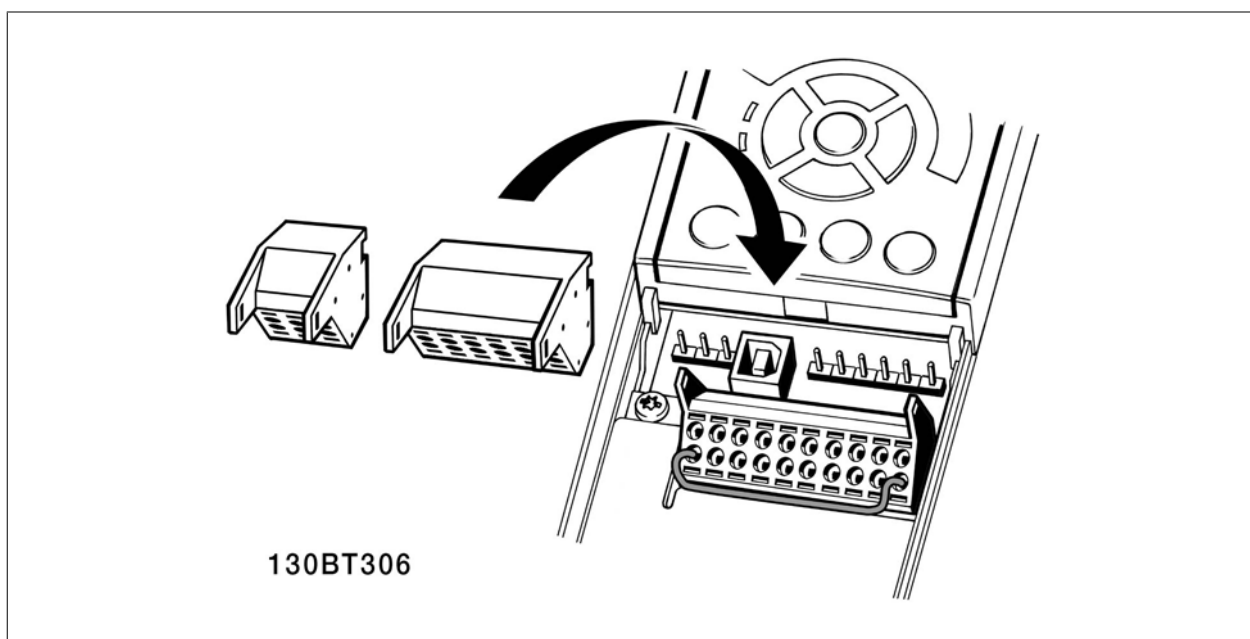
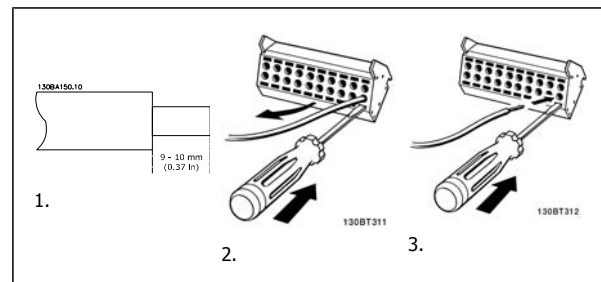
To mount the cable to the terminal:

1. Strip isolation of 0.34–0.39 in [9–10 mm]
2. Insert a screw driver<sup>1)</sup> in the square hole.
3. Insert the cable in the adjacent circular hole.
4. Remove the screwdriver. The cable is now mounted to the terminal.

To remove the cable from the terminal:

1. Insert a screw driver<sup>1)</sup> in the square hole.
2. Pull out the cable.

<sup>1)</sup> Max. 0.015 x 0.1 in. [0.4 x 2.5 mm]



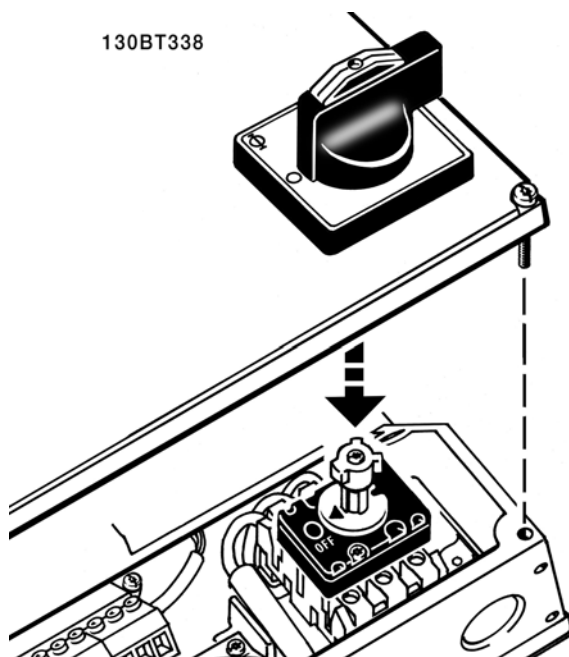


Figure 5.20: Assembling the IP21 / IP55 / NEMA TYPE 12 housing with line power disconnector.

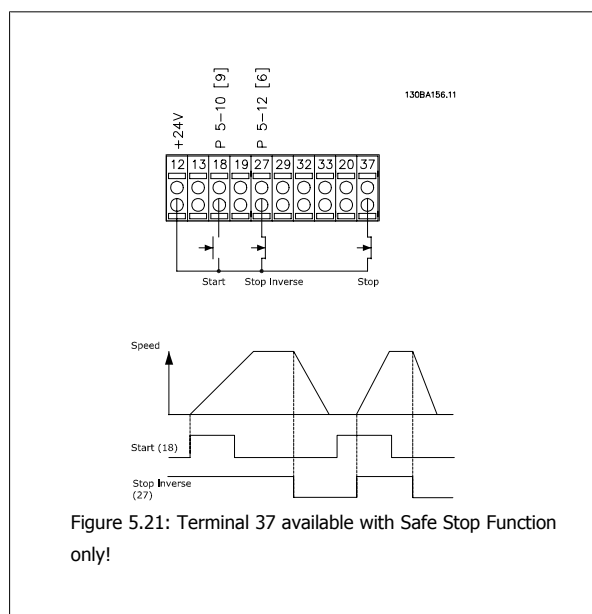
### 5.3.11 Basic Wiring Example

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

Default settings:

18 = Start

27 = stop inverse



### 5.3.12 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 k $\Omega$  adjustable frequency drive input impedance.

#### Analog in / analog out

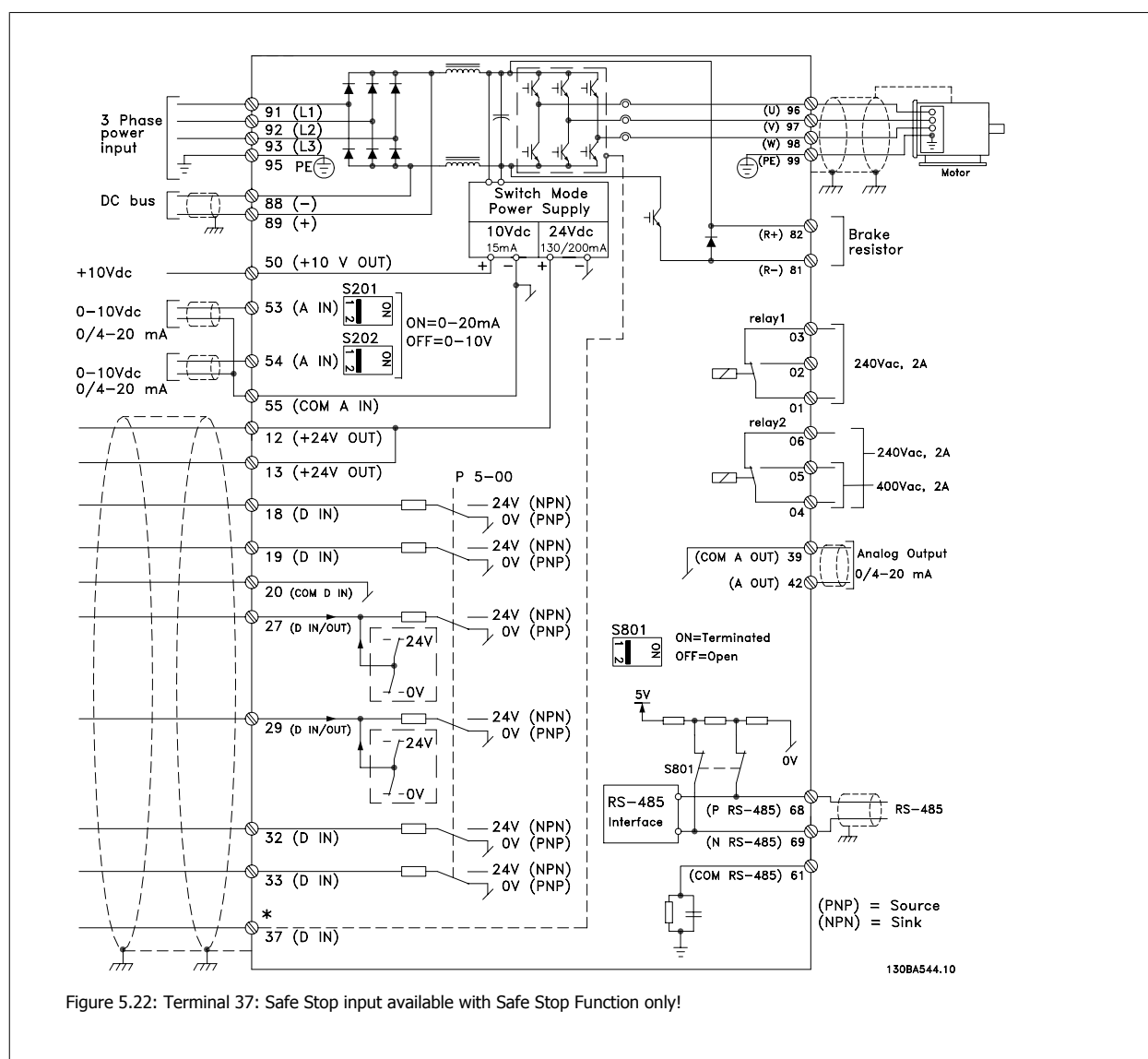
Again the electronics used puts a limitation on the cable length.

#### NOTE!

Noise is always a factor to be reckoned with.

### 5.3.13 Electrical Installation, Control Cables

5



In rare cases, and depending on the installation, very long control cables and analog signals may result in 50/60 Hz ground loops due to noise from line power supply cables.

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

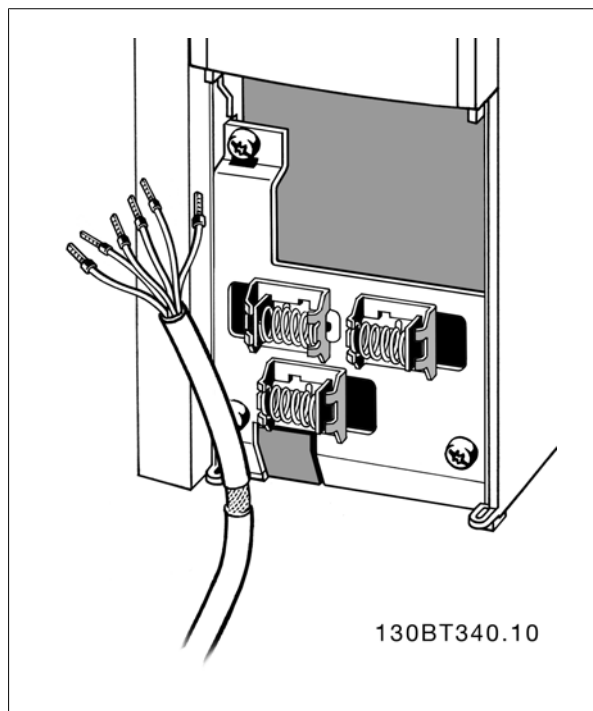
**NOTE!**

Control cables must be shielded/armored.

**5**

1. Use a clamp from the accessory bag to connect the shield to the adjustable frequency drive de-coupling plate for control cables.

See section entitled *Grounding of Shielded/Armored Control Cables* for the correct termination of control cables.





### 5.3.14 Switches S201, S202, and S801

Switches S201 (A53) and S202 (A54) are used to select a current (0–20 mA) or a voltage (0–10 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:

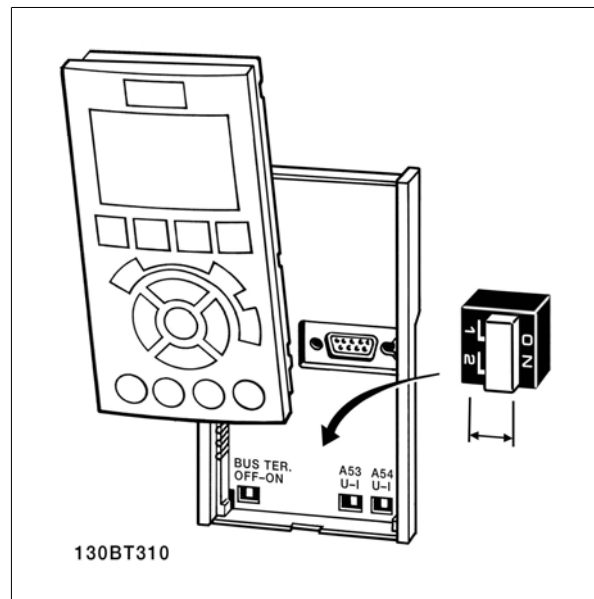
S201 (A53) = OFF (voltage input)

S202 (A54) = OFF (voltage input)

S801 (Bus termination) = OFF

**NOTE!**

It is recommended to only change switch position at power off.



## 5.4 Connections - Frame sizes D, E and F

### 5.4.1 Power Connections

#### Cabling and Fusing

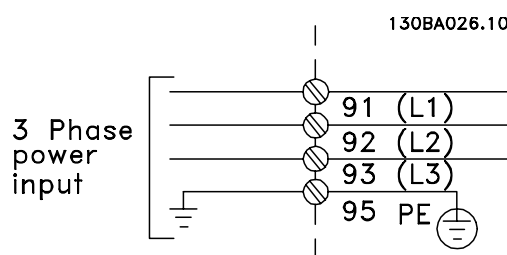

**NOTE!**
**Cables General**

All cabling must comply with national and local regulations on cable cross-sections and ambient temperature. Copper (167°F [75°C]) conductors are recommended.

The power cable connections are situated as shown below. Dimensioning of cable cross-section must be done in accordance with the current ratings and local legislation. See the *Specifications* section for details.

For protection of the adjustable frequency drive, the recommended fuses must be used or the unit must be with built-in fuses. Recommended fuses can be seen in the tables of the fuse section. Always ensure that proper fusing is made according to local regulation.

The AC line input connections are fitted to the line power switch if this is included.


**NOTE!**

The motor cable must be shielded/armored. If an unshielded/unarmored cable is used, some EMC requirements are not complied with. Use a shielded/armored motor cable to comply with EMC emission specifications. For more information, see *EMC specifications* in the *Design Guide*.

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

**Shielding of cables:**

Avoid installation with twisted shield ends (pigtailed). They spoil the shielding effect at higher frequencies. If it is necessary to break the shield to install a motor isolator or motor contactor, the shield must be continued at the lowest possible HF impedance.

Connect the motor cable shield to both the de-coupling plate of the adjustable frequency drive and to the metal housing of the motor.

Make the shield connections with the largest possible surface area (cable clamp). This is done by using the supplied installation devices within the adjustable frequency drive.

**Cable-length and cross-section:**

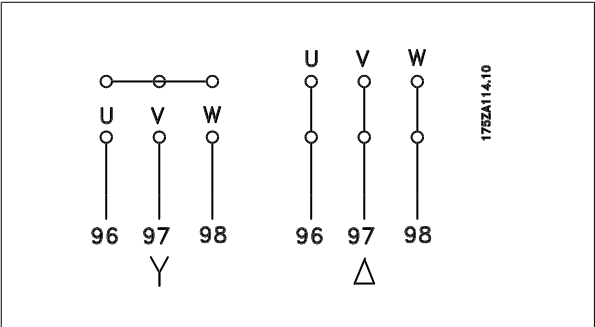
The adjustable frequency drive has been EMC tested with a given length of cable. Keep the motor cable as short as possible to reduce the noise level and leakage currents.

**Switching frequency:**

When adjustable frequency drives are used together with sine-wave filters to reduce the acoustic noise from a motor, the switching frequency must be set according to the instructions in par. 14-01 *Switching Frequency*.

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

1)Protected Ground Connection



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

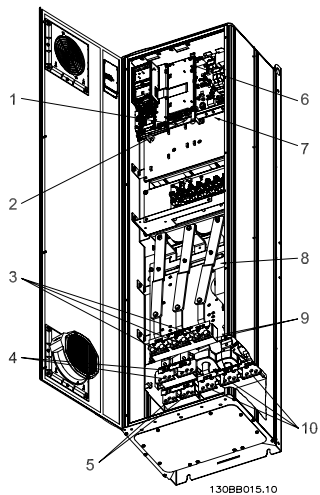


Figure 5.23: Compact IP 21 (NEMA 1) and IP 54 (NEMA 12), frame size D1

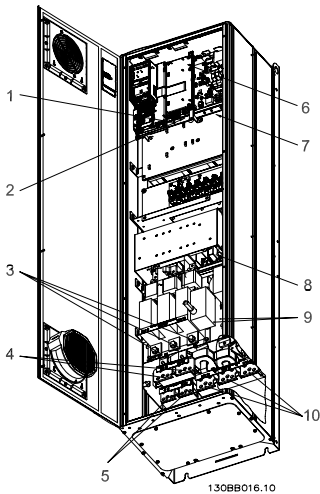


Figure 5.24: Compact IP 21 (NEMA 1) and IP 54 (NEMA 12) with disconnect, fuse and RFI filter, frame size D2

|                 |                                                |
|-----------------|------------------------------------------------|
| 1) AUX Relay    | 5) Brake                                       |
| 01 02 03        | -R +R                                          |
| 04 05 06        | 81 82                                          |
| 2) Temp Switch  | 6) SMPS Fuse (see fuse tables for part number) |
| 106 104 105     | 7) AUX Fan                                     |
| 3) Line         | 100 101 102 103                                |
| R S T           | L1 L2 L1 L2                                    |
| 91 92 93        | 8) Fan Fuse (see fuse tables for part number)  |
| L1 L2 L3        | 9) Line power ground                           |
| 4) Load sharing | 10) Motor                                      |
| -DC +DC         | U V W                                          |
| 88 89           | 96 97 98                                       |
|                 | T1 T2 T3                                       |

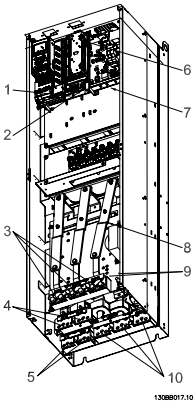


Figure 5.25: Compact IP 00 (Chassis), frame size D3

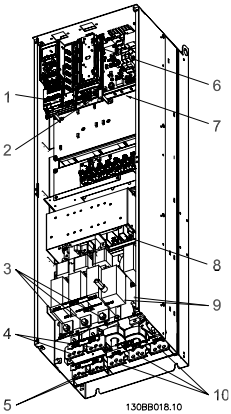


Figure 5.26: Compact IP 00 (Chassis) with disconnect, fuse and RFI filter, frame size D4

|                 |                                                |
|-----------------|------------------------------------------------|
| 1) AUX Relay    | 5) Brake                                       |
| 01 02 03        | -R +R                                          |
| 04 05 06        | 81 82                                          |
| 2) Temp Switch  | 6) SMPS Fuse (see fuse tables for part number) |
| 106 104 105     | 7) AUX Fan                                     |
| 3) Line         | 100 101 102 103                                |
| R S T           | L1 L2 L1 L2                                    |
| 91 92 93        | 8) Fan Fuse (see fuse tables for part number)  |
| L1 L2 L3        | 9) Line power ground                           |
| 4) Load sharing | 10) Motor                                      |
| -DC +DC         | U V W                                          |
| 88 89           | 96 97 98                                       |
|                 | T1 T2 T3                                       |

5

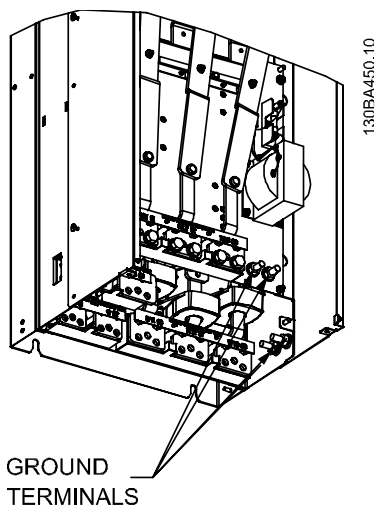


Figure 5.27: Position of ground terminals IP00, frame sizes D

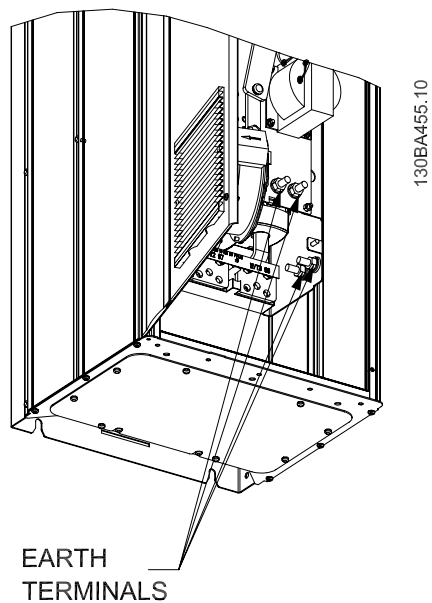


Figure 5.28: Position of ground terminals IP21 (NEMA type 1) and IP54 (NEMA type 12)

**NOTE!**

D2 and D4 shown as examples. D1 and D3 are equivalent.

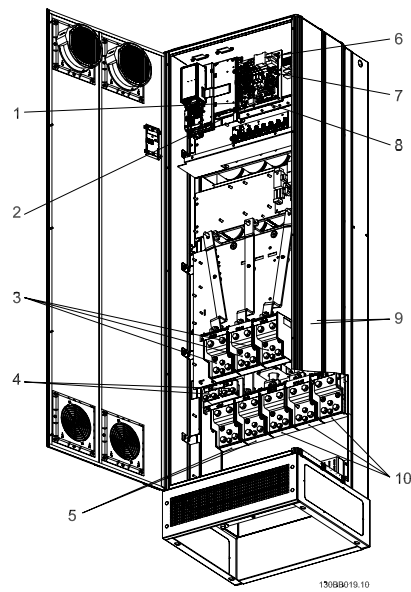


Figure 5.29: Compact IP 21 (NEMA 1) and IP 54 (NEMA 12) frame size E1

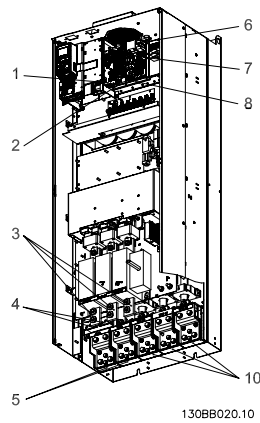


Figure 5.30: Compact IP 00 (Chassis) with disconnect, fuse and RFI filter, frame size E2

- 1) AUX Relay

01

02

03

04

05

06
- 2) Temp Switch

106

104

105
- 3) Line

R

S

T

91

92

93

L1

L2

L3
- 4) Brake

-R

+R

81

82
- 5) Load sharing

-DC

+DC

88

89
- 6) SMPS Fuse (see fuse tables for part number)
- 7) Fan Fuse (see fuse tables for part number)
- 8) AUX Fan

100

101

102

103

L1

L2

L1

L2
- 9) Line power ground
- 10) Motor

U

V

W

96

97

98

T1

T2

T3

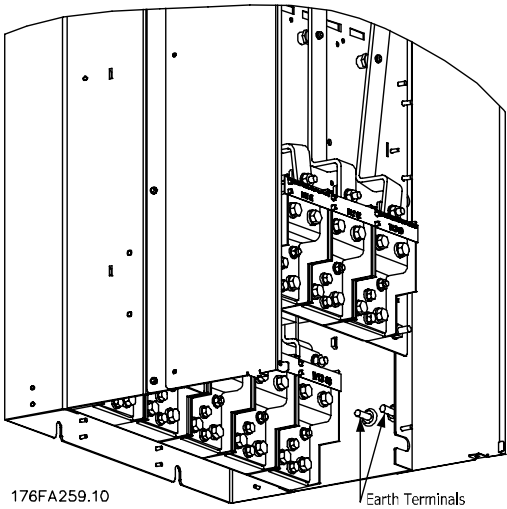


Figure 5.31: Position of ground terminals IP00, frame sizes E



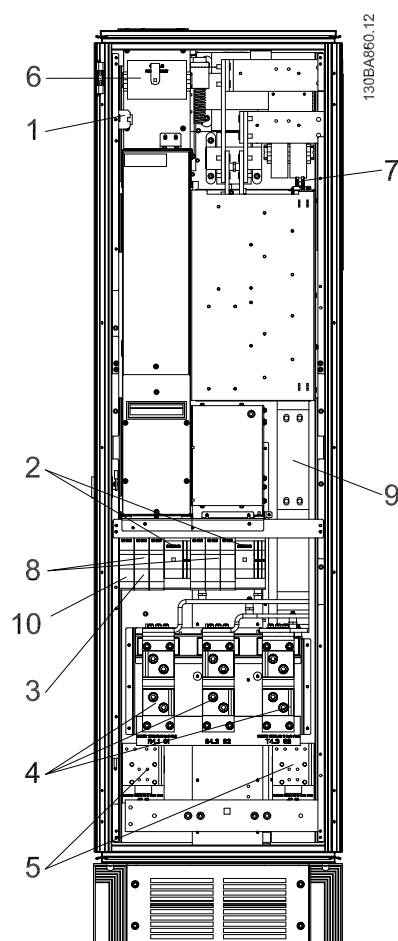


Figure 5.32: Rectifier Cabinet, frame size F1, F2, F3 and F4

- |                                                                 |                                                                                    |
|-----------------------------------------------------------------|------------------------------------------------------------------------------------|
| 1) 24 V DC, 5 A<br>T1 Output Taps<br>Temp Switch<br>106 104 105 | 5) Loadsharing<br>-DC +DC<br>88 89                                                 |
| 2) Manual Motor Starters                                        | 6) Control Transformer Fuses (2 or 4 pieces). See fuse tables for part numbers     |
| 3) 30 A Fuse Protected Power Terminals                          | 7) SMPS Fuse. See fuse tables for part numbers                                     |
| 4) Line<br>R S T<br>L1 L2 L3                                    | 8) Manual Motor Controller fuses (3 or 6 pieces). See fuse tables for part numbers |
|                                                                 | 9) Line Fuses, F1 and F2 frame (3 pieces). See fuse tables for part numbers        |
|                                                                 | 10) 30 Amp Fuse Protected Power fuses                                              |

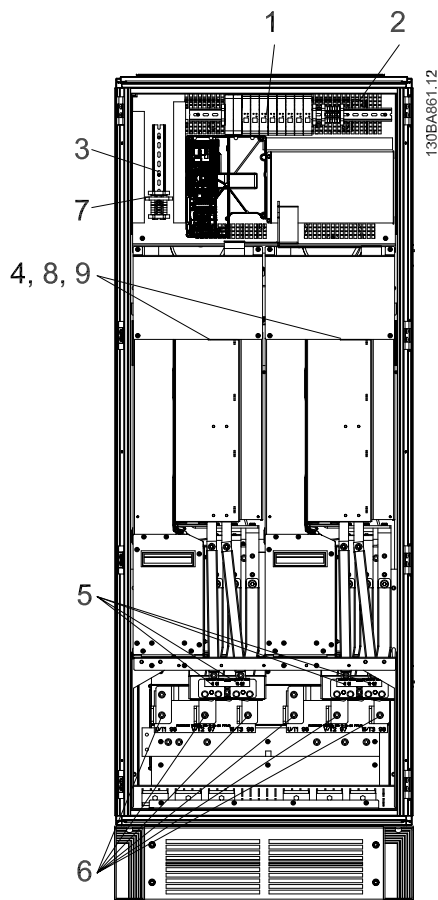


Figure 5.33: Inverter Cabinet, frame size F1 and F3

- |                                    |                                                 |
|------------------------------------|-------------------------------------------------|
| 1) External Temperature Monitoring | 6) Motor                                        |
| 2) AUX Relay                       | U V W                                           |
| 01 02 03                           | 96 97 98                                        |
| 04 05 06                           | T1 T2 T3                                        |
| 3) NAMUR                           | 7) NAMUR Fuse. See fuse tables for part numbers |
| 4) AUX Fan                         | 8) Fan Fuses. See fuse tables for part numbers  |
| 100 101 102 103                    | 9) SMPS Fuses. See fuse tables for part numbers |
| L1 L2 L1 L2                        |                                                 |
| 5) Brake                           |                                                 |
| -R +R                              |                                                 |
| 81 82                              |                                                 |

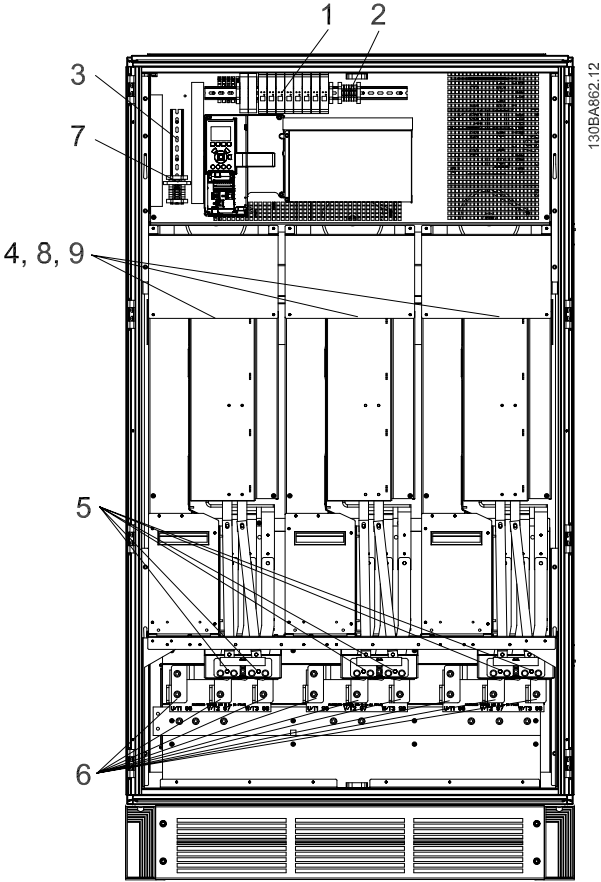


Figure 5.34: Inverter Cabinet, frame size F2 and F4

- |                                    |                                                 |
|------------------------------------|-------------------------------------------------|
| 1) External Temperature Monitoring | 6) Motor                                        |
| 2) AUX Relay                       | U V W                                           |
| 01 02 03                           | 96 97 98                                        |
| 04 05 06                           | T1 T2 T3                                        |
| 3) NAMUR                           | 7) NAMUR Fuse. See fuse tables for part numbers |
| 4) AUX Fan                         | 8) Fan Fuses. See fuse tables for part numbers  |
| 100 101 102 103                    | 9) SMPS Fuses. See fuse tables for part numbers |
| L1 L2 L1 L2                        |                                                 |
| 5) Brake                           |                                                 |
| -R +R                              |                                                 |
| 81 82                              |                                                 |

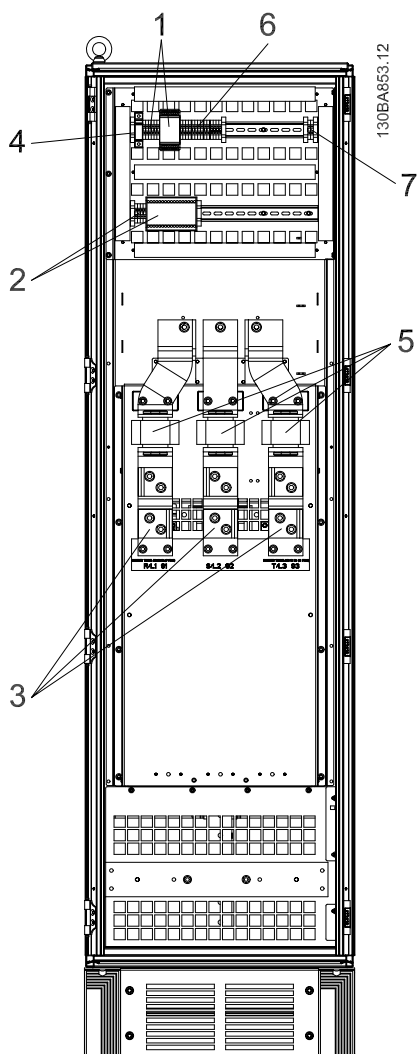


Figure 5.35: Options Cabinet, frame size F3 and F4

- |                        |                                                                        |
|------------------------|------------------------------------------------------------------------|
| 1) Pilz Relay Terminal | 4) Safety Relay Coil Fuse with PILS Relay                              |
| 2) RCD or IRM Terminal | See fuse tables for part numbers                                       |
| 3) Line power          | 5) Line Fuses, F3 and F4 (3 pieces)                                    |
| R S T                  | See fuse tables for part numbers                                       |
| 91 92 93               | 6) Contactor Relay Coil (230 V AC). N/C and N/O Aux Contacts           |
| L1 L2 L3               | 7) Circuit Breaker Shunt Trip Control Terminals (230 V AC or 230 V DC) |

5.4.2 Shielding against Electrical Noise

Before mounting the line power cable, mount the EMC metal cover to ensure best EMC performance.

NOTE: The EMC metal cover is only included in units with an RFI filter.



5.4.3 External Fan Supply

If the adjustable frequency drive is supplied by DC or if the fan must run independently of the power supply, an external power supply can be applied. The connection is made on the power card.

| Terminal No. | Function              |
|--------------|-----------------------|
| 100, 101     | Auxiliary supply S, T |
| 102, 103     | Internal supply S, T  |

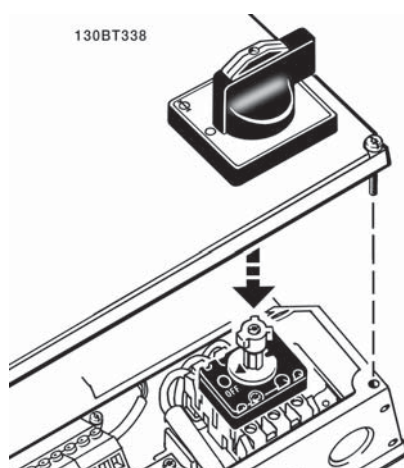
The connector located on the power card provides the AC line voltage connection for the cooling fans. The fans are factory-equipped to be supplied from a common AC line (jumpers between 100-102 and 101-103). If an external supply is needed, the jumpers are removed and the supply is connected to terminals 100 and 101. A 5 Amp fuse should be used for protection. In UL applications, this should be a LittleFuse KLK-5 or equivalent.

## 5.5 Disconnectors, circuit breakers and contactors

### 5.5.1 Line Power Disconnectors

Assembling of IP55 / NEMA Type 12 (A5 housing) with line power disconnector

The line power switch is placed on left side on frame sizes B1, B2, C1 and C2 . The line power switch on A5 frames is placed on right side



#### Frame size:

#### Type:

|                                      |                         |
|--------------------------------------|-------------------------|
| A5                                   | Kraus&Naimer KG20A T303 |
| B1                                   | Kraus&Naimer KG64 T303  |
| B2                                   | Kraus&Naimer KG64 T303  |
| C1 40 hp [30 kW] High Overload       | Kraus&Naimer KG100 T303 |
| C1 50–60 hp [37–45 kW] High Overload | Kraus&Naimer KG105 T303 |
| C2 75 hp [55 kW] High Overload       | Kraus&Naimer KG160 T303 |
| C2 100 hp [75 kW] High Overload      | Kraus&Naimer KG250 T303 |

### 5.5.2 Line power disconnectors - frame size D, E and F

| Frame size | Power & Voltage                                    | Type                           |
|------------|----------------------------------------------------|--------------------------------|
| D1/D3      | P90K-P110 380–500 V & P90K-P132 525–690 V          | ABB OETL-NF200A                |
| D2/D4      | P132-P200 380–500 V & P160-P315 525–690 V          | ABB OETL-NF400A                |
| E1/E2      | P250 380–500 V & P355-P560 500 HP–750 HP 525–690 V | ABB OETL-NF600A                |
| E1/E2      | P315-P400 380–500 V                                | ABB OETL-NF800A                |
| F3         | P450 380–500 V & P630-P710 525–690 V               | Merlin Gerin NPJF36000S12AAYP* |
| F4         | P500-P630 380–500 V & P800 525–690 V               | Merlin Gerin NRK36000S20AAYP*  |
| F4         | P710-P800 380–500 V & P900-P1M0 525–690 V          | Merlin Gerin NRK36000S20AAYP*  |

\* Drive SCCR rating maybe less than 100 kA when this option is added. See the drive label for SCCR rating.

### 5.5.3 F Frame Circuit Breakers

| Frame size                                                                                                 | Power & Voltage                      | Type                              |
|------------------------------------------------------------------------------------------------------------|--------------------------------------|-----------------------------------|
| F3                                                                                                         | P450 380–500 V & P630-P710 525–690 V | Merlin Gerin NPJF36120U31AABSCYP* |
| F4                                                                                                         | P500-P630 380–500 V & P800 525–690 V | Merlin Gerin NRJF36200U31AABSCYP* |
| F4                                                                                                         | P710 380–500 V & P900-P1M0 525–690 V | Merlin Gerin NRJF36200U31AABSCYP* |
| F4                                                                                                         | P800 380–500 V                       | Merlin Gerin NRJF36250U31AABSCYP* |
| * Drive SCCR rating maybe less than 100 kA when this option is added. See the drive label for SCCR rating. |                                      |                                   |

### 5.5.4 F-Frame Line Power Contactors

| Frame size                                                                                                 | Power & Voltage                           | Type               |
|------------------------------------------------------------------------------------------------------------|-------------------------------------------|--------------------|
| F3                                                                                                         | P450-P500 380–500 V & P630-P800 525–690 V | Eaton XTCE650N22A* |
| F3                                                                                                         | P560 380–500 V                            | Eaton XTCE820N22A* |
| F3                                                                                                         | P630 380–500 V                            | Eaton XTCEC14P22B* |
| F4                                                                                                         | P900 525–690 V                            | Eaton XTCE820N22A* |
| F4                                                                                                         | P710-P800 380–500 V & P1M0 525–690 V      | Eaton XTCEC14P22B* |
| * Drive SCCR rating maybe less than 100 kA when this option is added. See the drive label for SCCR rating. |                                           |                    |

## 5.6 Final Set-Up and Test

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

### Step 1. Locate the motor nameplate.



#### NOTE!

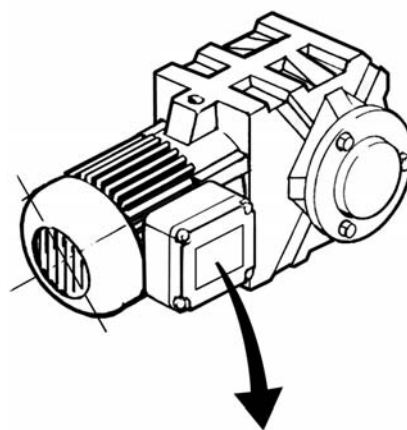
The motor is either star- (Y) or delta-connected ( $\Delta$ ). This information is located on the motor nameplate data.

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

To access this list, first press the [QUICK MENU] key, then select "Q2 Quick Set-up".

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|    |                                         |                        |
|----|-----------------------------------------|------------------------|
| 1. | Motor Power [kW]<br>or Motor Power [HP] | par. 1-20<br>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              |



|                               |       |       |     |      |    |
|-------------------------------|-------|-------|-----|------|----|
| <b>BAUER</b> D-73734 ESLINGEN |       |       |     |      |    |
| 3 ~ MOTOR NR. 1827421         |       |       |     | 2003 |    |
| S/E005A9                      |       |       |     |      |    |
|                               |       | 1,5   | kW  |      |    |
| $n_2$                         | 31,5  | /min. | 400 | Y    | V  |
| $n_1$                         | 1400  | /min. |     | 50   | Hz |
| $\cos \varphi$                | 0,80  |       |     | 3,6  | A  |
| 1,7L                          |       |       |     |      |    |
| B                             | IP 65 | H1/1A |     |      |    |

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### 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 adjustable frequency drive 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 adjustable frequency drive 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 adjustable frequency drive 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.



NOTE!

Unsuccessful AMA is often caused by incorrectly registered motor nameplate data or a difference between the motor power size and the VLT AQUA Drive power size that is too great.

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 |

5.7.1 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 the 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 adjustable frequency drive are placed in the same installation panel, you can use a regular cable instead of a protected one.

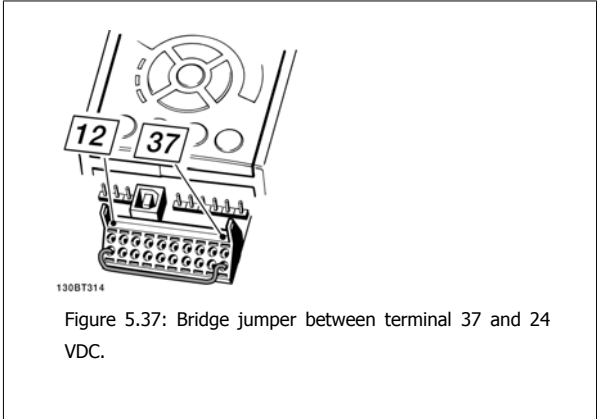
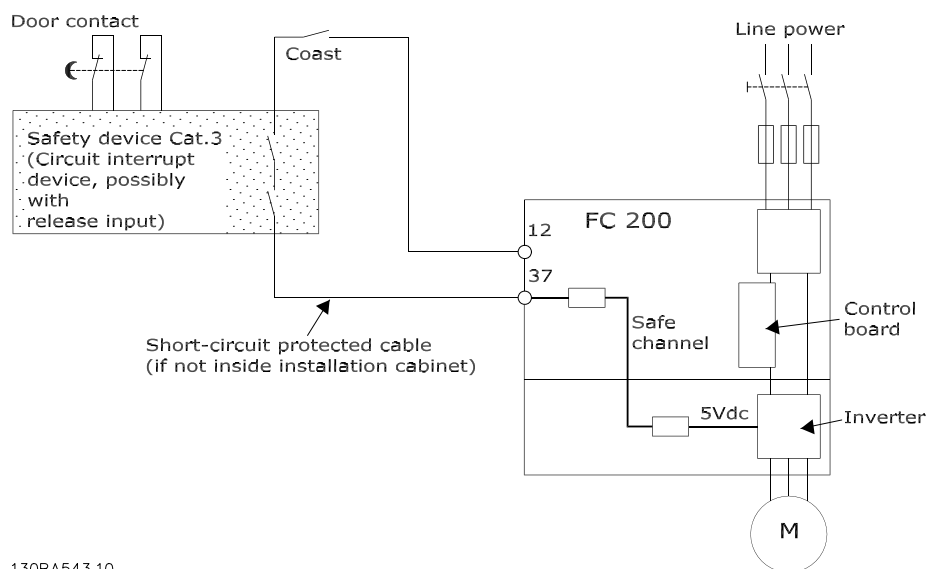


Figure 5.37: Bridge jumper between terminal 37 and 24 VDC.

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.



130BA543.10

Figure 5.38: Illustration of the essential aspects of an installation to achieve a Stopping Category 0 (EN 60204-1) with safety Cat. 3 (EN 954-1).

### 5.7.2 Safe Stop Commissioning Test

After installation and before first operation, perform a commissioning test of an installation or application making use of the 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 using the interrupt device while the motor is being run by the FC 202 (i.e., line power 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.

## 5.8 Additional Connections

### 5.8.1 Relay Output

#### Relay 1

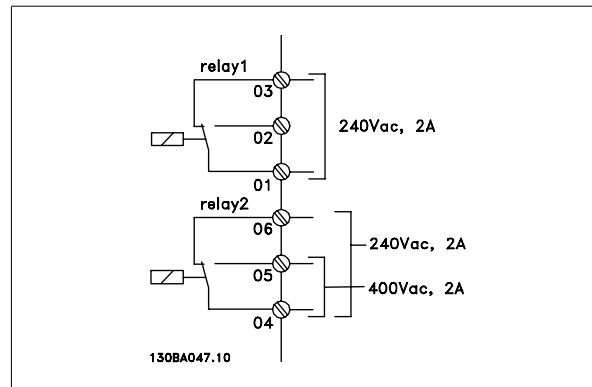
- Terminal 01: common
- Terminal 02: normal open 240 V AC
- Terminal 03: normal closed 240 V AC

#### 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.



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### 5.8.2 Parallel Connection of Motors

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



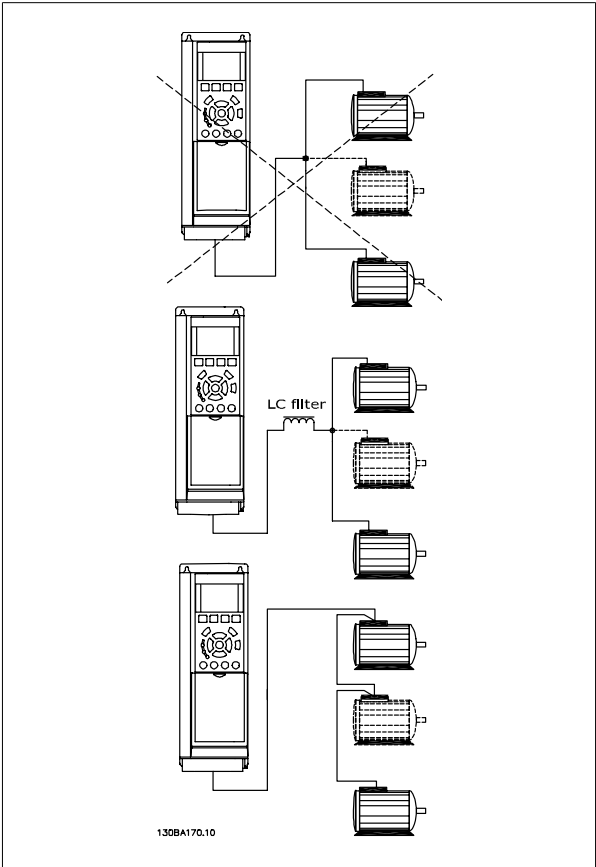
#### NOTE!

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 adjustable frequency drive cannot be used as motor protection for the individual motor of systems with parallel-connected motors. Provide further motor protection with, for example, thermistors in each motor or individual thermal relays (circuit breakers are not a suitable means of protection).

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### 5.8.3 Direction of Motor Rotation

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

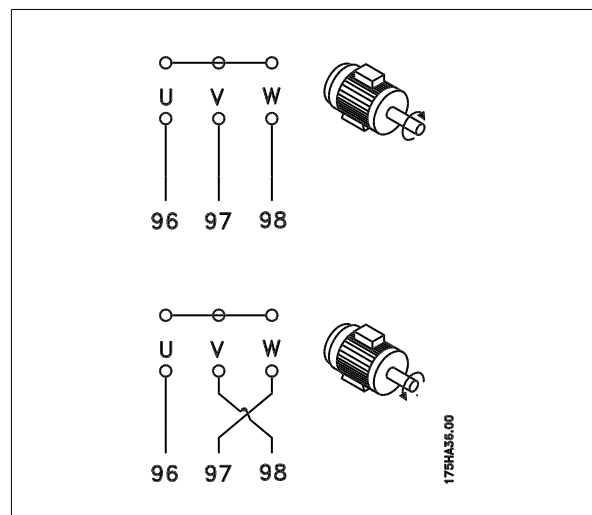
Terminal 96 connected to U-phase

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.



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### 5.8.4 Motor Thermal Protection

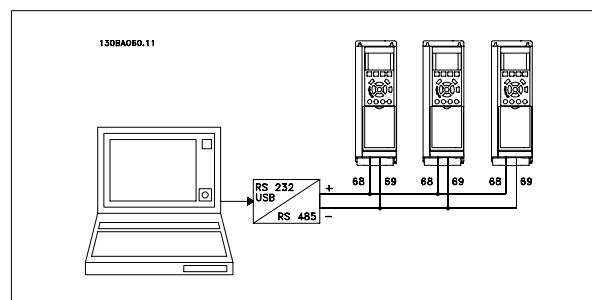
The electronic thermal relay in the adjustable frequency drive has received the UL approval for single motor protection, when par. 1-90 *Motor Thermal Protection* is set for *ETR Trip* and par. 1-24 *Motor Current* is set to the rated motor current (see motor nameplate).

## 5.9 Installation of misc. connections

### 5.9.1 RS-485 Bus Connection

One or more adjustable frequency drives can be connected to a control (or master) using the RS-485 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 adjustable frequency drive is connected to a master, use parallel connections.



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

#### Bus termination

The RS-485 bus must be terminated by a resistor network at both ends. For this purpose, set switch S801 on the control card to "ON".

For more information, see the paragraph *Switches S201, S202, and S801*.



#### NOTE!

Communication protocol must be set to FC MC 8-30 *Protocol*.

### 5.9.2 How to Connect a PC to the VLT AQUA Drive

To control or program the adjustable frequency drive from a PC, install the MCT 10 Set-up software.

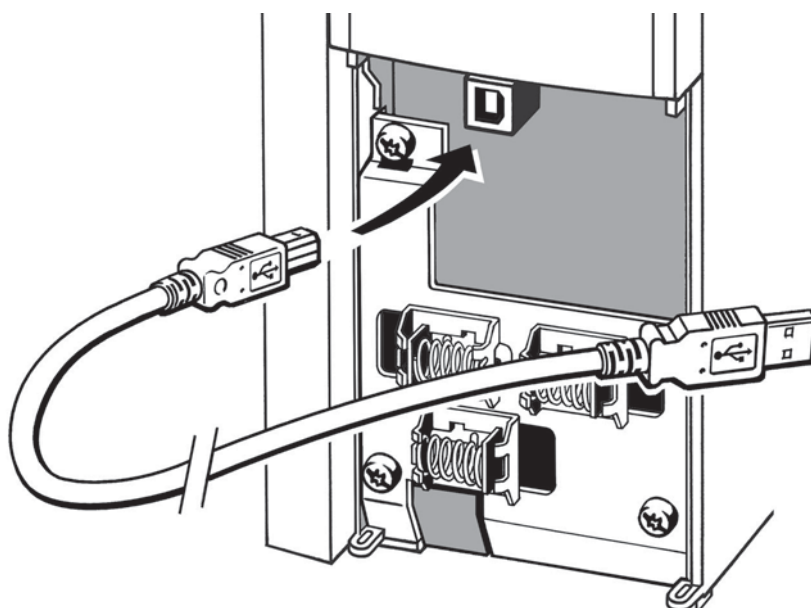
The PC is connected via a standard (host/device) USB cable, or via the RS-485 interface as shown in the **VLT AQUA Design Guide How to Install > Installation of misc. connections.**



**NOTE!**

The USB connection is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals. The USB connection is connected to protection ground on the adjustable frequency drive. Only use an isolated laptop as a PC connection to the USB connector on the VLT AQUA Drive.

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**PC Software - MCT 10**

All drives are equipped with a serial communication port. We provide a PC tool for communication between PC and adjustable frequency drive, called the 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 adjustable frequency drives.

**The MCT 10 Set-up software will be useful for:**

- Planning a communication network off-line. MCT 10 contains a complete adjustable frequency drive database
- Commissioning adjustable frequency drives on-line.
- Saving settings for all adjustable frequency drives.
- Replacing a drive in a network
- Expanding an existing network.
- Drives developed in the future will be fully supported.

**MCT 10**

Set-up Software support Profibus DP-V1 via a master class 2 connection. This makes it possible to access on-line read/write parameters in an adjustable frequency drive 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 the USB com port.
2. Open MCT 10 Set-up Software
3. Choose "Read from drive"
4. Choose "Save as"

All parameters are now stored on the PC.

**Load Drive Settings:**

1. Connect a PC to the unit via the USB com port.
2. Open MCT 10 Set-up software
3. Choose "Open"– stored files will be shown.
4. Open the appropriate file
5. Choose "Write to drive"

All parameter settings are now transferred to the drive.

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

**The MCT 10 Set-up Software Modules**

The following modules are included in the software package:

|                                                                                     |                                                                                                                                                                              |
|-------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | <b>MCT 10 Set-up Software</b><br>Setting parameters<br>Copy to and from adjustable frequency drives<br>Documentation and print-out of parameter settings incl. diagrams      |
|                                                                                     | <b>Ext. User Interface</b><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.

The MCT 10 can also be downloaded from the Danfoss Internet: [www.DANFOSS.COM](http://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 adjustable frequency drives as well as non-Danfoss adjustable frequency drives 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](http://www.DANFOSS.COM), Business Area: Motion Controls.

## 5.10 Safety

### 5.10.1 High Voltage Test

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



**NOTE!**

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

# 5

### 5.10.2 Safety Ground Connection

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



The ground leakage current from the adjustable frequency drive exceeds 3.5 mA. To ensure a good mechanical connection from the ground cable to the ground connection (terminal 95), the cable cross-section must be at least 0.39 in<sup>2</sup> [10 mm<sup>2</sup>] or 2 rated ground wires terminated separately.

## 5.11 EMC-correct Installation

### 5.11.1 Electrical Installation - EMC Precautions

The following is a guideline for good engineering practice when installing adjustable frequency drives. 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 Labeling*, *General Aspects of EMC Emission* and *EMC Test Results*.

**Good engineering practice to ensure EMC-correct electrical installation:**

- Use only braided shielded/armored motor cables and braided shielded/armored control cables. The shield should provide a minimum coverage of 80%. The shield material must be metal, not limited to, but typically, copper, aluminum, steel or lead. There are no special requirements for the line cable.
- Installations using rigid metal conduits are not required to contain shielded cable, but the motor cable must be installed in conduit separate from the control and line cables. Full connection of the conduit from the drive to the motor is required. The EMC performance of flexible conduits varies greatly, and information from the manufacturer must therefore be obtained.
- Connect the shield/armor/conduit to ground at both ends for motor cables as well as for control cables. In some cases, it is not possible to connect the shield at both ends. If so, connect the shield at the adjustable frequency drive. See also *Grounding of Braided Shielded/Armored Control Cables*.
- Avoid terminating the shield/armor with twisted ends (pigtails). It increases the high frequency impedance of the shield, which reduces its effectiveness at high frequencies. Use low impedance cable clamps or EMC cable connectors instead.
- Avoid using unshielded/unarmored motor or control cables inside cabinets housing the drive(s), whenever this can be avoided.

Leave the shield as close to the connectors as possible.



The illustration shows an example of an EMC-correct electrical installation of an IP 20 adjustable frequency drive. The adjustable frequency drive 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 performing the installation may result in an equally effective EMC performance, provided the above guidelines for engineering practice are followed.

If the installation is not carried out according to the guidelines, and if non-shielded cables and control wires are used, some emission requirements will not be fulfilled, although the immunity requirements will be. See the paragraph *EMC test results*.

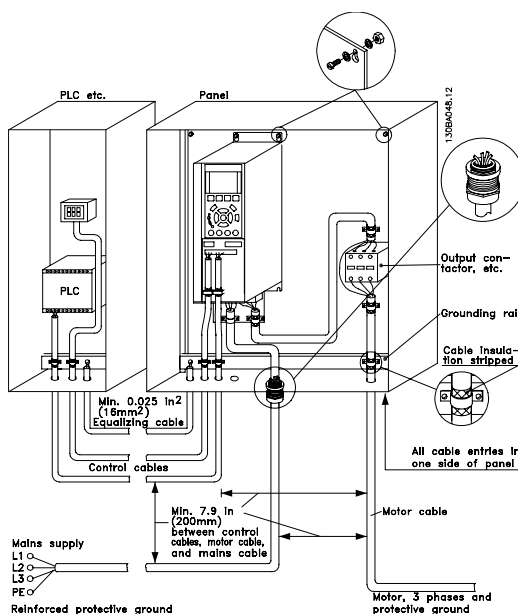


Figure 5.39: EMC-compliant electrical installation of an adjustable frequency drive in a cabinet.

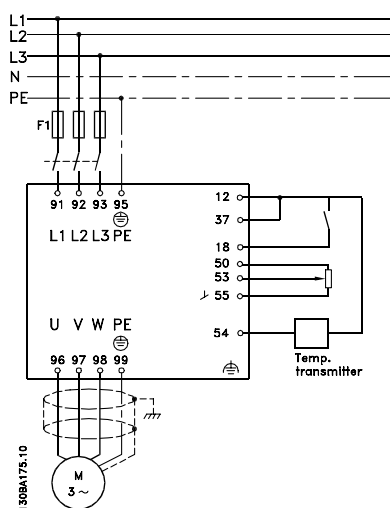


Figure 5.40: Electrical connection diagram.

### 5.11.2 Use of EMC-Compliant Cables

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

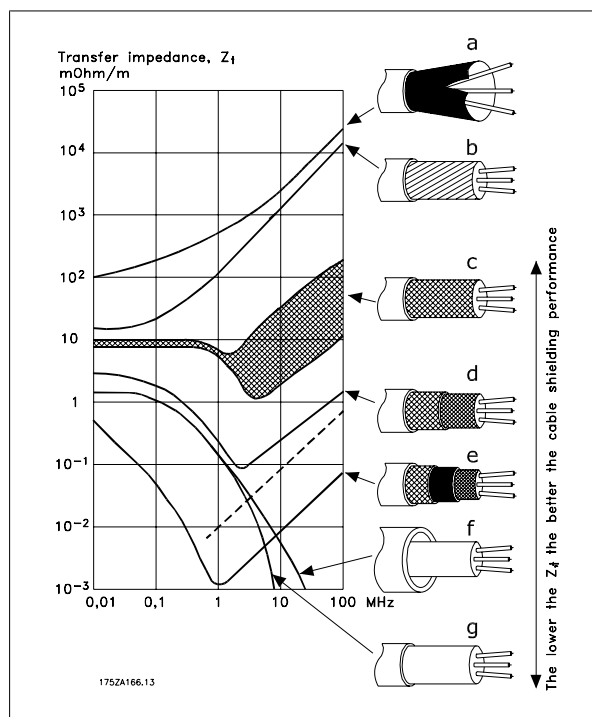
The ability of a cable to reduce the in and outgoing radiation of electric noise depends on the transfer impedance ( $Z_T$ ). The shield of a cable is normally designed to reduce the transfer of electric noise; however, a shield with a lower transfer impedance ( $Z_T$ ) value is more effective than a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

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

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

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

- a. Aluminum-clad with copper wire.
- b. Twisted copper wire or armored steel wire cable.
- c. Single-layer braided copper wire with varying percentage shield coverage.  
This is the typical Danfoss reference cable.
- d. Double-layer braided copper wire.
- e. Twin layer of braided copper wire with a magnetic, shielded/armored intermediate layer.
- f. Cable that runs in copper tube or steel tube.
- g. Lead cable with 0.43 in [1.1 mm] wall thickness.



### 5.11.3 Grounding of Shielded/Armored Control Cables

Generally speaking, control cables must be braided and shielded/armored, and the shield 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 grounding is carried out and what to do if in doubt.

a. **Correct grounding**

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 grounding**

Do not use twisted cable ends (pigtails). They increase the shield impedance at high frequencies.

c. **Protection with respect to ground potential between PLC and**

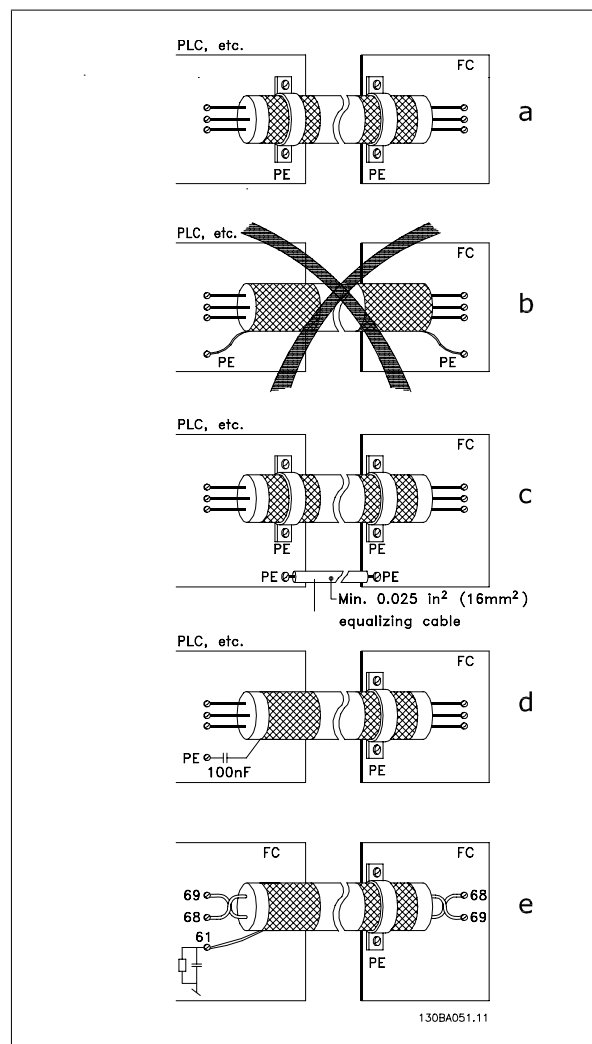
**PLC and**  
If the ground potential between the adjustable frequency drive and the PLC (etc.) is different, electric noise may occur that will disturb the entire system. Solve this problem by fitting an equalizing cable next to the control cable. Minimum cable cross-section: 0.025 in<sup>2</sup> [16 mm<sup>2</sup>].

d. **For 50/60 Hz ground loops**

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

e. **Cables for serial communication**

Eliminate low-frequency noise currents between two adjustable frequency drives by connecting one end of the shield to terminal 61. This terminal is grounded via an internal RC link. Use twisted-pair cables to reduce the differential mode interference between the conductors.



### 5.12.1 Residual Current Device

You can use RCD relays, multiple protective grounding or grounding as extra protection, provided that local safety regulations are complied with.

If a ground 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 *Ground Leakage Current* for further information.

## 6 Application Examples

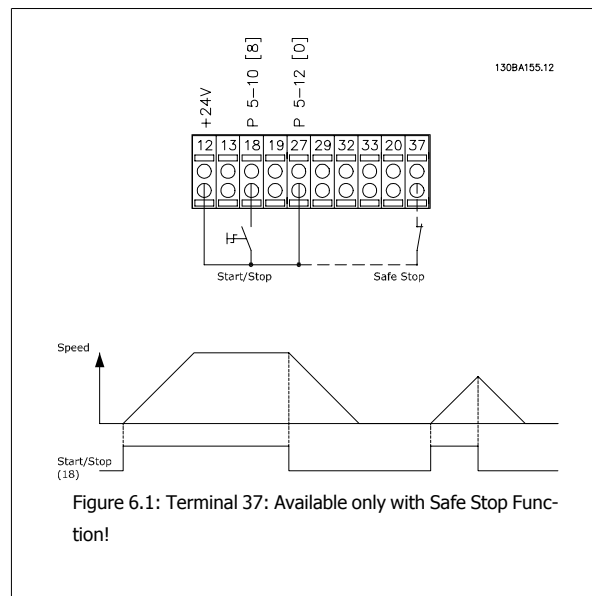
### 6.1.1 Start/Stop

Terminal 18 = start/stop par. 5-10 [8] *Start*

Terminal 27 = No operation par. 5-12 [0] *No operation* (Default *coast inverse*)

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

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



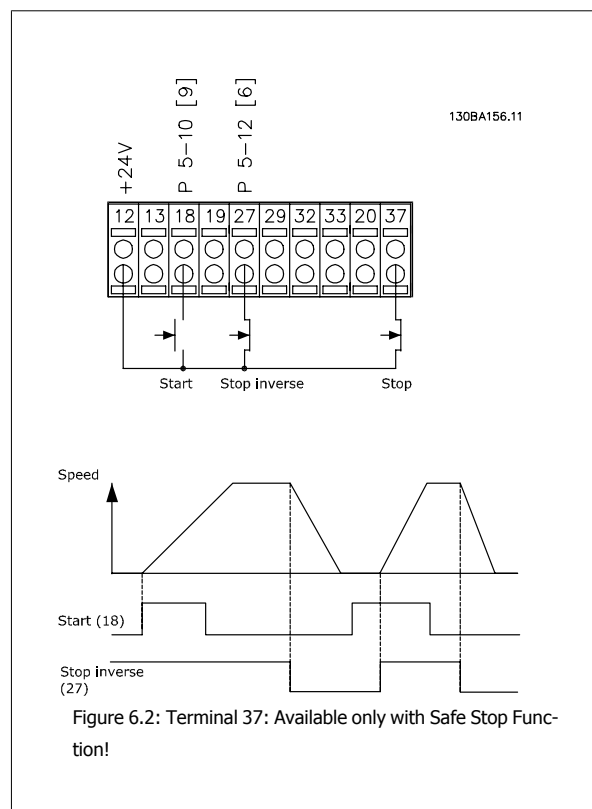
### 6.1.2 Pulse Start/Stop

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*

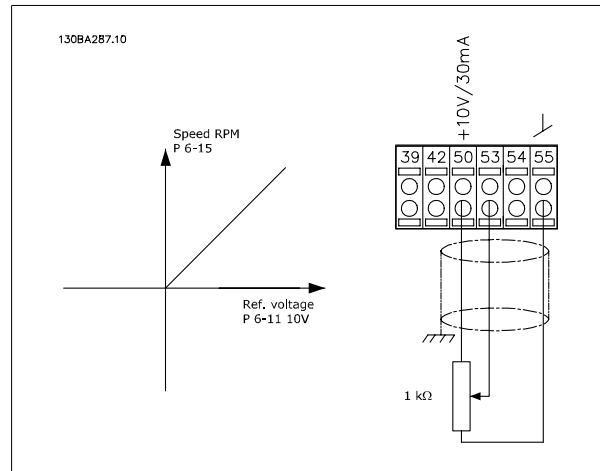
Par. 5-12 *Digital Input*, Terminal 27 = *Stop inverse*



### 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* = 1500 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 that AMA itself does not supply any torque.

AMA is useful when commissioning systems and optimizing the adjustment of the adjustable frequency drive to the applied motor. In particular, this feature is 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  $R_s$  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:

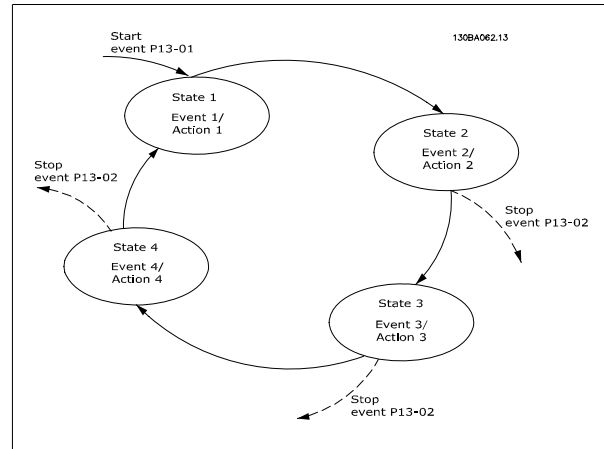
- For the AMA to determine the motor parameters optimally, enter the correct motor nameplate data in par. 1-20 *Motor Power [kW]* to par. 1-28 *Motor Rotation Check*.
- For the best adjustment of the adjustable frequency drive, carry out AMA on a cold motor. Repeated AMA runs may lead to a heating of the motor, which results in an increase of the stator resistance,  $R_s$ . 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 adjustable frequency drive. 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 adjustable frequency drive 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. 13-52 *SL Controller Action*) executed by the SLC when the associated user defined *event* (see par. 13-51 *SL Controller Event*) 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

A new useful facility in VLT AQUA Drive is the Smart Logic Control (SLC).

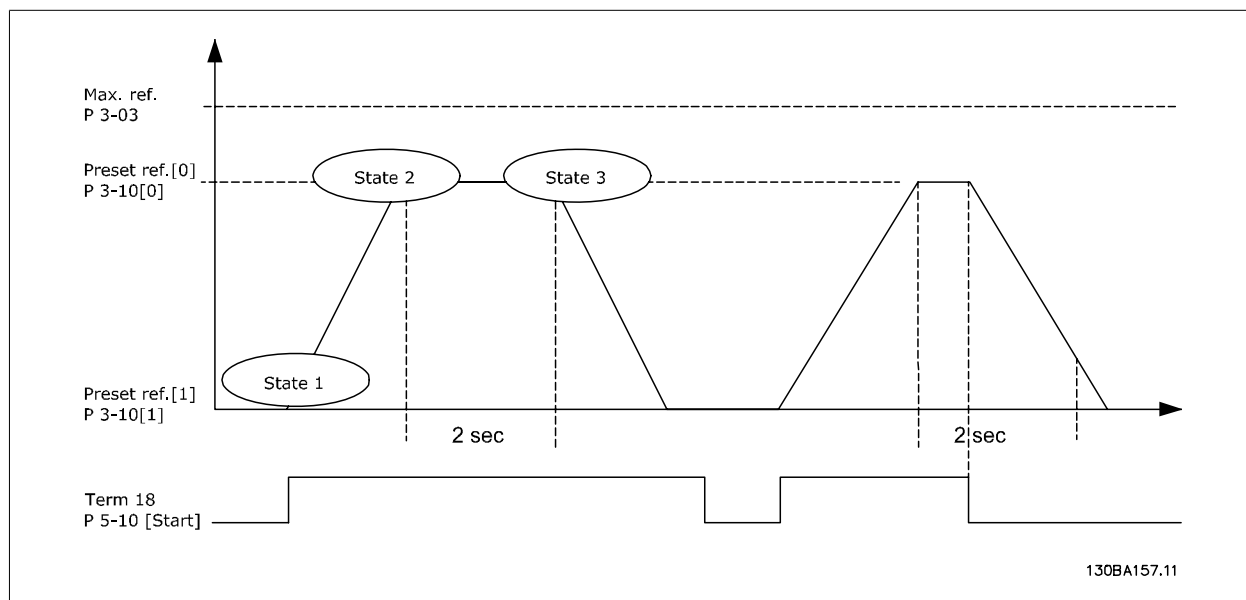
In applications where a PLC generates a simple sequence, the SLC may take over elementary tasks from the main control.

SLC is designed to act from event send to, or it is generated in the VLT AQUA Drive. The adjustable frequency drive 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

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

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]

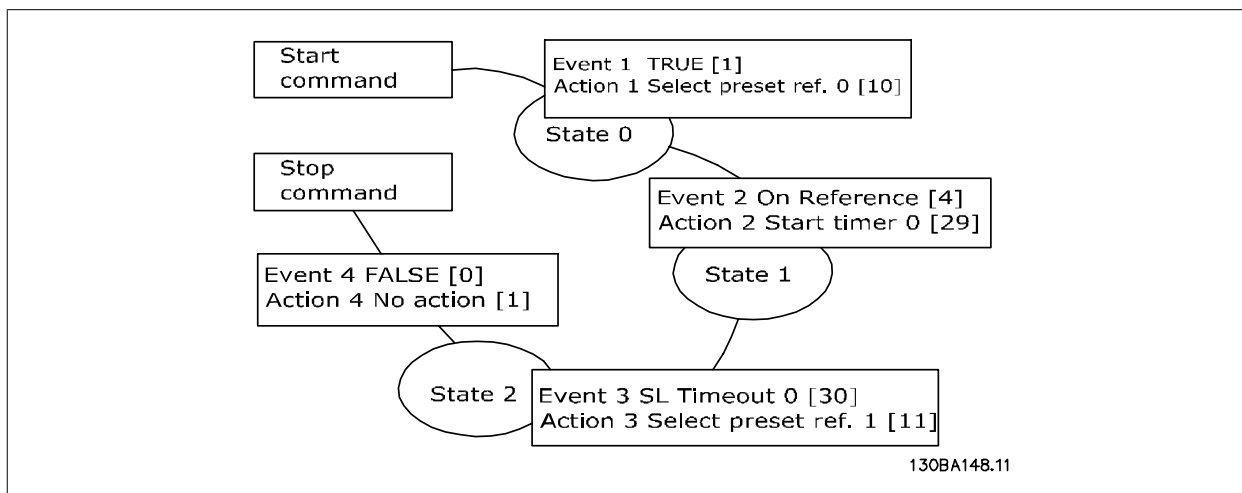
Set Action 1 in par. 13-52 *SL Controller Action* [1] to *Select preset 0* [10]

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.

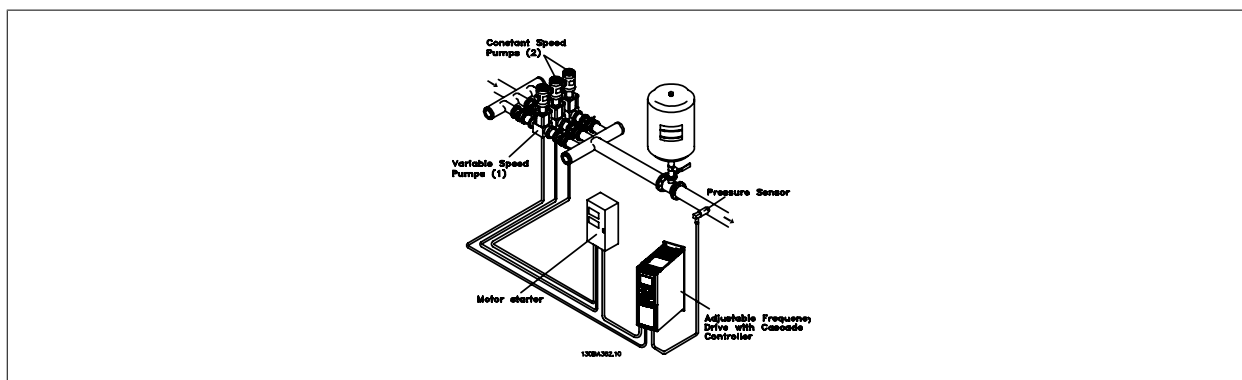
Start/stop command is applied on terminal 18. If stop signal is applied, the adjustable frequency drive will ramp down and go into free mode.

6

### 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 speeds over a wide range is not an ideal solution because of low pump efficiency at lower speeds. In a practical way, the limit is 25% of the rated full load speed for the pump.

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



#### Fixed Lead Pump

The motors must be of equal size. The BASIC cascade controller allows the adjustable frequency drive to control up to 3 equal size pumps using the drive's 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, thus reducing the required pump maintenance and increasing reliability and system lifetime. 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

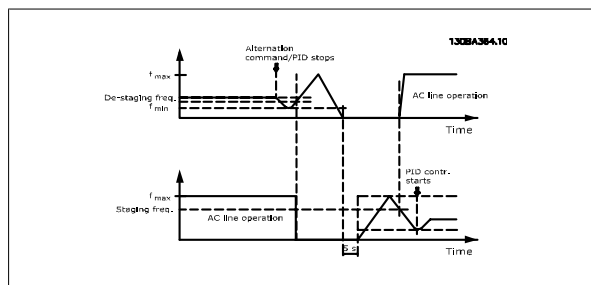
In cascade control systems, to avoid frequent switching of fixed speed pumps, the desired system pressure is kept within a bandwidth rather than at a constant level. Staging bandwidth provides the required bandwidth for operation. When a large and quick change in system pressure occurs, the override 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 has been established.

When the cascade controller is enabled and the drive issues a trip alarm, the system head is maintained by staging and de-staging fixed speed pumps. To prevent frequent staging and de-staging and minimize pressure fluctuations, a wider fixed speed bandwidth is used instead of the staging bandwidth.

## 6

### 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, 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 lines as the new fixed speed pump.

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 the programmed value of the timer expires, the lead pump is removed to avoid water heating problems.

### 6.1.9 System Status and Operation

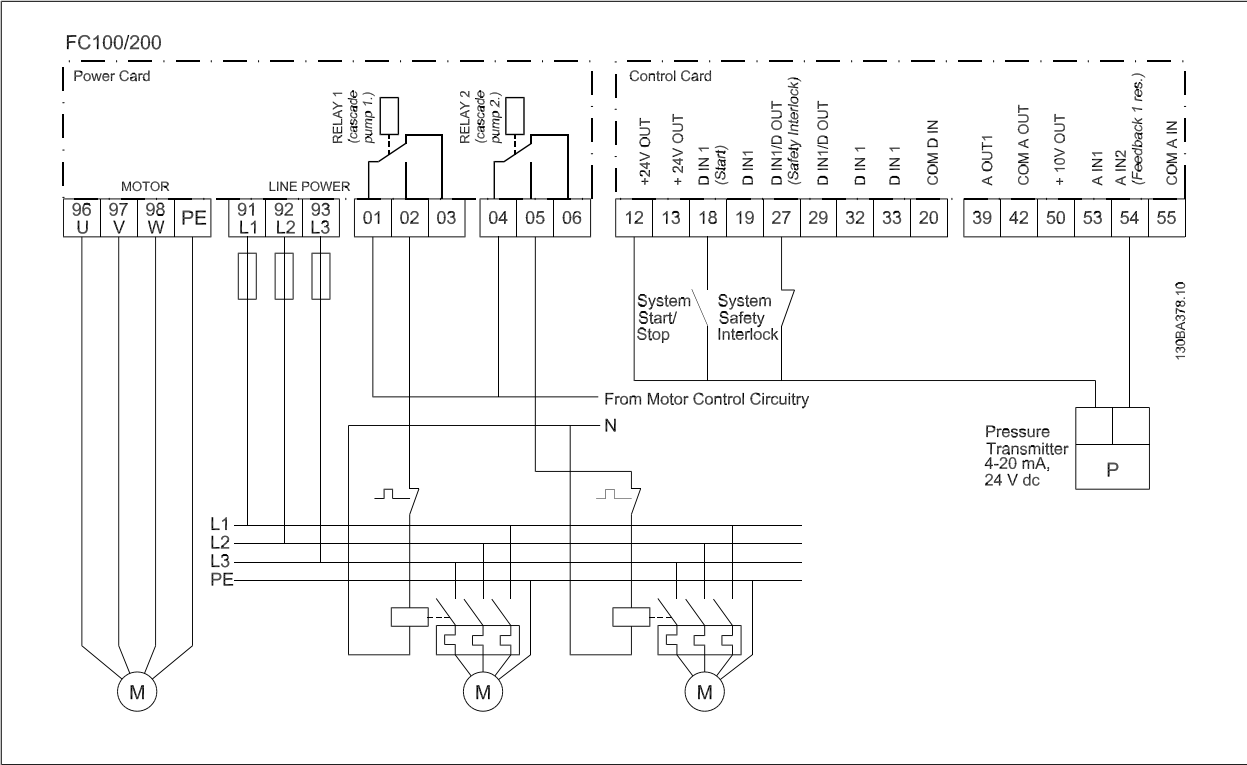
If the lead pump goes into sleep mode, the function is displayed on the local control panel. It is possible to alternate the lead pump on a sleep mode condition.

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, a read-out of the status for the relays assigned to each pump. The display shows pumps that are disabled, off, running on the adjustable frequency drive, or running on the line power/motor starter.
- Cascade Status, a readout of the status for the cascade controller. The display indicates when: the cascade controller is disabled, all pumps are off, emergency has stopped all pumps, all pumps are running, fixed speed pumps are being staged/de-staged, and lead pump alternation is occurring.
- De-staging at No-Flow ensures that all fixed speed pumps are stopped individually until the no-flow status disappears.

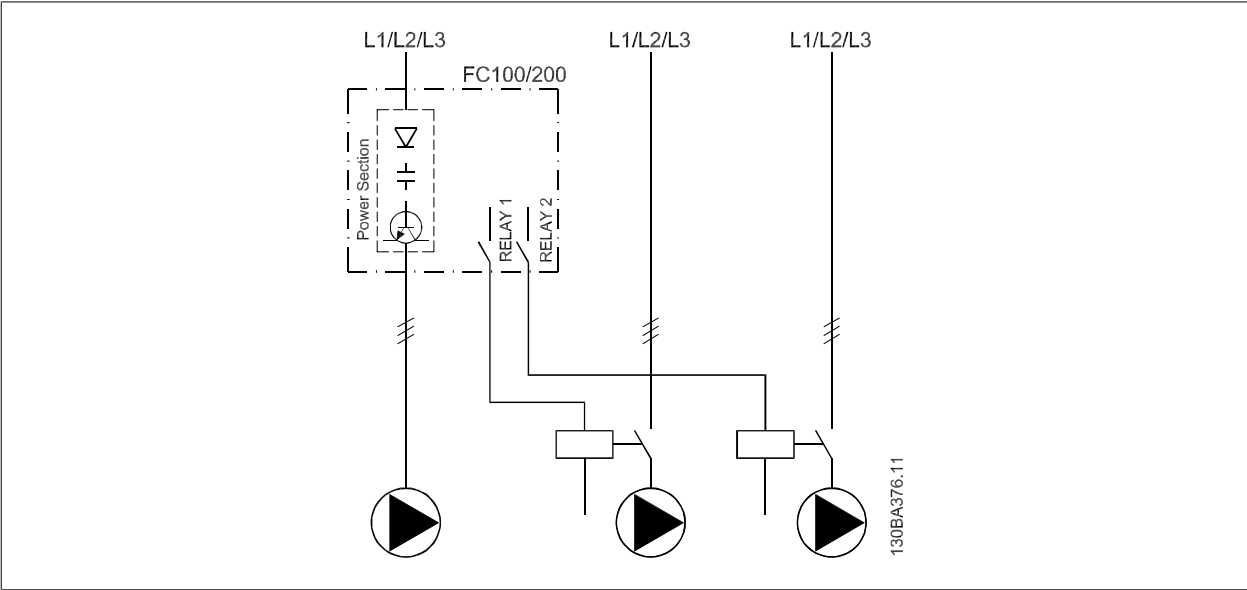
6.1.10 Cascade Controller Wiring Diagram

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.

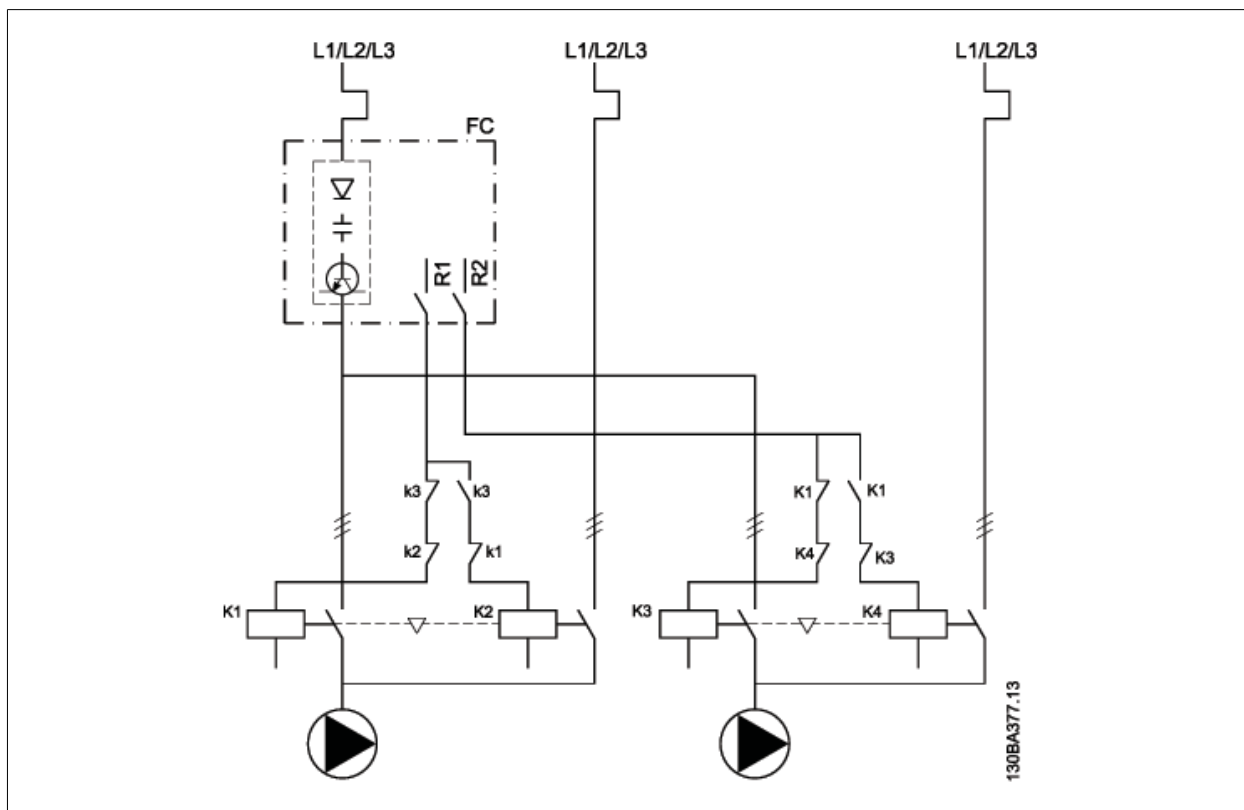


6

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 adjustable frequency drive.
- 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. For example, RELAY 1 cuts in contactor K1, which becomes the lead pump.
- K1 blocks K2 via the mechanical interlock, preventing line power to be connected to the output of the adjustable frequency drive (via K1).
- Auxiliary break contact on K1 prevents K3 from cutting in.
- RELAY 2 controls contactor K4 for on/off control of the fixed speed pump.
- At alternation, both relays de-energize, and 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 the 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. | De-staging (if running) |
| Off     | Ramps down                                                                               | Cut out                 |
| Auto On | Starts and stops according to commands sent via terminals or serial bus.                 | Staging/De-staging      |



## 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 adjustable frequency drives or a biased termination resistor network. Always use shielded twisted pair (STP) cable for bus cabling, and always follow good common installation practice.

Low-impedance ground connection of the shield at every node is very important, also at high frequencies. This can be achieved by connecting a large surface of the shield to ground, by means of a cable clamp or a conductive cable gland, for example. 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 adjustable frequency drive, always use shielded motor cable.

|                                                              |
|--------------------------------------------------------------|
| Cable: Shielded twisted pair (STP)                           |
| Impedance: 120 Ohm                                           |
| Cable length: Max. 3,396 ft [1,200 m] (including drop lines) |
| Max. 1,640 ft [500 m] station-to-station                     |

7.1.2 Network Connection

Connect the adjustable frequency drive 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 adjustable frequency drive.
- 2. Connect the cable shield to the cable clamps.



**NOTE!**  
Shielded, twisted-pair cables are recommended in order to reduce noise between conductors.

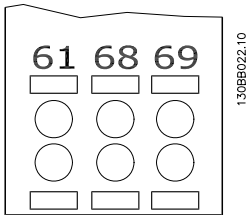


Figure 7.1: Network Terminal Connection

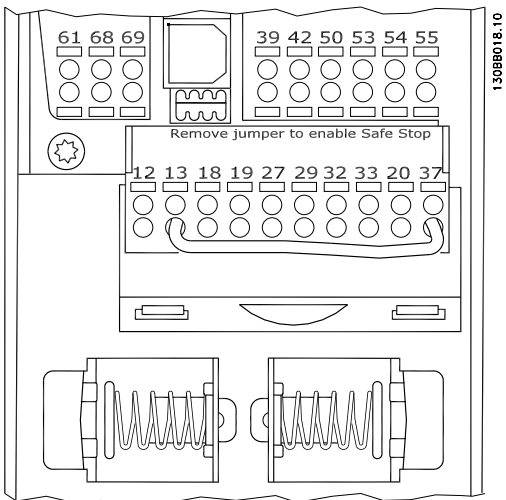
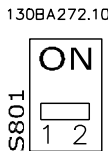


Figure 7.2: Control card terminals

7.1.3 VLT AQUA Hardware Set-up

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



Terminator Switch Factory Setting



**NOTE!**  
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

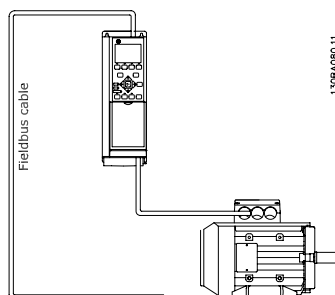
### 7.1.5 EMC Precautions

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



**NOTE!**

Relevant national and local regulations, for example, regarding protective ground 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 adjustable frequency protocol, also referred to as adjustable frequency bus or standard bus, is the Danfoss standard serial communication bus. 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 message. 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 adjustable frequency drive. The adjustable frequency protocol supports different message 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 message 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 adjustable frequency drive.

#### 7

**The control word allows the modbus master to control several important functions of the adjustable frequency drive:**

- Start
- Stop of the adjustable frequency drive 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 adjustable frequency drive

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 adjustable frequency drive when its internal PID controller is used.

7.3 Network Configuration

7.3.1 VLT AQUA Adjustable Frequency Drive Set-up

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

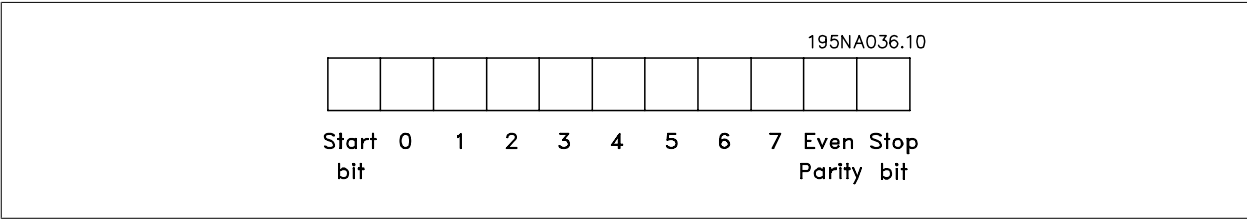
| Parameter Number | Parameter name   | Setting                           |
|------------------|------------------|-----------------------------------|
| 8-30             | Protocol         | FC                                |
| 8-31             | Address          | 1 - 126                           |
| 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)

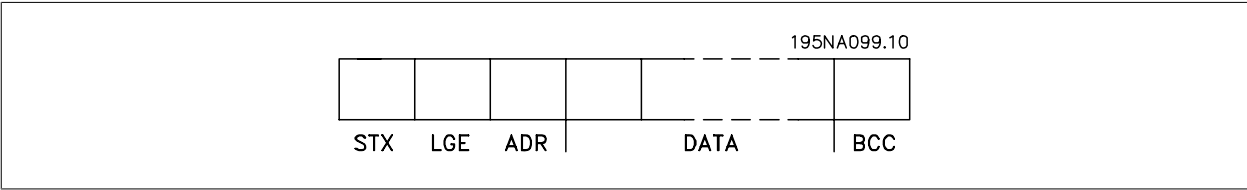
Each character transferred begins with a start bit. Then 8 data bits are transferred, corresponding to a byte. Each character is secured via a parity bit, which is set at "1" when it reaches parity (i.e., when there is an equal number of 1's in the 8 data bits and the parity bit in total). A character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

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7.4.2 Message Structure

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



### 7.4.3 Message Length (LGE)

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

|                                              |                               |
|----------------------------------------------|-------------------------------|
| The length of messages with 4 data bytes is  | $LGE = 4 + 1 + 1 = 6$ bytes   |
| The length of messages with 12 data bytes is | $LGE = 12 + 1 + 1 = 14$ bytes |
| The length of messages containing texts is   | $10^{1)} + n$ bytes           |

<sup>1)</sup> The 10 represents the fixed characters, while the "n" is variable (depending on the length of the text).

### 7.4.4 Adjustable Frequency Drive Address (ADR)

Two different address formats are used.

The address range of the adjustable frequency drive 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 = Adjustable frequency drive address 1-31

2. Address format 1-126:

Bit 7 = 1 (address format 1-126 active)

Bit 0-6 = Adjustable frequency drive 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

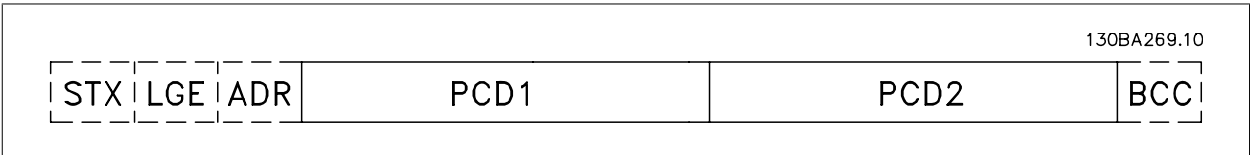
The structure of data blocks depends on the type of message. There are three message types, and the type applies for both control messages (master=>slave) and response messages (slave=>master).

The three types of message are:

Process block (PCD):

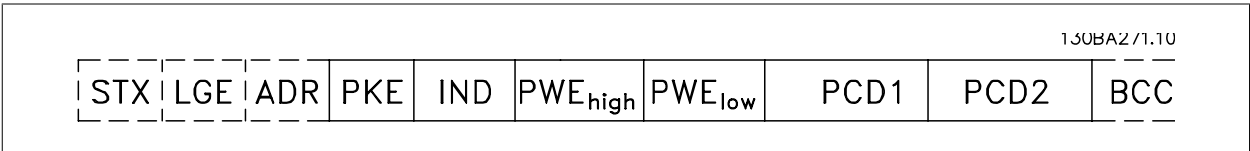
The PCD is made up of a data block of four bytes (2 words) and contains:

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



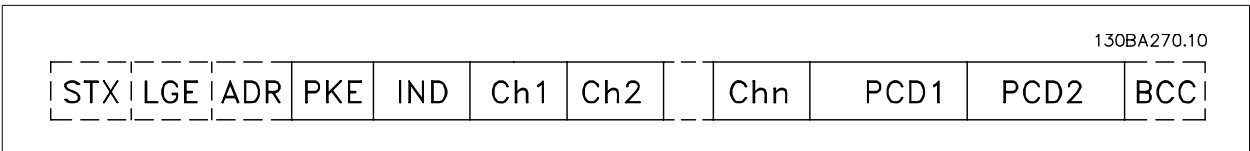
Parameter block:

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.



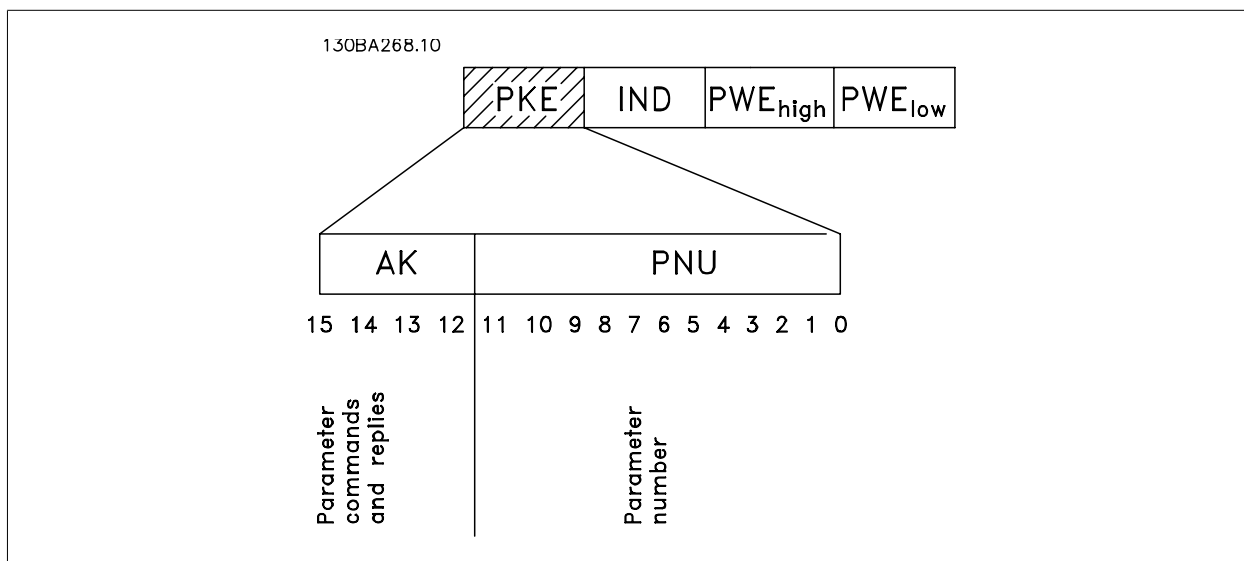
Text block:

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. | 15 | 14 | 13 | 12 | Parameter command                                     |
|---------|----|----|----|----|-------------------------------------------------------|
| 0       | 0  | 0  | 0  | 0  | No command                                            |
| 0       | 0  | 0  | 0  | 1  | Read parameter value                                  |
| 0       | 0  | 0  | 1  | 0  | Write parameter value in RAM (word)                   |
| 0       | 0  | 0  | 1  | 1  | Write parameter value in RAM (double word)            |
| 1       | 1  | 0  | 0  | 1  | Write parameter value in RAM and EEPROM (double word) |
| 1       | 1  | 1  | 1  | 0  | Write parameter value in RAM and EEPROM (word)        |
| 1       | 1  | 1  | 1  | 1  | Read/write text                                       |

#### Response slave ⇒ master

| Bit no. | 15 | 14 | 13 | 12 | Response                                  |
|---------|----|----|----|----|-------------------------------------------|
| 0       | 0  | 0  | 0  | 0  | No response                               |
| 0       | 0  | 0  | 0  | 1  | Parameter value transferred (word)        |
| 0       | 0  | 0  | 1  | 0  | Parameter value transferred (double word) |
| 0       | 1  | 1  | 1  | 1  | Command cannot be performed               |
| 1       | 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 adjustable frequency drive'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 the factory set-up is selected.                                                                                                         |

### 7.4.8 Parameter Number (PNU)

Bits no. 0-11 transfer parameter numbers. The function of the relevant parameter is defined in the parameter description in the chapter *How to Program*.

### 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.



#### NOTE!

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.

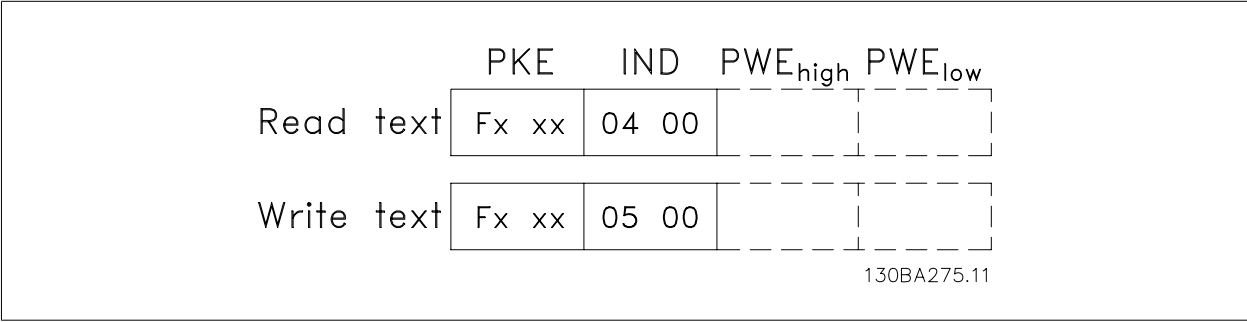
When a slave responds to a parameter request (read command), the present parameter value in the PWE block is transferred and returned to the master. If a parameter contains not a numerical value but several data options, e.g., par. 0-01 *Language* where [0] corresponds to English, and [4] corresponds 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 AC line voltage range in par. 15-40 *FC Type*. When a text string is transferred (read), the length of the message is variable, and the texts are of different lengths. The message length is defined in the second byte of the message, 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 character's high-byte must be "5".



7.4.11 Data Types Supported by VLT AQUA

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| 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 message.

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 message (master→slave control word) |  | Reference value          |  |
| Control message (slave →master) Status word |  | Present output 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 message will look like this:

|             |        |                     |                    |
|-------------|--------|---------------------|--------------------|
| 130BA092.10 |        |                     |                    |
| E19E H      | 0000 H | 0000 H              | 03E8 H             |
| PKE         | IND    | PWE <sub>high</sub> | PWE <sub>low</sub> |

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

The response from the slave to the master will be:

|             |        |                     |                    |
|-------------|--------|---------------------|--------------------|
| 130BA093.10 |        |                     |                    |
| 119E H      | 0000 H | 0000 H              | 03E8 H             |
| PKE         | IND    | PWE <sub>high</sub> | PWE <sub>low</sub> |

### 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:

|             |        |                     |                    |
|-------------|--------|---------------------|--------------------|
| 130BA094.10 |        |                     |                    |
| 1007 H      | 0000 H | 0000 H              | 0000 H             |
| PKE         | IND    | PWE <sub>high</sub> | PWE <sub>low</sub> |

|             |        |                     |                    |
|-------------|--------|---------------------|--------------------|
| 130BA267.10 |        |                     |                    |
| 1155 H      | 0000 H | 0000 H              | 03E8 H             |
| PKE         | IND    | PWE <sub>high</sub> | PWE <sub>low</sub> |



#### NOTE!

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

## 7.6 Modbus RTU Overview

### 7.6.1 Assumptions

This instruction manual assumes that the installed controller supports the interfaces in this document and that all the requirements stipulated in the controller, as well as the adjustable frequency drive, 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, among other things, 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.

While communicating over a Modbus RTU network, the protocol determines how each controller will learn its device address, recognize 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 taking the action requested in the query.

The master can address individual slaves or 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 timeout 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 Adjustable Frequency Drive with Modbus RTU

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

| Start bit | Data byte |  |  |  |  |  |  |  | Stop/<br>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)                                                                                                                                      |

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### 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 recognize when the message is completed. Partial messages are detected, and errors are set as a result. Characters for transmission must be in hexadecimal 00 to FF format in each field. The adjustable frequency drive continuously monitors the network bus, also during 'silent' intervals. When the first field (the address field) is received, each adjustable frequency drive 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 that 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.

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### 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 timeout 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        | Adjustable frequency drive control word (see table below)                                                                | Master to slave  |
| 17-32       | Adjustable frequency driver speed or setpoint reference Range 0x0–0xFFFF (-200% ... ~200%)                               | Master to slave  |
| 33-48       | Adjustable frequency drive status word (see table below)                                                                 | Slave to master  |
| 49-64       | Open-loop mode: adjustable frequency drive output frequency Closed-loop mode: Adjustable frequency drive 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 adjustable frequency drive.                                          |                  |
|             | 1 = Parameter changes are written to the RAM and EEPROM of the adjustable frequency drive.                               |                  |
| 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       |
| <b>Adjustable frequency drive control word (FC profile)</b> |                      |                 |

| Coil                                                       | 0                                    | 1                                |
|------------------------------------------------------------|--------------------------------------|----------------------------------|
| 33                                                         | Control not ready                    | Control ready                    |
| 34                                                         | Adjustable frequency drive not ready | Adjustable frequency drive 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                  |
| <b>Adjustable frequency drive status word (FC profile)</b> |                                      |                                  |

| Holding registers |                                                                           |
|-------------------|---------------------------------------------------------------------------|
| Register Number   | Description                                                               |
| 00001-00006       | Reserved                                                                  |
| 00007             | Last error code from an adjustable frequency drive data object interface  |
| 00008             | Reserved                                                                  |
| 00009             | Parameter index*                                                          |
| 00010-00990       | 000 parameter group (parameters 001 through 099)                          |
| 01000-01990       | 100 parameter group (parameters 100 through 199)                          |
| 02000-02990       | 200 parameter group (parameters 200 through 299)                          |
| 03000-03990       | 300 parameter group (parameters 300 through 399)                          |
| 04000-04990       | 400 parameter group (parameters 400 through 499)                          |
| ...               | ...                                                                       |
| 49000-49990       | 4900 parameter group (parameters 4900 through 4999)                       |
| 50000             | Input data: Adjustable frequency drive control word register (CTW).       |
| 50010             | Input data: Bus reference register (REF).                                 |
| ...               | ...                                                                       |
| 50200             | Output data: Adjustable frequency drive status word register (STW).       |
| 50210             | Output data: Adjustable frequency drive 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 the VLT AQUA

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

### 7.8.10 Function Codes Supported by Modbus RTU

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

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

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

7

### 7.8.11 Database Error Codes

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

| Error Code in data field (decimal) | Database Error Code description                                          |
|------------------------------------|--------------------------------------------------------------------------|
| 00                                 | The parameter number does not exist.                                     |
| 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 exist.                                     |
| 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 adjustable frequency drive is 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 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 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 adjustable frequency drive. 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 (adjustable frequency drive address) |
| Function            | 01 (read coils)                         |
| Starting Address HI | 00                                      |
| Starting Address LO | 20 (32 decimals) Coil 33                |
| No. of Points HI    | 00                                      |
| No. of Points LO    | 10 (16 decimals)                        |
| Error Check (CRC)   | -                                       |

#### Response

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

If the returned coil quantity is not a multiple of eight, the remaining bits in the final data byte will be padded with zeros (toward the high order end of the byte). The Byte Count field specifies the number of complete bytes of data.

| Field Name         | Example (HEX)                           |
|--------------------|-----------------------------------------|
| Slave Address      | 01 (adjustable frequency drive address) |
| Function           | 01 (read coils)                         |
| Byte Count         | 02 (2 bytes of data)                    |
| Data (Coils 40-33) | 07                                      |
| Data (Coils 48-41) | 06 (STW=0607hex)                        |
| Error Check (CRC)  | -                                       |



#### NOTE!

Coils and registers are addressed explicit with an off-set of -1 in Modbus.  
For example, Coil 33 is addressed as Coil 32.

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 (adjustable frequency drive address) |
| Function          | 05 (write single coil)                  |
| Coil Address HI   | 00                                      |
| Coil Address LO   | 40 (64 decimal) Coil 65                 |
| Force Data HI     | FF                                      |
| Force Data LO     | 00 (FF 00 = ON)                         |
| Error Check (CRC) | -                                       |

Response

The normal response is an echo of the query, which is 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 setpoint) to be forced.

**NOTE!**

Coil addresses start at zero, i.e., coil 17 is addressed as 16.

| Field Name                    | Example (HEX)                           |
|-------------------------------|-----------------------------------------|
| Slave Address                 | 01 (adjustable frequency drive 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<br>(Coils 8-1)  | 20                                      |
| Force Data LO<br>(Coils 10-9) | 00 (ref. = 2000hex)                     |
| Error Check (CRC)             | -                                       |

**Response**

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

| Field Name           | Example (HEX)                           |
|----------------------|-----------------------------------------|
| Slave Address        | 01 (adjustable frequency drive 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.

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

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

Response

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

Example: Hex 0016E360 = 1.500.000 = 1500 RPM.

| Field Name                 | Example (HEX) |
|----------------------------|---------------|
| Slave Address              | 01            |
| Function                   | 03            |
| Byte Count                 | 04            |
| Data HI<br>(Register 3030) | 00            |
| Data LO<br>(Register 3030) | 16            |
| Data HI<br>(Register 3031) | E3            |
| Data LO<br>(Register 3031) | 60            |
| Error Check<br>(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.

Example: Write to par. 1-00, register 1000.

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

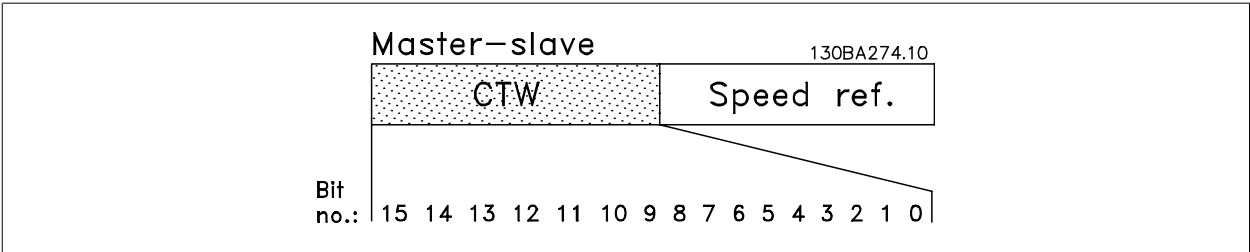
#### Response

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

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

7.11 Danfoss FC Control Profile

7.11.1 Control Word According to Adjustable Frequency Drive Profile(par. 8-10 *Control Profile* = Adjustable Frequency 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 <i>Preset Reference</i> [0] | 0      | 0      |
| 2                     | par. 3-10 <i>Preset Reference</i> [1] | 0      | 1      |
| 3                     | par. 3-10 <i>Preset Reference</i> [2] | 1      | 0      |
| 4                     | par. 3-10 <i>Preset Reference</i> [3] | 1      | 1      |



NOTE!

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

**NOTE!**

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*.

**NOTE!**

If freeze output is active, the adjustable frequency drive 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 adjustable frequency drive to start the motor, if the other starting conditions are met.

**NOTE!**

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 leading edge of the signal, 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 adjustable frequency drive 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 message always contains the control word, regardless of the message 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*.

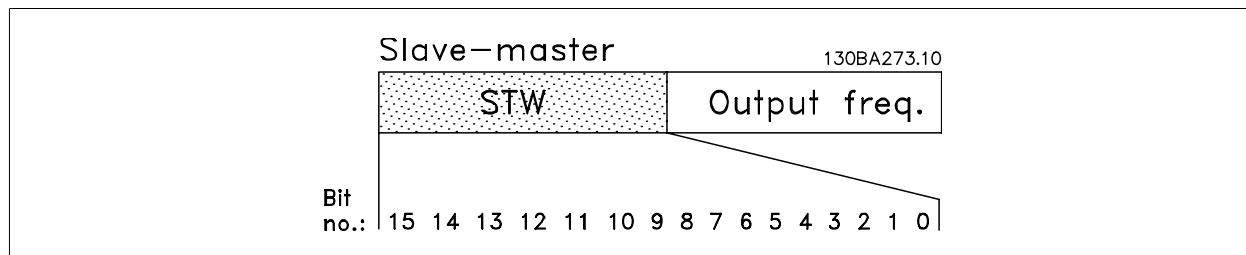
**NOTE!**

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 Adjustable Frequency Profile (STW) (par. 8-10 *Control Profile* = Adjustable Frequency 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 adjustable frequency drive trips. Bit 00 = '1': The adjustable frequency drive 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 adjustable frequency drive 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 adjustable frequency drive releases the motor. Bit 02 = '1': The adjustable frequency drive starts the motor with a start command.

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

Bit 03 = '0': The adjustable frequency drive is not in fault mode. Bit 03 = '1': The adjustable frequency drive trips. To re-establish operation, enter [Reset].

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

Bit 04 = '0': The adjustable frequency drive is not in fault mode. Bit 04 = '1': The adjustable frequency drive 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 adjustable frequency drive is not in fault mode. Bit 06 = "1": The adjustable frequency drive 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. For example, this might 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 adjustable frequency drive via serial communication. Bit 09 = '1' It is possible to control the adjustable frequency drive via serial communication or the serial communication bus.

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 adjustable frequency drive 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 overtemperature on the inverter. Bit 12 = '1': The inverter stops because of overtemperature 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 adjustable frequency drive'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:

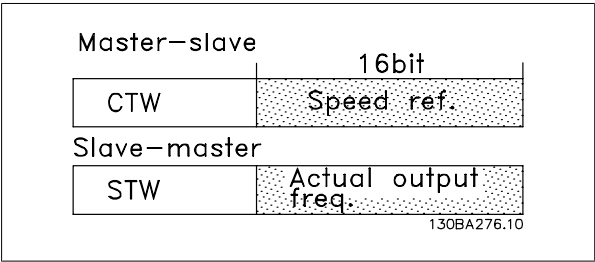
Bit 15 = '0': The timers for motor thermal protection and thermal protection are not exceeded 100%. Bit 15 = '1': One of the timers exceeds 100%.

**NOTE!**

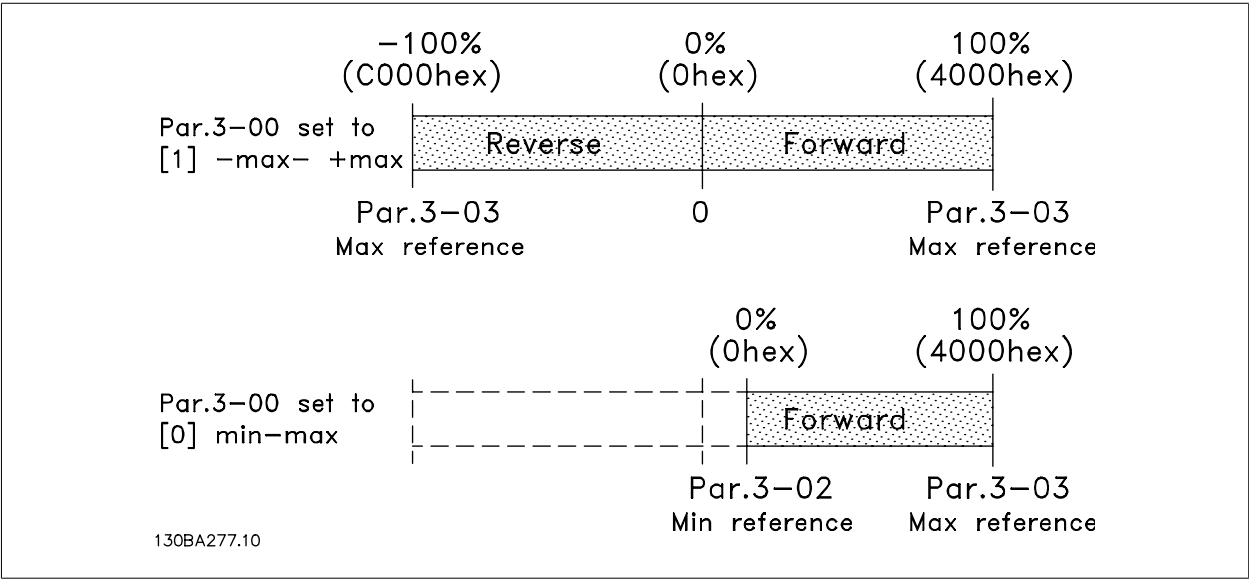
All bits in the STW are set to '0' if the connection between the Interbus option and the adjustable frequency drive is lost, or if an internal communication problem has occurred.

7.11.3 Bus Speed Reference Value

Speed reference value is transmitted to the adjustable frequency drive in a relative value expressed as %. 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 signaled by the relevant LED on the front of the adjustable frequency drive 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 adjustable frequency drive 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 serial communication bus.
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 Drive Programming Guide**



**NOTE!**

After a manual reset using the [RESET] button on the LCP, the [AUTO ON] or [HAND 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 the table on the following page).

Alarms that are trip-locked offer additional protection, means that the line power supply must be switched off before the alarm can be reset. After being switched back on, the adjustable frequency drive 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 par. 14-20 *Reset Mode* (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 par. 1-90 *Motor Thermal Protection*. After an alarm or trip, the motor carries on coasting, and the alarm and warning flash on the adjustable frequency drive. 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   | Line phase loss                        | (X)     | (X)        | (X)             | 14-12               |
| 5   | DC link voltage high                   | X       |            |                 |                     |
| 6   | DC link voltage low                    | X       |            |                 |                     |
| 7   | DC overvoltage                         | X       | X          |                 |                     |
| 8   | DC undervoltage                        | X       | X          |                 |                     |
| 9   | Inverter overloaded                    | X       | X          |                 |                     |
| 10  | Motor ETR overtemperature              | (X)     | (X)        |                 | 1-90                |
| 11  | Motor thermistor overtemperature       | (X)     | (X)        |                 | 1-90                |
| 12  | Torque limit                           | X       | X          |                 |                     |
| 13  | Overcurrent                            | X       | X          | X               |                     |
| 14  | Ground fault                           | X       | X          | X               |                     |
| 15  | Hardware mismatch                      |         | X          | X               |                     |
| 16  | Short Circuit                          |         | X          | X               |                     |
| 17  | Control word timeout                   | (X)     | (X)        |                 | 8-04                |
| 23  | Internal Fan Fault                     | X       |            |                 |                     |
| 24  | External Fan Fault                     | X       |            |                 | 14-53               |
| 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  | Drive overtemperature                  | 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  | Soft-charge fault                      |         | X          | X               |                     |
| 34  | Serial communication bus fault         | X       | X          |                 |                     |
| 35  | Out of frequency ranges                | X       | X          |                 |                     |
| 36  | Line failure                           | X       | X          |                 |                     |
| 37  | Phase Imbalance                        | X       | X          |                 |                     |
| 38  | Internal fault                         |         | X          | X               |                     |
| 39  | Heatsink sensor                        |         | X          | X               |                     |
| 40  | Overload of Digital Output Terminal 27 | (X)     |            |                 | 5-00, 5-01          |
| 41  | Overload of Digital Output Terminal 29 | (X)     |            |                 | 5-00, 5-02          |
| 42  | Overload of Digital Output On X30/6    | (X)     |            |                 | 5-32                |
| 42  | Overload of Digital Output On X30/7    | (X)     |            |                 | 5-33                |
| 46  | Pwr. card supply                       |         | X          | X               |                     |
| 47  | 24 V supply low                        | X       | X          | X               |                     |
| 48  | 1.8 V supply low                       |         | X          | X               |                     |
| 49  | Speed limit                            | 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       |            |                 |                     |

Table 8.1: Alarm/Warning code list

| No. | Description                                      | Warning | Alarm/Trip      | Alarm/Trip Lock | Parameter Reference |
|-----|--------------------------------------------------|---------|-----------------|-----------------|---------------------|
| 60  | External Interlock                               | X       |                 |                 |                     |
| 62  | Output Frequency at Maximum Limit                | X       |                 |                 |                     |
| 64  | Voltage Limit                                    | X       |                 |                 |                     |
| 65  | Control Board Overtemperature                    | X       | X               | X               |                     |
| 66  | Heatsink Temperature Low                         | X       |                 |                 |                     |
| 67  | Option Configuration has Changed                 |         | X               |                 |                     |
| 68  | Safe Stop Activated                              |         | X <sup>1)</sup> |                 |                     |
| 69  | Pwr. Card Temp                                   |         | X               | X               |                     |
| 70  | Illegal Adjustable Frequency Drive configuration |         |                 | X               |                     |
| 71  | PTC 1 Safe Stop                                  | X       | X <sup>1)</sup> |                 |                     |
| 72  | Dangerous Failure                                |         |                 | X <sup>1)</sup> |                     |
| 73  | Safe Stop Auto Restart                           |         |                 |                 |                     |
| 79  | Illegal PS config                                |         | X               | X               |                     |
| 80  | Drive Initialized to Default Value               |         | X               |                 |                     |
| 91  | Analog input 54 wrong settings                   |         |                 | X               |                     |
| 92  | NoFlow                                           | X       | X               |                 | 22-2*               |
| 93  | Dry Pump                                         | X       | X               |                 | 22-2*               |
| 94  | End of Curve                                     | X       | X               |                 | 22-5*               |
| 95  | Broken Belt                                      | X       | X               |                 | 22-6*               |
| 96  | Start Delayed                                    | X       |                 |                 | 22-7*               |
| 97  | Stop Delayed                                     | X       |                 |                 | 22-7*               |
| 98  | Clock Fault                                      | X       |                 |                 | 0-7*                |

| No. | Description       | Warning | Alarm/Trip | Alarm/Trip Lock | Parameter Reference |
|-----|-------------------|---------|------------|-----------------|---------------------|
| 220 | Overload Trip     |         | X          |                 |                     |
| 243 | Brake IGBT        | X       | X          |                 |                     |
| 244 | Heatsink temp     | X       | X          | X               |                     |
| 245 | Heatsink sensor   |         | X          | X               |                     |
| 246 | Pwr.card supply   |         | X          | X               |                     |
| 247 | Pwr.card temp     |         | X          | X               |                     |
| 248 | Illegal PS config |         | X          | X               |                     |
| 250 | New spare part    |         |            | X               |                     |
| 251 | New Type Code     |         | X          | X               |                     |

Table 8.2: Alarm/Warning code list

(X) Dependent on parameter

1) Can not be Auto reset via par. 14-20 *Reset Mode*

A trip is the action when an alarm has appeared. The trip will coast the motor and can be reset by pressing the reset button or make a reset by a digital input (Par. 5-1\* [1]). The original event that caused an alarm cannot damage the adjustable frequency drive or cause dangerous conditions. A trip lock is an action that occurs in conjunction with an alarm, which may cause damage to the adjustable frequency drive or connected parts. A trip lock situation can only be reset by power cycling.

*LED indication*

|             |                |
|-------------|----------------|
| Warning     | yellow         |
| Alarm       | flashing red   |
| Trip locked | yellow and red |

Alarm Word and Extended Status Word

| Bit | Hex      | Dec        | Alarm Word          | Warning Word        | Extended Status Word |
|-----|----------|------------|---------------------|---------------------|----------------------|
| 0   | 00000001 | 1          | Brake Check         | Brake Check         | Ramping              |
| 1   | 00000002 | 2          | Pwr. Card Temp      | Pwr. Card Temp      | AMA Running          |
| 2   | 00000004 | 4          | Ground Fault        | Ground 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         | Overcurrent         | Overcurrent         | 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 undervolt        | DC undervolt        | Output Freq Low      |
| 11  | 00000800 | 2048       | DC overvolt         | DC overvolt         | Brake Check OK       |
| 12  | 00001000 | 4096       | Short Circuit       | DC Voltage Low      | Braking Max          |
| 13  | 00002000 | 8192       | Soft-charge Fault   | DC Voltage High     | Braking              |
| 14  | 00004000 | 16384      | Line ph. Loss       | Line 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      | 10 V 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    | Ser. Com. Bus Fault | Ser. Com. Bus Fault |                      |
| 23  | 00800000 | 8388608    | 24 V Supply Low     | 24V Supply Low      |                      |
| 24  | 01000000 | 16777216   | Line failure        | Line failure        |                      |
| 25  | 02000000 | 33554432   | 1.8 V 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 Initialized   | Unused              |                      |
| 30  | 40000000 | 1073741824 | Safe Stop           | Unused              |                      |

Table 8.3: 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 serial communication bus for diagnosis. See also par. 16-90 *Alarm Word*, par. 16-92 *Warning Word* and par. 16-94 *Ext. Status Word*.



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