MAKING MODERN LIVING POSSIBLE

# Design Guide

# VLT® HVAC Drive FC 102

## 1.1–90 kW




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VLT®
THE REAL DRIVE

## Contents

 

 

 

# 1 How to Read this Design Guide

**VLT® HVAC Drive**
**FC 102 Series**

This guide can be used with all VLT® HVAC Drive adjustable frequency drives with software version 3.9x.
The actual software version number can be read from *15-43 Software Version*.

**Table 1.1 Software Version**



- Design Guide contains all the technical information about the adjustable frequency drive and customer design and applications.
- The Programming Guide provides information on how to program and includes complete parameter descriptions.
- *Application Note, Temperature Derating Guide.*
- *MCT 10 Set-up Software Instruction Manual* enables the user to configure the adjustable frequency drive from a Windows™-based PC environment.
- Danfoss VLT® Energy Box software at *www.danfoss.com/BusinessAreas/DrivesSolutions* then choose PC Software Download.
- *VLT® HVAC Drive BACnet, Instruction Manual.*
- *VLT® HVAC Drive Metasys, Instruction Manual.*
- *VLT® HVAC Drive FLN, Instruction Manual.*

Danfoss technical literature is available in print from local Danfoss Sales Offices or online at: *www.danfoss.com/BusinessAreas/DrivesSolutions/Documentations/Technical+Documentation.htm*

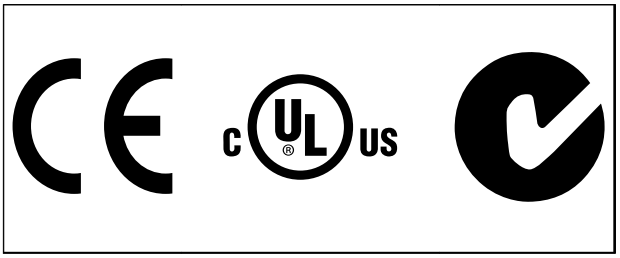

**Table 1.2**

The adjustable frequency drive complies with UL508C thermal memory retention requirements. For more information, refer to *chapter 6.4.2 Motor Thermal Protection*.

The following symbols are used in this document.

**⚠WARNING**

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

**⚠CAUTION**

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

***NOTICE!***

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

| | |
|---|---|
| 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 |
| Adjustable frequency drive | FC |
| Gram | g |
| Hertz | Hz |
| Horsepower | hp |
| 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 | $U_{M,N}$ |
| Permanent Magnet motor | PM motor |
| Protective Extra Low Voltage | PELV |
| Printed Circuit Board | PCB |
| Rated Inverter Output Current | $I_{INV}$ |
| Revolutions Per Minute | RPM |
| Regenerative terminals | Regen |
| Second | s |
| Synchronous Motor Speed | $n_s$ |
| Torque limit | $T_{LIM}$ |
| Volts | V |
| The maximum output current | $I_{VLT,MAX}$ |
| The rated output current supplied by the adjustable frequency drive | $I_{VLT,N}$ |

**Table 1.3 Abbreviations**

## 1.1.1 Definitions

**Adjustable Frequency 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.

**Input:**

| | | |
|---|---|---|
| **Control command** Start and stop the connected motor with the LCP or the digital inputs. Functions are divided into two groups. Functions in group 1 have higher priority than functions in group 2. | Group 1 | Reset, Coasting stop, Reset and Coasting stop, Quick stop, DC braking, Stop and the "Off" key |
| | Group 2 | Start, Pulse start, Reversing, Start reversing, Jog and Freeze output |

**Table 1.4 Function Groups**

**Motor:**

**$f_{JOG}$**
The motor frequency when the jog function is activated (via digital terminals).

**$f_M$**
The motor frequency.

**$f_{MAX}$**
The maximum motor frequency.

**$f_{MIN}$**
The minimum motor frequency.

**$f_{M,N}$**
The rated motor frequency (nameplate data).

**$I_M$**
The motor current.

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

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

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

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

**$U_M$**
The instantaneous motor voltage.

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

**Break-away torque**

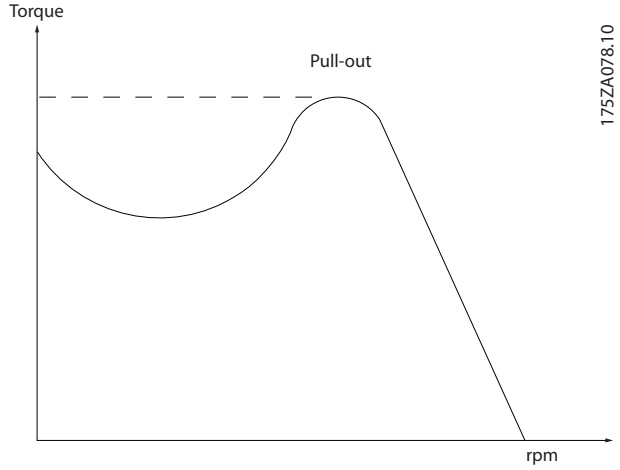


**Figure 1.1 Break-away Torque**

**$\eta_{VLT}$**
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 *Table 1.4*.

**Stop command**
See Control commands.

**References:**

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

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

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

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

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

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

**Miscellaneous:**

**Advanced Vector Control**
**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 screw and scroll refrigeration compressors.

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

**Digital Outputs**
The adjustable frequency 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 initialization is carried out (*14-22 Operation Mode*), 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 makes up a complete interface for control and programming of the adjustable frequency drive. The LCP is detachable and can be installed up to 10 ft [3 m] from the adjustable frequency drive, i.e., in a front panel by means of the installation kit option.
The LCP is available in two versions:

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

**lsb**
Least significant bit.

**MCM**
Short for Mille Circular Mil, an American measuring unit for cable cross-section. 1 MCM ≡ 0.00078 $in^2$ [0.5067 $mm^2$].

**msb**
Most significant bit.

**NLCP**
Numerical Local Control Panel LCP 101.

**Online/Offline Parameters**
Changes to online parameters are activated immediately after the data value is changed. Press [OK] to activate changes to offline parameters.

**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**
Save parameter settings in four set-ups. Change between the two parameter set-ups and edit one set-up, while another set-up is active.

**SFAVM**
Switching pattern called Stator Flux-oriented Asynchronous Vector Modulation (*14-00 Switching Pattern*).

  

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

**60° AVM**
Switching pattern called 60° Asynchronous Vector Modulation (See *14-00 Switching Pattern*).

## 1.1.2 Power Factor

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

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

The power factor for 3-phase control:

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

The power factor indicates to which extent the 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.

$$IRMS = \sqrt{I_1^2 + I_5^2 + I_7^2 + \ldots + I_n^2}$$

In addition, a high power factor indicates that the different harmonic currents are low.
The adjustable frequency drive's built-in DC coils produce a high power factor, which minimizes the imposed load on the line power supply.

  

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# 2 Introduction to VLT® HVAC Drive

## 2.1 Safety

### 2.1.1 Safety Note

**⚠WARNING**

**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 death, serious personal injury or damage to the equipment. Consequently, the instructions in this manual, as well as national and local rules and safety regulations, must be complied with.**

**Safety Regulations**

1. Disconnect the adjustable frequency drive 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 elapsed before removing motor and line power plugs.
2. The [Stop/Reset] key on the LCP 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. Established correct protective grounding of the equipment, protect the user against supply voltage, and protect the motor 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 *1-90 Motor Thermal Protection*. If this function is desired, set *1-90 Motor Thermal Protection* to data value [ETR trip] (default value) or data value [ETR warning]. Note: The function is initialized at 1.16 x rated motor current and rated motor frequency. For the North American market: The ETR functions provide class 20 motor overload protection in accordance with NEC.
6. Do not remove the plugs for the motor and 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 elapsed before removing motor and line power plugs.
7. 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**

**⚠CAUTION**

**380–500 V, enclosure types A, B and C: At altitudes above 6,600 ft [2 km], contact Danfoss regarding PELV. 525–690 V: At altitudes above 6,600 ft [2 km], contact Danfoss regarding PELV.**

**⚠WARNING**

**Warning against unintended start**

1. **The motor can be stopped with 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 [Reset] key must always be activated; after 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 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 backup. Refer to the *Instruction Manual* for further safety guidelines.

### 2.1.2 Caution

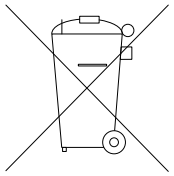
**⚠WARNING**

**The DC link capacitors remain charged after power has been disconnected. To avoid an electrical shock hazard, disconnect the 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 |
| 200–240 | 1.5–5 hp [1.1–3.7 kW] | 7.5–60 hp [5.5–45 kW] |
| 380–480 | 1.5–10 hp [1.1–7.5 kW] | 15–125 hp [11–90 kW] |
| 525–600 | 1.5–10 hp [1.1–7.5 kW] | 15–125 hp [11–90 kW] |
| 525–690 | | 15–125 hp [11–90 kW] |
| Be aware that there may be high voltage on the DC link even when the LEDs are turned off. | | |

**Table 2.1 Discharge Time**

### 2.1.3 Disposal Instruction



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

## 2.2 CE Labeling

### 2.2.1 CE Conformity and Labeling

**What is CE Conformity and Labeling?**
The purpose of CE labeling is to avoid technical trade obstacles within 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 (2006/42/EC)**
Adjustable frequency drives with the integrated safety function are now falling under the Machinery Directive. Danfoss uses CE labels in accordance with the directive and will issue a declaration of conformity upon request. Adjustable frequency drives without the safety function do 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.
**The low-voltage directive (2006/95/EC)**
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 (2004/108/EC)**
EMC is short for electromagnetic compatibility.
The presence of electromagnetic compatibility means that the mutual interference between different components/ appliances does not affect the way the appliances work. The EMC directive came into effect January 1, 1996. Danfoss CE labels in accordance with the directive and issues a declaration of conformity upon request. To carry out EMC-compatible installation, see the instructions in this Design Guide. In addition, Danfoss specifies which standards our products comply with. Danfoss offers the filters presented in the specifications and provide other types of assistance to ensure the optimum EMC result.

The 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.

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### 2.2.2 What Is Covered

The EU "*Guidelines on the Application of Council Directive 2004/108/EC*" outline three typical situations of using an adjustable frequency drive.

1. The adjustable frequency drive is sold directly to the end user. For such applications, the adjustable frequency drive must be CE labeled in accordance with the EMC directive.
2. The adjustable frequency drive is sold as part of a system. It is being marketed as complete system, e.g., 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 by testing the EMC of the system. The components of the system do not need to be CE marked.
3. The adjustable frequency drive is sold for installation in a plant. It could be a production or a heating/ventilation plant designed and installed by professionals of the trade. The adjustable frequency drive must be CE labeled under the EMC directive. The finished plant should not bear the CE mark. However, the installation must comply with the essential requirements of the directive. This is assumed by using appliances and systems that are CE labeled under the EMC directive

### 2.2.3 Danfoss Adjustable frequency drive and CE Labeling

The purpose of CE labeling is to facilitate trade within the EU and EFTA.

However, CE labeling may cover many different specifications. Thus, 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, Danfoss guarantees 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-compatible installation and filtering are followed. On this basis, a declaration of conformity in accordance with the EMC directive is issued.

This *Design Guide* offers detailed instructions for installation to ensure EMC-compatible installation. Furthermore, Danfoss specifies with what the different products comply.

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

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

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. Note that the responsibility for the final EMC properties of the appliance, system or installation rests with the installer. As an aid to the installer, Danfoss has prepared EMC installation guidelines for the Power Drive system. The standards and test levels stated for Power Drive systems are complied with, provided that the EMC-compatible instructions for installation are followed, see.

## 2.3 Air humidity

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].

## 2.4 Aggressive Environments

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

**⚠CAUTION**

**Do not install the adjustable frequency drive 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.**

**Degree of protection as per IEC 60529**
The Safe Torque Off function may only be installed and operated in a control cabinet with degree of protection IP54 or higher (or equivalent environment). This is required to avoid cross faults and short circuits between terminals, connectors, tracks and safety-related circuitry caused by foreign objects.

  

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/TYPE 1 equipment.

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

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

***NOTICE!***

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

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

## 2.5 Vibration and Shock

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

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

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.

## 2.6 Safe Torque Off

The FC 102 can perform the safety function *Safe Torque Off* (STO, as defined by EN IEC 61800-5-2[1]) and *Stop Category 0* (as defined in EN 60204-1[2]).
Before integrating and using Safe Torque Off in an installation, a thorough risk analysis on the installation must be carried out in order to determine whether the Safe Torque Off functionality and safety levels are appropriate and sufficient. It is designed and approved as suitable for the requirements of:

- Category 3 in EN ISO 13849-1
- Performance Level "d" in EN ISO 13849-1:2008
- SIL 2 Capability in IEC 61508 and EN 61800-5-2
- SILCL 2 in EN 62061

1) Refer to EN IEC 61800-5-2 for details of Safe torque off (STO) function.
2) Refer to EN IEC 60204-1 for details of stop category 0 and 1.

**Activation and Termination of Safe Torque Off**
The Safe Torque Off (STO) 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 delay, an installation for a Safe Torque Off Category 1 can be obtained. The Safe Torque Off function of FC 102 can be used for asynchronous, synchronous motors and permanent magnet motors. See examples in *chapter 2.6.1 Terminal 37 Safe Torque Off Function*.

**⚠WARNING**

**After installation of Safe Torque Off (STO), a commissioning test as specified in section *Safe Torque Off Commissioning Test* must be performed. A passed commissioning test is mandatory after first installation and after each change to the safety installation.**

  

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**Safe Torque Off Technical Data**
The following values are associated to the different types of safety levels:

**Reaction time for T37**

- Maximum reaction time: 20 ms

Reaction time = delay between de-energizing the STO input and switching off the output bridge.

**Data for EN ISO 13849-1**

- Performance Level "d"
- $MTTF_d$ (Mean Time To Dangerous Failure): 14,000 years
- DC (Diagnostic Coverage): 90%
- Category 3
- Lifetime 20 years

**Data for EN IEC 62061, EN IEC 61508, EN IEC 61800-5-2**

- SIL 2 Capability, SILCL 2
- PFH (Probability of dangerous Failure per Hour) = 1E-10/h
- SFF (Safe Failure Fraction) > 99%
- HFT (Hardware Fault Tolerance) = 0 (1001 architecture)
- Lifetime 20 years

**Data for EN IEC 61508 low demand**

- PFDavg for 1-year proof test: 1E-10
- PFDavg for 3-year proof test: 1E-10
- PFDavg for 5-year proof test: 1E-10

No maintenance of the STO functionality is needed.

Take security measures, e.g., only skilled personnel must be able to access and install in closed cabinets.

**SISTEMA Data**
Danfoss provides functional safety data via a data library for use with the SISTEMA calculation tool from IFA (Institute for Occupational Safety and Health of the German Social Accident Insurance), as well as data for manual calculation. The library is complete and continually extended.

| Abbrev. | Ref. | Description |
|---|---|---|
| Cat. | EN ISO 13849-1 | Category, level “B, 1-4” |
| FIT | | Failure In Time: 1E-9 hours |
| HFT | IEC 61508 | Hardware Fault Tolerance: HFT = n means that n+1 faults could cause a loss of the safety function |
| MTTFd | EN ISO 13849-1 | Mean Time To Failure - dangerous. Unit: years |
| PFH | IEC 61508 | Probability of Dangerous Failures per Hour. This value shall be considered if the safety device is operated in high demand (more often than once per year) or continuous mode of operation, where the frequency of demands for operation made on a safety-related system is greater than one per year |
| PFD | IEC 61508 | Average probability of failure on demand, value used for low demand operation |
| PL | EN ISO 13849-1 | Discrete level used to specify the ability of safety related parts of control systems to perform a safety function under foreseeable conditions. Levels a-e |
| SFF | IEC 61508 | Safe Failure Fraction [%]; Percentage part of safe failures and dangerous detected failures of a safety function or a subsystem related to all failures |
| SIL | IEC 61508 | Safety Integrity Level |
| STO | EN 61800-5-2 | Safe Torque Off |
| SS1 | EN 61800 -5-2 | Safe Stop 1 |

**Table 2.2 Abbreviations Related to Functional Safety**

## 2.6.1 Terminal 37 Safe Torque Off Function

The FC 102 is available with Safe Torque Off functionality via control terminal 37. Safe Torque Off disables the control voltage of the power semiconductors of the adjustable frequency drive output stage which in turn prevents generating the voltage required to rotate the motor. When the Safe Torque Off (T37) is activated, the adjustable frequency drive issues an alarm, trips the unit, and coasts the motor to a stop. Manual restart is required. The Safe Torque Off function can be used for stopping the adjustable frequency drive in emergency stop situations. In the normal operating mode when Safe Torque Off is not required, use the adjustable frequency drive’s regular stop function instead. When automatic restart is used – the requirements according to ISO 12100-2 paragraph 5.3.2.5 must be fulfilled.

  

**Liability Conditions**
It is the user's responsibility to ensure that personnel installing and operating the Safe Torque Off function:

- Read and understand the safety regulations concerning health and safety/accident prevention
- Understand the generic and safety guidelines given in this description and the extended description in the *Design Guide*
- Have a good knowledge of the generic and safety standards applicable to the specific application

**Standards**
Use of Safe Torque Off on terminal 37 requires that the user satisfies all provisions for safety including relevant laws, regulations and guidelines. The optional Safe Torque Off function complies with the following standards.

IEC 60204-1: 2005 category 0 – uncontrolled stop

IEC 61508: 1998 SIL2

IEC 61800-5-2: 2007 – safe torque off (STO) function

IEC 62061: 2005 SIL CL2

ISO 13849-1: 2006 Category 3 PL d

ISO 14118: 2000 (EN 1037) – prevention of unexpected startup

The information and instructions of the *Instruction Manual* are not sufficient for a proper and safe use of the Safe Torque Off functionality. The related information and instructions in the relevant *Design Guide* must be followed.

**Protective Measures**

- Safety engineering systems may only be installed and commissioned by qualified and skilled personnel
- The unit must be installed in an IP54 cabinet or in an equivalent environment. In special applications, a higher IP degree may be necessary
- The cable between terminal 37 and the external safety device must be short-circuit-protected according to ISO 13849-2 table D.4
- If any external forces influence the motor axis (e.g., suspended loads), additional measures (e.g., a safety holding brake) are required to eliminate hazards.

**Safe Torque Off Installation and Set-up**

**⚠WARNING**

**SAFE TORQUE OFF FUNCTION!**

**The Safe Torque Off function does NOT isolate AC line voltage to the adjustable frequency drive or auxiliary circuits. Perform work on electrical parts of the adjustable frequency drive or the motor only after isolating the AC line voltage supply and waiting the length of time specified under Safety in this manual. Failure to isolate the AC line voltage supply from the unit and waiting the time specified could result in death or serious injury.**

- It is not recommended to stop the adjustable frequency drive by using the Safe Torque Off function. If a running adjustable frequency drive is stopped by using the function, the unit trips and stops by coasting. If this is not acceptable, e.g., causes danger, the adjustable frequency drive and machinery must be stopped using the appropriate stopping mode before using this function. Depending on the application, a mechanical brake may be required.
- Concerning synchronous and permanent magnet motor adjustable frequency drives in case of a multiple IGBT power semiconductor failure: In spite of the activation of the Safe Torque Off function, the adjustable frequency drive system can produce an alignment torque which maximally rotates the motor shaft by 180/p degrees. p denotes the pole pair number.
- This function is suitable for performing mechanical work on the adjustable frequency drive system or affected area of a machine only. It does not provide electrical safety. This function should not be used as a control for starting and/or stopping the adjustable frequency drive.

Meet the following requirements to perform a safe installation of the adjustable frequency drive:

1. Remove the jumper wire between control terminals 37 and 12 or 13. Cutting or breaking the jumper is not sufficient to avoid short-circuiting. (See jumper on *Figure 2.1*.)
2. Connect an external safety monitoring relay via a NO safety function (the instruction for the safety device must be followed) to terminal 37 (Safe Torque Off) and either terminal 12 or 13 (24 V DC). The Safety monitoring relay must comply with Category 3/PL "d" (ISO 13849-1) or SIL 2 (EN 62061).

  

2

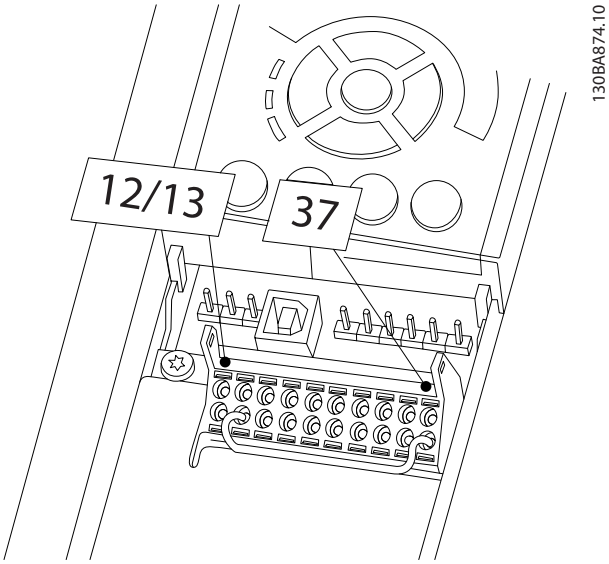


**Figure 2.1 Jumper between Terminal 12/13 (24 V) and 37**

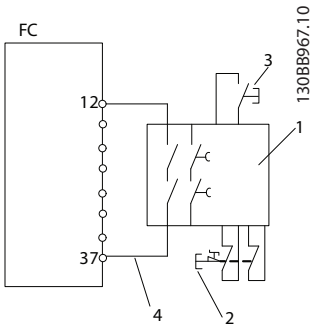


**Figure 2.2 Installation to Achieve a Stopping Category 0 (EN 60204-1) with Safety Cat. 3/PL "d" (ISO 13849-1) or SIL 2 (EN 62061).**

| | |
|---|---|
| 1 | Safety relay (cat. 3, PL d or SIL2 |
| 2 | Emergency stop button |
| 3 | Reset button |
| 4 | Short-circuit protected cable (if not inside installation IP54 cabinet) |

**Table 2.3 Legend to *Figure 2.2***

**Safe Torque Off Commissioning Test**
After installation and before first operation, perform a commissioning test of the installation making use of Safe Torque Off. Also, perform the test after each modification of the installation.

**Example with STO**
A safety relay evaluates the E-Stop button signals and triggers an STO function on the adjustable frequency drive in the event of an activation of the E-Stop button (See *Figure 2.3*). This safety function corresponds to a category 0 stop (uncontrolled stop) in accordance with IEC 60204-1. If the function is triggered during operation, the motor runs down in an uncontrolled manner. The power to the motor is safely removed, so that no further movement is possible. It is not necessary to monitor plant at a standstill. If an external force effect is to be anticipated, provide additional measures to safely prevent any potential movement (e.g., mechanical brakes).

***NOTICE!***

**For all applications with Safe Torque Off, it is important that short circuit in the wiring to T37 can be excluded. This can be done as described in EN ISO 13849-2 D4 by the use of protected wiring, (shielded or segregated).**

**Example with SS1**
SS1 correspond to a controlled stop, stop category 1 according to IEC 60204-1 (see *Figure 2.4*). When activating the safety function, a normal controlled stop is performed. This can be activated through terminal 27. After the safe delay time has expired on the external safety module, the STO is triggered and terminal 37 is set low. Ramp-down is performed as configured in the adjustable frequency drive. If the adjustable frequency drive is not stopped after the safe delay time, the activation of STO coasts the adjustable frequency drive.

***NOTICE!***

**When using the SS1 function, the brake ramp of the adjustable frequency drive is not monitored with respect to safety.**

**Example with Category 4/PL e application**
Where the safety control system design requires two channels for the STO function to achieve Category 4/PL e, one channel can be implemented by Safe Torque Off T37 (STO) and the other by a contactor which may be connected in either the adjustable frequency drive input or output power circuits and controlled by the safety relay (see *Figure 2.5*). The contactor must be monitored through an auxiliary guided contact and connected to the reset input of the safety relay.

  

**Paralleling of Safe Torque Off inputs via one safety relay**
Safe Torque Off inputs T37 (STO) may be connected directly if the situation is required to control multiple adjustable frequency drives from the same control line via one safety relay (see *Figure 2.6*). Connecting inputs increases the probability of a fault in the unsafe direction, since a fault in one adjustable frequency drive might result in all adjustable frequency drives becoming enabled. The probability of a fault for T37 is so low, that the resulting probability still meets the requirements for SIL2.

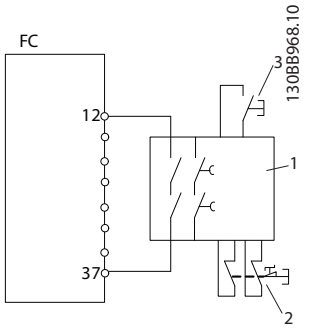


**Figure 2.3 STO Example**

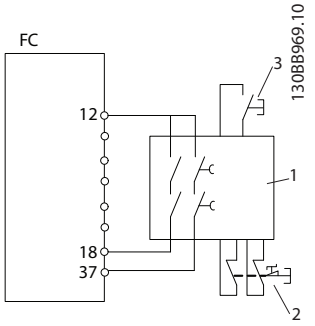


**Figure 2.4 SS1 Example**

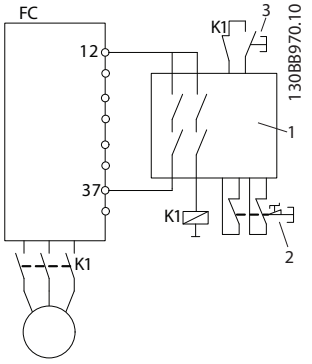


**Figure 2.5 STO Category 4 Example**

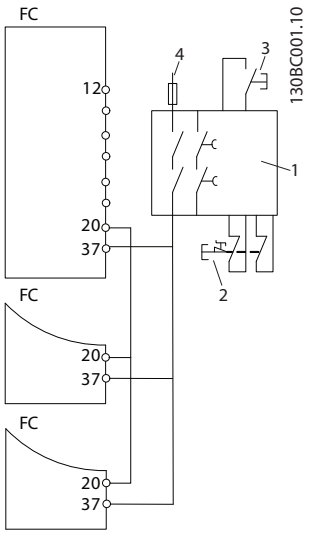


**Figure 2.6 Paralleling of Multiple Adjustable Frequency Drives Example**

| | |
|---|---|
| 1 | Safety relay |
| 2 | Emergency stop button |
| 3 | Reset button |
| 4 | 24 V DC |

**Table 2.4 Legend to *Figure 2.3* to *Figure 2.6***

**⚠WARNING**

**Safe Torque Off activation (i.e., removal of 24 V DC voltage supply to terminal 37) does not provide electrical safety. The Safe Torque Off function itself is therefore not sufficient to implement the Emergency Off function as defined by EN 60204-1. Emergency Off requires measures of electrical isolation, e.g., by switching off line power via an additional contactor.**

1. Activate the Safe Torque Off function by removing the 24 V DC voltage supply to the terminal 37.
2. After activation of Safe Torque Off (i.e., after the response time), the adjustable frequency drive coasts (stops creating a rotational field in the motor). The response time is typically shorter than 10 ms for the complete performance range of the adjustable frequency drive.

  

2

The adjustable frequency drive is guaranteed not to restart creation of a rotational field by an internal fault (in accordance with Cat. 3 PL d acc. EN ISO 13849-1 and SIL 2 acc. EN 62061). After activation of Safe Torque Off, the adjustable frequency drive display shows the text Safe Torque Off activated. The associated help text says "Safe Torque Off has been activated". This means that the Safe Torque Off has been activated, or that normal operation has not been resumed yet after Safe Torque Off activation.

***NOTICE!***

**The requirements of Cat. 3/PL "d" (ISO 13849-1) are only fulfilled while 24 V DC supply to terminal 37 is kept removed or low by a safety device, which itself fulfills Cat. 3/PL "d" (ISO 13849-1). If external forces act on the motor, e.g., in case of vertical axis (suspended loads) - and an unwanted movement, for example caused by gravity, could cause a hazard, the motor must not be operated without additional measures for fall protection. For example, mechanical brakes must be installed additionally.**

To resume operation after activation of Safe Torque Off, first reapply 24 V DC voltage to terminal 37 (text Safe Torque Off activated is still displayed), then create a reset signal (via bus, Digital I/O, or [Reset] key on inverter).

By default, the Safe Torque Off functions is set to an Unintended Restart Prevention behavior. This means, in order to terminate Safe Torque Off and resume normal operation, the 24 V DC must first be reapplied to Terminal 37. Subsequently, send a reset signal (via Bus, Digital I/O, or [Reset] key).

The Safe Torque Off function can be set to an Automatic Restart Behavior by setting the value of *5-19 Terminal 37 Safe Stop* from default value [1] to value [3]. If a MCB 112 Option is connected to the adjustable frequency drive, then Automatic Restart Behavior is set by values [7] and [8].
Automatic Restart means that Safe Torque Off is terminated and normal operation is resumed as soon as the 24 V DC is applied to Terminal 37, and no reset signal is required.

**⚠WARNING**

**Automatic Restart Behavior is only allowed in one of the two situations:**

1. **The Unintended Restart Prevention is implemented by other parts of the Safe Torque Off installation.**
2. **A presence in the dangerous zone can be physically excluded when Safe Torque Off is not activated. In particular, paragraph 5.3.2.5 of ISO 12100-2 2003 must be observed.**

### 2.6.2 Installation of External Safety Device in Combination with MCB 112

If the ex-certified thermistor module MCB 112, which uses Terminal 37 as its safety-related switch-off channel, is connected, then the output X44/12 of MCB 112 must be AND-ed with the safety-related sensor (such as emergency stop button, safety-guard switch, etc.) that activates Safe Torque Off. This means that the output to Safe Torque Off terminal 37 is HIGH (24 V) only if both the signal from MCB 112 output X44/12 and the signal from the safety-related sensor are HIGH. If at least one of the two signals is LOW, the output to Terminal 37 must be LOW, too. The safety device with this AND logic itself must conform to IEC 61508, SIL 2. The connection from the output of the safety device with safe AND logic to Safe Torque Off terminal 37 must be short-circuit protected. See *Figure 2.7*.

  

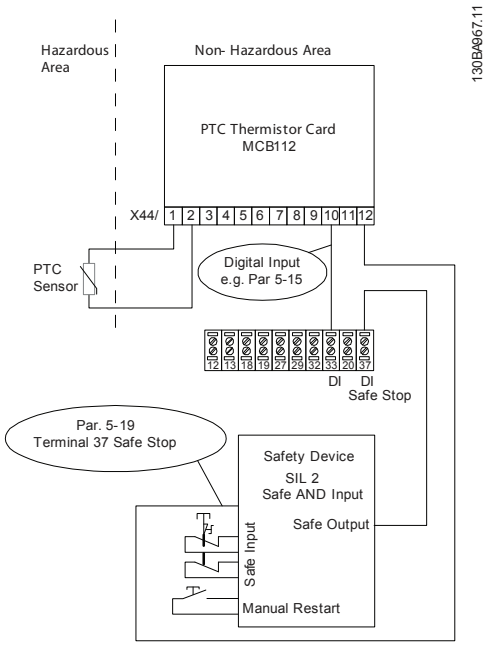


**Figure 2.7 Figure of the essential aspects for installing a combination of a Safe Torque Off application and an MCB 112 application. The diagram shows a Restart input for the external Safety Device. This means that in this installation, *5-19 Terminal 37 Safe Stop* might be set to value *[7] PTC 1 & Relay W* or [8] *[8] PTC 1 & Relay A/W*. Refer to *MCB 112 Instruction Manual* for further details.**

**Parameter settings for external safety device in combination with MCB112**

If MCB 112 is connected, then additional selections (*[4] PTC 1 Alarm* to *[9] PTC 1 & Relay W/A*) become possible for *5-19 Terminal 37 Safe Stop*. Selections *[1] Safe Torque Off Alarm* and *[3] Safe Torque Off Warning* are still available but are not to be used as these are for installations without MCB 112 or any external safety devices. If *[1] Safe Torque Off Alarm* or *[3] Safe Torque Off Warning* should be selected by mistake and MCB 112 is triggered, then the adjustable frequency drive reacts with an alarm "Dangerous Failure [A72]" and coasts the adjustable frequency drive safely, without Automatic Restart. Selections *[4] PTC 1 Alarm* and *[5] PTC 1 Warning* are not to be selected when an external safety device is used. These selections are for when only MCB 112 uses the Safe Torque Off. If selection *[4] PTC 1 Alarm* or *[5] PTC 1 Warning* is selected by mistake and the external safety device triggers Safe Torque Off, the adjustable frequency drive issues an alarm "Dangerous Failure [A72]" and coasts the adjustable frequency drive safely, without Automatic Restart.

Selections *[6] PTC 1 & Relay A* to *[9] PTC 1 & Relay W/A* must be selected for the combination of external safety device and MCB 112.

***NOTICE!***

**Note that selections *[7] PTC 1 & Relay W* and *[8] PTC 1 & Relay A/W* open up for automatic restart when the external safety device is de-activated again.**

This is only allowed in the following cases:

- The unintended restart prevention is implemented by other parts of the Safe Torque Off installation.
- A presence in the dangerous zone can be physically excluded when Safe Torque Off is not activated. In particular, paragraph 5.3.2.5 of ISO 12100-2 2003 must be observed.

See *MCB 112 Instruction Manual* for further information.

## 2.6.3 Safe Torque Off Commissioning Test

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

***NOTICE!***

**A passed commissioning test is mandatory after first installation and after each change to the safety installation.**

**The commissioning test (select one of cases 1 or 2 as applicable):**

**Case 1: Restart prevention for Safe Torque Off is required (i.e., Safe Torque Off only where *5-19 Terminal 37 Safe Stop* is set to default value [1], or combined Safe Torque Off and MCB112 where *5-19 Terminal 37 Safe Stop* is set to [6] or [9]):**

1.1 Remove the 24 V DC voltage supply to terminal 37 using the interrupt device while the motor is driven by the FC 102 (i.e., the 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, and if an LCP is mounted, the alarm "Safe Torque Off [A68]" is displayed.

  

2

1.2 Send reset signal (via Bus, Digital I/O, or [Reset] key). The test step is passed if the motor remains in the Safe Torque Off state, and the mechanical brake (if connected) remains activated.

1.3 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.

1.4 Send reset signal (via Bus, Digital I/O, or [Reset] key). The test step is passed if the motor becomes operational again.

The commissioning test is passed if all four test steps 1.1, 1.2, 1.3 and 1.4 are passed.

**Case 2: Automatic Restart of Safe Torque Off is wanted and allowed (i.e., Safe Torque Off only where *5-19 Terminal 37 Safe Stop* is set to [3], or combined Safe Torque Off and MCB112 where *5-19 Terminal 37 Safe Stop* is set to [7] or [8]):**

2.1 Remove the 24 V DC voltage supply to terminal 37 by the interrupt device while the motor is driven by the FC 102 (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, and if an LCP is mounted, the warning "Safe Torque Off [W68]" is displayed.

2.2 Reapply 24 V DC to terminal 37.

The test step is passed if the motor becomes operational again. The commissioning test is passed if both test steps 2.1 and 2.2 are passed.

***NOTICE!***

**See warning on the restart behavior in *chapter 2.6.1 Terminal 37 Safe Torque Off Function*.**

## 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 and figure *The Laws of Proportionality*.

### 2.7.2 The Clear Advantage - Energy Savings

The 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.

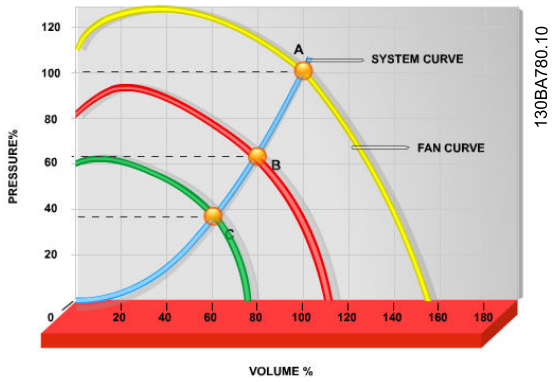


**Figure 2.8 Fan Curves (A, B and C) for Reduced Fan Volumes**

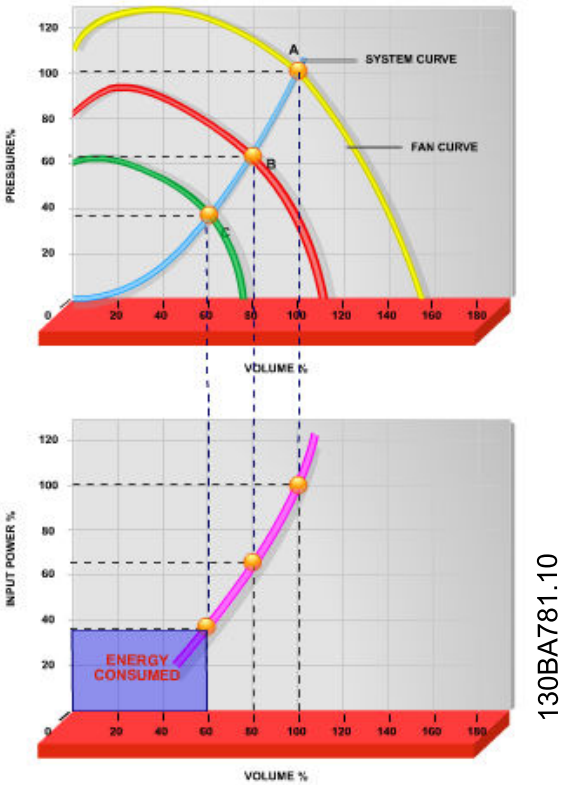


**Figure 2.9 When Using an Adjustable Frequency Drive to Reduce Fan Capacity to 60% - More Than 50% Energy Savings may Be Obtained in Typical Applications.**

## 2.7.3 Example of Energy Savings

As shown in 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** | |
|---|---|
| *Figure 2.10* describes the dependence of flow, pressure and power consumption on RPM. | |
| Q = Flow | P = Power |
| $Q_1$ = Rated flow | $P_1$ = Rated power |
| $Q_2$ = Reduced flow | $P_2$ = Reduced power |
| H = Pressure | n = Speed regulation |
| $H_1$ = Rated pressure | $n_1$ = Rated speed |
| $H_2$ = Reduced pressure | $n_2$ = Reduced speed |

**Table 2.5 Abbreviations Used in Equation**

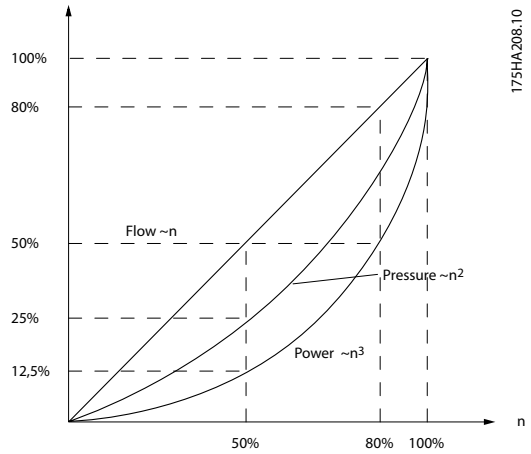


**Figure 2.10 The Dependence of Flow, Pressure and Power Consumption on RPM**

$$Flow: \frac{Q1}{Q2} = \frac{n1}{n2}$$

$$Pressure: \frac{H1}{H2} = \left(\frac{n1}{n2}\right)^2$$

$$Power: \frac{P1}{P2} = \left(\frac{n1}{n2}\right)^3$$

## 2.7.4 Comparison of Energy Savings

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

*Figure 2.12* shows typical energy savings obtainable with three well-known solutions when fan volume is reduced to, e.g., 60%.
*Figure 2.12* shows more than 50% energy savings can be achieved in typical applications.

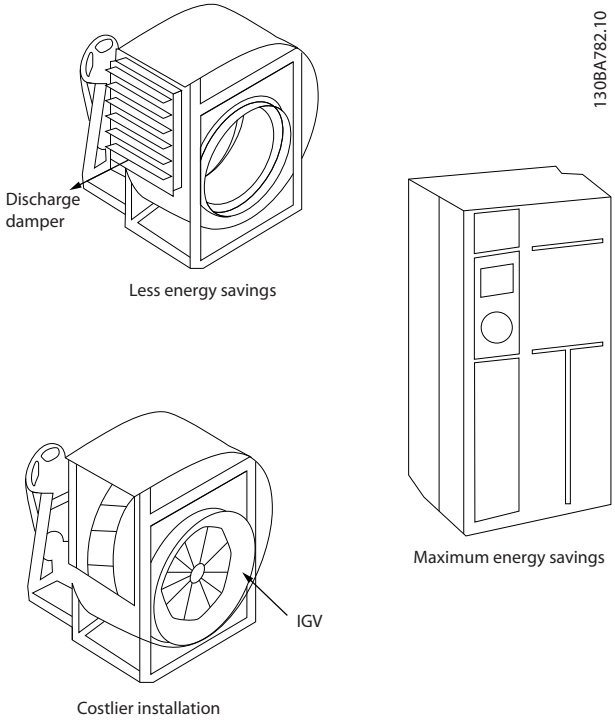


**Figure 2.11 The Three Common Energy Saving Systems**

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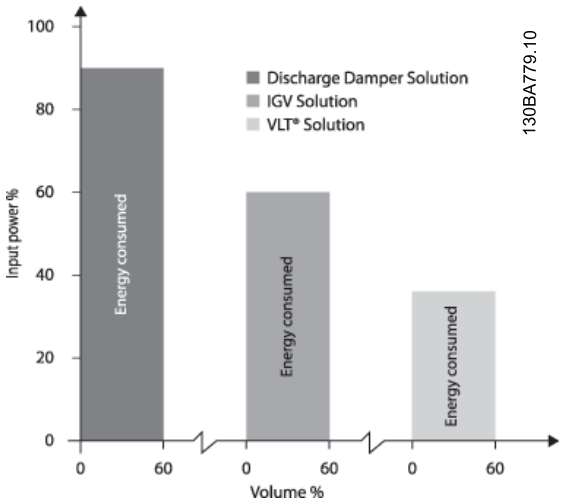



**Figure 2.12 Discharge dampers reduce power consumption somewhat. Inlet guide vans offer a 40% reduction but are expensive to install. The Danfoss adjustable frequency drive solution reduces energy consumption with more than 50% and is easy to install.**

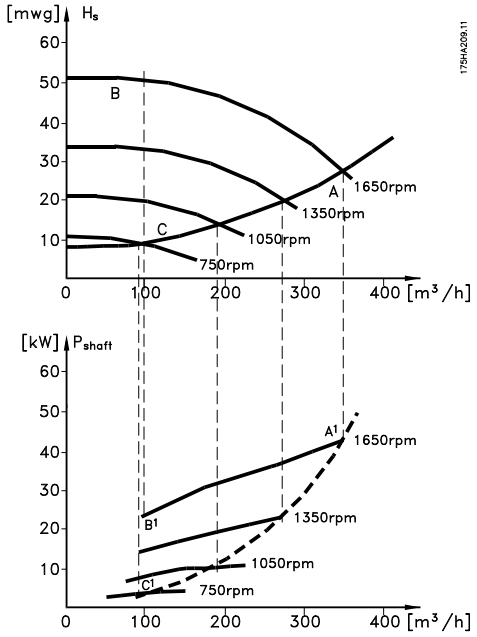



**Figure 2.13 Example with Varying Flow**

## 2.7.5 Example with Varying Flow over 1 Year

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

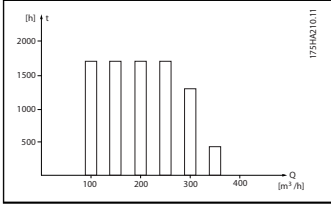
| Flow distribution over 1 year |
|---|
| $P_{shaft}$=$P_{shaft\ output}$ |
|  |

**Table 2.6 Energy Savings**

| $m^3$/h | Distribution | | Valve regulation | | Adjustable frequency drive control | |
|---|---|---|---|---|---|---|
| | % | Hours | Power | Consumption | Power | Consumption |
| | | | $A_1$–$B_1$ | kWh | $A_1$–$C_1$ | kWh |
| 350 | 5 | 438 | 42.5 | 18.615 | 42.5 | 18.615 |
| 300 | 15 | 1314 | 38.5 | 50.589 | 29.0 | 38.106 |
| 250 | 20 | 1752 | 35.0 | 61.320 | 18.5 | 32.412 |
| 200 | 20 | 1752 | 31.5 | 55.188 | 11.5 | 20.148 |
| 150 | 20 | 1752 | 28.0 | 49.056 | 6.5 | 11.388 |
| 100 | 20 | 1752 | 23.0 | 40.296 | 3.5 | 6.132 |
| Σ | 100 | 8760 | | 275.064 | | 26.801 |

**Table 2.7 Consumption**

## 2.7.6 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.

## 2.7.7 Cos φ Compensation

Generally speaking, the VLT® HVAC Drive has a cos φ of 1 and provides power factor correction for the cos φ of the motor, which means that there is no need to make allowance for the cos φ of the motor when sizing the power factor correction unit.

## 2.7.8 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.

As illustrated in *Figure 2.14*, an adjustable frequency drive does not consume more than rated current.

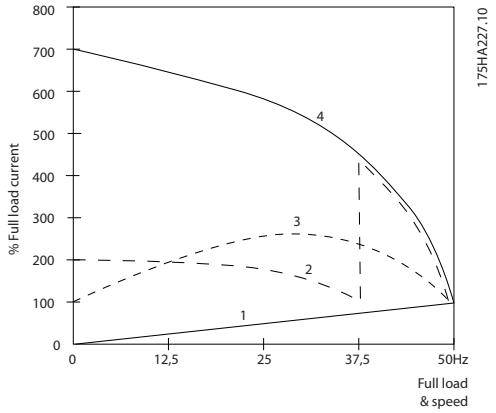



**Figure 2.14 An Adjustable Frequency Drive Does Not Consume More Than Rated Current**

| |
|---|
| 1 VLT® HVAC Drive |
| 2 Star/delta starter |
| 3 Soft-starter |
| 4 Start directly on line power |

**Table 2.8 Legend to *Figure 2.14***

2

## 2.7.9 Using an Adjustable Frequency Drive Saves Money

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

## 2.7.10 Without an Adjustable Frequency Drive

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

**Table 2.9 Abbreviations used in *Figure 2.15* and *Figure 2.16***

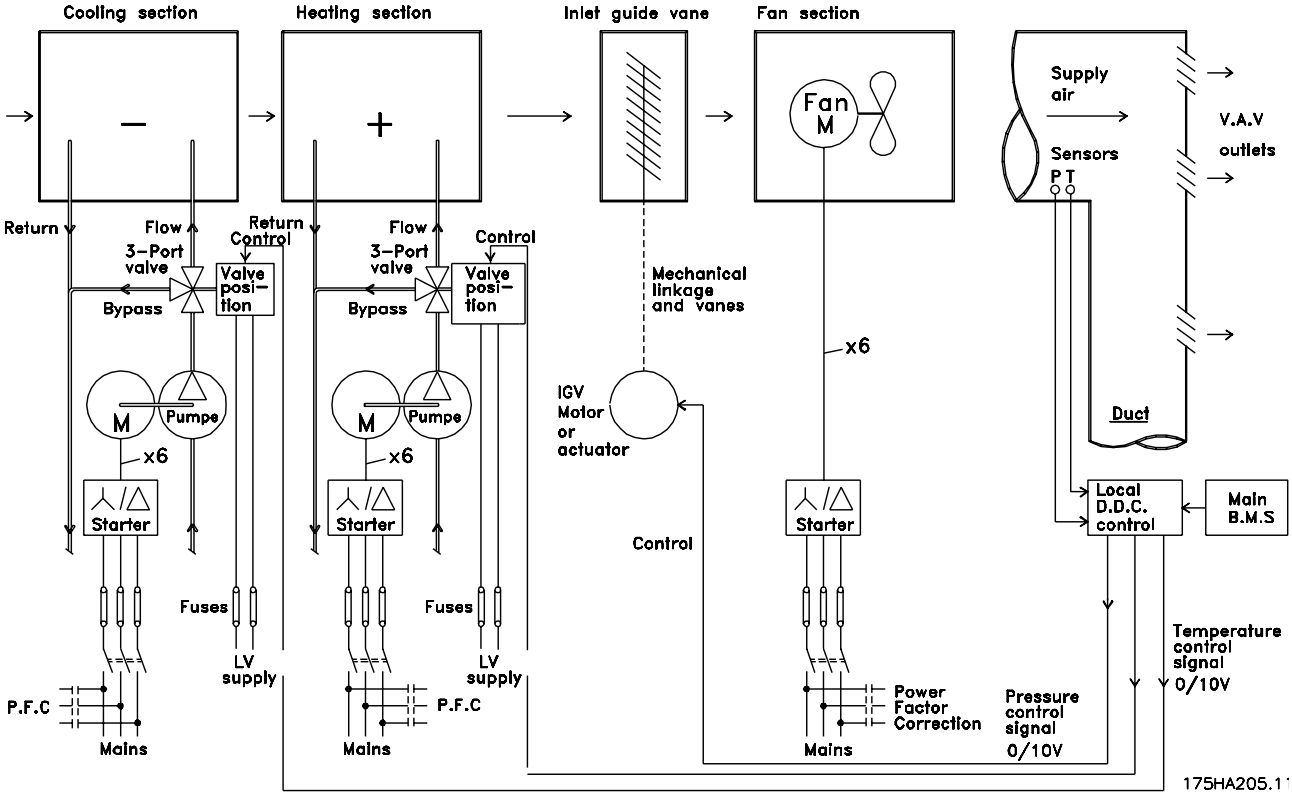



**Figure 2.15 Traditional Fan System**

## 2.7.11 With an Adjustable Frequency Drive

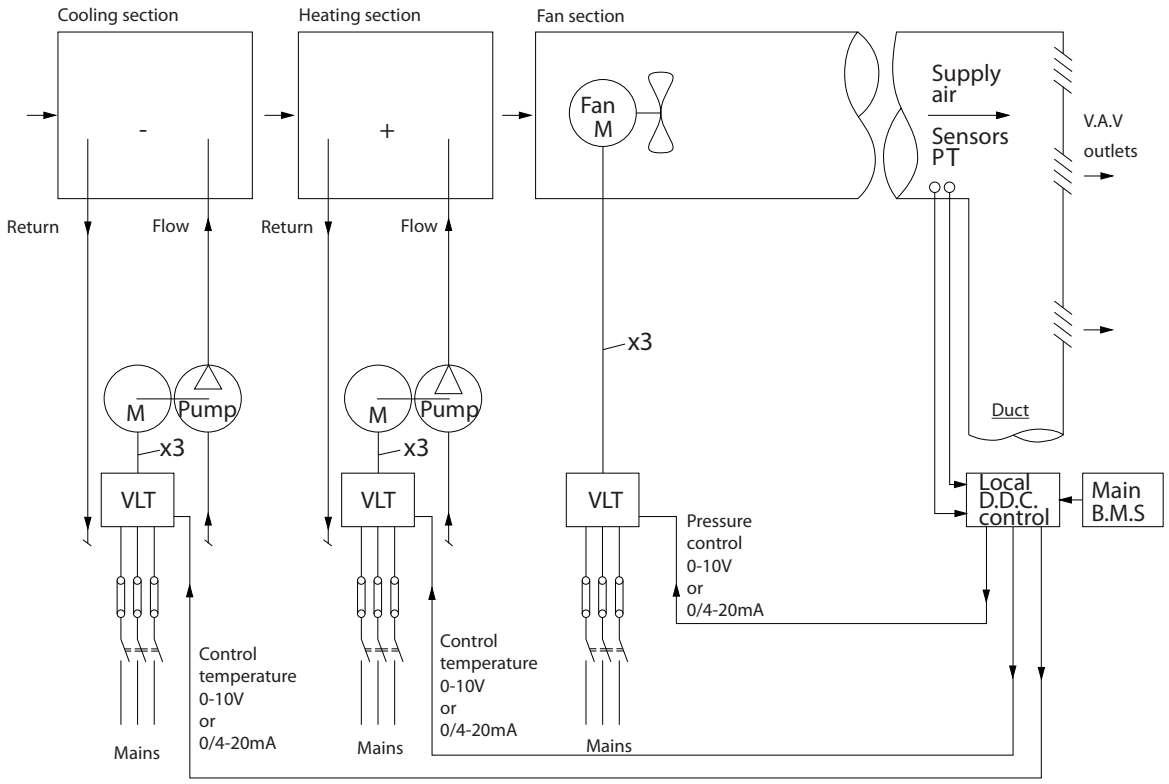



**Figure 2.16 Fan System Controlled by Adjustable Frequency Drives.**

## 2.7.12 Application Examples

The following pages give typical examples of applications within HVAC.
For further information about a given application, ask a Danfoss supplier for an information sheet that gives a full description of the application.

Variable Air Volume

*Ask for The Drive to...Improving Variable Air Volume Ventilation Systems MN.60.A1.02*

Constant Air Volume

*Ask for The Drive to...Improving Constant Air Volume Ventilation Systems MN.60.B1.02*

Cooling Tower Fan

*Ask for The Drive to...Improving fan control on cooling towers MN.60.C1.02*

Condenser pumps

*Ask for The Drive to...Improving condenser water pumping systems MN.60.F1.02*

Primary pumps

*Ask for The Drive to...Improve your primary pumping in primary/secondary pumping systems MN.60.D1.02*

Secondary pumps

*Ask for The Drive to...Improve your secondary pumping in primary/secondary pumping systems MN.60.E1.02*

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## 2.7.13 Variable Air Volume

VAV or Variable Air Volume systems, are used to control both the ventilation and temperature to satisfy the requirements of a building. Central VAV systems are considered to be the most energy efficient method to air condition buildings. By designing central systems instead of distributed systems, greater efficiency can be obtained.
The efficiency comes from utilizing larger fans and larger chillers which have much higher efficiencies than small motors and distributed air-cooled chillers. Savings are also a result of decreased maintenance requirements.

## 2.7.14 The VLT Solution

While dampers and IGVs work to maintain a constant pressure in the ductwork, a solution saves much more energy and reduces the complexity of the installation. Instead of creating an artificial pressure drop or causing a decrease in fan efficiency, the decreases the speed of the fan to provide the flow and pressure required by the system.
Centrifugal devices such as fans behave according to the centrifugal laws. This means the fans decrease the pressure and flow they produce as their speed is reduced. Their power consumption is thereby significantly reduced.
The return fan is frequently controlled to maintain a fixed difference in airflow between the supply and return. The advanced PID controller of the HVAC can be used to eliminate the need for additional controllers.

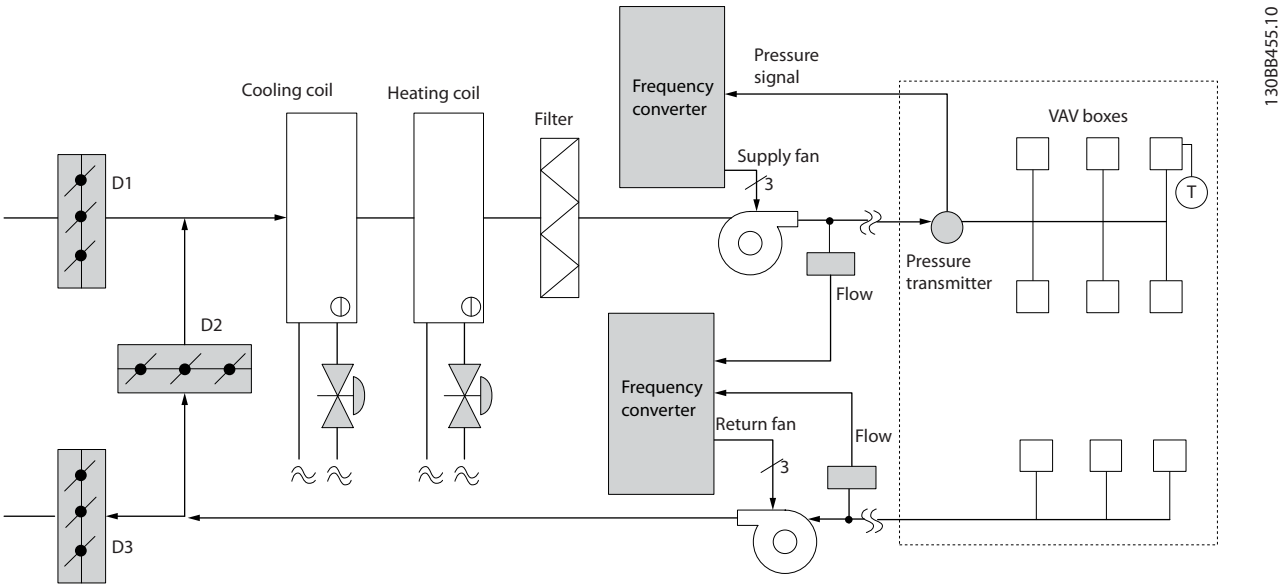


**Figure 2.17 The VLT Solution**

## 2.7.15 Constant Air Volume

CAV, or Constant Air Volume systems, are central ventilation systems usually used to supply large common zones with the minimum amounts of fresh tempered air. They preceded VAV systems and therefore are found in older, multi-zoned commercial buildings as well. These systems preheat amounts of fresh air utilizing Air Handling Units (AHUs) with a heating coil, and many are also used to air condition buildings and have a cooling coil. Fan coil units are frequently used to assist in the heating and cooling requirements in the individual zones.

## 2.7.16 The VLT Solution

With an adjustable frequency drive, significant energy savings can be obtained while maintaining decent control of the building. Temperature sensors or $CO_2$ sensors can be used as feedback signals to adjustable frequency drives. Whether controlling temperature, air quality, or both, a CAV system can be controlled to operate based on actual building conditions. As the number of people in the controlled area decreases, the need for fresh air decreases. The $CO_2$ sensor detects lower levels and decreases the supply fans speed. The return fan modulates to maintain a static pressure setpoint or fixed difference between the supply and return air flows.

With temperature control (especially used in air conditioning systems), as the outside temperature varies and the number of people in the controlled zone changes, different cooling requirements arise. As the temperature decreases below the setpoint, the supply fan can decrease its speed. The return fan modulates to maintain a static pressure setpoint. By decreasing the air flow, energy used to heat or cool the fresh air is also reduced, adding further savings.
Several features of the Danfoss HVAC dedicated adjustable frequency drive can be utilized to improve the performance of a CAV system. One concern of controlling a ventilation system is poor air quality. The programmable minimum frequency can be set to maintain a minimum amount of supply air, regardless of the feedback or reference signal. The adjustable frequency drive also includes a 3-zone, 3-setpoint PID controller which allows monitoring of both temperature and air quality. Even if the temperature requirement is satisfied, the adjustable frequency drive will maintain enough supply air to satisfy the air quality sensor. The adjustable frequency drive is capable of monitoring and comparing two feedback signals to control the return fan by maintaining a fixed differential air flow between the supply and return ducts as well.

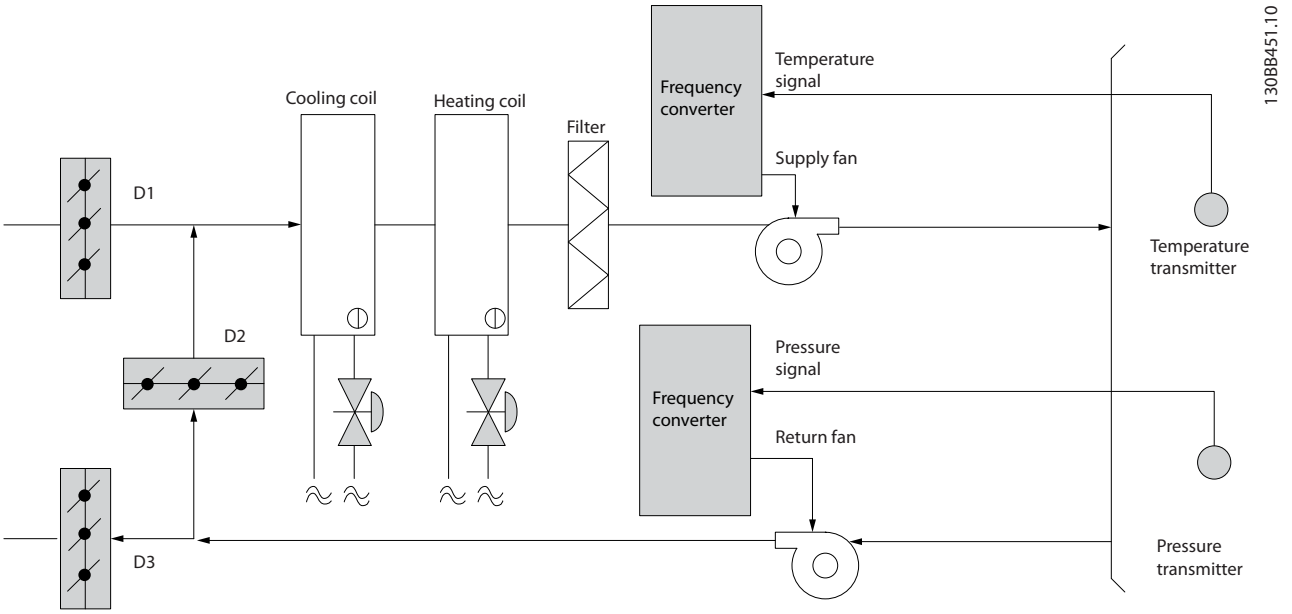


**Figure 2.18 The VLT Solution**

  

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## 2.7.17 Cooling Tower Fan

Cooling tower fans are used to cool condenser water in water-cooled chiller systems. Water-cooled chillers provide the most efficient means of creating chilled water. They are as much as 20% more efficient than air-cooled chillers. Depending on climate, cooling towers are often the most energy efficient method of cooling the condenser water from chillers.
They cool the condenser water by evaporation.
The condenser water is sprayed into the cooling tower, onto the cooling tower's “fill” to increase its surface area. The tower fan blows air through the fill and sprayed water to aid in the evaporation. Evaporation removes energy from the water, thus dropping its temperature. The cooled water collects in the cooling towers basin, where it is pumped back into the chiller's condenser, and the cycle is then repeated.

## 2.7.18 The VLT Solution

With an adjustable frequency drive, the cooling towers fans can be set to the speed required to maintain the condenser water temperature. The adjustable frequency drives can also be used to turn the fan on and off as needed.

Several features of the Danfoss HVAC dedicated adjustable frequency drive, the HVAC adjustable frequency drive can be utilized to improve the performance of a cooling tower fans application. As the cooling tower fans drop below a certain speed, the effect the fan has on cooling the water becomes insignificant. Also, when utilizing a gear box to frequency control the tower fan, a minimum speed of 40–50% may be required.
The customer programmable minimum frequency setting is available to maintain this minimum frequency even as the feedback or speed reference calls for lower speeds.

Also as a standard feature, program the adjustable frequency drive to enter a “sleep” mode and stop the fan until a higher speed is required. Additionally, some cooling tower fans have undesirable frequencies that may cause vibrations. These frequencies can easily be avoided by programming the bypass frequency ranges in the adjustable frequency drive.

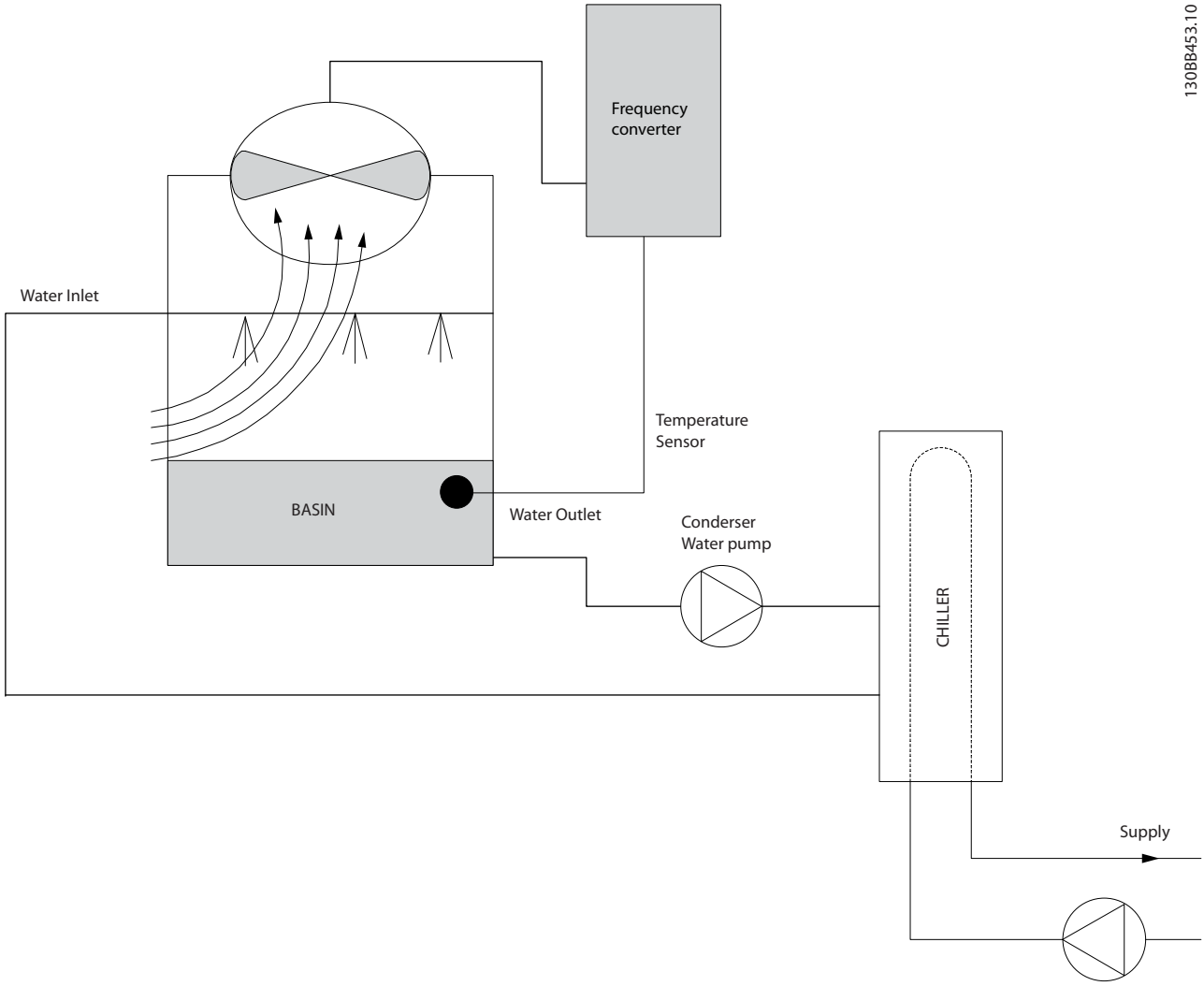


**Figure 2.19 The VLT Solution**

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## 2.7.19 Condenser Pumps

Condenser water pumps are primarily used to circulate water through the condenser section of water cooled chillers and their associated cooling tower. The condenser water absorbs the heat from the chiller's condenser section and releases it into the atmosphere in the cooling tower. These systems are used to provide the most efficient means of creating chilled water, and they are as much as 20% more efficient than air cooled chillers.

## 2.7.20 The VLT Solution

Adjustable frequency drives can be added to condenser water pumps instead of balancing the pumps with a throttling valve or trimming the pump impeller.

Using an adjustable frequency drive instead of a throttling valve simply saves the energy that would have been absorbed by the valve. This can amount to savings of 15–20% or more. Trimming the pump impeller is irreversible, thus if the conditions change and higher flow is required the impeller must be replaced.

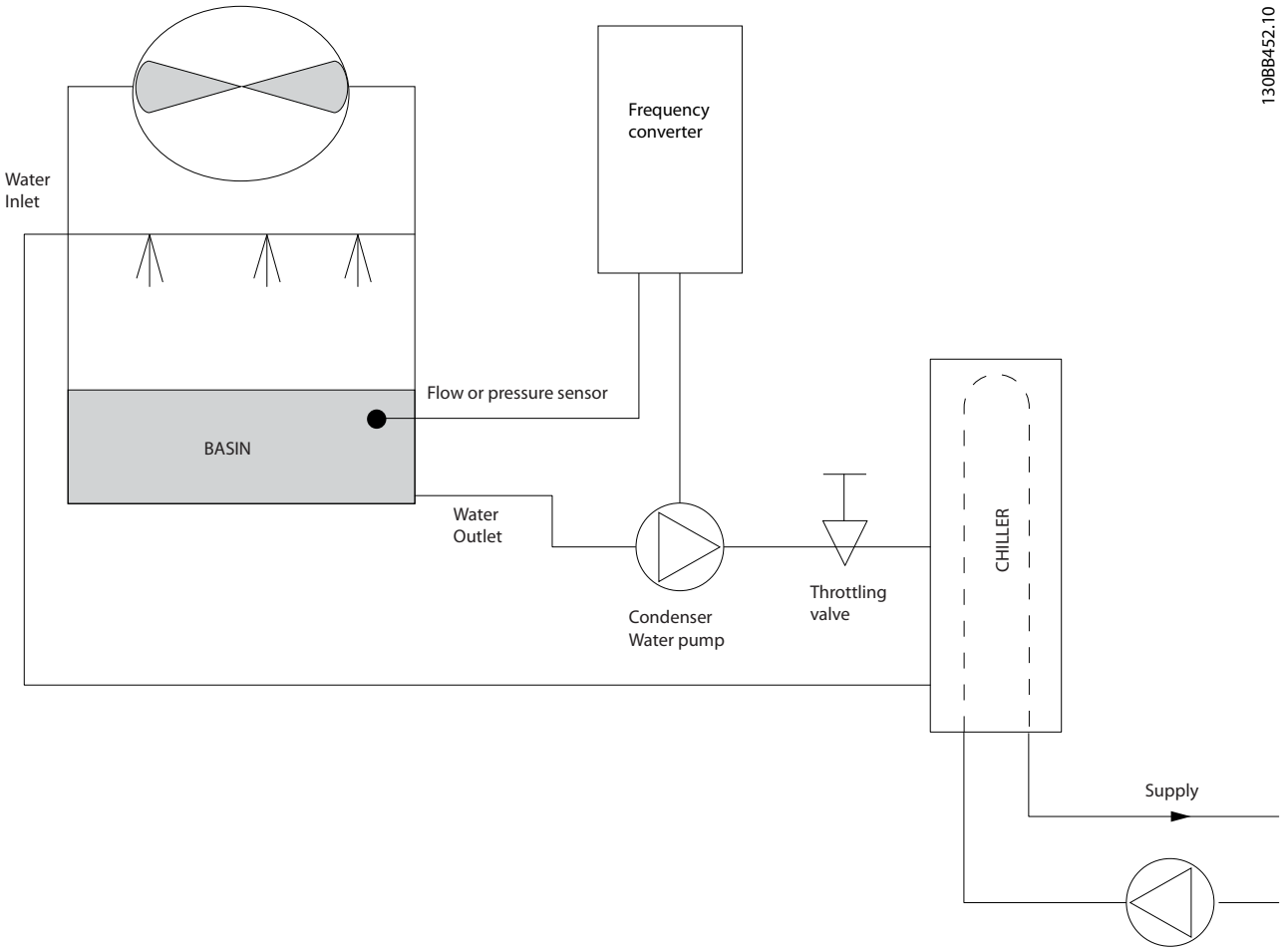


**Figure 2.20 The VLT Solution**

## 2.7.21 Primary Pumps

Primary pumps in a primary/secondary pumping system can be used to maintain a constant flow through devices that encounter operation or control difficulties when exposed to variable flow. The primary/secondary pumping technique decouples the “primary” production loop from the “secondary” distribution loop. This allows devices such as chillers to obtain constant design flow and operate properly, while allowing the rest of the system to vary in flow.

As the evaporator flow rate decreases in a chiller, the chilled water begins to become overly chilled. As this happens, the chiller attempts to decrease its cooling capacity. If the flow rate drops far enough, or too quickly, the chiller cannot shed its load sufficiently and the chiller’s low evaporator temperature safety trips the chiller, requiring a manual reset. This situation is common in large installations especially when two or more chillers are installed in parallel, if primary/secondary pumping is not utilized.

## 2.7.22 The VLT Solution

Depending on the size of the system and the size of the primary loop, the energy consumption of the primary loop can become substantial.
An adjustable frequency drive can be added to the primary system, to replace the throttling valve and/or trimming of the impellers, leading to reduced operating expenses. Two control methods are common:

The first method uses a flow meter. Because the desired flow rate is known and constant, a flow meter installed at the discharge of each chiller can be used to control the pump directly. Using the built-in PID controller, the adjustable frequency drive always maintains the appropriate flow rate, even compensating for the changing resistance in the primary piping loop as chillers and their pumps are staged on and off.

The other method is local speed determination. The operator simply decreases the output frequency until the design flow rate is achieved.
Using an adjustable frequency drive to decrease the pump speed is very similar to trimming the pump impeller, except it does not require any labor and the pump efficiency remains higher. The balancing contractor simply decreases the speed of the pump until the proper flow rate is achieved and leaves the speed fixed. The pump operates at this speed any time the chiller is staged on. Because the primary loop does not have control valves or other devices that can cause the system curve to change, and the variance due to staging pumps and chillers on and off is usually small, this fixed speed remains appropriate. In the event the flow rate needs to be increased later in the systems life, the adjustable frequency drive can simply increase the pump speed instead of requiring a new pump impeller.

  

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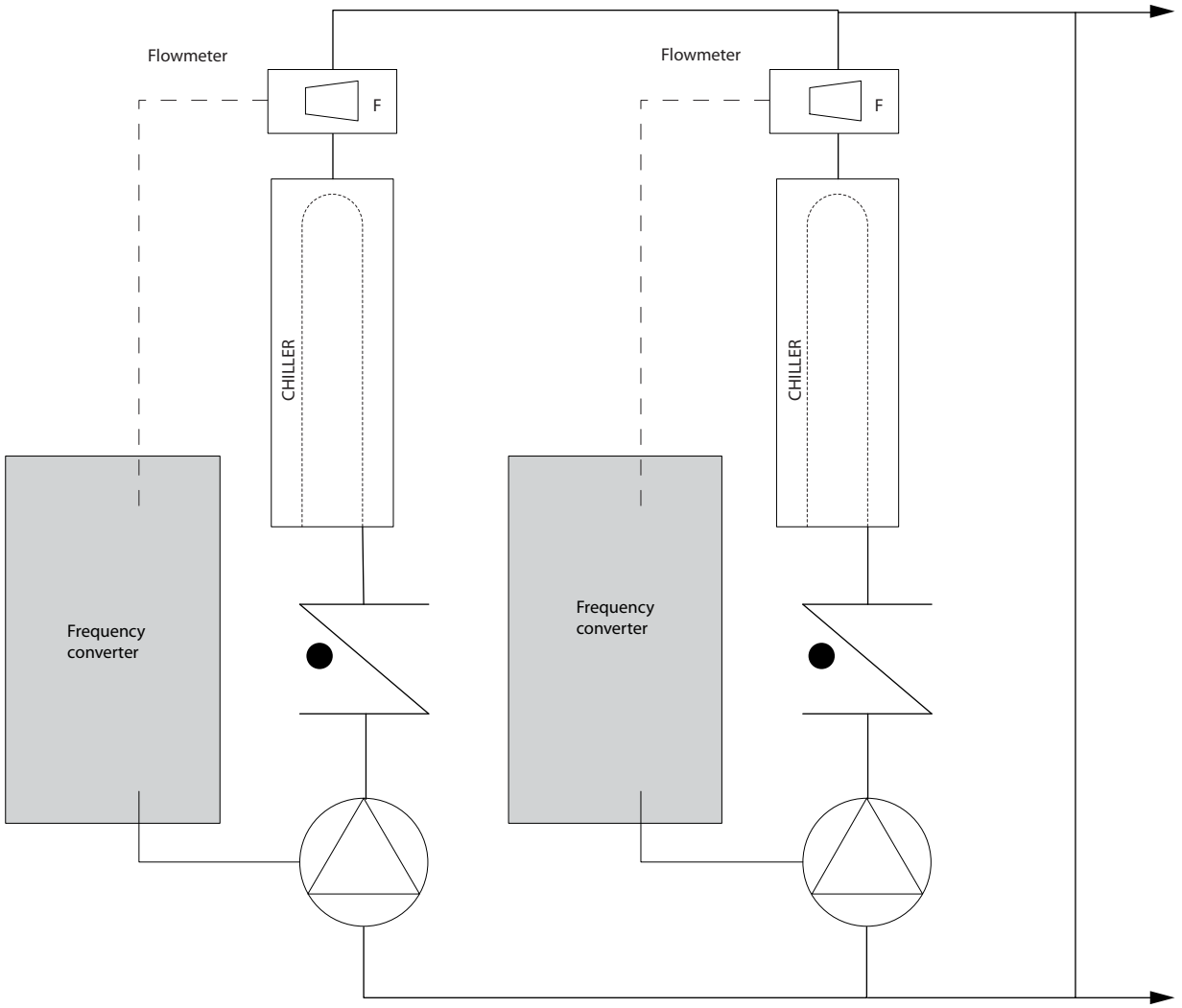


**Figure 2.21 The VLT Solution**

## 2.7.23 Secondary Pumps

Secondary pumps in a primary/secondary chilled water pumping system are used to distribute the chilled water to the loads from the primary production loop. The primary/secondary pumping system is used to hydraulically de-couple one piping loop from another. In this case, the primary pump is used to maintain a constant flow through the chillers while allowing the secondary pumps to vary in flow, increase control and save energy.
If the primary/secondary design concept is not used and a variable volume system is designed, the chiller cannot shed its load properly when the flow rate drops far enough or too quickly. The chiller's low evaporator temperature safety then trips the chiller, requiring a manual reset. This situation is common in large installations, especially when two or more chillers are installed in parallel.

## 2.7.24 The VLT Solution

While the primary-secondary system with two-way valves improves energy savings and eases system control problems, the true energy savings and control potential is realized by adding adjustable frequency drives.
With the proper sensor location, the addition of adjustable frequency drives allows the pumps to vary their speed to follow the system curve instead of the pump curve.
This results in the elimination of wasted energy and eliminates most of the over-pressurization two-way valves can be subjected to.
As the monitored loads are reached, the two-way valves close down. This increases the differential pressure measured across the load and two-way valve. As this differential pressure starts to rise, the pump is slowed to maintain the control head also called setpoint value. This setpoint value is calculated by summing up the pressure drop of the load and two-way valve under design conditions.

Note that when running multiple pumps in parallel, they must run at the same speed to maximize energy savings, either with individual dedicated drives or one running multiple pumps in parallel.

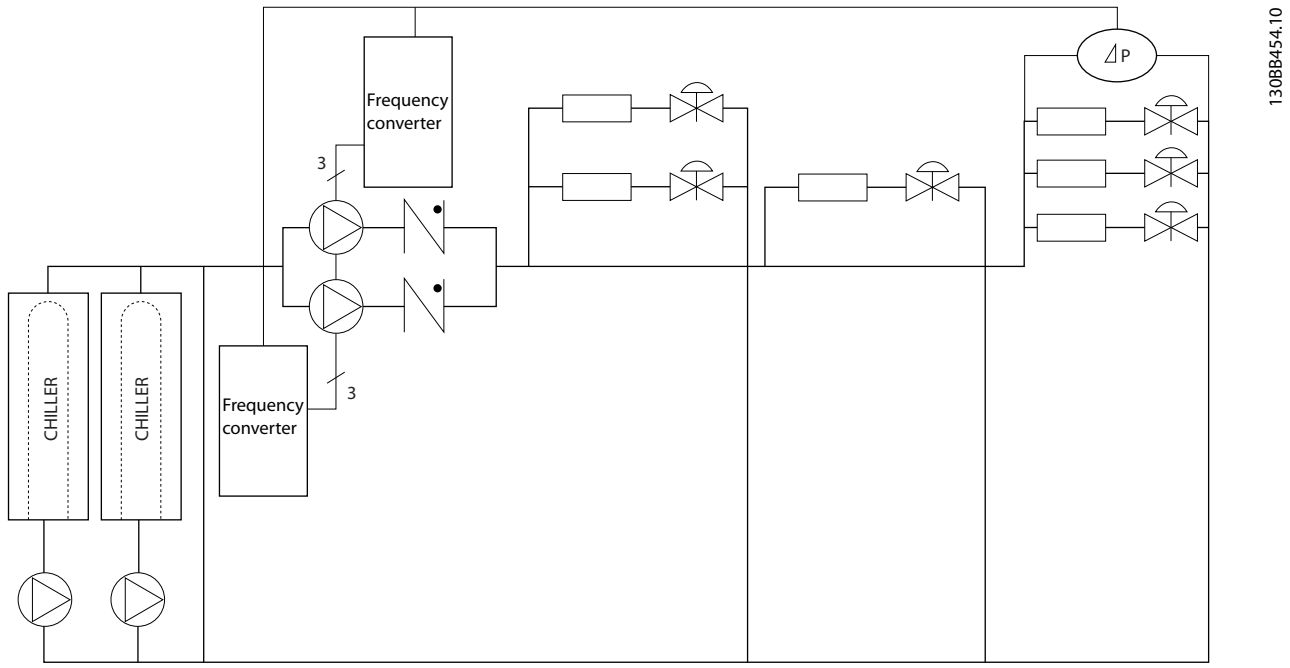


**Figure 2.22 The VLT Solution**

  

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## 2.8 Control Structures

### 2.8.1 Control Principle

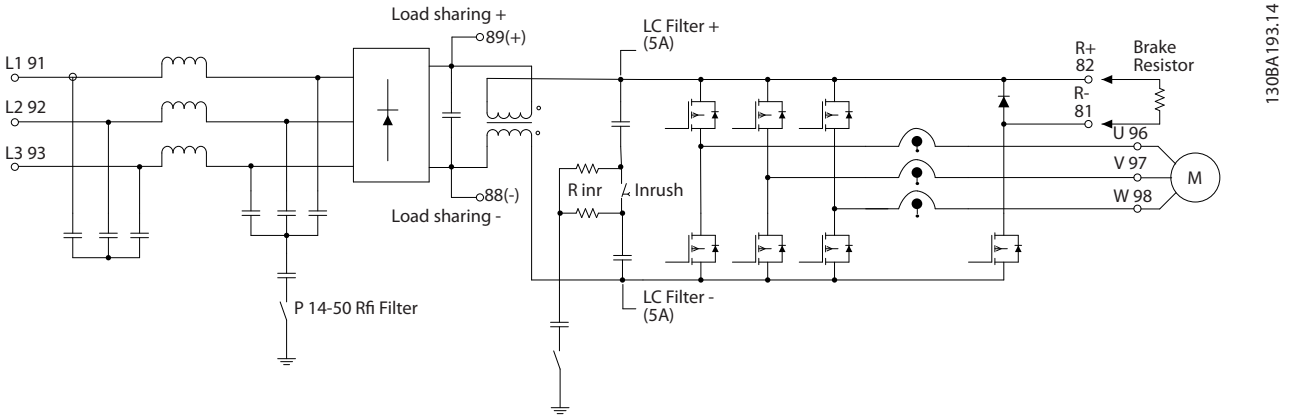


**Figure 2.23 Control Structures**

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 three current transducers in the motor phases.

Select between open-loop and closed-loop in *1-00 Configuration Mode*.

### 2.8.2 Control Structure Open-loop

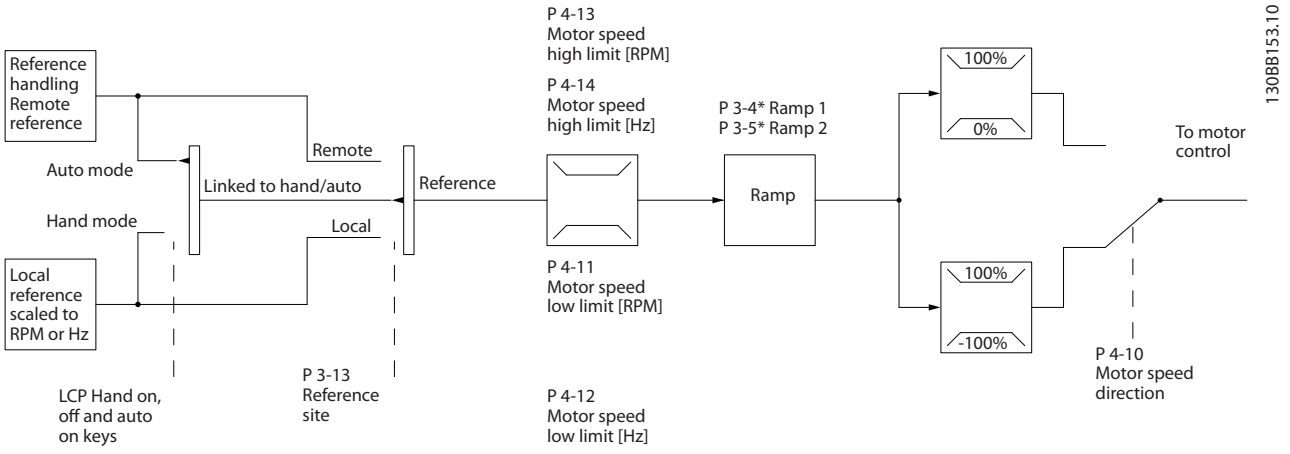


**Figure 2.24 Open-loop Structure**

In the configuration shown in *Figure 2.24*, *1-00 Configuration Mode* is set to *[0] Open-loop*. The resulting reference from the reference handling system or the local reference is received and fed through the ramp limitation and speed limitation before being sent to the motor control.
The output from the motor control is then limited by the maximum frequency limit.

  

### 2.8.3 PM/EC+ Motor Control

The Danfoss EC+ concept provides the possibility for using high efficient PM motors in IEC standard enclosure types operated by Danfoss adjustable frequency drives.
The commissioning procedure is comparable to the existing one for asynchronous (induction) motors by utilizing the Danfoss VVC$^{plus}$ PM control strategy.

Customer advantages:

- Free choice of motor technology (permanent magnet or induction motor)
- Installation and operation as known for induction motors
- Manufacturer independent when choosing system components (e.g., motors)
- Best system efficiency by choosing best components
- Possible retrofit of existing installations
- Power range: 1.5–30 hp [1.1–22 kW]

Current limitations:

- Currently only supported up to 30 hp [22 kW]
- Currently limited to non-salient type PM motors
- LC filters not supported together with PM motors
- Over Voltage Control algorithm is not supported with PM motors
- Kinetic backup algorithm is not supported with PM motors
- AMA algorithm is not supported with PM motors
- No missing motor phase detection
- No stall detection
- No ETR function

### 2.8.4 Sizing of Adjustable Frequency Drive and PM motor

The low motor inductances of PM motors can cause current ripples in the adjustable frequency drive.

To select the right adjustable frequency drive for a given PM motor, ensure that:

- The adjustable frequency drive can deliver the required power and current in all operating conditions.
- The power rating of the adjustable frequency drive is equal to or higher than the power rating of the motor.
- Size the adjustable frequency drive for a constant 100% operating load with sufficient safety margin.

The current (A) and the typical power rating (kW) for a PM motor can be found in *chapter 9.1 Line Power Supply Tables* for different voltages.

  

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**Sizing examples for nominal power rating**
**Example 1**

- PM motor size: 1.5 kW / 2.9 A
- Line power: 3 x 400 V

| Adjustable Frequency Drive | Typical [kW] | Typical [hp] at 460 V | Continuous [A] (3x380–440 V) | Intermitted [A] (3x380–440 V) | Continuous [A] (3x441–480 V) | Intermitted [A] (3x441–480 V) |
|---|---|---|---|---|---|---|
| P1K1 | 1.1 | 1.5 | 3.0 | 3.3 | 2.7 | 3.0 |
| P1K5 | 1.5 | 2.0 | 4.1 | 4.5 | 3.4 | 3.7 |

**Table 2.10 Sizing Data for 1.5 and 2 hp [1.1 and 1.5 kW] Adjustable Frequency Drives**

The current rating of the PM motor (2.9 A) matches the current rating of both the 1.5 hp [1.1 kW] adjustable frequency drive (3 A @ 400 V) and the 2 hp [1.5 kW] adjustable frequency drive (4.1 A @ 400 V). However, since the power rating of the motor is 2 hp [1.5 kW], the 2 hp [1.5 kW] adjustable frequency drive is the correct choice.

| | Motor | Adjustable Frequency Drive 2 hp [1.5 kW] |
|---|---|---|
| Power | 2 hp [1.5 kW] | 2 hp [1.5 kW] |
| Current | 2.9 A | 4.1 A @ 400V |

**Table 2.11 Correctly Sized Adjustable Frequency Drive**

**Example 2**

- PM motor size: 7.5 hp [5.5 kW] / 12.5 A
- Line power: 3 x 400 V

| Adjustable Frequency Drive | Typical [kW] | Typical [hp] at 460 V | Continuous [A] (3x380–440 V) | Intermitted [A] (3x380–440 V) | Continuous [A] (3x441–480 V) | Intermitted [A] (3x441–480 V) |
|---|---|---|---|---|---|---|
| P4K0 | 4.0 | 5.0 | 10.0 | 11.0 | 8.2 | 9.0 |
| P5K5 | 5.5 | 7.5 | 13.0 | 14.3 | 11.0 | 12.1 |

**Table 2.12 Sizing Data for 5 and 7.5 hp [4.0 and 5.5 kW] Adjustable Frequency Drives**

The current rating of the PM motor (12.5 A) matches the current rating of the 7.5 hp [5.5 kW] adjustable frequency drive (13 A @ 400 V), not the current rating of the 5 hp [4.0 kW] adjustable frequency drive (10 A @ 400 V). Since the power rating of the motor is 7.5 hp [5.5 kW], the 7.5 hp [5.5 kW] adjustable frequency drive is the correct choice.

| | Motor | Adjustable Frequency Drive 7.5 hp [5.5 kW] |
|---|---|---|
| Power | 7.5 hp [5.5 kW] | 7.5 hp [5.5 kW] |
| Current | 12.5 A | 13 A @ 400 V |

**Table 2.13 Correctly Sized Adjustable Frequency Drive**

## 2.8.5 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 *0-40 [Hand on] Key on LCP*, *0-41 [Off] Key on LCP*, *0-42 [Auto on] Key on LCP*, and *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 [Hand On], the adjustable frequency drive goes into Hand Mode and follows (as default) the local reference set by using [▲] and [▼].

After pressing [Auto On], 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 parameter group *5-1* Digital Inputs* or parameter group *8-5* Serial Communication*.

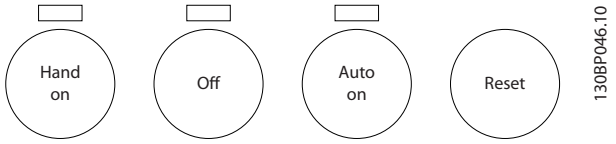


**Figure 2.25 Operation Keys**

| **Hand Off Auto LCP Keys** | ***3-13 Reference Site*** | **Active Reference** |
|---|---|---|
| Hand | Linked to Hand/ Auto | Local |
| Hand ⇒ Off | Linked to Hand/ Auto | Local |
| Auto | Linked to Hand/ Auto | Remote |
| Auto ⇒ Off | Linked to Hand/ Auto | Remote |
| All keys | Local | Local |
| All keys | Remote | Remote |

**Table 2.14 Conditions for Either Local or Remote Reference**

*Table 2.14* shows under which conditions either the local reference or the remote reference is active. One of them is always active, but both cannot be active at the same time.

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

Local reference is restored at power-down.

## 2.8.6 Control Structure Closed-loop

The internal controller allows the adjustable frequency drive to become an integral part of the controlled system. The adjustable frequency 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 adjustable frequency drive as the setpoint reference. A static pressure sensor measures the actual static pressure in the pipe and supplies this to the adjustable frequency drive as a feedback signal. If the feedback signal is greater than the setpoint reference, the adjustable frequency drive slows down to reduce the pressure. In a similar way, if the pipe pressure is lower than the setpoint reference, the adjustable frequency drive automatically speed up to increase the pressure provided by the pump.

  

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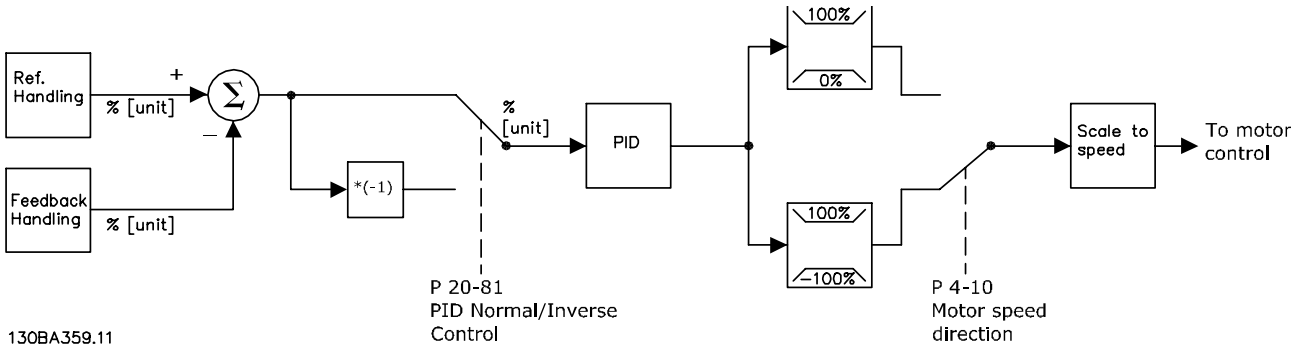


**Figure 2.26 Block Diagram of Closed-loop Controller**

While the default values for the adjustable frequency drive's closed-loop controller often provides 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.

## 2.8.7 Feedback Handling

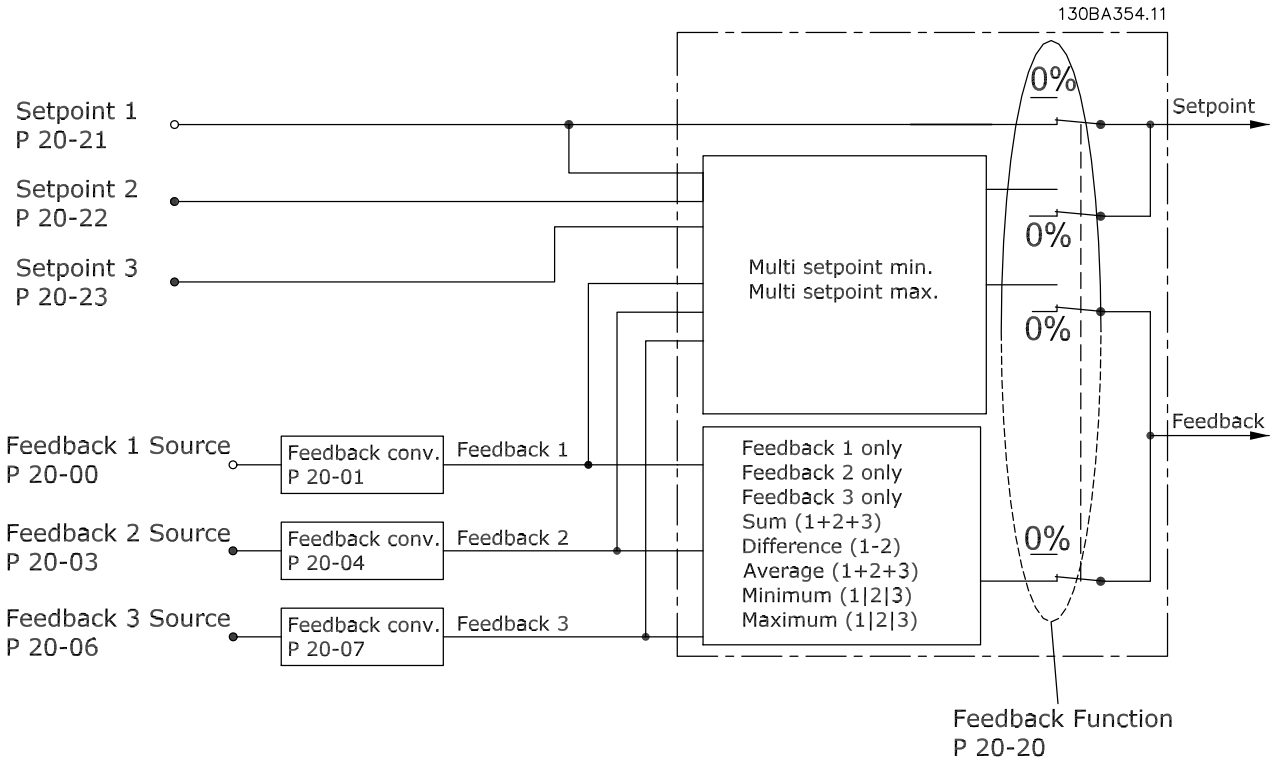


**Figure 2.27 Block Diagram of Feedback Signal Processing**

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 *20-20 Feedback Function*.

**Multi-zone, Single Setpoint**
Multi-zone, Single Setpoint uses two or three feedback sensors, but only one setpoint. Feedback 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 *[5] Multi Setpoint Min* is selected, the setpoint/feedback pair with the largest difference controls the speed of the adjustable frequency drive. *[6] Multi Setpoint Max* attempts to keep all zones at or below their respective setpoints, while *[5] Multi Setpoint Min* attempts to keep all zones at or above their respective setpoints.

**Example**
A two-zone two setpoint application Zone 1 setpoint is 15 bar and the feedback is 5.5 bar. Zone 2 setpoint is 4.4 bar and the feedback is 4.6 bar. If *[14] Multi Setpoint Max* 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 *[13] Multi Setpoint Min* 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).

## 2.8.8 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 in *Figure 2.28*.

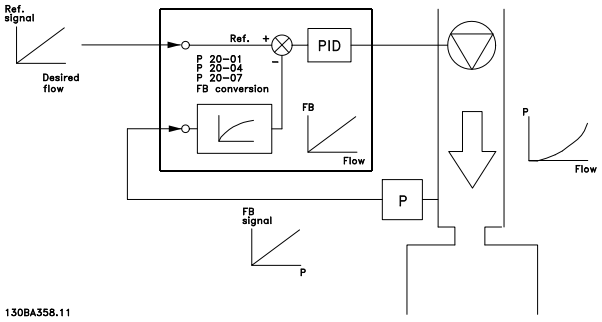


**Figure 2.28 Feedback Conversion**

  

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## 2.8.9 Reference Handling

**Details for Open-loop and Closed-loop operation**

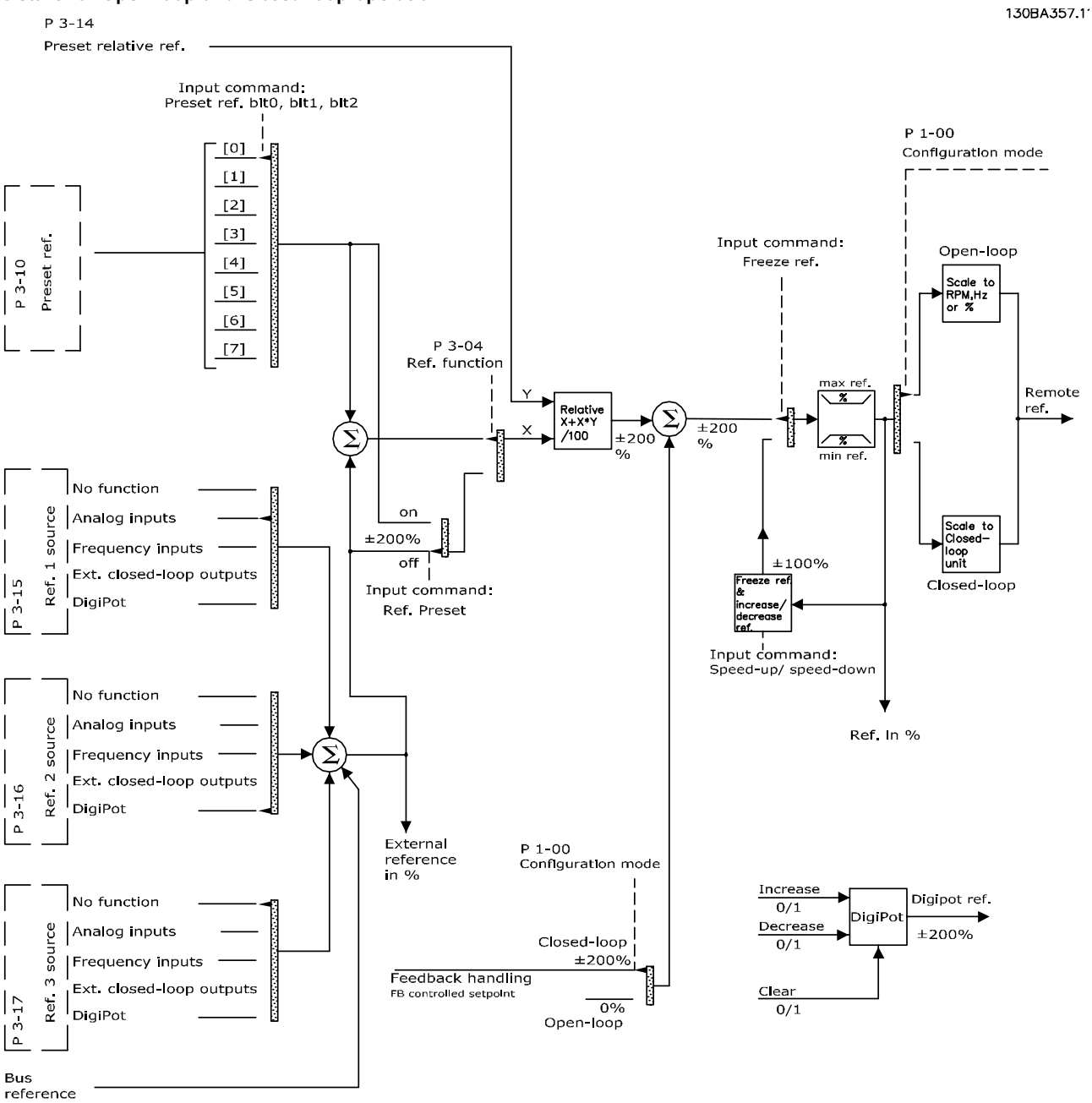


**Figure 2.29 Block Diagram Showing Remote Reference**

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 eight preset references can be programmed in the adjustable frequency 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 three Reference Source parameters (*3-15 Reference 1 Source*, *3-16 Reference 2 Source* and *3-17 Reference 3 Source*). Digipot is a digital potentiometer. This is also commonly called a Speed Up/Slow 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 by using *3-14 Preset Relative Reference*.

The scaled reference is calculated as follows:

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

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

If Y, *3-14 Preset Relative Reference* is set to 0%, the reference is affected by the scaling.

## 2.8.10 Example of Closed-loop PID Control

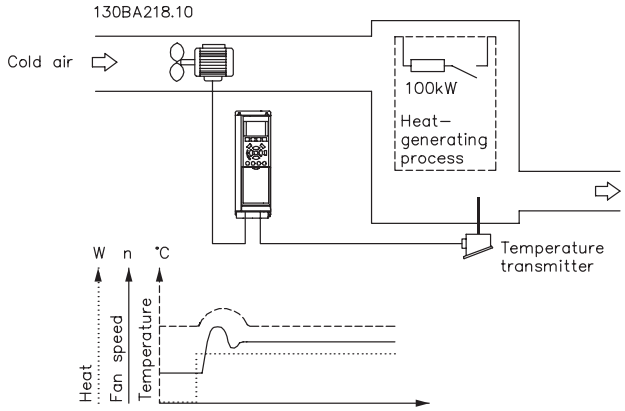


**Figure 2.30 Closed-loop Control for a Ventilation System**

In a ventilation system, the temperature is to be maintained at a constant value. The desired temperature is set between 23–95 °F [-5–+35 °C] using a 0–10 V potentiometer. Because this is a cooling application, if the temperature is above the setpoint value, the speed of the fan must be increased to provide more cooling air flow. The temperature sensor has a range of 14–104 °F [-10–+40 °C] and uses a two-wire transmitter to provide a 4–20 mA signal. The output frequency range of the adjustable frequency drive is 10 to 50 Hz.

1. Start/Stop via switch connected between terminals 12 (+24 V) and 18.
2. Temperature reference via a potentiometer (23–95 °F [-5–+35 °C], 0 to 10 V) connected to terminals 50 (+10 V), 53 (input) and 55 (common).
3. Temperature feedback via transmitter (14–104 °F [-10–+40 °C], 4–20 mA) connected to terminal 54. Switch S202 behind the LCP set to ON (current input).

  

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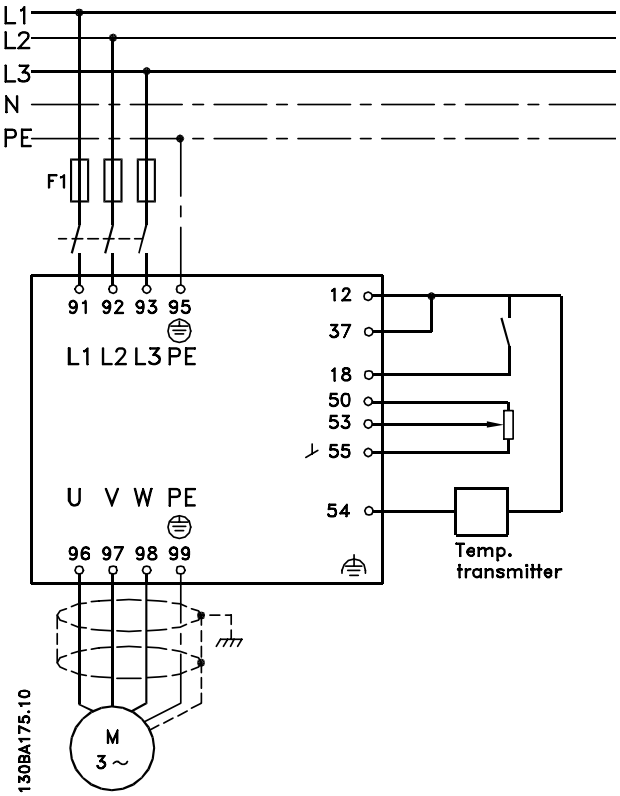


**Figure 2.31 Example of Closed-loop PID Control**

## 2.8.11 Programming Order

***NOTICE!***

**In this example, it is assumed that an induction motor is used, i.e., that *1-10 Motor Construction* = [0] Asynchron.**

| Function | Para-- meter | Setting |
|---|---|---|
| 1) Make sure the motor runs properly. Do the following: | | |
| Set the motor parameters using nameplate data. | 1-2* | As specified by motor nameplate |
| Run Automatic Motor Adaptation. | 1-29 | *[1] Enable complete AMA* and then run the AMA function |
| 2) Check that the motor is running in the right direction. | | |
| Run Motor Rotation Check. | 1-28 | 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. | | |
| Check that the ramp settings are within capabilities of the adjustable frequency drive and allowed application operating specifications. | 3-41<br>3-42 | 60 s<br>60 s<br>Depends on motor/load size!<br>Also active in hand mode. |
| Prohibit the motor from reversing (if necessary). | 4-10 | *[0] Clockwise* |
| Set acceptable limits for the motor speed. | 4-12<br>4-14<br>4-19 | 10 Hz, *Motor min speed*<br>50 Hz, *Motor max speed*<br>50 Hz, *Drive max output frequency* |
| Switch from open-loop to closed-loop. | 1-00 | *[3] Closed-loop* |
| 4) Configure the feedback to the PID controller. | | |
| Select the appropriate reference/feedback unit. | 20-12 | *[71] Bar* |
| 5) Configure the setpoint reference for the PID controller. | | |
| Set acceptable limits for the setpoint reference. | 20-13<br>20-14 | 0 Bar<br>10 Bar |
| Select current or voltage by switches S201 / S202. | | |
| 6) Scale the analog inputs used for setpoint reference and feedback. | | |
| Scale Analog Input 53 for the pressure range of the potentiometer (0–10 Bar, 0–10 V). | 6-10<br>6-11<br>6-14<br>6-15 | 0 V<br>10 V (default)<br>0 Bar<br>10 Bar |
| Scale Analog Input 54 for pressure sensor (0–10 Bar, 4–20 mA). | 6-22<br>6-23<br>6-24<br>6-25 | 4 mA<br>20 mA (default)<br>0 Bar<br>10 Bar |
| 7) Tune the PID controller parameters. | | |
| Adjust the adjustable frequency drive's closed-loop controller, if needed. | 20-93<br>20-94 | See Optimization of the PID Controller, below |
| 8) Save to finish. | | |
| Save the parameter settings to the LCP for safekeeping. | 0-50 | *[1] All to LCP* |

**Table 2.15 Programming Order**

### 2.8.12 Tuning the Adjustable Frequency Drive Closed-loop Controller

Once the adjustable frequency 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 *20-93 PID Proportional Gain* and *20-94 PID Integral Time*. However, in some cases it may be helpful to optimize these parameter values to provide faster system response while still controlling speed overshoot.

### 2.8.13 Manual PID Adjustment

1. Start the motor.
2. Set *20-93 PID Proportional Gain* to 0.3 and increase it until the feedback signal begins to oscillate. If necessary, start and stop the adjustable frequency 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 *20-94 PID Integral Time* to 20 s and reduce it until the feedback signal begins to oscillate. If necessary, start and stop the adjustable frequency drive or make step changes in the setpoint reference to attempt to cause oscillation. Next, increase the PID integral time until the feedback signal stabilizes. Then increase of the integral time by 15–50%.
4. *20-95 PID Differentiation Time* should only be used for very fast-acting systems. The typical value is 25% of *20-94 PID Integral Time*. 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 (parameters 6-16, 6-26, 5-54 or 5-59 as required).

  

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## 2.9 General Aspects of EMC

Electrical interference is usually conducted at frequencies in the range 150 kHz to 30 MHz. Airborne interference from the adjustable frequency drive system in the range 30 MHz to 1 GHz is generated from the inverter, motor cable, and the motor.
As shown in *Figure 2.32*, capacitance in the motor cable coupled with a high dU/dt from the motor voltage generate leakage currents.
The use of a shielded motor cable increases the leakage current (see *Figure 2.32*) because shielded cables have higher capacitance to ground than non-shielded cables. If the leakage current is not filtered, it causes greater interference on the line power in the radio frequency range below approximately 5 MHz. Since the leakage current ($I_1$) is carried back to the unit through the shield ($I_3$), there is in principle only a small electro-magnetic field ($I_4$) from the shielded motor cable according to *Figure 2.32*.

The shield reduces the radiated interference, but increases the low-frequency interference in the line power supply. Connect the motor cable shield 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) Pigtails increase the shield impedance at higher frequencies, which reduces the shield effect and increases the leakage current ($I_4$).
If a shielded cable is used for relay, control cable, signal interface and brake, mount the shield on the enclosure at both ends. In some situations, however, it is necessary to break the shield to avoid current loops.

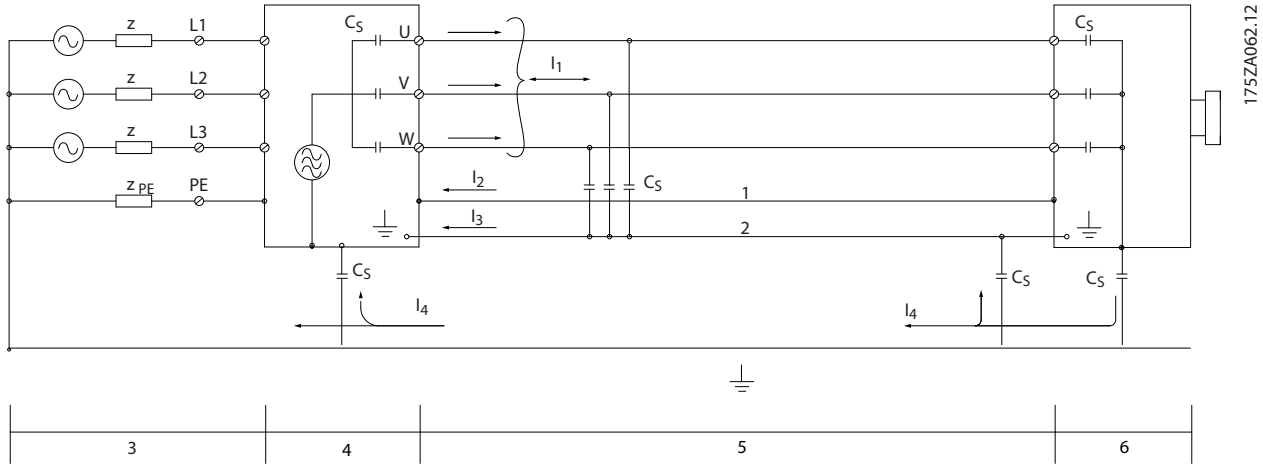


**Figure 2.32 Situation that Generates Leakage Currents**

| | | | |
|---|---|---|---|
| 1 | Ground wire | 4 | Adjustable frequency drive |
| 2 | Shield | 5 | Shielded motor cable |
| 3 | AC line power supply | 6 | Motor |

**Table 2.16 Legend to *Figure 2.32***

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

When non-shielded cables are used, some emission requirements are not complied with, although most immunity requirements are observed.

  

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

## 2.9.1 Emission Requirements

According to the EMC product standard for adjustable speed adjustable frequency drives EN/IEC 61800-3:2004, 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 *Table 2.17*.

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

**Table 2.17 Emission Requirements**

When the generic (conducted) 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 EN 55011 |
|---|---|---|
| First environment (home and office) | EN/IEC 61000-6-3 Emission standard for residential, commercial and light industrial environments. | Class B |
| Second environment (industrial environment) | EN/IEC 61000-6-4 Emission standard for industrial environments. | Class A Group 1 |

**Table 2.18 Limits at Generic Emission Standards**

## 2.9.2 EMC Test Results

The following test results have been obtained using a system with an adjustable frequency drive, a shielded control cable, a control box with potentiometer, as well as a motor and shielded motor cable at nominal switching frequency. In *Table 2.19*, the maximum motor cable lengths for compliance are stated.

  

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| RFI filter type | | Conducted emission | | | Radiated emission | | |
|---|---|---|---|---|---|---|---|
| | | Cable length (ft [m]) | | | Cable length (ft [m]) | | |
| **Standards and requirements** | **EN 55011** | **Class B** Housing, trades and light industries | **Class A Group 1** Industrial environment | **Class A Group 2** Industrial environment | **Class B** Housing, trades and light industries | **Class A Group 1** Industrial environment | **Class A Group 2** Industrial environment |
| | **EN/IEC 61800-3** | **Category C1** First environment Home and office | **Category C2** First environment Home and office | **Category C3** Second environment Industrial | **Category C1** First environment home and office | **Category C2** First environment home and office | **Category C3** Second environment Industrial |
| **H1** | | | | | | | |
| FC 102 | 1.5–30 hp [1.1–22 kW] 220–240 V | 164 [50] | 492 [150] | 492 [150] | No | Yes | N/A |
| | 1.5–60 hp [1.1–45 kW] 200–240 V | 164 [50] | 492 [150] | 492 [150] | No | Yes | Yes |
| | 1.5–125 hp [1.1–90 kW] 380–480 V | 164 [50] | 492 [150] | 492 [150] | No | Yes | Yes |
| **H2** | | | | | | | |
| FC 102 | 1.5–30 hp [1.1–22 kW] 220–240 V | No | No | 82 [25] | No | No | N/A |
| | 1.5–5 hp [1.1–3.7 kW] 200–240 V | No | No | 16.4 [5] | No | No | No |
| | 7.5–60 hp [5.5–45 kW] 200–240 V | No | No | 82 [25] | No | No | No |
| | 1.5–10 hp [1.1–7.5 kW] 380–500 V | No | No | 16.4 [5] | No | No | No |
| | 15–125 hp [11–90 kW] 380–500 V[4)] | No | No | 82 [25] | No | No | No |
| | 15–30 hp [11–22 kW] 525–690 V[1, 4)] | No | No | 82 [25] | No | No | No |
| | 40–125 hp [30–90 kW] 525–690 V[2, 4)] | No | No | 82 [25] | No | No | No |
| **H3** | | | | | | | |
| FC 102 | 1.5–60 hp [1.1–45 kW] 200–240 V | 33 [10] | 164 [50] | 250 [75] | No | Yes | Yes |
| | 1.5–125 hp [1.1–90 kW] 380–480 V | 33 [10] | 164 [50] | 250 [75] | No | Yes | Yes |
| **H4** | | | | | | | |
| FC 102 | 15–40 hp [11–30 kW] 525–690 V[1)] | No | 330 [100] | 330 [100] | No | Yes | Yes |
| | 50–125 hp [37–90 kW] 525–690 V[2)] | No | 492 [150] | 492 [150] | No | Yes | Yes |
| **Hx**[3)] | | | | | | | |
| FC 102 | 1.5–125 hp [1.1–90 kW] 525–600 V | No | No | No | No | No | No |

**Table 2.19 EMC Test Results (Emission)**

*1) Enclosure Type B*

*2) Enclosure Type C*

*3) Hx versions can be used according to EN/IEC 61800-3 category C4*

  

*4) T7, 50–125 hp [37–90 kW] complies with class A group 1 with 82 ft [25 m] motor cable. Some restrictions for the installation apply (contact Danfoss for details).*
*HX, H1, H2, H3, H4 or H5 is defined in the type code pos. 16-17 for EMC filters*
*HX - No EMC filters built in the adjustable frequency drive (600 V units only)*
*H1 - Integrated EMC filter. Fulfill EN 55011 Class A1/B and EN/IEC 61800-3 Category 1/2*
*H2 - No additional EMC filter. Fulfill EN 55011 Class A2 and EN/IEC 61800-3 Category 3*
*H3 - Integrated EMC filter. Fulfill EN 55011 class A1/B and EN/IEC 61800-3 Category 1/2*
*H4 - Integrated EMC filter. Fulfill EN 55011 class A1 and EN/IEC 61800-3 Category 2*
*H5 – Marine versions. Fulfill same emissions levels as H2 versions*

## 2.9.3 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 with a Fourier analysis and split into sine-wave currents with different frequencies, that is, different harmonic currents $I_n$ with 50 Hz basic frequency:

| | $I_1$ | $I_5$ | $I_7$ |
|---|---|---|---|
| Hz | 50 | 250 | 350 |

**Table 2.20 Harmonic Currents**

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

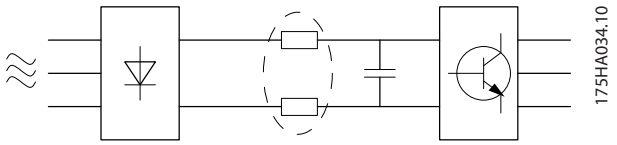


**Figure 2.33 Harmonic Currents**

***NOTICE!***

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

To ensure low harmonic currents, the adjustable frequency drive is equipped with intermediate circuit coils as standard. 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 based on the individual voltage harmonics using this formula:

$$THD\% = \sqrt{U_5^2 + U_7^2 + \ldots + U_N^2}$$

($U_N$% of U)

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## 2.9.4 Harmonics Emission Requirements

**Equipment connected to the public supply network**

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

**Table 2.21 Connected Equipment**

## 2.9.5 Harmonics Test Results (Emission)

Power sizes up to PK75 in T2 and T4 comply with IEC/EN 61000-3-2 Class A. Power sizes from P1K1 and up to P18K in T2 and up to P90K in T4 comply with IEC/EN 61000-3-12, Table 4. Power sizes P110 - P450 in T4 also comply with IEC/EN 61000-3-12 even though not required because currents are above 75 A.

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

**Table 2.22 Harmonics Test Results (Emission)**

If the short-circuit power of the supply $S_{sc}$ is greater than or equal to:

$$SSC = \sqrt{3} \times RSCE \times Uline\ power \times Iequ = \sqrt{3} \times 120 \times 400 \times Iequ$$

at the interface point between the user's supply and the public system ($R_{sce}$).

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

Compliance with various system level guidelines:
The harmonic current data in *Table 2.22* are given in accordance with IEC/EN61000-3-12 with reference to the Power Drive Systems product standard. The data may be used to calculate the harmonic currents' influence on the power supply system and to document compliance with relevant regional guidelines: IEEE 519 -1992; G5/4.

## 2.9.6 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.

To document immunity against electrical interference from electrical phenomena, the following immunity tests have been made in accordance with 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 *Table 2.23*.

  

| Basic standard | Electrical interference IEC 61000-4-4 | Surge IEC 61000-4-5 | ESD IEC 61000-4-2 | Radiated electromagnetic field IEC 61000-4-3 | RF common mode voltage IEC 61000-4-6 |
|---|---|---|---|---|---|
| **Acceptance criterion** | **B** | **B** | **B** | **A** | **A** |
| **Voltage range: 200–240 V, 380–500 V, 525–600 V, 525–690 V** | | | | | |
| Line | 4 kV CM | 2 kV/2 Ω DM<br>4 kV/12 Ω CM | — | — | 10 $V_{RMS}$ |
| Motor | 4 kV CM | 4 kV/2 Ω[1)] | — | — | 10 $V_{RMS}$ |
| Brake | 4 kV CM | 4 kV/2 Ω[1)] | — | — | 10 $V_{RMS}$ |
| Load sharing | 4 kV CM | 4 kV/2 Ω[1)] | — | — | 10 $V_{RMS}$ |
| Control wires | 2 kV CM | 2 kV/2 Ω[1)] | — | — | 10 $V_{RMS}$ |
| Standard bus | 2 kV CM | 2 kV/2 Ω[1)] | — | — | 10 $V_{RMS}$ |
| Relay wires | 2 kV CM | 2 kV/2 Ω[1)] | — | — | 10 $V_{RMS}$ |
| Application and serial communication options | 2 kV CM | 2 kV/2 Ω[1)] | — | — | 10 $V_{RMS}$ |
| LCP cable | 2 kV CM | 2 kV/2 Ω[1)] | — | — | 10 $V_{RMS}$ |
| External 24 V DC | 2 V CM | 0.5 kV/2 Ω DM<br>1 kV/12 Ω CM | — | — | 10 $V_{RMS}$ |
| Enclosure | — | — | 8 kV AD<br>6 kV CD | 10 V/m | — |

**Table 2.23 EMC Immunity Form**

*1) Injection on cable shield*
*AD: Air Discharge*
*CD: Contact Discharge*
*CM: Common mode*
*DM: Differential mode*

## 2.10 Galvanic Isolation (PELV)

### 2.10.1 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), with the exception of the 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 *Figure 2.34*):

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

  

2

1. Power supply (SMPS) incl. signal isolation of $U_{DC}$, indicating the voltage of intermediate DC link circuit.
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.
7. Mechanical brake.

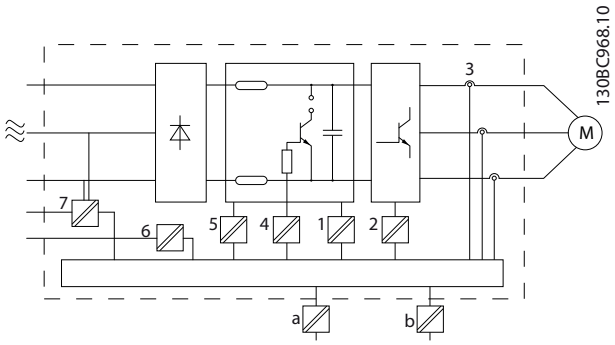


**Figure 2.34 Galvanic Isolation**

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

**⚠WARNING**

**Installation at high altitude:**
**380–500 V, enclosure types A, B and C: At altitudes above 6,600 ft [2 km], contact Danfoss regarding PELV.**
**525–690 V: At altitudes above 6,600 ft [2 km], contact Danfoss regarding PELV.**

**⚠WARNING**

**Touching the electrical parts could 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 *Table 2.19*.**
**Shorter time is allowed only if indicated on the nameplate for the specific unit.**

## 2.11 Ground Leakage Current

Follow national and local codes regarding protective grounding of equipment with a leakage current > 3.5 mA. Adjustable frequency drive technology implies high frequency switching at high power. This generates a leakage current in the ground connection. A fault current in the adjustable frequency drive at the output power terminals might contain a DC component which can charge the filter capacitors and cause a transient ground current.
The ground leakage current is made up from several contributions and depends on various system configurations including RFI filtering, shielded motor cables and adjustable frequency drive power.

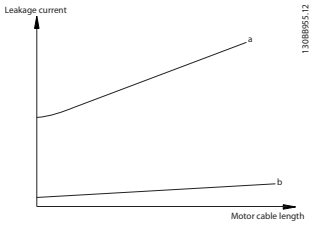


**Figure 2.35 Cable Length and Power Size Influence on Leakage Current. Pa > Pb**

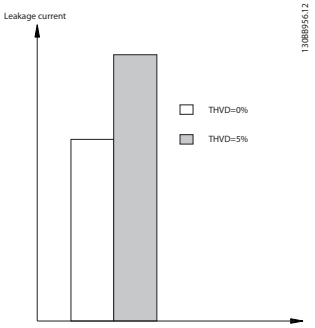


**Figure 2.36 Line Distortion Influences Leakage Current**

***NOTICE!***

**When a filter is used, turn off *14-50 RFI 1* when charging the filter to avoid that a high leakage current makes the RCD switch.**

EN/IEC61800-5-1 (Power Drive System Product Standard) requires special care if the leakage current exceeds 3.5 mA. Grounding must be reinforced in one of the following ways:

- Ground wire (terminal 95) of at least 0.016 in$^2$ [10 mm$^2$]
- Two separate ground wires both complying with the dimensioning rules

See EN/IEC61800-5-1 and EN50178 for further information.

**Using RCDs**
Where residual current devices (RCDs), also known as ground leakage circuit breakers (GLCBs), are used, comply with the following:

- Use RCDs of type B only which are capable of detecting AC and DC currents
- Use RCDs with a soft-charge delay to prevent faults due to transient ground currents
- Dimension RCDs according to the system configuration and environmental considerations

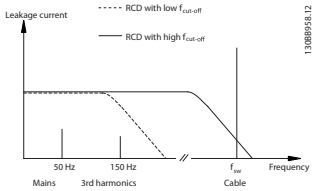


**Figure 2.37 Main Contributions to Leakage Current**

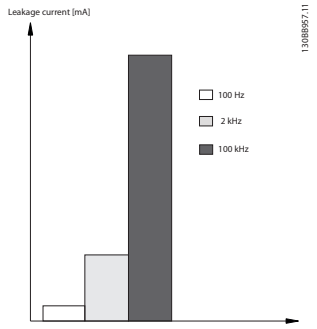


**Figure 2.38 The Influence of the Cut-off Frequency of the RCD on What Is Responded to/Measured**

See also *RCD Application Note, MN90G*.

## 2.12 Brake Function

### 2.12.1 Selection of Brake Resistor

In certain applications, such as in tunnels or underground railway station ventilation systems, it is desirable to bring the motor to a stop more rapidly than can be achieved through controlling via ramp-down or free-wheeling. In such applications, dynamic braking with a brake resistor may be utilized. Using a brake 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. *Figure 2.39* shows a typical braking cycle.

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

*Duty Cycle = $t_b$ / T*

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

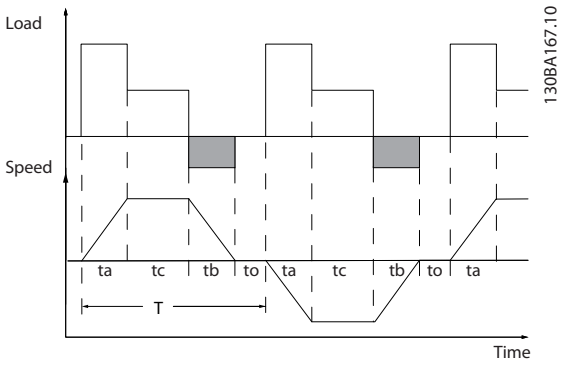


**Figure 2.39 Intermittent Duty Cycle for the Resistor**

Danfoss offers brake resistors with duty cycle of 5%, 10% and 40% suitable for use with the VLT® HVAC Drive adjustable frequency 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, contact Danfoss.

  

2

## 2.12.2 Brake Resistor Calculation

The brake resistance is calculated as shown:

| |
|---|
| $Rbr\,[\Omega] = \frac{U_{dc}^2}{Ppeak}$ |
| where |
| $P_{peak} = P_{motor} \times M_{br} \times \eta_{motor} \times \eta[W]$ |

**Table 2.24 Brake Resistor Calculation**

As can be seen, the brake resistance depends on the intermediate circuit voltage ($U_{DC}$).
The brake function of the adjustable frequency drive is settled in three areas of the line power supply:

| Size [V] | Brake active [V] | Warning before cut-out [V] | Cut-out (trip) [V] |
|---|---|---|---|
| 3x200–240 | 390 ($U_{DC}$) | 405 | 410 |
| 3x380–480 | 778 | 810 | 820 |
| 3x525–690 | 1084 | 1109 | 1130 |

**Table 2.25 Brake Function Settled in Three Areas of Line Power Supply**

**NOTICE!**

**Make sure that the brake resistor can cope with a voltage of 410 V, 820 V or 975 V, unless Danfoss brake resistors are used.**

Danfoss recommends the brake resistance $R_{rec}$, i.e., one that guarantees that the is able to brake at the highest braking torque ($M_{br(\%)}$) of 110%. The formula can be written as:

$$R_{rec}[\Omega] = \frac{U_{dc}^2 \times 100}{P_{motor} \times Mbr\,(\%) \times \times motor}$$

$\eta_{motor}$ is typically at 0.90
$\eta$ is typically at 0.98

For 200 V, 480 V and 600 V adjustable frequency drives, $R_{rec}$ at 160% braking torque is written as:

$$200\,V: Rrec = \frac{107780}{Pmotor}[\Omega]$$
$$480\,V: Rrec = \frac{375300}{Pmotor}[\Omega]^{1)}$$
$$480\,V: Rrec = \frac{428914}{Pmotor}[\Omega]^{2)}$$
$$600\,V: Rrec = \frac{630137}{Pmotor}[\Omega]$$
$$690\,V: Rrec = \frac{832664}{Pmotor}[\Omega]$$

*1) For adjustable frequency drives ≤ 7.5 kW shaft output*
*2) For adjustable frequency drives > 7.5 kW shaft output*

**NOTICE!**

**The brake resistor circuit resistance selected should not be higher than that recommended by Danfoss. If a brake resistor with a higher ohmic value is selected, the braking torque may not be achieved because there is a risk that the adjustable frequency drive cuts out for safety reasons.**

**NOTICE!**

**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).**

**⚠WARNING**

**Do not touch the brake resistor, as it can get very hot during/after braking.**

## 2.12.3 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 enables reading out the momentary power and the mean power for the latest 120 s. The brake can also monitor the power energizing and ensure that it does not exceed the limit selected in *2-12 Brake Power Limit (kW)*. In *2-13 Brake Power Monitoring*, select the function to carry out when the power transmitted to the brake resistor exceeds the limit set in *2-12 Brake Power Limit (kW)*.

**NOTICE!**

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

Overvoltage control (OVC) (exclusive brake resistor) can be selected as an alternative brake function in *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 useful function, e.g., if the ramp-down time is too short since tripping of the adjustable frequency drive is avoided. In this situation, the ramp-down time is extended.

  

***NOTICE!***

**OVC cannot be activated when running a PM motor (when *1-10 Motor Construction* is set to *[1] PM non salient SPM*).**

### 2.12.4 Brake Resistor Cabling

**EMC (twisted cables/shielding)**
Twist the wires to reduce the electrical noise from the wires between the brake resistor and the adjustable frequency drive.

For enhanced EMC performance, use a metal shield.

## 2.13 Extreme Running Conditions

**Short Circuit (Motor Phase – Phase)**
The adjustable frequency drive is protected against short circuits by current measurement in each of the three motor phases or in the DC link. A short circuit between two output phases causes an overcurrent in the inverter. The inverter is turned off individually when the short circuit current exceeds the permitted value (Alarm 16 Trip Lock).
To protect the adjustable frequency drive against a short circuit at the load sharing and brake outputs, see the design guidelines.

**Switching on the output**
Switching on the output between the motor and the adjustable frequency drive is permitted. Fault messages may appear. Enable flying start to catch a spinning motor.

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

- The load drives the motor (at constant output frequency from the adjustable frequency drive), i.e., the load generates energy.
- 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.
- Incorrect slip compensation setting may cause higher DC link voltage.
- Back-EMF from PM motor operation. If coasted at high RPM, the PM motor back-EMF may potentially exceed the maximum voltage tolerance of the adjustable frequency drive and cause damage. To help prevent this, the value of *4-19 Max Output Frequency* is automatically limited based on an internal calculation based on the value of *1-40 Back EMF at 1000 RPM*, *1-25 Motor Nominal Speed* and *1-39 Motor Poles*. If it is possible that the motor may overspeed (e.g., due to excessive windmilling effects), Danfoss recommends using a brake resistor.

**⚠WARNING**

**The adjustable frequency drive must be equipped with a brake chopper.**

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

***NOTICE!***

**OVC cannot be activated when running a PM motor (when *1-10 Motor Construction* is set to [1] PM non salient SPM).**

**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$^{plus}$ mode**
When the adjustable frequency drive is overloaded (the torque limit in *4-16 Torque Limit Motor Mode*/*4-17 Torque Limit Generator Mode* is reached), the controls 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 *14-25 Trip Delay at Torque Limit*.

  

2

## 2.13.1 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 *Figure 2.40*

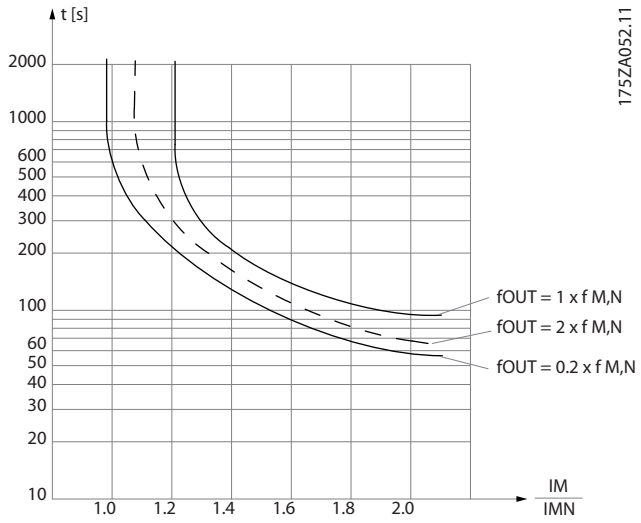


**Figure 2.40 The X-axis show the ratio between $I_{motor}$ and $I_{motor}$ nominal. The Y-axis is showing the time in seconds before the ETR cuts off and trips the adjustable frequency drive. The curves show the characteristic nominal speed at twice the nominal speed and at 0.2x the nominal speed.**

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 *16-18 Motor Thermal* in the adjustable frequency drive.

The thermistor cut-out value is > 3 kΩ.

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

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

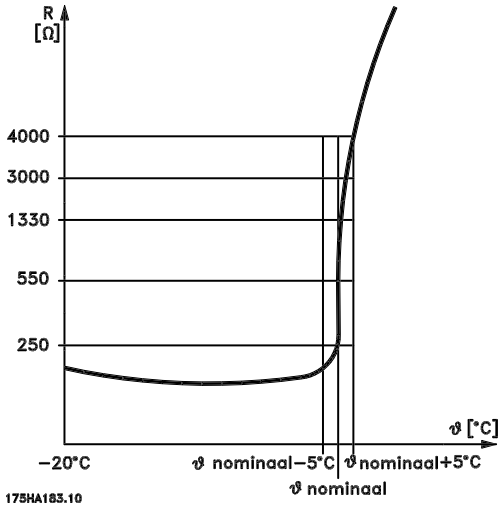


**Figure 2.41 The Thermistor Cut-out**

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 *1-90 Motor Thermal Protection* to *[2] Thermistor Trip*
Set *1-93 Thermistor Source* to *[6] Digital Input 33*

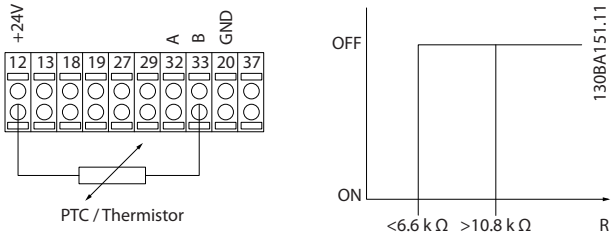


**Figure 2.42 Using a Digital Input and 24 V as Power Supply**

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 *1-90 Motor Thermal Protection* to *[2] Thermistor Trip*
Set *1-93 Thermistor Source* to *[6] Digital Input 33*

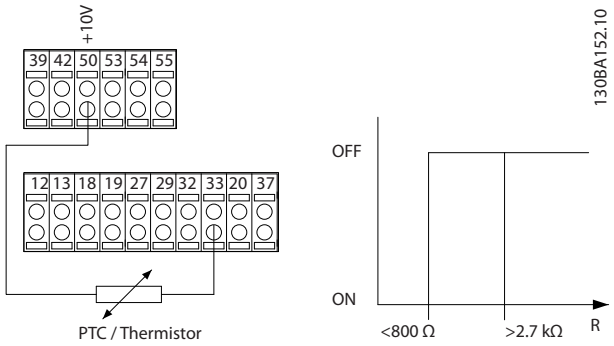


**Figure 2.43 Using a Digital Input and 10 V as Power Supply**

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 *1-90 Motor Thermal Protection* to *[2] Thermistor Trip*
Set *1-93 Thermistor Source* to *[2] Analog Input 54*
Do not select a reference source.

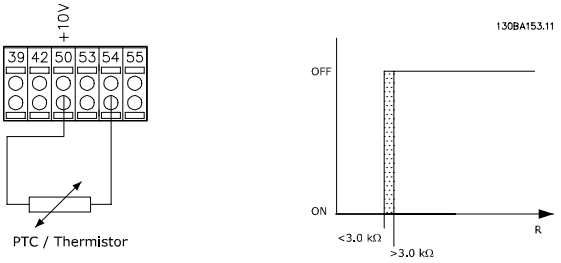


**Figure 2.44 Using an Analog Input and 10 V as Power Supply**

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

**Table 2.26 Threshold Cut-out Values**

***NOTICE!***

**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 from being overheated and there is no need for any further motor protection. That means when the motor is heated up, the ETR timer controls for how long time the motor can be running at the high temperature before it is stopped 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.

ETR is activated in *1-90 Motor Thermal Protection* and is controlled in *4-16 Torque Limit Motor Mode*. The time before the torque limit warning trips the adjustable frequency drive is set in *14-25 Trip Delay at Torque Limit*.

  

# 3 Selection

3

## 3.1 Options and Accessories

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

### 3.1.1 Mounting Option Modules in Slot B

Disconnect power to the adjustable frequency drive.

For A2 and A3 enclosure types:

1. Remove the LCP, the terminal cover, and the LCP frame from the adjustable frequency drive.
2. Fit the MCB1xx option card into slot B.
3. Connect the control cables and fasten the cables with the enclosed cable strips.
   Remove the knockout in the extended LCP frame delivered in the option set so that the option fits under the extended LCP frame.
4. Fit the extended LCP frame and terminal cover.
5. Fit the LCP or blind cover in the extended LCP frame.
6. Connect power to the adjustable frequency drive.
7. Set up the input/output functions in the corresponding parameters, as mentioned in *chapter 9.2 General Specifications*.

For B1, B2, C1 and C2 enclosure types:

1. Remove the LCP and the LCP cradle.
2. Fit the MCB 1xx option card into slot B.
3. Connect the control cables and fasten the cables with the enclosed cable strips.
4. Fit the cradle.
5. Fit the LCP.

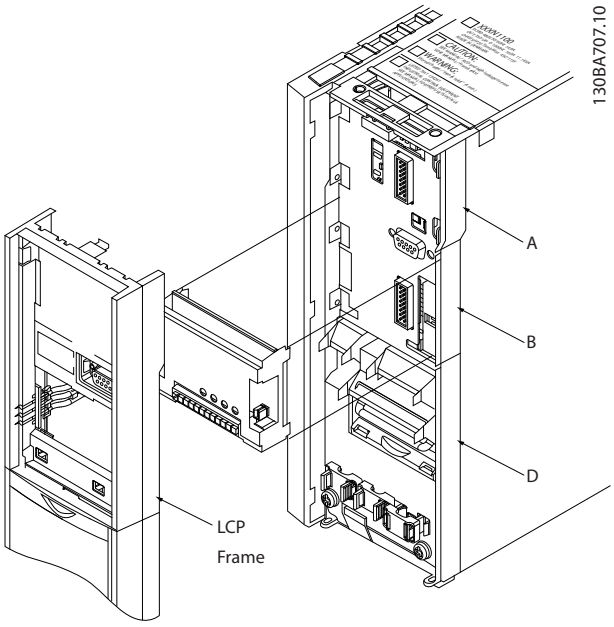


**Figure 3.1 A2, A3 and B3 Enclosure Types**

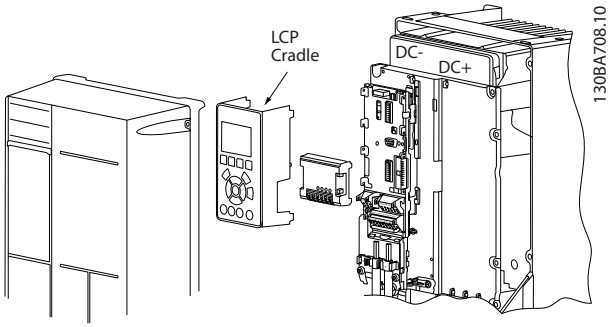


**Figure 3.2 A5, B1, B2, B4, C1, C2, C3 and C4 Enclosure Types**

## 3.1.2 General Purpose I/O Module MCB 101

MCB 101 is used for extension of the number of digital and analog inputs and outputs of the adjustable frequency drive.

MCB 101 must be fitted into slot B in the adjustable frequency drive. Contents:

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

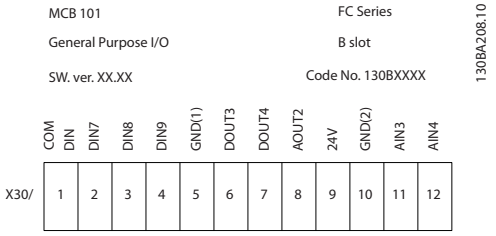


**Figure 3.3**

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

If the digital inputs 7, 8 or 9 are to be switched by use of the internal 24 V power supply (terminal 9) the connection between terminal 1 and 5 which is shown in *Figure 3.4* has to be established.

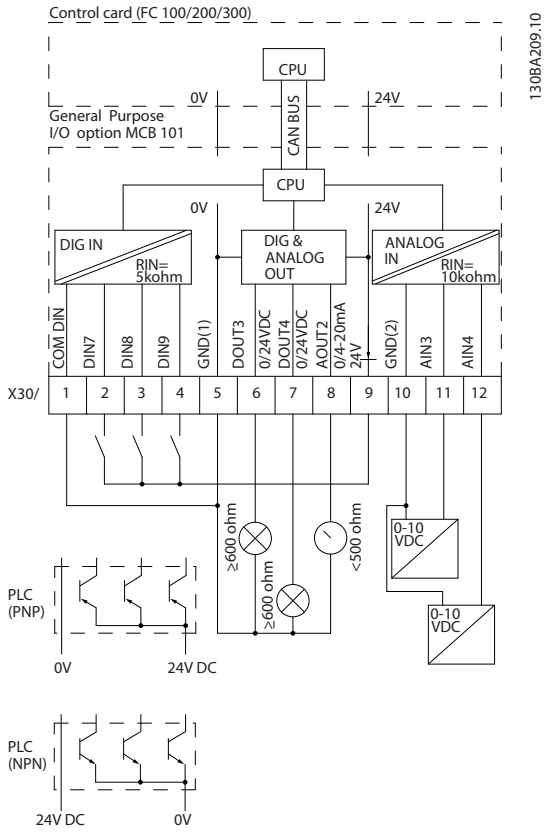


**Figure 3.4 Principle Diagram**

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### 3.1.3 Digital Inputs - Terminal X30/1-4

| 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 s | Approx. 5 kΩ |

**Table 3.1 Parameters for set-up: 5-16, 5-17 and 5-18**

### 3.1.4 Analog Voltage Inputs - Terminal X30/10-12

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

**Table 3.2 Parameters for set-up: 6-3*, 6-4* and 16-76**

### 3.1.5 Digital Outputs - Terminal X30/5-7

| Number of digital outputs | Output level | Tolerance | Max.impedance |
|---|---|---|---|
| 2 | 0 or 2 V DC | ± 4 V | ≥ 600 Ω |

**Table 3.3 Parameters for set-up: 5-32 and 5-33**

### 3.1.6 Analog Outputs - Terminal X30/5+8

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

**Table 3.4 Parameters for set-up: 6-6* and 16-77**

## 3.1.7 Relay Option MCB 105

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

3

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

*[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

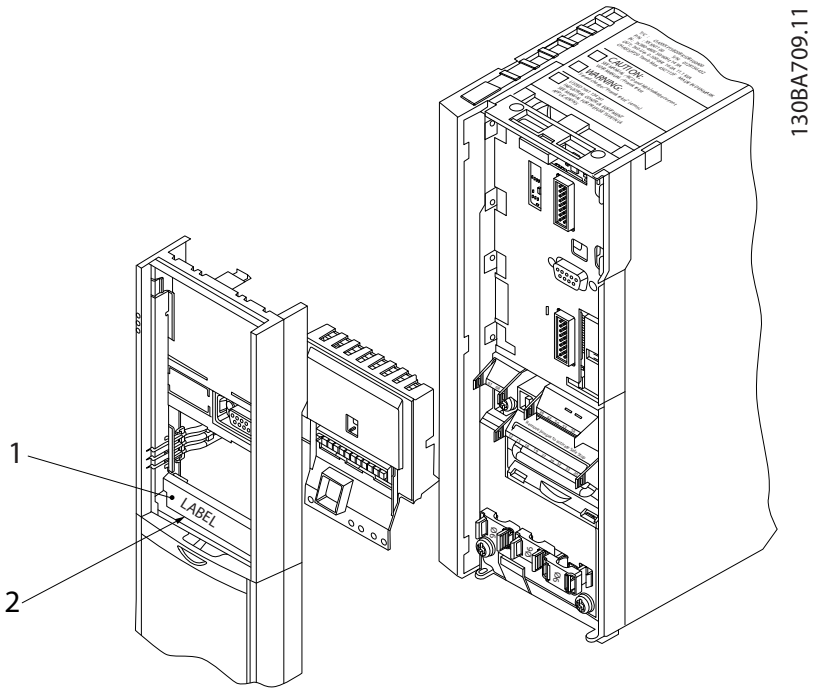


**Figure 3.5 Relay Option MCB 105**

| A2-A3-A4-B3 | A5-B1-B2-B4-C1-C2-C3-C4 |
|---|---|

***NOTICE!***

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

**Table 3.5 Legend to *Figure 3.5* and *Figure 3.6***

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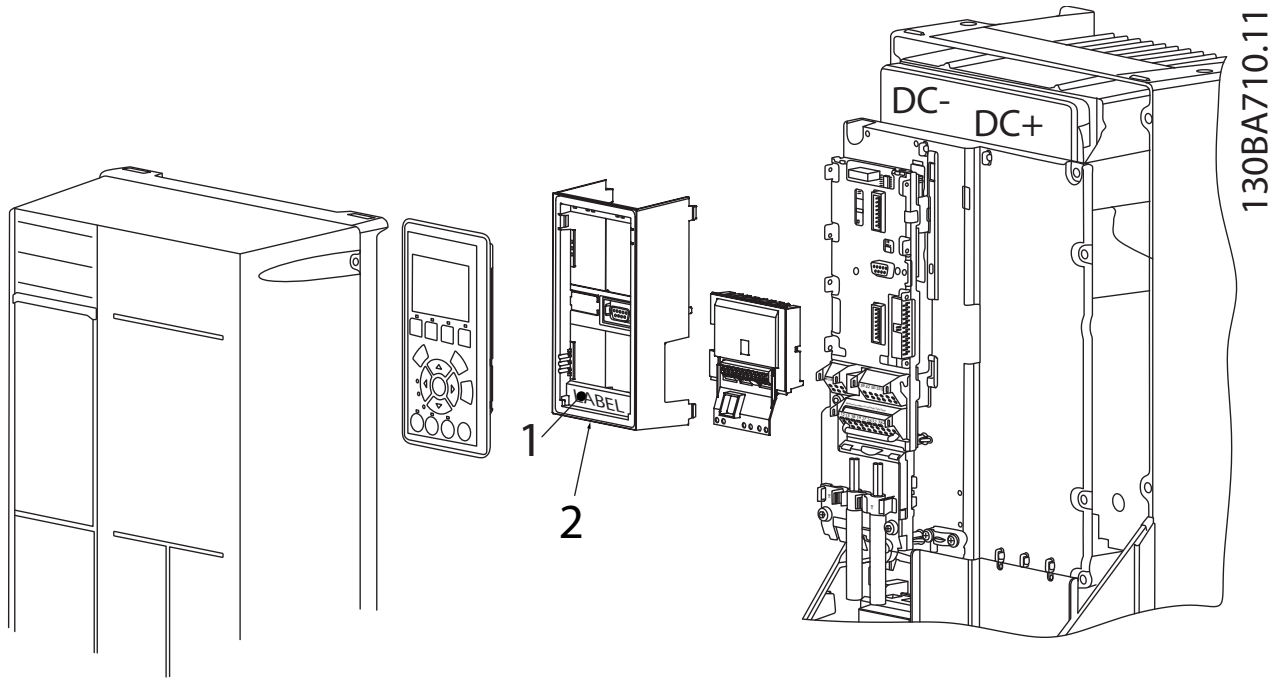


**Figure 3.6 Relay Option Kit**

## ⚠WARNING

**Warning Dual supply.**

How to add the MCB 105 option:

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

## *NOTICE!*

**Index [6] is relay 7, index [7] is relay 8, and index [8] is relay 9.**

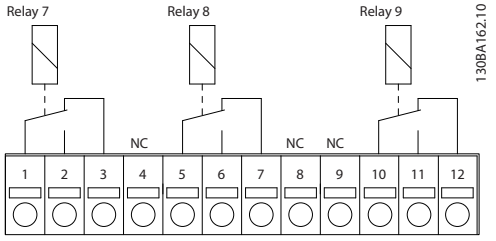


**Figure 3.7 Relay 7, Relay 8, and Relay 9**

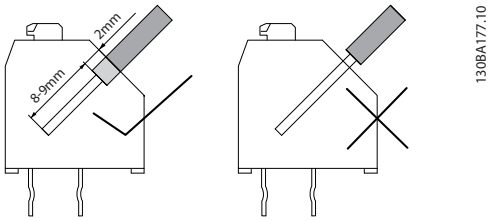


**Figure 3.8 Mounting**

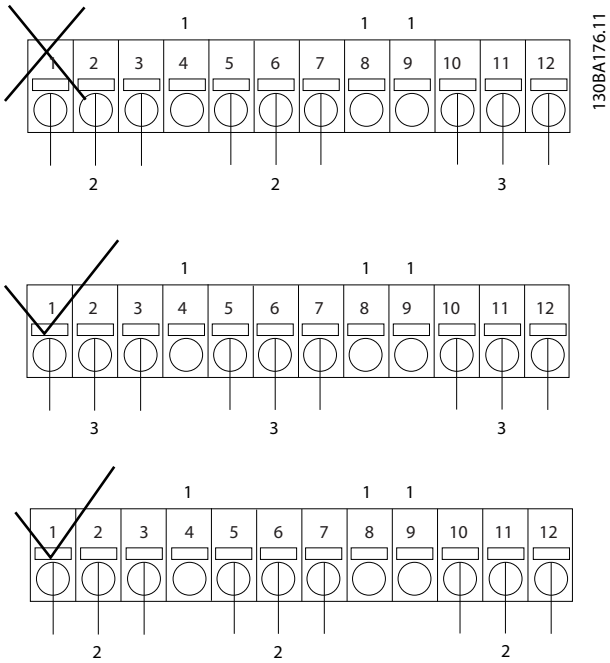


**Figure 3.9 Connection**

| | |
|---|---|
| 1 | NC |
| 2 | Live part |
| 3 | PELV |

**Table 3.6 Legend to *Figure 3.9***

**WARNING**

**Do not combine low voltage parts and PELV systems. At a single fault the whole system might become dangerous to touch, and it could result in death or serious injury.**

## 3.1.8 24 V Backup 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 busses without line power supplied to the power section.

| | |
|---|---|
| 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 | 250 ft [75 m] |
| Input capacitance load | <10 uF |
| Power-up delay | <0.6 s |

**Table 3.7 External 24 V DC Supply Specification**

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 decoupling plate and the plastic cover underneath.
4. Insert the 24 V DC backup 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.

3

When 24 V backup option MCB 107 supplies the control circuit, the internal 24 V supply is automatically disconnected.

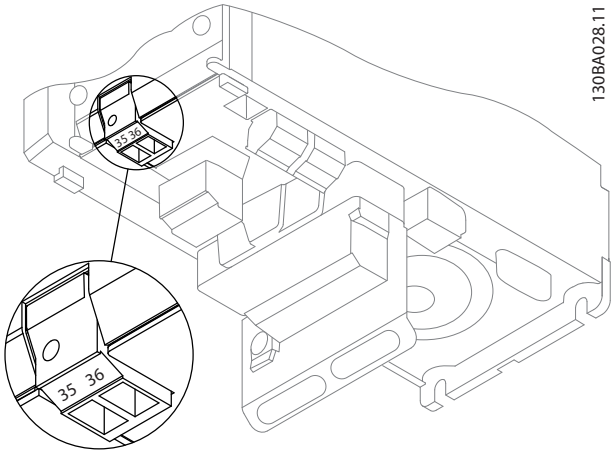


**Figure 3.10 Connection to 24 V Backup Supplier (A2-A3).**

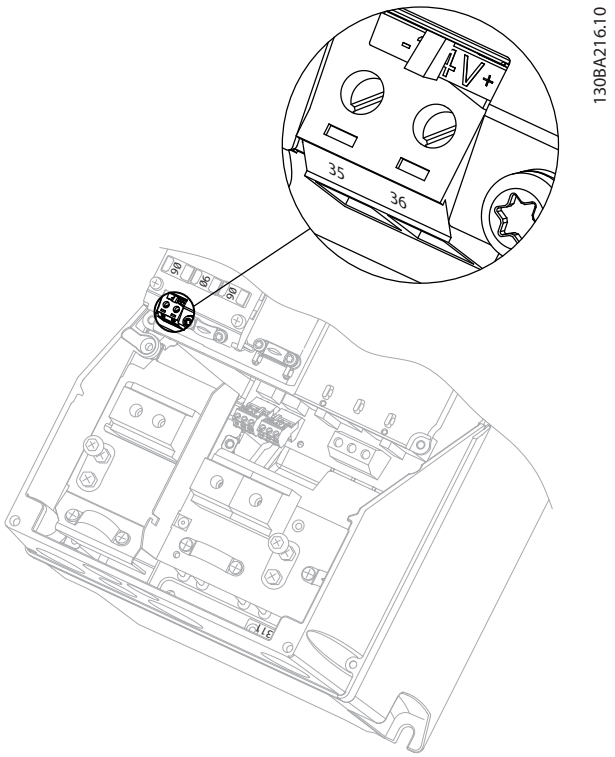


**Figure 3.11 Connection to 24 V Backup Supplier (A5-C2).**

## 3.1.9 Analog I/O option MCB 109

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

- Providing battery backup 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 servos

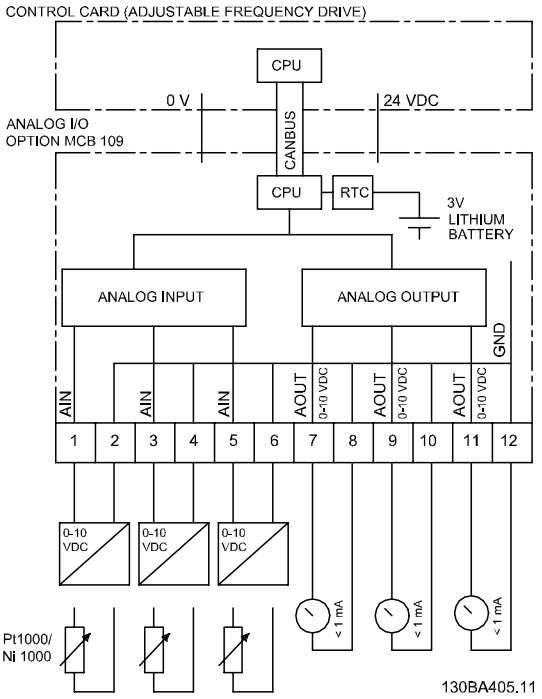


**Figure 3.12 Principle Diagram for Analog I/O Mounted in Adjustable Frequency Drive.**

  

**Analog I/O configuration**
3 x analog inputs, capable of handling following:

- 0–10 V DC

OR

- 0–20 mA (voltage input 0–10 V) by mounting a 510 Ω resistor across terminals (see **NOTICE**)
- 4–20 mA (voltage input 2–10 V) by mounting a 510 Ω resistor across terminals (see **NOTICE**)
- Ni1000 temperature sensor of 1000 Ω at 32 °F [0 °C]. Specifications according to DIN43760
- Pt1000 temperature sensor of 1000 Ω at 32 °F [0 °C]. Specifications according to IEC 60751

3 x Analog Outputs supplying 0–10 V DC.

***NOTICE!***

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

**Analog inputs - terminal X42/1-6**
Parameter group: 18-3*. See also *VLT® HVAC Drive Programming Guide*.

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

| **3 x analog inputs** | Used as temperature sensor input | Used as voltage input |
|---|---|---|
| **Operating range** | -58–+302 °F [-50–+150 °C] | 0–10 V DC |
| **Resolution** | 11 bits | 10 bits |
| **Accuracy** | -58 °F [-50 °C] ±1 Kelvin 302 °F [+150 °C] ±2 Kelvin | 0.2% of full scale at cal. temperature |
| **Sampling** | 3 Hz | 2.4 Hz |
| **Max load** | - | ± 20 V continuously |
| **Impedance** | - | Approximately 5 kΩ |

**Table 3.8 Analog inputs - terminal X42/1-6**

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 the feedback value in both °C and °F.

When operating with temperature sensors, maximum cable length to connect sensors is 270 ft [82 m] non-shielded/ non-twisted wires.

**Analog outputs - terminal X42/7-12**
Parameter group: 18-3*. See also *VLT® HVAC Drive Programming Guide*.
Parameter groups for set-up: 26-4*, 26-5* and 26-6*. See also *VLT® HVAC Drive Programming Guide*.

| **3 x analog outputs** | **Output signal level** | **Resolution** | **Linearity** | **Max load** |
|---|---|---|---|---|
| Volt | 0–10 V DC | 11 bits | 1% of full scale | 1 mA |

**Table 3.9 Analog outputs - terminal X42/7-12**

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, refer to the *VLT® HVAC Drive Programming Guide*.

**Real time clock (RTC) with backup**
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 backup battery lasts on average for minimum 10 years, when adjustable frequency drive is operating at 104 °F [40 °C] ambient temperature. If the battery backup pack fails, the analog I/O option must be replaced.

3

## 3.1.10 PTC Thermistor Card MCB 112

The MCB 112 option makes it possible to monitor the temperature of an electrical motor through a galvanically-isolated PTC thermistor input. It is a B option for adjustable frequency drive with Safe Torque Off.

For information on mounting and installation of the option, see *chapter 3.1.1 Mounting Option Modules in Slot B*. See also *chapter 7 Application Examples* for different application possibilities.

X44/1 and X44/2 are the thermistor inputs. X44/12 enables Safe Torque Off of the adjustable frequency drive (T-37), if the thermistor values make it necessary, and X44/10 informs the adjustable frequency drive that a request for safe torque off came from the MCB 112 to ensure a suitable alarm handling. One of the digital inputs parameters (or a digital input of a mounted option) must be set to *[80] PTC Card 1* to use the information from X44/10. Configure *5-19 Terminal 37 Safe Stop* to the desired Safe Torque Off functionality (default is Safe Stop Alarm).

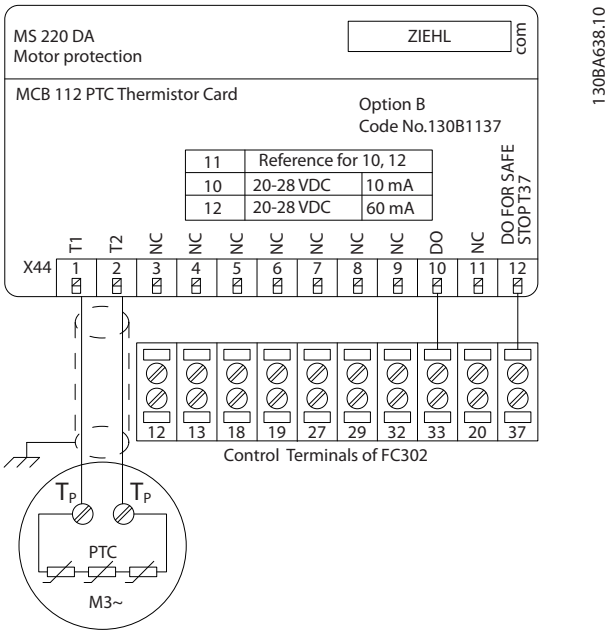


**Figure 3.13 Installation of MCB 112**

**ATEX Certification with FC 102**

The MCB 112 has been certified for ATEX, which means that the adjustable frequency drive with the MCB 112 can now be used with motors in potentially explosive atmospheres. See the Instruction Manual for the MCB 112 for more information.

**Figure 3.14 ATmosphère EXplosive (ATEX)**

**Electrical Data**

| Resistor connection | |
|---|---|
| PTC compliant with DIN 44081 and DIN 44082. | |
| Number | 1..6 resistors in series |
| Shut-off value | 3.3 Ω.... 3.65 Ω.... 3.85 Ω |
| Reset value | 1.7 Ω.... 1.8 Ω... 1.95 Ω |
| Trigger tolerance | ± 11 °F [± 6 °C] |
| Collective resistance of the sensor loop | < 1.65 Ω |
| Terminal voltage | ≤ 2.5 V for R ≤ 3.65 Ω, ≤ 9 V for R = ∞ |
| Sensor current | ≤ 1 mA |
| Short-circuit | 20 Ω ≤ R ≤ 40 Ω |
| Power consumption | 60 mA |

| Testing conditions | |
|---|---|
| EN 60 947-8 | |
| Measurement voltage surge resistance | 6000 V |
| Overvoltage category | III |
| Pollution degree | 2 |
| Measurement isolation voltage Vbis | 690 V |
| Reliable galvanic isolation until Vi | 500 V |
| Perm. ambient temperature | -4–+140 °F [-20–+60 °C] |
| | EN 60068-2-1 Dry heat |
| Moisture | 5–95%, no condensation permissible |
| EMC resistance | EN61000-6-2 |
| EMC emissions | EN61000-6-4 |
| Vibration resistance | 10 ... 1000 Hz 1.14 g |
| Shock resistance | 50 g |

| Safety system values | |
|---|---|
| EN 61508 for Tu = 75 °C ongoing | |
| SIL | 2 for maintenance cycle of 2 years |
| | 1 for maintenance cycle of 3 years |
| HFT | 0 |
| PFD (for yearly functional test) | $4.10 * 10^{-3}$ |
| SFF | 78% |
| $\lambda_s + \lambda_{DD}$ | 8494 FIT |
| $\lambda_{DU}$ | 934 FIT |
| Ordering number 130B1137 | |

## 3.1.11 Sensor Input Option MCB 114

The sensor input option card MCB 114 can be used in the following cases:

- Sensor input for temperature transmitters PT100 and PT1000 for monitoring bearing temperatures
- As general extension of analog inputs with one additional input for multi-zone control or differential pressure measurements
- Support extended PID controllers with I/Os for setpoint, transmitter/sensor inputs

Typical motors, designed with temperature sensors for protecting bearings from being overloaded, are fitted with three PT100/1000 temperature sensors. One in front, one in the back-end bearing, and one in the motor windings. The sensor input Option MCB 114 supports two or three-wire sensors with individual temperature limits for under/over temperature. An auto detection of sensor type PT100 or PT1000 takes place at power-up.

The option can generate an alarm if the measured temperature is either below low limit or above high limit specified by the user. The individual measured temperature on each sensor input can be read out in the display or by readout parameters. If an alarm occurs, the relays or digital outputs can be programmed to be active high by selecting *[21] Thermal Warning* in parameter group 5-**.

3

A fault condition has a common warning/alarm number associated with it, which is Alarm/Warning 20, Temp. input error. Any present output can be programmed to be active in case the warning or alarm appears.

### 3.1.11.1 Ordering Code Numbers and Parts Delivered

Standard version code no: 130B1172.
Coated version code no: 130B1272.

### 3.1.11.2 Electrical and Mechanical Specifications

| Analog Input | |
|---|---|
| Number of analog inputs | 1 |
| Format | 0–20 mA or 4–20 mA |
| Wires | 2 |
| Input impedance | <200 Ω |
| Sample rate | 1 kHz |
| Third order filter | 100 Hz at 3 dB |

The option is able to supply the analog sensor with 24 V DC (terminal 1).

| Temperature Sensor Input | |
|---|---|
| Number of analog inputs supporting PT100/1000 | 3 |
| Signal type | PT100/1000 |
| Connection | PT 100 2 or 3 wire/PT1000 2 or 3 wire |
| Frequency PT100 and PT1000 input | 1Hz for each channel |
| Resolution | 10 bit |
| Temperature range | -50–+204 °C<br>-58–+399 °F |

| Galvanic Isolation | |
|---|---|
| The sensors to be connected are expected to be galvanically isolated from the AC line voltage level. | IEC 61800-5-1 and UL508C |

| Cabling | |
|---|---|
| Maximum signal cable length | 1640 ft [500 m] |

  

### 3.1.11.3 Electrical Wiring

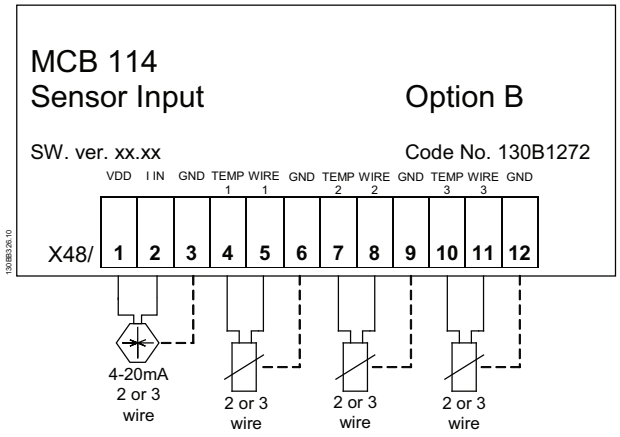


**Figure 3.15 Electrical Wiring**

| Terminal | Name | Function |
|---|---|---|
| 1 | VDD | 24 V DC to supply 4–20 mA sensor |
| 2 | I in | 4–20 mA input |
| 3 | GND | Analog input GND |
| 4, 7, 10 | Temp 1, 2, 3 | Temperature input |
| 5, 8, 11 | Wire 1, 2, 3 | Third wire input if three wire sensors are used |
| 6, 9, 12 | GND | Temp. input GND |

**Table 3.10 Terminals**

### 3.1.12 Remote Mounting Kit for LCP

The LCP can be moved to the front of a cabinet by using the remote built-in kit. The enclosure is the IP66. The fastening screws must be tightened with a torque of max. 1 Nm.

| Enclosure | IP66 front |
|---|---|
| Max. cable length between and unit | 10 ft [3 m] |
| Communication std | RS-485 |

**Table 3.11 Technical Data**

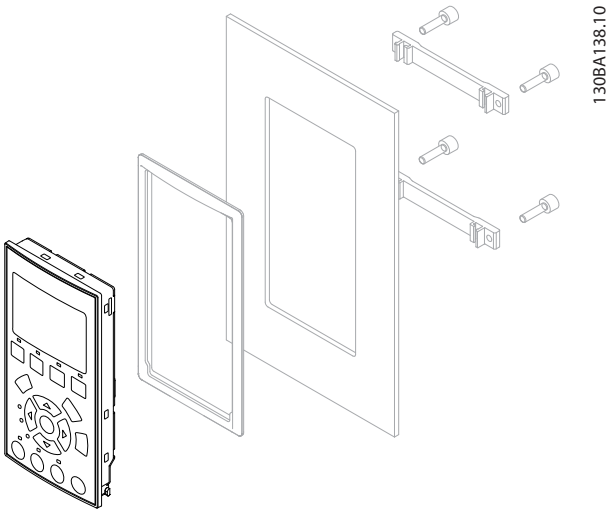


**Figure 3.16 LCP Kit with Graphical LCP, Fasteners, 10 ft [3 m] Cable and Gasket**
**Ordering No. 130B1113**

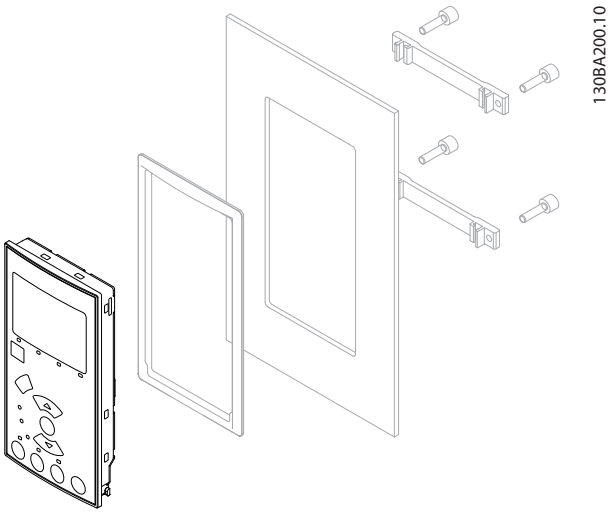


**Figure 3.17 LCP Kit with Numerical LCP, Fasteners and Gasket**
**Ordering no. 130B1114**

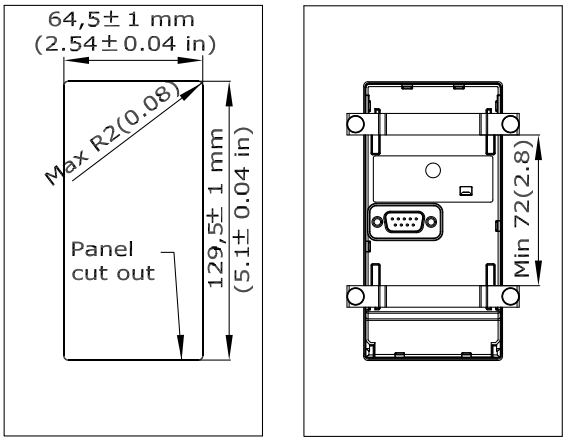


**Figure 3.18 Dimensions**

## 3.1.13 IP21/IP41/ TYPE1 Enclosure Kit

IP21/IP41 top/ TYPE 1 is an optional enclosure element available for IP20 compact units, enclosure size A2-A3, B3+B4 and C3+C4.
If the enclosure kit is used, an IP20 unit is upgraded to comply with enclosure IP21/41 top/TYPE 1.

The IP41 top can be applied to all standard IP20 VLT® HVAC Drive variants.

## 3.1.14 IP21/Type 1 Enclosure Kit

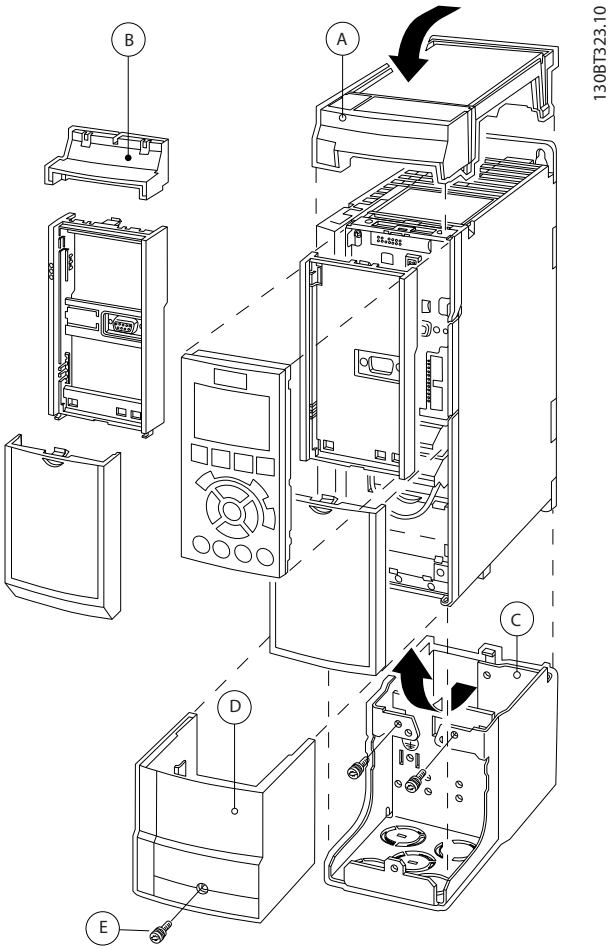


**Figure 3.19 Enclosure Type A2**

  

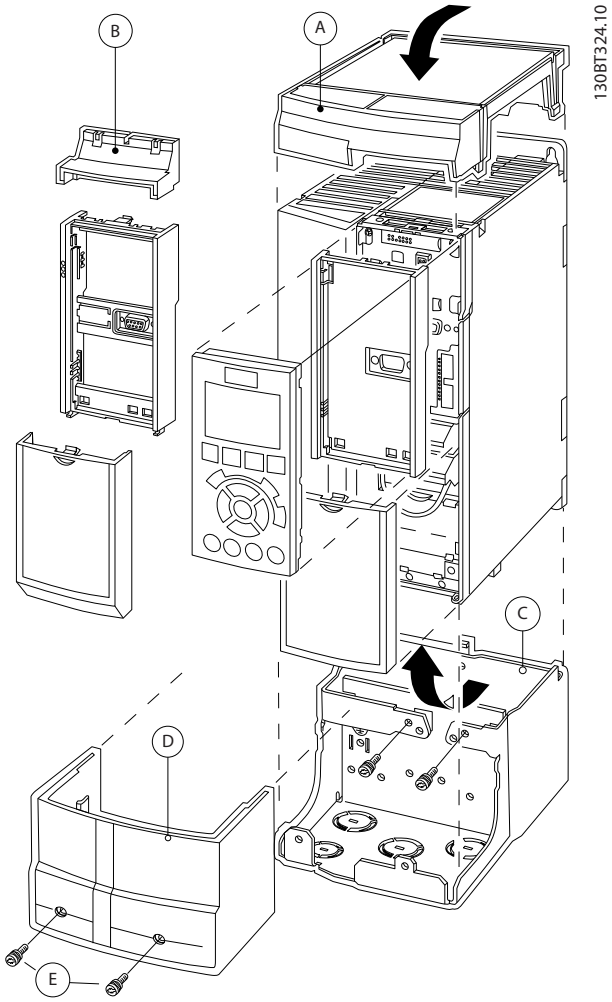


**Figure 3.20 Enclosure Type A3**

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

**Table 3.12 Legend to *Figure 3.19* and *Figure 3.20***

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 adjustable frequency 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

| Enclosure type | Height A (in [mm]) | Width B (in [mm]) | Depth C* (in [mm]) |
|---|---|---|---|
| A2 | 14.65 [372] | 3.54 [90] | 8.07 [205] |
| A3 | 14.65 [372] | 5.12 [130] | 8.07 [205] |
| B3 | 18.7 [475] | 6.5 [165] | 9.8 [249] |
| B4 | 26.38 [670] | 10.04 [255] | 9.69 [246] |
| C3 | 29.72 [755] | 12.95 [329] | 13.27 [337] |
| C4 | 37.4 [950] | 15.39 [391] | 13.27 [337] |

**Table 3.13 Dimensions**

** If option A/B is used, the depth increases*
*(see chapter 5.1.2 Mechanical Dimensions for details)*

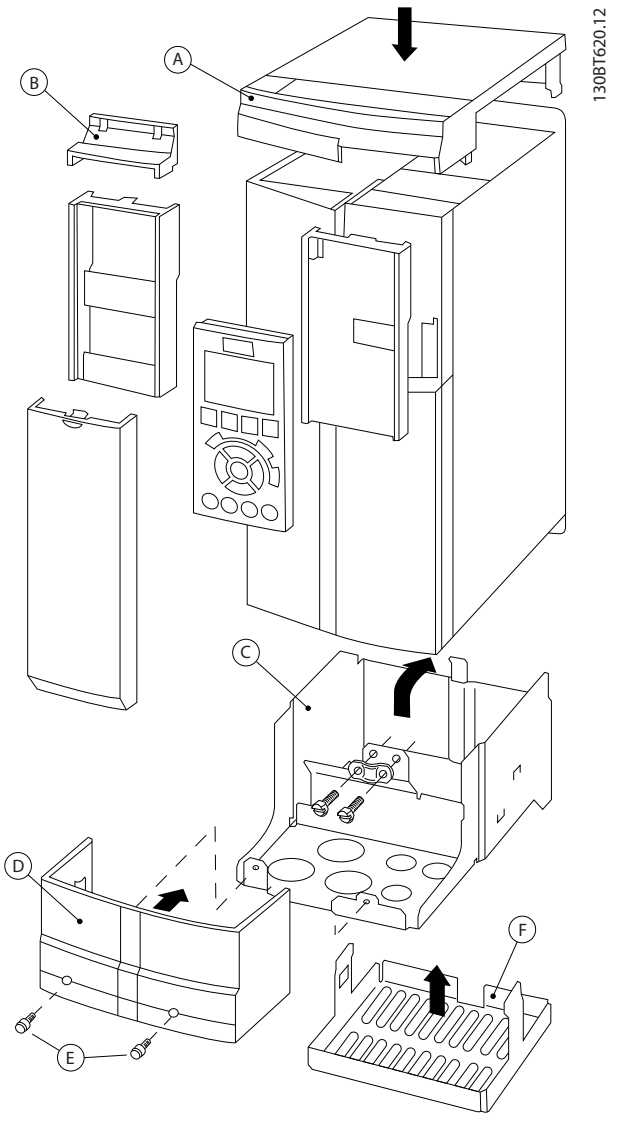


**Figure 3.21 Enclosure Type B3**

3

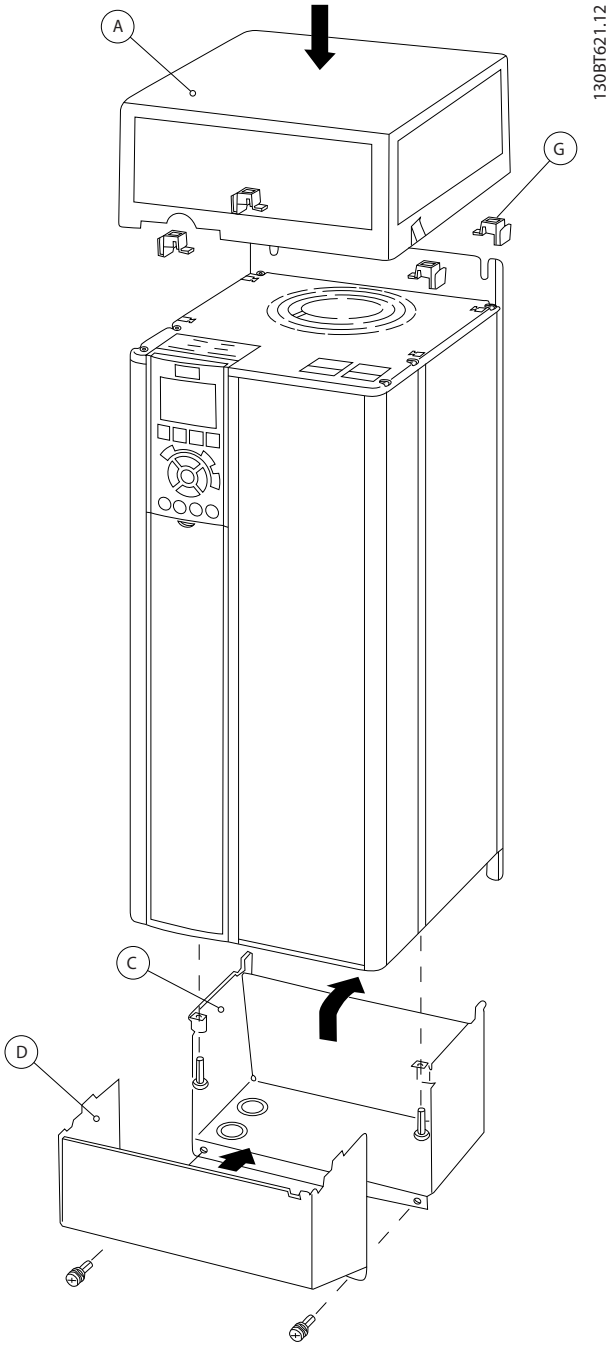


**Figure 3.22 Enclosure Types B4 - C3 - C4**

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

**Table 3.14 Legend to *Figure 3.21* and *Figure 3.21***

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

***NOTICE!***

**Side-by-side installation is not possible when using the *IP21/IP4X/TYPE 1 Enclosure Kit.***

## 3.1.15 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 shutdown. The dU/dt filter is designed to reduce the voltage rise time/the rapid energy change in the motor and by that intervention avoid premature aging and flashover in the motor insulation. dU/dt filters have a positive influence on the radiation of magnetic noise in the cable that connects the adjustable frequency 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 services. Sine-wave filters enable use of longer motor cables in applications where the motor is installed far from the adjustable frequency drive. The length is unfortunately limited because the filter does not reduce leakage currents in the cables.

  

# 4 How to Order

## 4.1 Ordering Form

### 4.1.1 Drive Configurator

It is possible to design an adjustable frequency drive according to the application requirements by using the ordering number system.

Order the adjustable frequency drive as either standard or with integral options by sending a type code string describing the product a to the local Danfoss sales office, i.e.:

FC-102P18KT4E21H1XGCXXXSXXXXAGBKCXXXXDX

The meaning of the characters in the string can be located in the pages containing the ordering numbers in *chapter 3 Selection*. In the example above, a Profibus LON works option and a general purpose I/O option is included in the adjustable frequency drive.

Ordering numbers for adjustable frequency drive standard variants can also be located in *chapter 4 How to Order*.

Configure the right adjustable frequency drive for the right application and generate the type code string in the Internet-based Drive Configurator. The Drive Configurator automatically generates an 8-digit sales number to be delivered to the local sales office.
Furthermore, 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*.

**Example of Drive Configurator interface set-up:**
The numbers shown in the boxes refer to the letter/figure number of the type code string; read from left to right.

| | | |
|---|---|---|
| Product groups | 1-3 | |
| Adjustable frequency drive series | 4-6 | |
| Power rating | 8-10 | |
| Phases | 11 | |
| AC Line Voltage | 12 | |
| Enclosure | 13-15 | |
| Enclosure type | | |
| Enclosure class | | |
| Control supply voltage | | |
| Hardware configuration | | |
| RFI filter | 16-17 | |
| Brake | 18 | |
| Display (LCP) | 19 | |
| Coating PCB | 20 | |
| Line power option | 21 | |
| Adaptation A | 22 | |
| Adaptation B | 23 | |
| Software release | 24-27 | |
| Software language | 28 | |
| A options | 29-30 | |
| B options | 31-32 | |
| C0 options, MCO | 33-34 | |
| C1 options | 35 | |
| C option software | 36-37 | |
| D options | 38-39 | |

**Table 4.1 Example of Drive Configurator Interface Set-up**

## 4.1.2 Type Code String Low and Medium Power

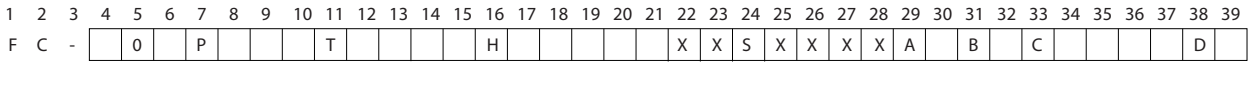


**Figure 4.1 Type Code String**

4

| Description | Pos. | Possible choice |
|---|---|---|
| Product group & FC Series | 1-6 | FC 102 |
| Power rating | 8-10 | 1.1–90 kW (P1K1–P90K) |
| Number of phases | 11 | 3 phases (T) |
| AC line voltage | 11-12 | S 2: 220–240 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: IP21/NEMA Type 1<br>E55: IP55/NEMA Type 12<br>E66: IP66<br>P21: IP21/NEMA Type 1 w/backplate<br>P55: IP55/NEMA Type 12 w/backplate<br>Z55: A4 Frame IP55<br>Z66: A4 Frame IP66 |
| RFI filter | 16-17 | H1: RFI filter class A1/B<br>H2: RFI filter class A2<br>H3: RFI filter class A1/B (reduced cable length)<br>Hx: No RFI filter |
| 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 | X: No line power disconnect switch and load sharing<br>1: With line power disconnect switch (IP55 only)<br>8: Line power disconnect and Load Sharing<br>D: Load Sharing<br>See Chapter 9 for max. cable sizes. |
| Adaptation | 22 | X: Standard cable entries<br>O: European metric thread in cable entries (A4, A5, B1, B2 only)<br>S: Imperial cable entries (A5, B1, B2 only) |
| Adaptation | 23 | Reserved |
| Software release | 24-27 | Current software |
| Software language | 28 | |

  

| Description | Pos. | Possible choice |
|---|---|---|
| A options | 29-30 | AX: No options<br>A0: MCA 101 Profibus DP V1<br>A4: MCA 104 DeviceNet<br>AG: MCA 108 Lonworks<br>AJ: MCA 109 BACnet gateway<br>AL: MCA 120 Profinet<br>AN: MCA 121 EtherNet/IP<br>AQ: MCA 122 Modbus TCP |
| 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>B2: MCB 112 PTC Thermistor Card<br>B4: MCB 114 Sensor input option |
| C0 options MCO | 33-34 | CX: No options |
| C1 options | 35 | X: No options |
| C option software | 36-37 | XX: Standard software |
| D options | 38-39 | DX: No option<br>D0: 24 V backup |

**Table 4.2 Type Code Description**

## 4.2 Ordering Numbers

### 4.2.1 Ordering Numbers: Options and Accessories

| Type | Description | Ordering no. |
|---|---|---|
| **Miscellaneous hardware I** | | |
| DC link connector | Terminal block for DC link connnection on A2/A3 | 130B1064 |
| IP 21/4X top/TYPE 1 kit | IP21/NEMA1 Top + bottom A2 | 130B1122 |
| IP 21/4X top/TYPE 1 kit | IP21/NEMA1 Top + bottom A3 | 130B1123 |
| IP 21/4X top/TYPE 1 kit | IP21/NEMA1 Top + bottom B3 | 130B1187 |
| IP 21/4X top/TYPE 1 kit | IP21/NEMA1 Top + bottom B4 | 130B1189 |
| IP 21/4X top/TYPE 1 kit | IP21/NEMA1 Top + bottom C3 | 130B1191 |
| IP 21/4X top/TYPE 1 kit | IP21/NEMA1 Top + bottom C4 | 130B1193 |
| IP21/4X top | IP21 Top Cover A2 | 130B1132 |
| IP21/4X top | IP21 Top Cover A3 | 130B1133 |
| IP 21/4X top | IP21 Top Cover B3 | 130B1188 |
| IP 21/4X top | IP21 Top Cover B4 | 130B1190 |
| IP 21/4X top | IP21 Top Cover C3 | 130B1192 |
| IP 21/4X top | IP21 Top Cover C4 | 130B1194 |
| Panel Through Mount Kit | Enclosure, enclosure type A5 | 130B1028 |
| Panel Through Mount Kit | Enclosure, enclosure type B1 | 130B1046 |
| Panel Through Mount Kit | Enclosure, enclosure type B2 | 130B1047 |
| Panel Through Mount Kit | Enclosure, enclosure type C1 | 130B1048 |
| Panel Through Mount Kit | Enclosure, enclosure type C2 | 130B1049 |
| Profibus D-Sub 9 | Connector kit for IP20 | 130B1112 |
| Profibus top entry kit | Top entry kit for Profibus connection - D + E enclosure types | 176F1742 |
| 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 | A5 IP55/NEMA 12 | 130B1098 |
| Backplate | B1 IP21/IP55 / NEMA 12 | 130B3383 |

4

| Type | Description | Ordering no. |
|---|---|---|
| **Miscellaneous hardware I** | | |
| Backplate | B2 IP21/IP55 / NEMA 12 | 130B3397 |
| Backplate | C1 IP21/IP55 / NEMA 12 | 130B3910 |
| Backplate | C2 IP21/IP55 / NEMA 12 | 130B3911 |
| Backplate | A5 IP66 | 130B3242 |
| Backplate | B1 IP66 | 130B3434 |
| Backplate | B2 IP66 | 130B3465 |
| Backplate | C1 IP66 | 130B3468 |
| Backplate | C2 IP66 | 130B3491 |
| **LCPs and kits** | | |
| LCP 101 | Numerical Local Control Panel (NLCP) | 130B1124 |
| 102 | Graphical Local Control Panel (GLCP) | 130B1107 |
| cable | Separate cable, 10 ft [3 m] | 175Z0929 |
| kit | Panel mounting kit including graphical LCP, fasteners, 10 ft [3 m] cable and gasket | 130B1113 |
| LCP kit | Panel mounting kit including numerical LCP, fasteners and gasket | 130B1114 |
| kit | Panel mounting kit for all LCPs including fasteners, 10 ft [3 m] cable and gasket | 130B1117 |
| kit | Front mounting kit, IP55 enclosures | 130B1129 |
| kit | Panel mounting kit for all LCPs including fasteners and gasket - without cable | 130B1170 |

**Table 4.3 Options can be ordered as factory built-in options, see ordering information.**

| Type | Description | Comments |
|---|---|---|
| **Options for Slot A** | | **Ordering no. Coated** |
| MCA 101 | Profibus option DP V0/V1 | 130B1200 |
| MCA 104 | DeviceNet option | 130B1202 |
| MCA 108 | Lonworks | 130B1206 |
| MCA 109 | BACnet gateway for built-in. Not to be used with the relay option MCB 105 card | 130B1244 |
| MCA 120 | Profinet | 130B1135 |
| MCA 121 | Ethernet | 130B1219 |
| **Options for Slot B** | | |
| MCB 101 | General purpose Input Output option | |
| MCB 105 | Relay option | |
| MCB 109 | Analog I/O option and battery backup for real-time clock | 130B1243 |
| MCB 112 | ATEX PTC | 130B1137 |
| MCB 114 | Sensor input - uncoated | 130B1172 |
| | Sensor input - coated | 130B1272 |
| **Option for Slot D** | | |
| MCB 107 | 24 V DC backup | 130B1208 |
| **External Options** | | |
| Ethernet IP | Ethernet master | |

**Table 4.4 Ordering Information Options**

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

  

| Type | Description | | |
|---|---|---|---|
| **Spare Parts** | | **Ordering no.** | **Comments** |
| Control board FC | With Safe Stop Function | 130B1150 | |
| Control board FC | Without Safe Stop Function | 130B1151 | |
| Fan A2 | Fan, enclosure type A2 | 130B1009 | |
| Fan A3 | Fan, enclosure type A3 | 130B1010 | |
| Fan A5 | Fan, enclosure type A5 | 130B1017 | |
| Fan B1 | Fan external, enclosure type B1 | 130B3407 | |
| Fan B2 | Fan external, enclosure type B2 | 130B3406 | |
| Fan B3 | Fan external, enclosure type B3 | 130B3563 | |
| Fan B4 | Fan external, 18.5/22 kW | 130B3699 | |
| Fan B4 | Fan external 22/30 kW | 130B3701 | |
| Fan C1 | Fan external, enclosure type C1 | 130B3865 | |
| Fan C2 | Fan external, enclosure type C2 | 130B3867 | |
| Fan C3 | Fan external, enclosure type C3 | 130B4292 | |
| Fan C4 | Fan external, enclosure type C4 | 130B4294 | |
| **Miscellaneous hardware II** | | | |
| Accessory bag A2 | Accessory bag, enclosure type A2 | 130B1022 | |
| Accessory bag A3 | Accessory bag, enclosure type A3 | 130B1022 | |
| Accessory bag A4 | Accessory bag for frame A4 w/o thread | 130B0536 | |
| Accessory bag A5 | Accessory bag, enclosure type A5 | 130B1023 | |
| Accessory bag B1 | Accessory bag, enclosure type B1 | 130B2060 | |
| Accessory bag B2 | Accessory bag, enclosure type B2 | 130B2061 | |
| Accessory bag B3 | Accessory bag, enclosure type B3 | 130B0980 | |
| Accessory bag B4 | Accessory bag, enclosure type B4 | 130B1300 | Small |
| Accessory bag B4 | Accessory bag, enclosure type B4 | 130B1301 | Big |
| Accessory bag C1 | Accessory bag, enclosure type C1 | 130B0046 | |
| Accessory bag C2 | Accessory bag, enclosure type C2 | 130B0047 | |
| Accessory bag C3 | Accessory bag, enclosure type C3 | 130B0981 | |
| Accessory bag C4 | Accessory bag, enclosure type C4 | 130B0982 | Small |
| Accessory bag C4 | Accessory bag, enclosure type C4 | 130B0983 | Big |

**Table 4.5 Accessories Ordering Information**

## 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

4

| $I_{AHF, N}$ [A] | Typical Motor Used [kW] | Danfoss Ordering Number | | Adjustable frequency drive size |
|---|---|---|---|---|
| | | AHF 005 | AHF 010 | |
| 10 | 1.1–4 | 175G6600 | 175G6622 | P1K1, P4K0 |
| 19 | 5.5–7.5 | 175G6601 | 175G6623 | P5K5–P7K5 |
| 26 | 11 | 175G6602 | 175G6624 | P11K |
| 35 | 15–18.5 | 175G6603 | 175G6625 | P15K–P18K |
| 43 | 22 | 175G6604 | 175G6626 | P22K |
| 72 | 30–37 | 175G6605 | 175G6627 | P30K–P37K |
| 101 | 45–55 | 175G6606 | 175G6628 | P45K–P55K |
| 144 | 75 | 175G6607 | 175G6629 | P75K |
| 180 | 90 | 175G6608 | 175G6630 | P90K |
| 217 | 110 | 175G6609 | 175G6631 | P110 |
| 289 | 132 | 175G6610 | 175G6632 | P132–P160 |
| 324 | 160 | 175G6611 | 175G6633 | |
| 370 | 200 | 175G6688 | 175G6691 | P200 |
| 506 | 250 | 175G6609 + 175G6610 | 175G6631 + 175G6632 | P250 |
| 578 | 315 | 2x 175G6610 | 2x 175G6632 | P315 |
| 648 | 355 | 2x175G6611 | 2x175G6633 | P355 |
| 694 | 400 | 175G6611 + 175G6688 | 175G6633 + 175G6691 | P400 |
| 740 | 450 | 2x175G6688 | 2x175G6691 | P450 |

**Table 4.6 380–415 V AC, 50 Hz**

| $I_{AHF, N}$ [A] | Typical Motor Used [hp] | Danfoss Ordering Number | | Adjustable frequency drive size |
|---|---|---|---|---|
| | | AHF 005 | AHF 010 | |
| 10 | 1.1–4 | 130B2540 | 130B2541 | P1K1–P4K0 |
| 19 | 5.5–7.5 | 130B2460 | 130B2472 | P5K5–P7K5 |
| 26 | 11 | 130B2461 | 130B2473 | P11K |
| 35 | 15–18.5 | 130B2462 | 130B2474 | P15K, P18K |
| 43 | 22 | 130B2463 | 130B2475 | P22K |
| 72 | 30–37 | 130B2464 | 130B2476 | P30K–P37K |
| 101 | 45–55 | 130B2465 | 130B2477 | P45K–P55K |
| 144 | 75 | 130B2466 | 130B2478 | P75K |
| 180 | 90 | 130B2467 | 130B2479 | P90K |
| 217 | 110 | 130B2468 | 130B2480 | P110 |
| 289 | 132 | 130B2469 | 130B2481 | P132 |
| 324 | 160 | 130B2470 | 130B2482 | P160 |
| 370 | 200 | 130B2471 | 130B2483 | P200 |
| 506 | 250 | 130B2468 + 130B2469 | 130B2480 + 130B2481 | P250 |
| 578 | 315 | 2x 130B2469 | 2x 130B2481 | P315 |
| 648 | 355 | 2x130B2470 | 2x130B2482 | P355 |
| 694 | 400 | 130B2470 + 130B2471 | 130B2482 + 130B2483 | P400 |
| 740 | 450 | 2x130B2471 | 130B2483 | P450 |

**Table 4.7 380–415 V AC, 60 Hz**

| $I_{AHF, N}$ [A] | Typical Motor Used [hp] | Danfoss Ordering Number | | Adjustable frequency drive size |
|---|---|---|---|---|
| | | AHF 005 | AHF 010 | |
| 10 | 1.5–7.5 | 130B2538 | 130B2539 | P1K1–P5K5 |
| 19 | 10–15 | 175G6612 | 175G6634 | P7K5–P11K |
| 26 | 20 | 175G6613 | 175G6635 | P15K |
| 35 | 25–30 | 175G6614 | 175G6636 | P18K–P22K |
| 43 | 40 | 175G6615 | 175G6637 | P30K |
| 72 | 50–60 | 175G6616 | 175G6638 | P37K–P45K |
| 101 | 75 | 175G6617 | 175G6639 | P55K |
| 144 | 100–125 | 175G6618 | 175G6640 | P75K–P90K |
| 180 | 150 | 175G6619 | 175G6641 | P110 |
| 217 | 200 | 175G6620 | 175G6642 | P132 |
| 289 | 250 | 175G6621 | 175G6643 | P160 |
| 370 | 350 | 175G6690 | 175G6693 | P200 |
| 434 | 350 | 2x175G6620 | 2x175G6642 | P250 |
| 506 | 450 | 175G6620 + 175G6621 | 175G6642 + 175G6643 | P315 |
| 578 | 500 | 2x 175G6621 | 2x 175G6643 | P355 |
| 648 | 550-600 | 2x175G6689 | 2x175G6692 | P400 |
| 694 | 600 | 175G6689 + 175G6690 | 175G6692 + 175G6693 | P450 |
| 740 | 650 | 2x175G6690 | 2x175G6693 | P500 |

**Table 4.8 440–480 V AC, 60 Hz**

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.

4

| $I_{AHF, N}$ [A] | Typical Motor Used [kW] | Danfoss Ordering Number | | Adjustable frequency drive size |
|---|---|---|---|---|
| | | AHF 005 | AHF 010 | |
| 10 | 1.1–7.5 | 175G6644 | 175G6656 | P1K1–P7K5 |
| 19 | 11 | 175G6645 | 175G6657 | P11K |
| 26 | 15–18.5 | 175G6646 | 175G6658 | P15K–P18K |
| 35 | 22 | 175G6647 | 175G6659 | P22K |
| 43 | 30 | 175G6648 | 175G6660 | P30K |
| 72 | 37–45 | 175G6649 | 175G6661 | P45K–P55K |
| 101 | 55 | 175G6650 | 175G6662 | P75K |
| 144 | 75-90 | 175G6651 | 175G6663 | P90K–P110 |
| 180 | 110 | 175G6652 | 175G6664 | P132 |
| 217 | 132 | 175G6653 | 175G6665 | P160 |
| 289 | 160–200 | 175G6654 | 175G6666 | P200–P250 |
| 324 | 250 | 175G6655 | 175G6667 | P315 |
| 397 | 315 | 175G6652 + 175G6653 | 175G6641 + 175G6665 | P400 |
| 434 | 355 | 2x175G6653 | 2x175G6665 | P450 |
| 506 | 400 | 175G6653 + 175G6654 | 175G6665 + 175G6666 | P500 |
| 578 | 450 | 2X 175G6654 | 2X 175G6666 | P560 |
| 613 | 500 | 175G6654 + 175G6655 | 175G6666 + 175G6667 | P630 |

**Table 4.9 500–525 V AC, 50 Hz**

| $I_{AHF, N}$ [A] | Typical Motor Used [kW] | Danfoss Ordering Number | | Adjustable frequency drive size |
|---|---|---|---|---|
| | | AHF 005 | AHF 010 | |
| 43 | 45 | 130B2328 | 130B2293 | |
| 72 | 45–55 | 130B2330 | 130B2295 | P37K–P45K |
| 101 | 75-90 | 130B2331 | 130B2296 | P55K–P75K |
| 144 | 110 | 130B2333 | 130B2298 | P90K–P110 |
| 180 | 132 | 130B2334 | 130B2299 | P132 |
| 217 | 160 | 130B2335 | 130B2300 | P160 |
| 288 | 200–250 | 2x130B2333 | 130B2301 | P200–P250 |
| 324 | 315 | 130B2334 + 130B2335 | 130B2302 | P315 |
| 397 | 400 | 130B2334 + 130B2335 | 130B2299 + 130B2300 | P400 |
| 434 | 450 | 2x130B2335 | 2x130B2300 | P450 |
| 505 | 500 | * | 130B2300 + 130B2301 | P500 |
| 576 | 560 | * | 2x130B2301 | P560 |
| 612 | 630 | * | 130B2301 + 130B2300 | P630 |
| 730 | 710 | * | 2x130B2302 | P710 |

**Table 4.10 690 V AC, 50 Hz**

** For higher currents, contact Danfoss.*

## 4.2.3 Ordering Numbers: Sine-Wave Filter Modules, 200–500 V AC

| Adj. Frequency Drive Size | | | Minimum switching frequency [kHz] | Maximum output frequency [Hz] | Part No. IP20 | Part No. IP00 | Rated filter current at 50 Hz [A] |
|---|---|---|---|---|---|---|---|
| 200–240 [V AC] | 380–440 [V AC] | 440–480 [V AC] | | | | | |
| | P1K1 | P1K1 | 5 | 120 | 130B2441 | 130B2406 | 4.5 |
| | P1K5 | P1K5 | 5 | 120 | 130B2441 | 130B2406 | 4.5 |
| | P2K2 | P2K2 | 5 | 120 | 130B2443 | 130B2408 | 8 |
| P1K5 | P3K0 | P3K0 | 5 | 120 | 130B2443 | 130B2408 | 8 |
| | P4K0 | P4K0 | 5 | 120 | 130B2444 | 130B2409 | 10 |
| P2K2 | P5K5 | P5K5 | 5 | 120 | 130B2446 | 130B2411 | 17 |
| P3K0 | P7K5 | P7K5 | 5 | 120 | 130B2446 | 130B2411 | 17 |
| P4K0 | | | 5 | 120 | 130B2446 | 130B2411 | 17 |
| P5K5 | P11K | P11K | 4 | 100 | 130B2447 | 130B2412 | 24 |
| P7K5 | P15K | P15K | 4 | 100 | 130B2448 | 130B2413 | 38 |
| | P18K | P18K | 4 | 100 | 130B2448 | 130B2413 | 38 |
| P11K | P22K | P22K | 4 | 100 | 130B2307 | 130B2281 | 48 |
| P15K | P30K | P30K | 3 | 100 | 130B2308 | 130B2282 | 62 |
| P18K | P37K | P37K | 3 | 100 | 130B2309 | 130B2283 | 75 |
| P22K | P45K | P55K | 3 | 100 | 130B2310 | 130B2284 | 115 |
| P30K | P55K | P75K | 3 | 100 | 130B2310 | 130B2284 | 115 |
| P37K | P75K | P90K | 3 | 100 | 130B2311 | 130B2285 | 180 |
| P45K | P90K | P110 | 3 | 100 | 130B2311 | 130B2285 | 180 |
| | P110 | P132 | 3 | 100 | 130B2312 | 130B2286 | 260 |
| | P132 | P160 | 3 | 100 | 130B2313 | 130B2287 | 260 |
| | P160 | P200 | 3 | 100 | 130B2313 | 130B2287 | 410 |
| | P200 | P250 | 3 | 100 | 130B2314 | 130B2288 | 410 |
| | P250 | P315 | 3 | 100 | 130B2314 | 130B2288 | 480 |
| | P315 | P315 | 2 | 100 | 130B2315 | 130B2289 | 660 |
| | P355 | P355 | 2 | 100 | 130B2315 | 130B2289 | 660 |
| | P400 | P400 | 2 | 100 | 130B2316 | 130B2290 | 750 |
| | | P450 | 2 | 100 | 130B2316 | 130B2290 | 750 |
| | P450 | P500 | 2 | 100 | 130B2317 | 130B2291 | 880 |
| | P500 | P560 | 2 | 100 | 130B2317 | 130B2291 | 880 |
| | P560 | P630 | 2 | 100 | 130B2318 | 130B2292 | 1200 |
| | P630 | P710 | 2 | 100 | 130B2318 | 130B2292 | 1200 |
| | P710 | P800 | 2 | 100 | 2x130B2317 | 2x130B2291 | 1500 |
| | P800 | P1M0 | 2 | 100 | 2x130B2317 | 2x130B2291 | 1500 |
| | P1M0 | | 2 | 100 | 2x130B2318 | 2x130B2292 | 1700 |

**Table 4.11 Line Power Supply 3x200 to 480 V AC**

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

***NOTICE!***

**See also *Output Filter Design Guide*.**

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## 4.2.4 Ordering Numbers: Sine-Wave Filter Modules, 525–600/690 V AC

| Adj. Frequency Drive Size | | Minimum switching frequency [kHz] | Maximum output frequency [Hz] | Part No. IP20 | Part No. IP00 | Rated filter current at 50 Hz [A] |
|---|---|---|---|---|---|---|
| 525–600 [V AC] | 690 [V AC] | | | | | |
| P1K1 | | 2 | 100 | 130B2341 | 130B2321 | 13 |
| P1K5 | | 2 | 100 | 130B2341 | 130B2321 | 13 |
| P2k2 | | 2 | 100 | 130B2341 | 130B2321 | 13 |
| P3K0 | | 2 | 100 | 130B2341 | 130B2321 | 13 |
| P4K0 | | 2 | 100 | 130B2341 | 130B2321 | 13 |
| P5K5 | | 2 | 100 | 130B2341 | 130B2321 | 13 |
| P7K5 | | 2 | 100 | 130B2341 | 130B2321 | 13 |
| P11K | | 2 | 100 | 130B2342 | 130B2322 | 28 |
| P15K | | 2 | 100 | 130B2342 | 130B2322 | 28 |
| P18K | | 2 | 100 | 130B2342 | 130B2322 | 28 |
| P22K | | 2 | 100 | 130B2342 | 130B2322 | 28 |
| P30K | | 2 | 100 | 130B2343 | 130B2323 | 45 |
| P37K | P45K | 2 | 100 | 130B2344 | 130B2324 | 76 |
| P45K | P55K | 2 | 100 | 130B2344 | 130B2324 | 76 |
| P55K | P75K | 2 | 100 | 130B2345 | 130B2325 | 115 |
| P75K | P90K | 2 | 100 | 130B2345 | 130B2325 | 115 |
| P90K | P110 | 2 | 100 | 130B2346 | 130B2326 | 165 |
| | P132 | 2 | 100 | 130B2346 | 130B2326 | 165 |
| | P160 | 2 | 100 | 130B2347 | 130B2327 | 260 |
| | P200 | 2 | 100 | 130B2347 | 130B2327 | 260 |
| | P250 | 2 | 100 | 130B2348 | 130B2329 | 303 |
| | P315 | 2 | 100 | 130B2370 | 130B2341 | 430 |
| | P355 | 1.5 | 100 | 130B2370 | 130B2341 | 430 |
| | P400 | 1.5 | 100 | 130B2370 | 130B2341 | 430 |
| | P450 | 1.5 | 100 | 130B2371 | 130B2342 | 530 |
| | P500 | 1.5 | 100 | 130B2371 | 130B2342 | 530 |
| | P560 | 1.5 | 100 | 130B2381 | 130B2337 | 660 |
| | P630 | 1.5 | 100 | 130B2381 | 130B2337 | 660 |
| | P710 | 1.5 | 100 | 130B2382 | 130B2338 | 765 |
| | P800 | 1.5 | 100 | 130B2383 | 130B2339 | 940 |
| | P900 | 1.5 | 100 | 130B2383 | 130B2339 | 940 |
| | P1M0 | 1.5 | 100 | 130B2384 | 130B2340 | 1320 |
| | P1M2 | 1.5 | 100 | 130B2384 | 130B2340 | 1320 |
| | P1M4 | 1.5 | 100 | 2x130B2382 | 2x130B2338 | 1479 |

**Table 4.12 Line Power Supply 3 x 525–690 V AC**

***NOTICE!***

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

***NOTICE!***

**See also *Output Filter Design Guide*.**

## 4.2.5 Ordering Numbers: dU/dt Filters, 380–480 V AC

| Adj. Frequency Drive Size | | Minimum switching frequency [kHz] | Maximum output frequency [Hz] | Part No. IP20 | Part No. IP00 | Rated filter current at 50 Hz [A] |
|---|---|---|---|---|---|---|
| 380–439 [V AC] | 440–480 [V AC] | | | | | |
| P11K | P11K | 4 | 100 | 130B2396 | 130B2385 | 24 |
| P15K | P15K | 4 | 100 | 130B2397 | 130B2386 | 45 |
| P18K | P18K | 4 | 100 | 130B2397 | 130B2386 | 45 |
| P22K | P22K | 4 | 100 | 130B2397 | 130B2386 | 45 |
| P30K | P30K | 3 | 100 | 130B2398 | 130B2387 | 75 |
| P37K | P37K | 3 | 100 | 130B2398 | 130B2387 | 75 |
| P45K | P45K | 3 | 100 | 130B2399 | 130B2388 | 110 |
| P55K | P55K | 3 | 100 | 130B2399 | 130B2388 | 110 |
| P75K | P75K | 3 | 100 | 130B2400 | 130B2389 | 182 |
| P90K | P90K | 3 | 100 | 130B2400 | 130B2389 | 182 |
| P110 | P110 | 3 | 100 | 130B2401 | 130B2390 | 280 |
| P132 | P132 | 3 | 100 | 130B2401 | 130B2390 | 280 |
| P160 | P160 | 3 | 100 | 130B2402 | 130B2391 | 400 |
| P200 | P200 | 3 | 100 | 130B2402 | 130B2391 | 400 |
| P250 | P250 | 3 | 100 | 130B2277 | 130B2275 | 500 |
| P315 | P315 | 2 | 100 | 130B2278 | 130B2276 | 750 |
| P355 | P355 | 2 | 100 | 130B2278 | 130B2276 | 750 |
| P400 | P400 | 2 | 100 | 130B2278 | 130B2276 | 750 |
| | P450 | 2 | 100 | 130B2278 | 130B2276 | 750 |
| P450 | P500 | 2 | 100 | 130B2405 | 130B2393 | 910 |
| P500 | P560 | 2 | 100 | 130B2405 | 130B2393 | 910 |
| P560 | P630 | 2 | 100 | 130B2407 | 130B2394 | 1500 |
| P630 | P710 | 2 | 100 | 130B2407 | 130B2394 | 1500 |
| P710 | P800 | 2 | 100 | 130B2407 | 130B2394 | 1500 |
| P800 | P1M0 | 2 | 100 | 130B2407 | 130B2394 | 1500 |
| P1M0 | | 2 | 100 | 130B2410 | 130B2395 | 2300 |

**Table 4.13 Line Power supply 3x380 to 3x480 V AC**

***NOTICE!***

**See also *Output Filter Design Guide*.**

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

| Adj. Frequency Drive Size | | Minimum switching frequency [kHz] | Maximum output frequency [Hz] | Part No. IP20 | Part No. IP00 | Rated filter current at 50 Hz [A] |
|---|---|---|---|---|---|---|
| 525–600 [V AC] | 690 [V AC] | | | | | |
| P1K1 | | 4 | 100 | 130B2423 | 130B2414 | 28 |
| P1K5 | | 4 | 100 | 130B2423 | 130B2414 | 28 |
| P2K2 | | 4 | 100 | 130B2423 | 130B2414 | 28 |
| P3K0 | | 4 | 100 | 130B2423 | 130B2414 | 28 |
| P4K0 | | 4 | 100 | 130B2424 | 130B2415 | 45 |
| P5K5 | | 4 | 100 | 130B2424 | 130B2415 | 45 |
| P7K5 | | 3 | 100 | 130B2425 | 130B2416 | 75 |
| P11K | | 3 | 100 | 130B2425 | 130B2416 | 75 |
| P15K | | 3 | 100 | 130B2426 | 130B2417 | 115 |
| P18K | | 3 | 100 | 130B2426 | 130B2417 | 115 |
| P22K | | 3 | 100 | 130B2427 | 130B2418 | 165 |
| P30K | | 3 | 100 | 130B2427 | 130B2418 | 165 |
| P37K | P45K | 3 | 100 | 130B2425 | 130B2416 | 75 |
| P45K | P55K | 3 | 100 | 130B2425 | 130B2416 | 75 |
| P55K | P75K | 3 | 100 | 130B2426 | 130B2417 | 115 |
| P75K | P90K | 3 | 100 | 130B2426 | 130B2417 | 115 |
| P90K | P110 | 3 | 100 | 130B2427 | 130B2418 | 165 |
| | P132 | 2 | 100 | 130B2427 | 130B2418 | 165 |
| | P160 | 2 | 100 | 130B2428 | 130B2419 | 260 |
| | P200 | 2 | 100 | 130B2428 | 130B2419 | 260 |
| | P250 | 2 | 100 | 130B2429 | 130B2420 | 310 |
| | P315 | 2 | 100 | 130B2238 | 130B2235 | 430 |
| | P400 | 2 | 100 | 130B2238 | 130B2235 | 430 |
| | P450 | 2 | 100 | 130B2239 | 130B2236 | 530 |
| | P500 | 2 | 100 | 130B2239 | 130B2236 | 530 |
| | P560 | 2 | 100 | 130B2274 | 130B2280 | 630 |
| | P630 | 2 | 100 | 130B2274 | 130B2280 | 630 |
| | P710 | 2 | 100 | 130B2430 | 130B2421 | 765 |
| | P800 | 2 | 100 | 130B2431 | 130B2422 | 1350 |
| | P900 | 2 | 100 | 130B2431 | 130B2422 | 1350 |
| | P1M0 | 2 | 100 | 130B2431 | 130B2422 | 1350 |
| | P1M2 | 2 | 100 | 130B2431 | 130B2422 | 1350 |
| | P1M4 | 2 | 100 | 2x130B2430 | 2x130B2421 | 1530 |

**Table 4.14 Line Power Supply 3x525 to 3x690 V AC**

***NOTICE!***

**See also *Output Filter Design Guide*.**

## 4.2.7 Ordering Numbers: Brake Resistors

***NOTICE!***

**See *Brake Resistor Design Guide*.**

# 5 Mechanical Installation

## 5.1 Mechanical Installation

### 5.1.1 Safety Requirements of Mechanical Installation

**⚠WARNING**

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

**CAUTION**

**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 *chapter 9.6.2 Derating for Ambient Temperature*.**

**If the ambient temperature is in the range of 113–131 °F [45 °C–55 °C], derating of the adjustable frequency drive becomes relevant, see *chapter 9.6.2 Derating for Ambient Temperature*.**

**The service life of the adjustable frequency drive is reduced if derating for ambient temperature is not taken into account.**

## 5.1.2 Mechanical Dimensions

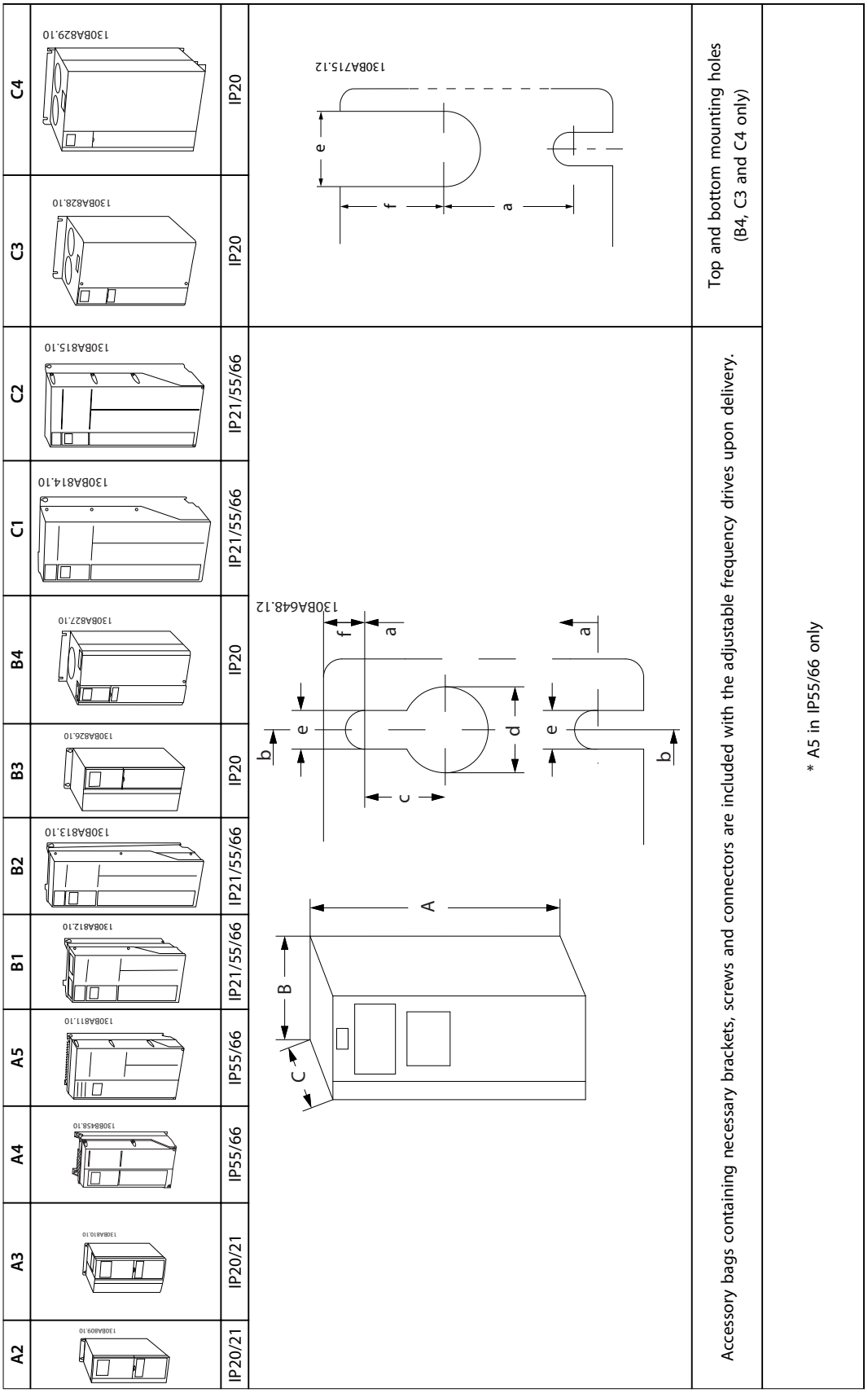


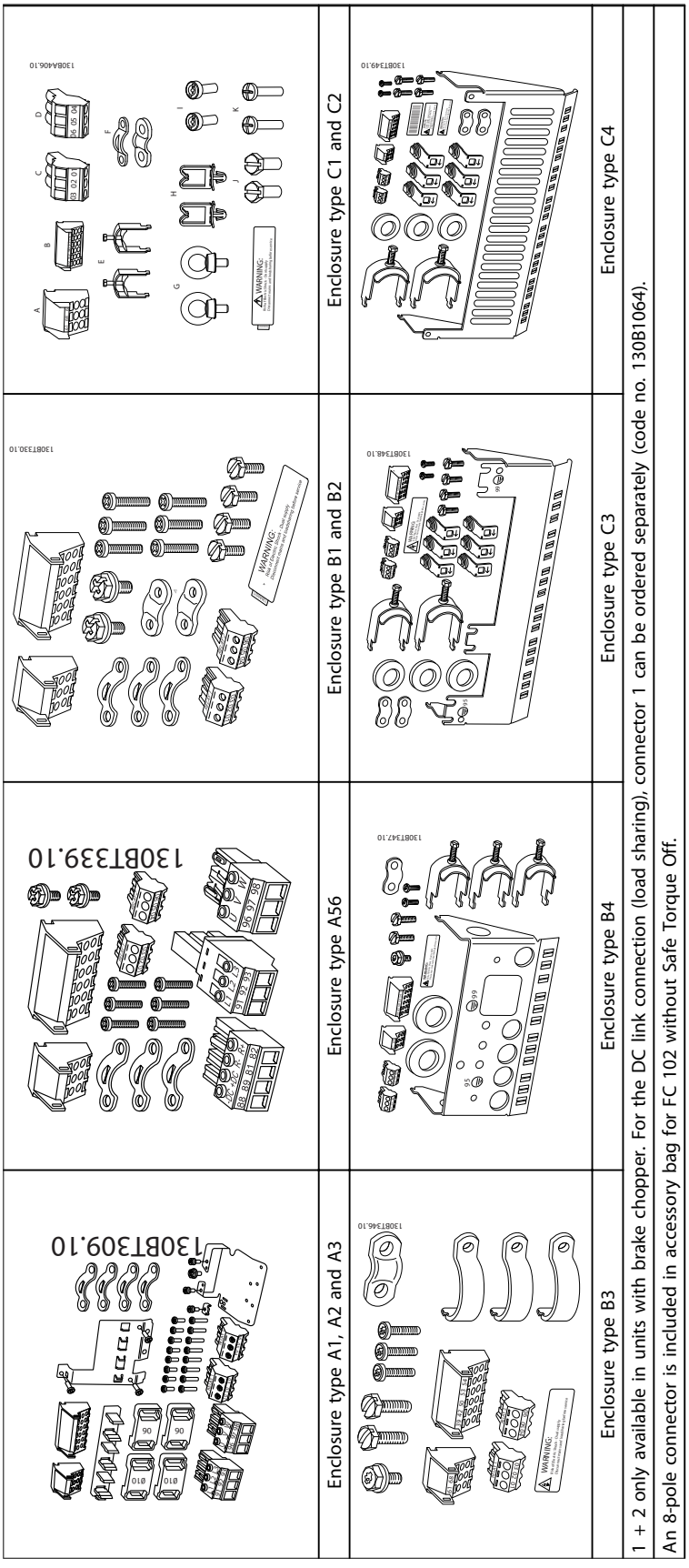

**Table 5.1 Mechanical Dimensions**

| Enclosure Type | | | A2 | | A3 | | A4 | A5 | B1 | B2 | B3 | B4 | C1 | C2 | C3 | C4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rated Power (hp [kW]) | 200–240 V | | 1.5–3 [1.1–2.2] | | 4–5 [3–3.7] | | 1.5–3 [1.1–2.2] | 1.5–5 [1.1–3.7] | 7.5–15 [5.5–11] | 20 [15] | 7.5–15 [5.5–11] | 11–25 [15–18] | 25–40 [18–30] | 50–60 [37–45] | 30–40 [22–30] | 50–60 [37–45] |
| | 380–480/ 500 V | | 1.5–5 [1.1–4.0] | | 7.5–10 [5.5–7.5] | | 1.5–5 [1.1–4] | 1.5–10 [1.1–7.5] | 15–25 [11–18] | 30–40 [22–30] | 15–25 [11–18] | 30–50 [22–37] | 50–75 [37–55] | 100–125 [75–90] | 60–75 [45–55] | 100–125 [75–90] |
| | 525–600 V | | | | 1.5–10 [1.1–7.5] | | | 1.5–10 [1.1–7.5] | 15–25 [11–18] | 30–40 [22–30] | 15–25 [11–18] | 30–50 [22–37] | 50–75 [37–55] | 100–125 [75–90] | 60–75 [45–55] | 100–125 [75–90] |
| | 525–690 V | | | | | | | | | 15–40 [11–30] | | | | 50–125 [37–90] | | |
| IP NEMA | | | 20 Chassis | 21 Type 1 | 20 Chassis | 21 Type 1 | 55/66 Type 12 | 55/66 Type 12 | 21/ 55/66 Type 1/ Type 12 | 21/55/66 Type 1/ Type 12 | 20 Chassis | 20 Chassis | 21/55/66 Type 1/ Type 12 | 21/55/66 Type 1/ Type 12 | 20 Chassis | 20 Chassis |
| **Height (in [mm])** | | | | | | | | | | | | | | | | |
| Height of backplate | | A | 10.60 [268] | 14.76 [375] | 10.6 [268] | 14.76 [375] | 15.35 [390] | 16.54 [420] | 18.90 [480] | 25.59 [650] | 15.71 [399] | 20.47 [520] | 26.77 [680] | 30.32 [770] | 21.65 [550] | 25.98 [660] |
| Height with decoupling plate for serial communication bus cables | | A | 14.72 [374] | | 14.72 [374] | - | - | - | - | - | 16.54 [420] | 23.43 [595] | | | 24.8 [630] | 31.5 [800] |
| Distance between mounting holes | | a | 10.12 [257] | 13.80 [350] | 10.12 [257] | 13.80 [350] | 15.80 [401] | 15.83 [402] | 17.87 [454] | 24.57 [624] | 14.96 [380] | 19.50 [495] | 25.51 [648] | 29.1 [739] | 20.51 [521] | 24.84 [631] |
| **Width (in [mm])** | | | | | | | | | | | | | | | | |
| Width of backplate | | B | 3.54 [90] | 3.54 [90] | 5.12 [130] | 5.12 [130] | 7.87 [200] | 9.53 [242] | 9.53 [242] | 9.53 [242] | 6.5 [165] | 9.06 [230] | 12.13 [308] | 14.57 [370] | 12.13 [308] | 14.57 [370] |
| Width of backplate with one C option | | B | 5.12 [130] | 5.12 [130] | 6.69 [170] | 6.69 [170] | | 9.53 [242] | 9.53 [242] | 9.53 [242] | 8.07 [205] | 9.06 [230] | 12.13 [308] | 14.57 [370] | 12.13 [308] | 14.57 [370] |
| Width of backplate with two C options | | B | 5.91 [150] | 5.91 [150] | 7.48 [190] | 7.48 [190] | | 9.53 [242] | 9.53 [242] | 9.53 [242] | 8.86 [225] | 9.06 [230] | 12.13 [308] | 14.57 [370] | 12.13 [308] | 14.57 [370] |
| Distance between mounting holes | | b | 2.76 [70] | 2.76 [70] | 4.33 [110] | 4.33 [110] | 6.73 [171] | 8.47 [215] | 8.27 [210] | 8.27 [210] | 5.51 [140] | 7.87 [200] | 10.71 [272] | 13.15 [334] | 10.63 [270] | 13 [330] |
| **Depth (in [mm])** | | | | | | | | | | | | | | | | |
| Depth without option A/B | | C | 8.07 [205] | 18.15 [207] | 8.07 [205] | 18.15 [207] | 6.89 [175] | 7.87 [200] | 10.24 [260] | 10.24 [260] | 9.8 [249] | 9.53 [242] | 12.21 [310] | 13.19 [335] | 12.99 [333] | 12.99 [333] |
| With option A/B | | C | 8.66 [220] | 8.74 [222] | 8.66 [220] | 8.74 [222] | 6.89 [175] | 7.87 [200] | 10.24 [260] | 10.24 [260] | 10.32 [262] | 9.53 [242] | 12.21 [310] | 13.19 [335] | 12.99 [333] | 12.99 [333] |

| Enclosure Type | | | A2 | | A3 | | A4 | A5 | B1 | B2 | B3 | B4 | C1 | C2 | C3 | C4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rated Power (hp [kW]) | 200–240 V | | 1.5–3 [1.1–2.2] | | 4–5 [3–3.7] | | 1.5–3 [1.1–2.2] | 1.5–5 [1.1–3.7] | 7.5–15 [5.5–11] | 20 [15] | 7.5–15 [5.5–11] | 11–25 [15–18] | 25–40 [18–30] | 50–60 [37–45] | 30–40 [22–30] | 50–60 [37–45] |
| | 380–480/ 500 V | | 1.5–5 [1.1–4.0] | | 7.5–10 [5.5–7.5] | | 1.5–5 [1.1–4] | 1.5–10 [1.1–7.5] | 15–25 [11–18] | 30–40 [22–30] | 15–25 [11–18] | 30–50 [22–37] | 50–75 [37–55] | 100–125 [75–90] | 60–75 [45–55] | 100–125 [75–90] |
| | 525–600 V | | | | 1.5–10 [1.1–7.5] | | | 1.5–10 [1.1–7.5] | 15–25 [11–18] | 30–40 [22–30] | 15–25 [11–18] | 30–50 [22–37] | 50–75 [37–55] | 100–125 [75–90] | 60–75 [45–55] | 100–125 [75–90] |
| | 525–690 V | | | | | | | | | 15–40 [11–30] | | | | 50–125 [37–90] | | |
| IP NEMA | | | 20 Chassis | 21 Type 1 | 20 Chassis | 21 Type 1 | 55/66 Type 12 | 55/66 Type 12 | 21/ 55/66 Type 1/ Type 12 | 21/55/66 Type 1/ Type 12 | 20 Chassis | 20 Chassis | 21/55/66 Type 1/ Type 12 | 21/55/66 Type 1/ Type 12 | 20 Chassis | 20 Chassis |
| Screw holes (in [mm]) | | | | | | | | | | | | | | | | |
| | | c | 0.32 [8.0] | 0.32 [8.0] | 0.32 [8.0] | 0.32 8.0] | 0.33 [8.25] | 0.33 [8.25] | 0.47 [12] | 0.47 [12] | 8 | | 0.49 [12.5] | 0.49 [12.5] | | |
| | | d | ø0.43 [ø11] | ø0.43 [ø11] | ø0.43 [ø11] | ø0.43 [ø11] | ø0.47 [ø12] | ø0.47 [ø12] | ø0.75 [ø19] | ø0.75 [ø19] | 0.47 [12] | | ø0.75 [ø19] | ø0.75 [ø19] | | |
| | | e | ø0.22 [ø5.5] | ø0.22 [ø5.5] | ø0.22 [ø5.5] | ø0.22 [ø5.5] | ø0.26 [ø6.5] | ø0.26 [ø6.5] | ø0.35 [ø9] | ø0.35 [ø9] | 0.27 [6.8] | 0.34 [8.5] | ø0.35 [ø9] | ø0.35 [ø9] | 0.34 [8.5] | 0.34 [8.5] |
| | | f | 0.35 [9] | 0.35 [9] | 0.26 [6.5] | 0.26 [6.5] | 0.24 [6] | 0.35 [9] | 0.35 [9] | 0.35 [9] | 0.31 [7.9] | 0.59 [15] | 0.39 [9.8] | 0.39 [9.8] | 0.67 [17] | 0.67 [17] |
| Max weight lbs [kg] | | | 10.8 [4.9] | 11.68 [5.3] | 14.6 [6.6] | 15.5 [7.0] | 21.5 [9.7] | 30/31.5 [13.5/14.2] | 50.7 [23] | 59.53 [27] | 26.5 [12] | 52 [23.5] | 99.21 [45] | 143.3 [65] | 77.2 [35] | 110.2 [50] |
| Front cover tightening torque [Nm] | | | | | | | | | | | | | | | | |
| Plastic cover (low IP) | | | Click | | Click | | - | - | Click | Click | Click | Click | Click | Click | 2.0 | 2.0 |
| Metal cover (IP55/66) | | | - | | - | | 1.5 | 1.5 | 2.2 | 2.2 | - | - | 2.2 | 2.2 | 2.0 | 2.0 |

**Table 5.2 Weight and Dimensions**

## 5.1.3 Accessory Bags




| | | | |
|---|---|---|---|
| Enclosure type A1, A2 and A3 | Enclosure type A56 | Enclosure type B4 | Enclosure type C4 |
| Enclosure type B3 | Enclosure type B1 and B2 | Enclosure type C3 | Enclosure type C1 and C2 |

1 + 2 only available in units with brake chopper. For the DC link connection (load sharing), connector 1 can be ordered separately (code no. 130B1064).

An 8-pole connector is included in accessory bag for FC 102 without Safe Torque Off.

**Table 5.3 Parts included in Accessory Bags**

## 5.1.4 Mechanical Mounting

All enclosure types allow side-by-side installation except when a *IP21/IP4X/TYPE 1 Enclosure Kit* is used (see *chapter 3.1 Options and Accessories*).

**Side-by-side mounting**
IP20 A and B enclosures can be arranged side-by-side with no clearance required between them, but the mounting order is important. *Figure 5.1* shows how to mount the frames correctly.

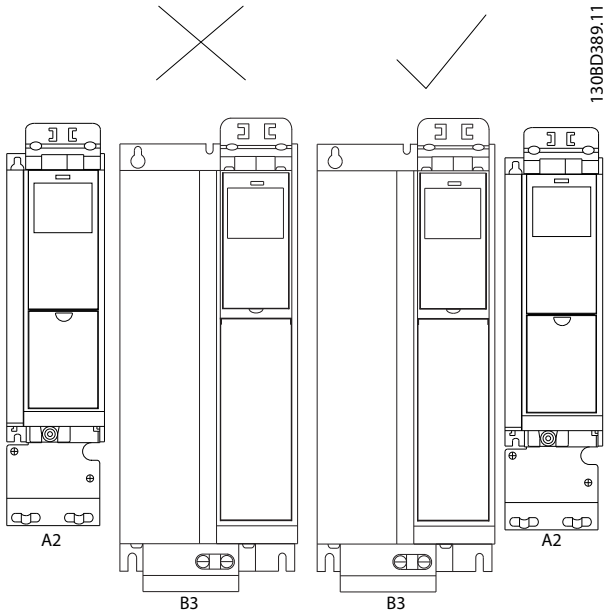



**Figure 5.1 Correct Side-by-side Mounting**

If the IP 21 Enclosure kit is used on enclosure type A2 or A3, there must be a clearance between the adjustable frequency drives of min. 2 in [50 mm].

For optimal cooling conditions, allow a free-air passage above and below the adjustable frequency drive. See *Table 5.4*.

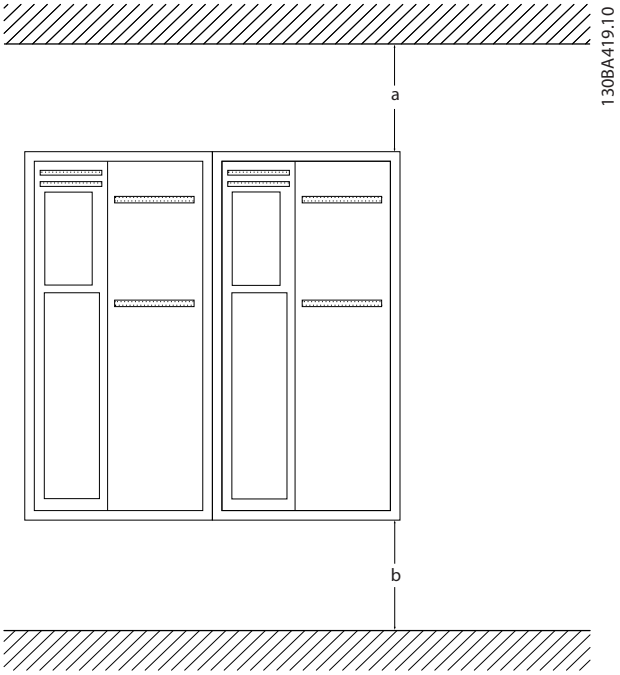



**Figure 5.2 Clearance**

| Enclosure type | A2/A3/A4/A5/B1 | B2/B3/B4/C1/C3 | C2/C4 |
|---|---|---|---|
| a (ins [mm]) | 3.94 [100] | 7.87 [200] | 8.86 [225] |
| b (ins [mm]) | 3.94 [100] | 7.87 [200] | 8.86 [225] |

**Table 5.4 Air Passage for Different Enclosure Types**

1. Drill holes in accordance with the measurements given.
2. Provide screws suitable for the surface for mounting the adjustable frequency drive. Retighten all four screws.

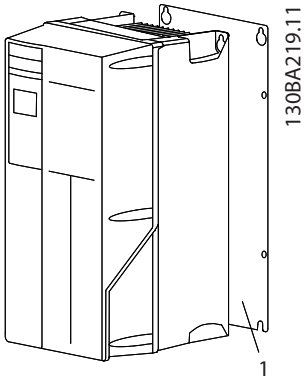



**Figure 5.3 Proper Mounting with Backplate**

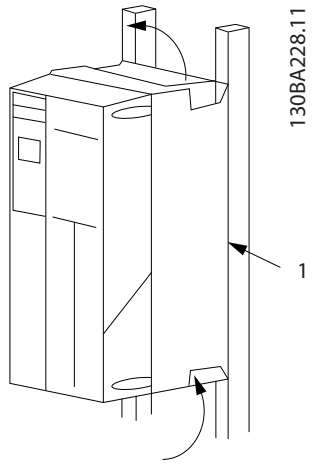



**Figure 5.4 Proper Mounting with Railings**

| Item | Description |
|---|---|
| 1 | Backplate |

**Table 5.5 Legend to *Figure 5.4***

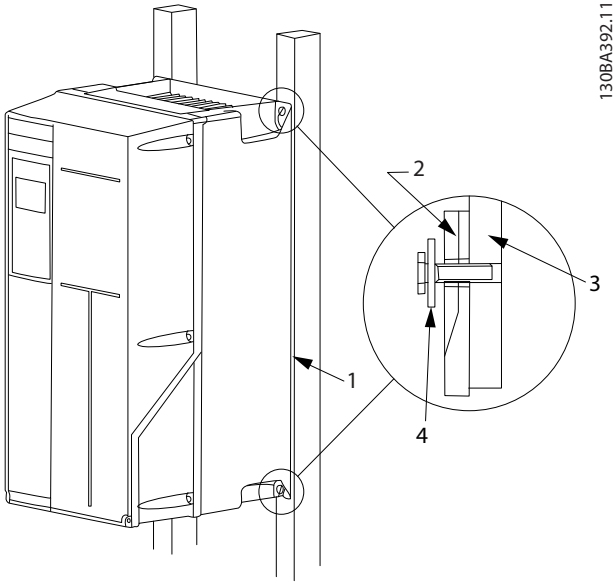



**Figure 5.5 Mounting on a Non-solid Back Wall**

Mounting enclosure types A4, A5, B1, B2, C1 and C2 on a non-solid back wall, the adjustable frequency drive must be provided with a backplate, "1", due to insufficient cooling air over the heatsink.

| Enclosure | IP20 | IP21 | IP55 | IP66 |
|---|---|---|---|---|
| A2 | * | * | - | - |
| A3 | * | * | - | - |
| A4/A5 | - | - | 1.48 [2] | 1.48 [2] |
| B1 | - | * | 1.62 [2.2] | 1.62 [2.2] |
| B2 | - | * | 1.62 [2.2] | 1.62 [2.2] |
| B3 | * | - | - | - |
| B4 | 1.48 [2] | - | - | - |
| C1 | - | * | 1.62 [2.2] | 1.62 [2.2] |
| C2 | - | * | 1.62 [2.2] | 1.62 [2.2] |
| C3 | 1.48 [2] | - | - | - |
| C4 | 1.48 [2] | - | - | - |
| * = No screws to tighten<br>- = Does not exist | | | | |

**Table 5.6 Tightening torque for covers (lb/ft [Nm])**

## 5.1.5 Field Mounting

For field mounting the IP21/IP4X top/TYPE 1 kits or IP54/55 units are recommended.



# 6 Electrical Installation

## 6.1 Connections - Enclosure Types A, B and C

### 6.1.1 Torque

***NOTICE!***

**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.**

**Aluminum Conductors**
Terminals can accept aluminum conductors, but the conductor surface must be clean, and the oxidation must be removed and sealed by neutral acid-free Vaseline grease before the conductor is connected.
Furthermore, the terminal screw must be retightened after two days due to softness of the aluminum. It is crucial to keep the connection a gas-tight joint; otherwise, the aluminum surface will oxidize again.

| Enclosure type | 200–240 V (hp [kW]) | 380–480 V (hp [kW]) | 525–690 V (hp [kW]) | Cable for | Tightening up torque (lb/ft [Nm]) |
|---|---|---|---|---|---|
| A2 | 1.5–3 [1.1–2.2] | 1.5–5 [1.1–4] | - | | |
| A3 | 4–5 [3–3.7] | 7.5–10 [5.5–7.5] | - | | |
| A4 | 1.5–3 [1.1–2.2] | 1.5–5 [1.1–4] | | | |
| A5 | 1.5–5 [1.1–3.7] | 1.5–10 [1.1–7.5] | - | | |
| B1 | 7.5–15 [5.5–11] | 15–25 [11–18] | - | Line power, brake resistor, load sharing, motor cables | 1.33 [1.8] |
| | | | | Relay | 0.37–0.44 [0.5–0.6] |
| | | | | Ground | 1.48–2.21 [2–3] |
| B2 | 20 [15] | 30–40 [22–30] | 15–40 [11–30] | Line power, brake resistor, load sharing cables | 3.32 [4.5] |
| | | | | Motor cables | 3.32 [4.5] |
| | | | | Relay | 0.37–0.44 [0.5–0.6] |
| | | | | Ground | 1.48–2.21 [2–3] |
| B3 | 7.5–15 [5.5–11] | 15–25 [11–18] | - | Line power, brake resistor, load sharing, motor cables | 1.33 [1.8] |
| | | | | Relay | 0.37–0.44 [0.5–0.6] |
| | | | | Ground | 1.48–2.21 [2–3] |
| B4 | 11–25 [15–18] | 30–50 [22–37] | - | Line power, brake resistor, load sharing, motor cables | 3.32 [4.5] |
| | | | | Relay | 0.37–0.44 [0.5–0.6] |
| | | | | Ground | 1.48–2.21 [2–3] |
| C1 | 25–40 [18–30] | 50–75 [37–55] | - | Line power, brake resistor, load sharing cables | 7.38 [10] |
| | | | | Motor cables | 7.38 [10] |
| | | | | Relay | 0.37–0.44 [0.5–0.6] |
| | | | | Ground | 1.48–2.21 [2–3] |
| C2 | 50–60 [37–45] | 100–125 [75–90] | 50–125 [37–90] | Line power, motor cables | 10.33 [14] (up to 4/0 AWG [95 $mm^2$]) 17.7 [24] (over 4/0 AWG [95 $mm^2$]) |
| | | | | Load sharing, brake cables | 10.33 [14] |
| | | | | Relay | 0.37–0.44 [0.5–0.6] |
| | | | | Ground | 1.48–2.21 [2–3] |
| C3 | 30–40 [22–30] | 60–75 [45–55] | - | Line power, brake resistor, load sharing, motor cables | 7.38 [10] |
| | | | | Relay | 0.37–0.44 [0.5–0.6] |
| | | | | Ground | 1.48–2.21 [2–3] |
| C4 | 50–60 [37–45] | 100–125 [75–90] | - | Line power, motor cables | 10.33 [14] (up to 4/0 AWG [95 $mm^2$]) 17.7 [24] (over 4/0 AWG [95 $mm^2$]) |
| | | | | Load sharing, brake cables | 10.33 [14] |
| | | | | Relay | 0.37–0.44 [0.5–0.6] |
| | | | | Ground | 1.48–2.21 [2–3] |

**Table 6.1 Tightening-up Torque**

### 6.1.2 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. Cable entry has to be supported around the knockout to be removed.
3. The knockout can now be removed with a strong mandrel and a hammer.
4. Remove burrs from the hole.
5. Mount the cable entry on the adjustable frequency drive.



### 6.1.3 Connection to Line and Grounding

***NOTICE!***

**The plug connector for power can be plugged on adjustable frequency drives of up to 10 hp [7.5 kW].**

1. Fit the two screws in the de-coupling plate, slide it into place and tighten the screws.
2. Make sure the adjustable frequency drive is properly grounded. Connect to ground connection (terminal 95). Use screw from the accessory bag.
3. Place plug connector 91 (L1), 92 (L2), 93 (L3) from the accessory bag onto the terminals labeled MAINS at the bottom of the adjustable frequency drive.
4. Attach the line wires to the line power plug connector.
5. Support the cable with the enclosed supporting brackets.

***NOTICE!***

**Ensure that AC line voltage corresponds to the AC line voltage on the nameplate.**

**⚠CAUTION**

**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.**

**⚠CAUTION**

**The ground connection cable cross-section must be at least 10 mm$^2$ or 2 x rated line power wires terminated separately according to EN 50178.**

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

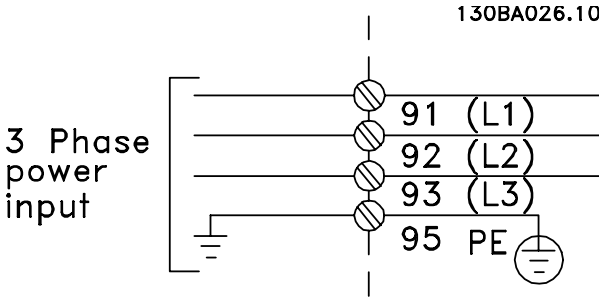



**Figure 6.1 AC line input connections**

**AC line input connection for enclosure types A1, A2 and A3:**

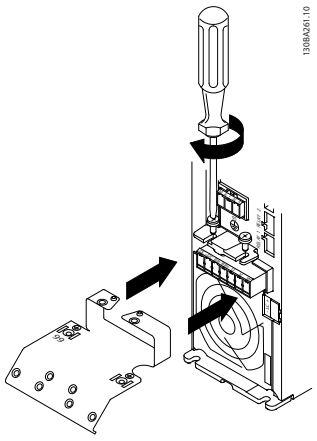



**Figure 6.2 Fitting the Mounting Plate**

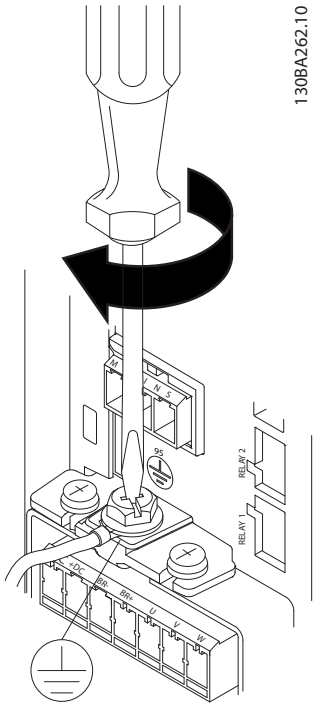



**Figure 6.3 Tightening the Ground Cable**

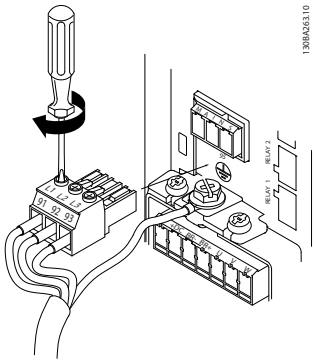



**Figure 6.4 Mounting Line Power Plug and Tightening Wires**

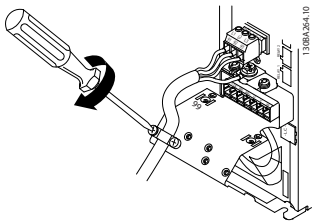



**Figure 6.5 Tighten Support Bracket**

**AC line input connector enclosure type A4/A5 (IP55/66)**

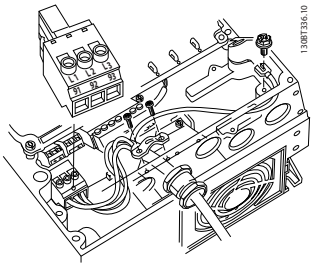



**Figure 6.6 Connecting to Line Power and Grounding without Disconnector**

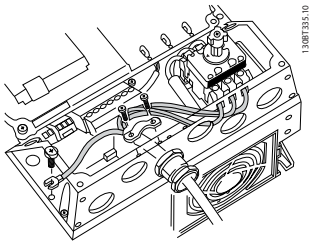



**Figure 6.7 Connecting to Line Power and Grounding with Disconnector**

When disconnector is used (enclosure type A4/A5), the PE must be mounted on the left side of the adjustable frequency drive.

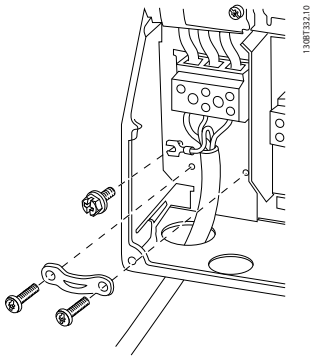



**Figure 6.8 AC Line Input Connection Enclosure Types B1 and B2 (IP21/NEMA Type 1 and IP55/66/ NEMA Type 12)**

6

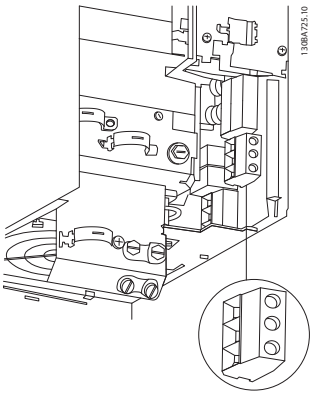



**Figure 6.9 AC Line Input Connection Enclosure Type B3 (IP20)**

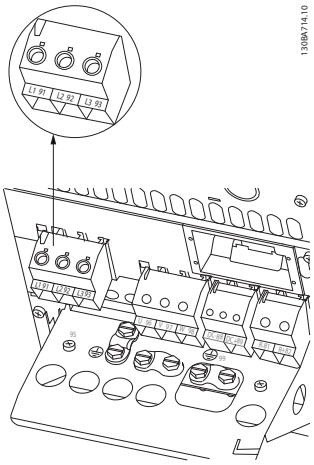



**Figure 6.10 AC Line Input Connection Enclosure Type B4 (IP20)**

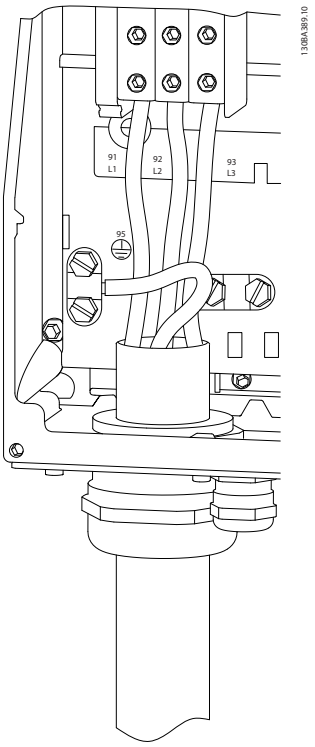



**Figure 6.11 AC Line Input Connection Enclosure Types C1 and C2 (IP21/NEMA Type 1 and IP55/66/NEMA Type 12).**

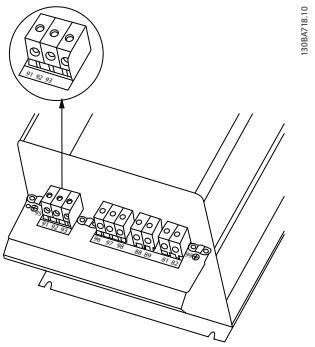



**Figure 6.12 AC Line Input Connection Enclosure Type C3 (IP20).**

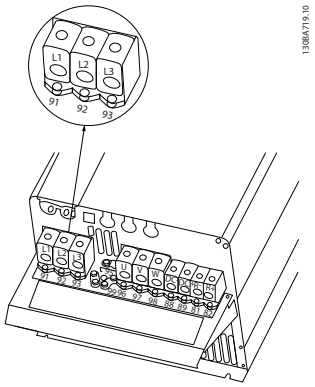



**Figure 6.13 AC Line Input Connection Enclosure Type C4 (IP20).**

Usually the power cables for line power are non-shielded cables.

## 6.1.4 Motor Connection

***NOTICE!***

**To comply with EMC emission specifications, shielded/ armored cables are required. For more information, see *chapter 2.9.2 EMC Test Results*.**

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

**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.
Connect the motor cable shield to both the decoupling plate on the adjustable frequency drive and to the metal housing on 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.
If it is necessary to split the shield to install a motor isolator or motor relay, continue the shield with 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. Keep the motor cable as short as possible to reduce the noise level and leakage currents.

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

1. Fasten 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 plug connectors 96 (U), 97 (V), 98 (W) (up to 10 hp [7.5 kW]) 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, Y). Large motors are normally delta-connected (400/690 V, Δ). Refer to the motor nameplate for correct connection mode and voltage.

**Procedure**

1. Strip a section of the outer cable insulation.
2. Position the stripped wire under the cable clamp to establish mechanical fixation and electrical contact between cable shield and ground.
3. Connect ground wire to the nearest grounding terminal in accordance with grounding instructions.
4. Connect the three-phase motor wiring to terminals 96 (U), 97 (V), and 98 (W), see *Figure 6.14*.
5. Tighten terminals in accordance with the information provided in *chapter 6.1.1 Torque*.

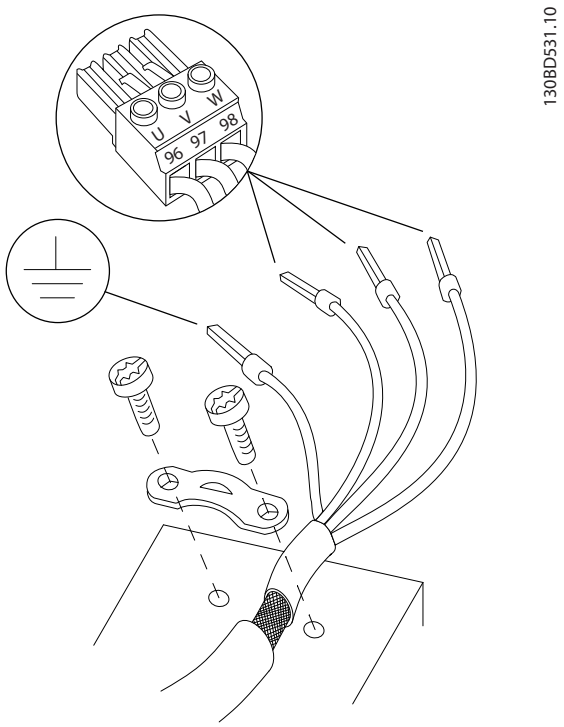



**Figure 6.14 Motor Connection**

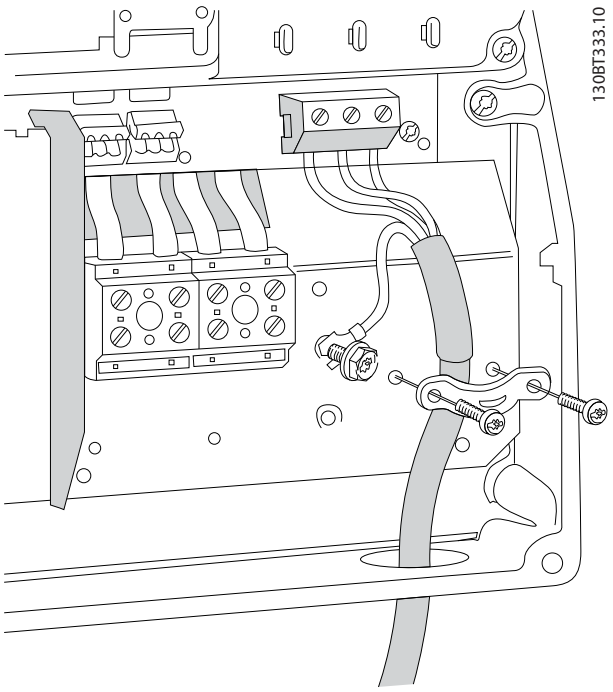



**Figure 6.15 Motor Connection for Enclosure Type B1 and B2 (IP21/NEMA Type 1, IP55/NEMA Type 12 and IP66/NEMA Type 4X)**

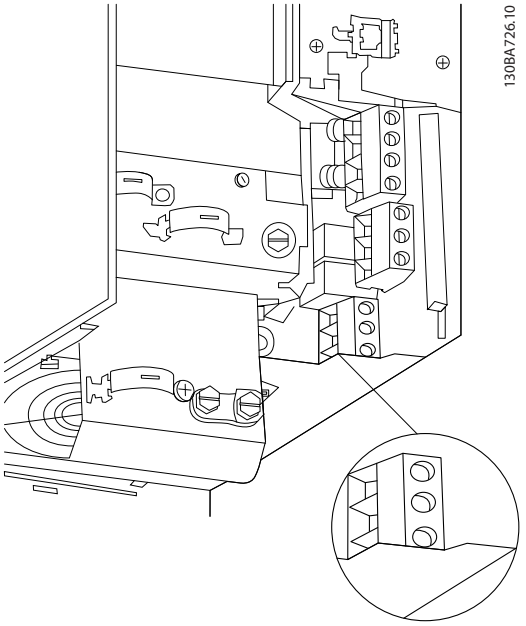



**Figure 6.16 Motor Connection for Enclosure Type B3**

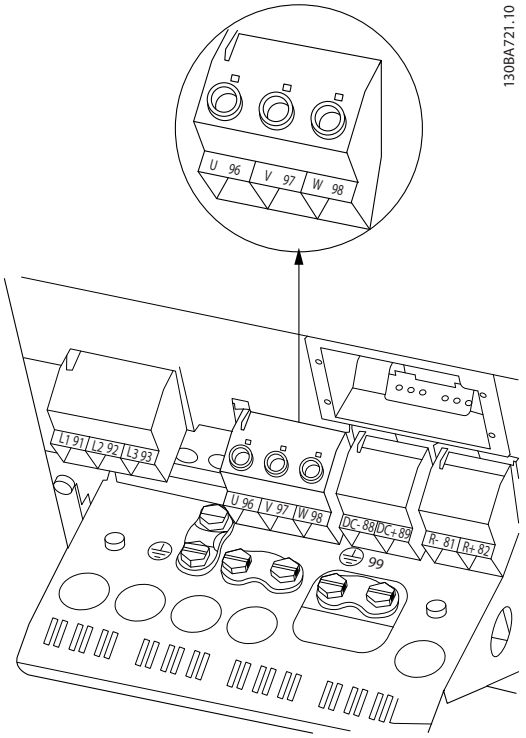



**Figure 6.17 Motor Connection for Enclosure Type B4**

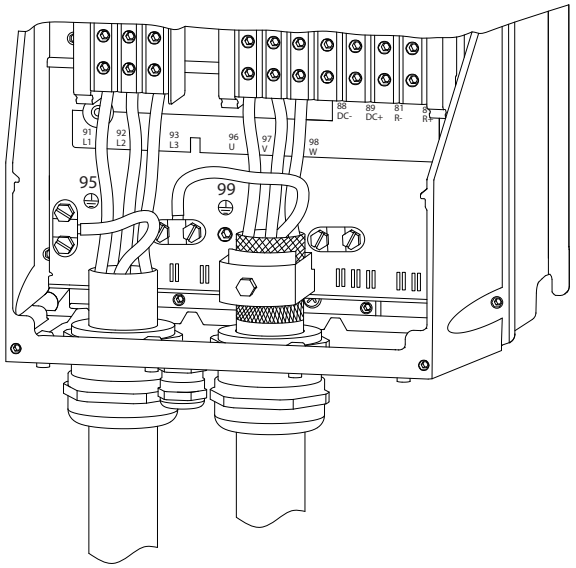



**Figure 6.18 Motor Connection Enclosure Type C1 and C2 (IP21/NEMA Type 1 and IP55/66/NEMA Type 12)**

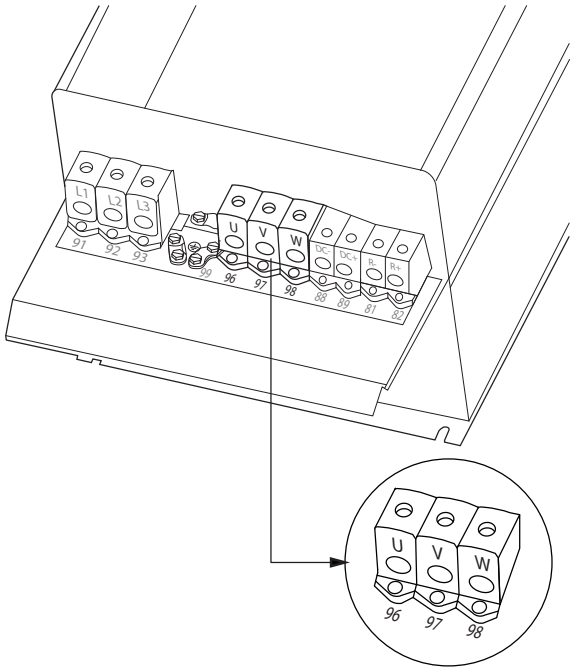



**Figure 6.19 Motor Connection for Enclosure Type C3 and C4**

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

**Table 6.2 Terminal Descriptions**

*1) Protected Ground Connection*

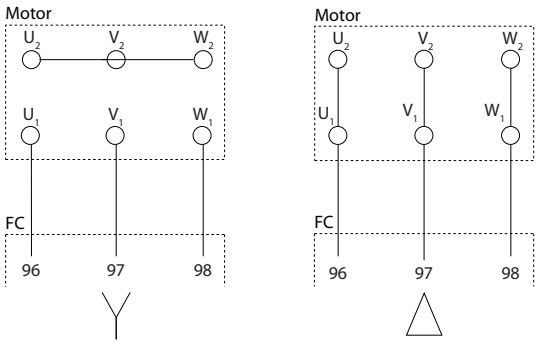



**Figure 6.20 Star and Delta Connections**

## *NOTICE!*

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

6

**Cable entry holes**

The suggested use of the holes are purely recommendations, and other solutions are possible. Unused cable entry holes can be sealed with rubber grommets (for IP21).

* Tolerance ± 0.007 in [0.2 mm]

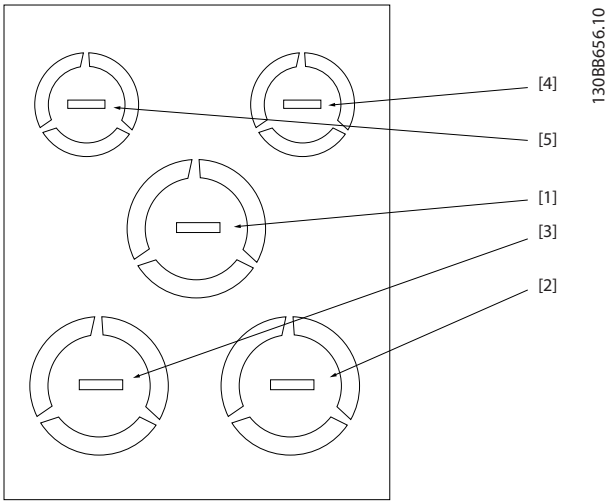



**Figure 6.21 A2 - IP21**

| Hole number and recommended use | Dimensions[1)] | | Nearest metric |
|---|---|---|---|
| | UL [in] | [mm] | |
| 1) Line power | 3/4 | 28.4 | M25 |
| 2) Motor | 3/4 | 28.4 | M25 |
| 3) Brake/Load S | 3/4 | 28.4 | M25 |
| 4) Control Cable | 1/2 | 22.5 | M20 |
| 5) Control Cable | 1/2 | 22.5 | M20 |

**Table 6.3 Legend to *Figure 6.21***

*1) Tolerance ± 0.007 in [0.2 mm]*

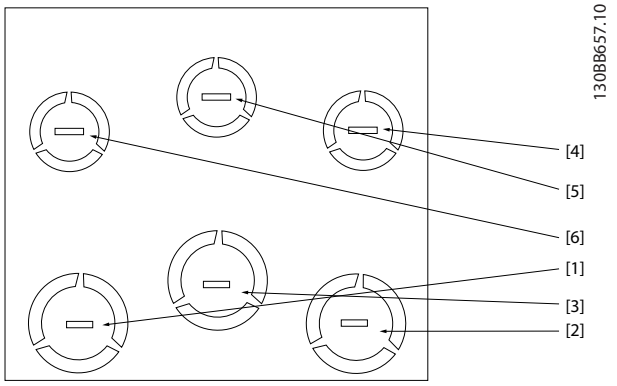



**Figure 6.22 A3 - IP21**

| Hole number and recommended use | Dimensions[1)] | | Nearest metric |
|---|---|---|---|
| | UL [in] | [mm] | |
| 1) Line power | 3/4 | 28.4 | M25 |
| 2) Motor | 3/4 | 28.4 | M25 |
| 3) Brake/Load Sharing | 3/4 | 28.4 | M25 |
| 4) Control Cable | 1/2 | 22.5 | M20 |
| 5) Control Cable | 1/2 | 22.5 | M20 |
| 6) Control Cable | 1/2 | 22.5 | M20 |

**Table 6.4 Legend to *Figure 6.22***

*1) Tolerance ± 0.007 in [0.2 mm]*

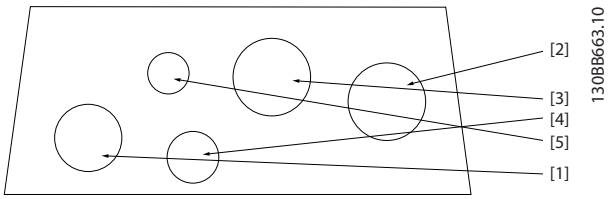



**Figure 6.23 A4 - IP55**

| Hole number and recommended use | Dimensions[1)] | | Nearest metric |
|---|---|---|---|
| | UL [in] | [mm] | |
| 1) Line power | 3/4 | 28.4 | M25 |
| 2) Motor | 3/4 | 28.4 | M25 |
| 3) Brake/Load Sharing | 3/4 | 28.4 | M25 |
| 4) Control Cable | 1/2 | 22.5 | M20 |
| 5) Removed | - | - | - |

**Table 6.5 Legend to *Figure 6.23***

*1) Tolerance ± 0.007 in [0.2 mm]*

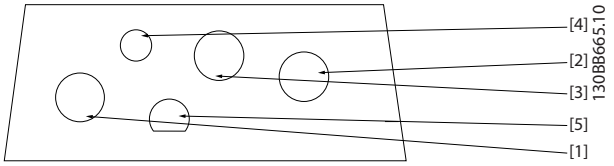



**Figure 6.24 A4 - IP55 Threaded Connector Holes**

| Hole number and recommended use | Nearest metric |
|---|---|
| 1) Line power | M25 |
| 2) Motor | M25 |
| 3) Brake/Load Sharing | M25 |
| 4) Control Cable | M16 |
| 5) Control Cable | M20 |

**Table 6.6 Legend to *Figure 6.24***

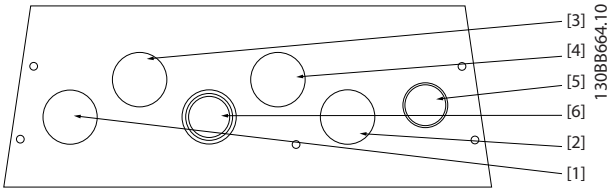



**Figure 6.25 A5 - IP55**

| Hole number and recommended use | Dimensions[1] | | Nearest metric |
|---|---|---|---|
| | UL [in] | [mm] | |
| 1) Line power | 3/4 | 28.4 | M25 |
| 2) Motor | 3/4 | 28.4 | M25 |
| 3) Brake/Load Sharing | 3/4 | 28.4 | M25 |
| 4) Control Cable | 3/4 | 28.4 | M25 |
| 5) Control Cable[2] | 3/4 | 28.4 | M25 |
| 6) Control Cable[2] | 3/4 | 28.4 | M25 |

**Table 6.7 Legend to *Figure 6.25***

*1) Tolerance ± 0.007 in [0.2 mm]*

*2) Knockout hole*

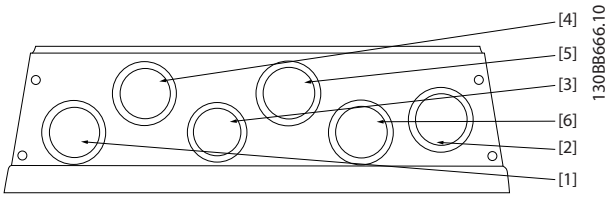



**Figure 6.26 A5- IP55 Threaded Connector Holes**

| Hole number and recommended use | Nearest metric |
|---|---|
| 1) Line power | M25 |
| 2) Motor | M25 |
| 3) Brake/Load S | 1.12 in [28.4 mm][1] |
| 4) Control Cable | M25 |
| 5) Control Cable | M25 |
| 6) Control Cable | M25 |

**Table 6.8 Legend to *Figure 6.26***

*1) Knockout hole*

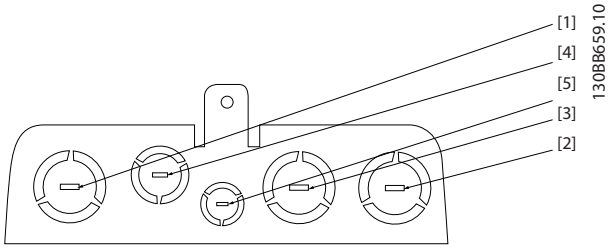



**Figure 6.27 B1 - IP21**

| Hole number and recommended use | Dimensions[1] | | Nearest metric |
|---|---|---|---|
| | UL [in] | [mm] | |
| 1) Line power | 1 | 34.7 | M32 |
| 2) Motor | 1 | 34.7 | M32 |
| 3) Brake/Load Sharing | 1 | 34.7 | M32 |
| 4) Control Cable | 1 | 34.7 | M32 |
| 5) Control Cable | 1/2 | 22.5 | M20 |

**Table 6.9 Legend to *Figure 6.27***

*1) Tolerance ± 0.007 in [0.2 mm]*

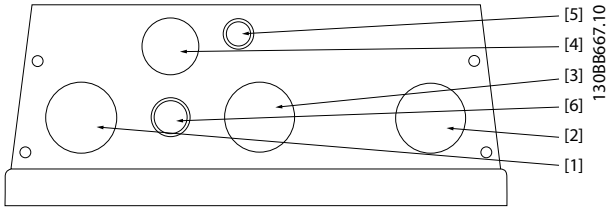



**Figure 6.28 B1 - IP55**

| Hole number and recommended use | Dimensions[1] | | Nearest metric |
|---|---|---|---|
| | UL [in] | [mm] | |
| 1) Line power | 1 | 34.7 | M32 |
| 2) Motor | 1 | 34.7 | M32 |
| 3) Brake/Load Sharing | 1 | 34.7 | M32 |
| 4) Control Cable | 3/4 | 28.4 | M25 |
| 5) Control Cable | 1/2 | 22.5 | M20 |
| 5) Control Cable[2] | 1/2 | 22.5 | M20 |

**Table 6.10 Legend to *Figure 6.28***

*1) Tolerance ± 0.007 in [0.2 mm]*

*2) Knockout hole*

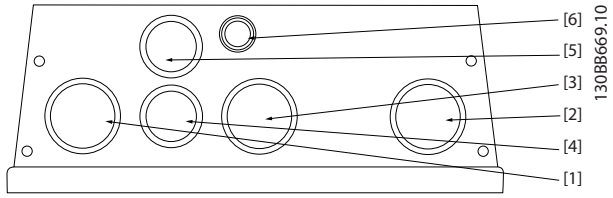



**Figure 6.29 B1 - IP55 Threaded Connector Holes**

| Hole number and recommended use | Nearest metric |
|---|---|
| 1) Line power | M32 |
| 2) Motor | M32 |
| 3) Brake/Load Sharing | M32 |
| 4) Control Cable | M25 |
| 5) Control Cable | M25 |
| 6) Control Cable | 0.89 in [22.5 mm][1] |

**Table 6.11 Legend to *Figure 6.29***

*1) Knockout hole*

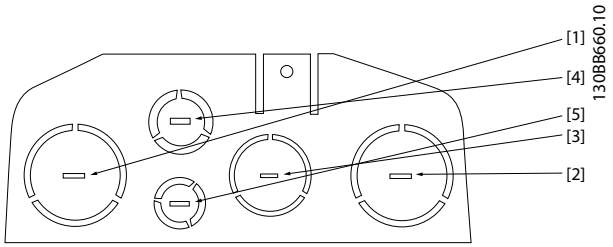



**Figure 6.30 B2 - IP21**

| Hole number and recommended use | Dimensions[1] | | Nearest metric |
|---|---|---|---|
| | UL [in] | [mm] | |
| 1) Line power | 1 1/4 | 44.2 | M40 |
| 2) Motor | 1 1/4 | 44.2 | M40 |
| 3) Brake/Load Sharing | 1 | 34.7 | M32 |
| 4) Control Cable | 3/4 | 28.4 | M25 |
| 5) Control Cable | 1/2 | 22.5 | M20 |

**Table 6.12 Legend to *Figure 6.30***

*1) Tolerance ± 0.007 in [0.2 mm]*

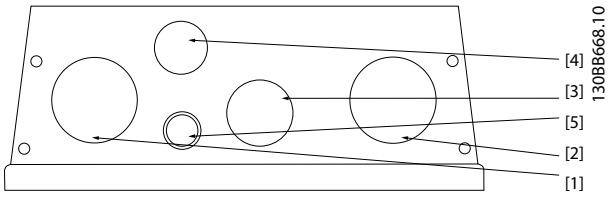



**Figure 6.31 B2 - IP55**

| Hole number and recommended use | Dimensions[1] | | Nearest metric |
|---|---|---|---|
| | UL [in] | [mm] | |
| 1) Line power | 1 1/4 | 44.2 | M40 |
| 2) Motor | 1 1/4 | 44.2 | M40 |
| 3) Brake/Load Sharing | 1 | 34.7 | M32 |
| 4) Control Cable | 3/4 | 28.4 | M25 |
| 5) Control Cable[2] | 1/2 | 22.5 | M20 |

**Table 6.13 Legend to *Figure 6.31***

*1) Tolerance ± 0.007 in [0.2 mm]*

*2) Knockout hole*

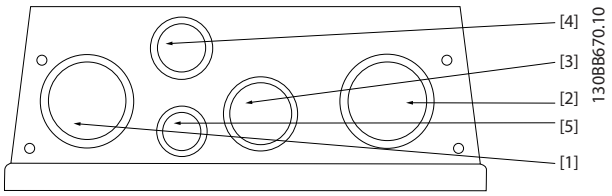



**Figure 6.32 B2 - IP55 Threaded Connector Holes**

| Hole number and recommended use | Nearest metric |
|---|---|
| 1) Line power | M40 |
| 2) Motor | M40 |
| 3) Brake/Load Sharing | M32 |
| 4) Control Cable | M25 |
| 5) Control Cable | M20 |

**Table 6.14 Legend to *Figure 6.32***

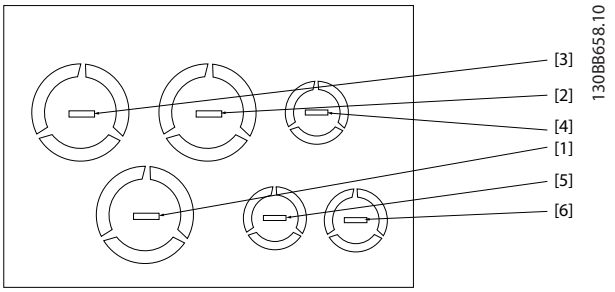



**Figure 6.33 B3 - IP21**

| Hole number and recommended use | Dimensions[1)] | | Nearest metric |
|---|---|---|---|
| | UL [in] | [mm] | |
| 1) Line power | 1 | 34.7 | M32 |
| 2) Motor | 1 | 34.7 | M32 |
| 3) Brake/Load Sharing | 1 | 34.7 | M32 |
| 4) Control Cable | 1/2 | 22.5 | M20 |
| 5) Control Cable | 1/2 | 22.5 | M20 |
| 6) Control Cable | 1/2 | 22.5 | M20 |

**Table 6.15 Legend to *Figure 6.33***

*1) Tolerance ± 0.007 in [0.2 mm]*

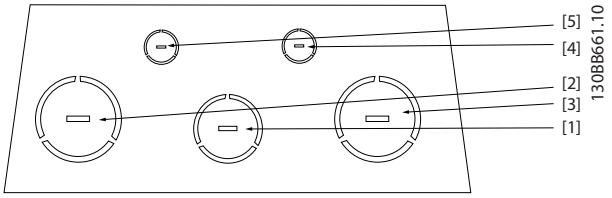



**Figure 6.34 C1 - IP21**

| Hole number and recommended use | Dimensions[1)] | | Nearest metric |
|---|---|---|---|
| | UL [in] | [mm] | |
| 1) Line power | 2 | 63.3 | M63 |
| 2) Motor | 2 | 63.3 | M63 |
| 3) Brake/Load Sharing | 1 1/2 | 50.2 | M50 |
| 4) Control Cable | 3/4 | 28.4 | M25 |
| 5) Control Cable | 1/2 | 22.5 | M20 |

**Table 6.16 Legend to *Figure 6.34***

*1) Tolerance ± 0.007 in [0.2 mm]*

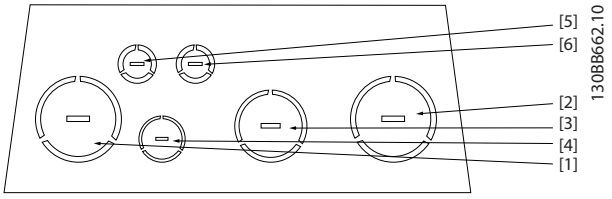



**Figure 6.35 C2 - IP21**

| Hole number and recommended use | Dimensions[1)] | | Nearest metric |
|---|---|---|---|
| | UL [in] | [mm] | |
| 1) Line power | 2 | 63.3 | M63 |
| 2) Motor | 2 | 63.3 | M63 |
| 3) Brake/Load Sharing | 1 1/2 | 50.2 | M50 |
| 4) Control Cable | 3/4 | 28.4 | M25 |
| 5) Control Cable | 1/2 | 22.5 | M20 |
| 6) Control Cable | 1/2 | 22.5 | M20 |

**Table 6.17 Legend to *Figure 6.35***

*1) Tolerance ± 0.007 in [0.2 mm]*

## 6.1.5 Relay Connection

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

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

**Table 6.18 Description of Relays**

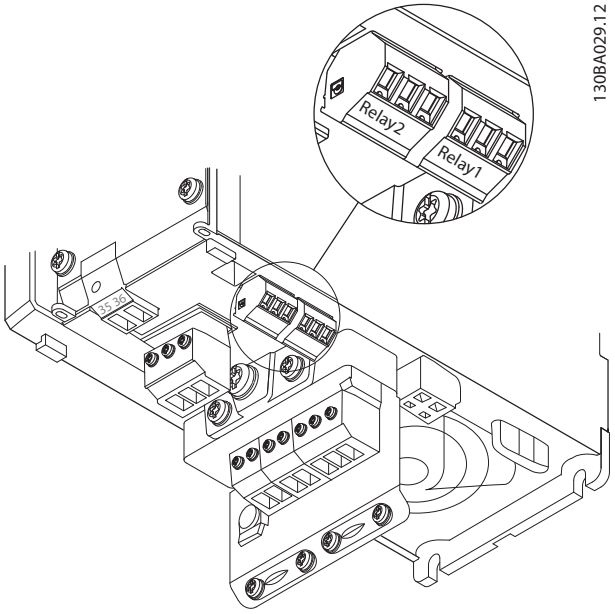



**Figure 6.36 Terminals for Relay Connection (Enclosure Types A1, A2 and A3).**

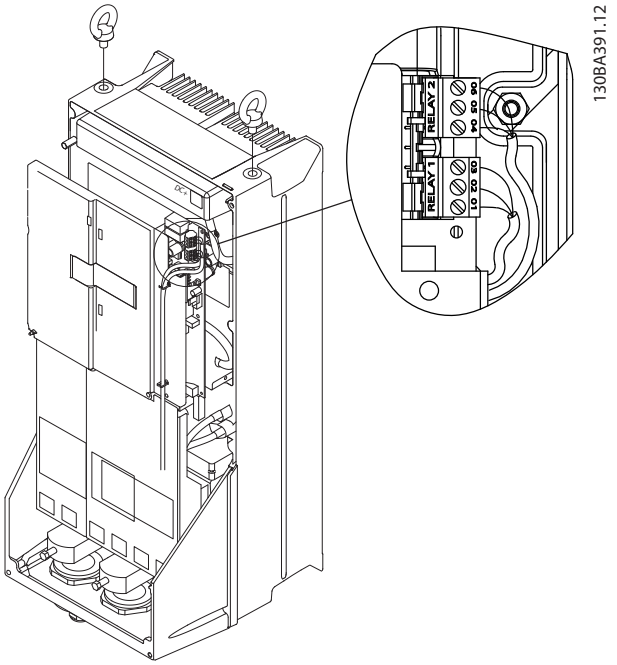



**Figure 6.37 Terminals for Relay Connection (Enclosure Types C1 and C2).**

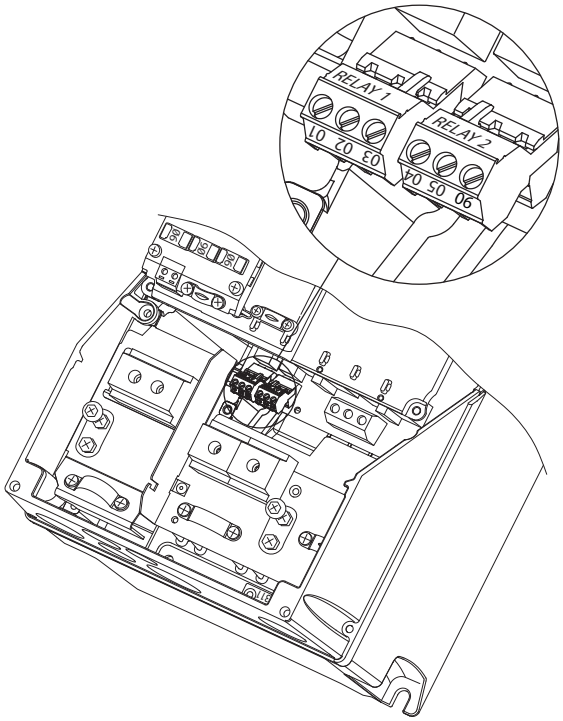



**Figure 6.38 Terminals for Relay Connection (Enclosure Types A5, B1 and B2).**

## 6.2 Fuses and Circuit Breakers

### 6.2.1 Fuses

It is recommended to use fuses and/or circuit breakers on the supply side as protection in case of component breakdown inside the adjustable frequency drive (first fault).

***NOTICE!***

**Using fuses and/or circuit breakers on the supply side is mandatory to ensure compliance with IEC 60364 for CE or NEC 2009 for UL.**

**⚠WARNING**

**Protect personnel and property against the consequence of component breakdown internally in the adjustable frequency drive.**

**Branch Circuit Protection**
To protect the installation against electrical and fire hazard, all branch circuits in an installation, switch gear, machines, etc., must be protected against short-circuit and overcurrent according to national/international regulations.

***NOTICE!***

**The recommendations given do not cover branch circuit protection for UL.**

**Short-circuit protection**
Danfoss recommends using the fuses/circuit breakers mentioned below to protect service personnel and property in case of component breakdown in the adjustable frequency drive.

### 6.2.2 Recommendations

**⚠WARNING**

**In case of malfunction, not following the recommendation may result in risk to personnel and damage to the adjustable frequency drive and other equipment.**

The tables in *chapter 6.2.4 Fuse Tables* list the recommended rated current. Recommended fuses are of the type gG for small to medium power sizes. For larger powers, aR fuses are recommended. For circuit breakers, Moeller types are recommended. Other types of circuit breakers may be used provided they limit the energy into the adjustable frequency drive to a level equal to or lower than the Moeller types.

If fuses/circuit breakers according to recommendations are selected, possible damage on the adjustable frequency drive is mainly limited to damages inside the unit.

For further information, see Application Note *Fuses and Circuit Breakers*.

### 6.2.3 CE Compliance

Fuses or circuit breakers are mandatory to comply with IEC 60364. Danfoss recommend using a selection of the following.

The fuses below are suitable for use on a circuit capable of delivering 100,000 Arms (symmetrical), 240 V, 480 V, 600 V, or 690 V depending on the adjustable frequency drive voltage rating. With the proper fusing the adjustable frequency drive, short-circuit current rating (SCCR) is 100,000 Arms.

The following UL-listed fuses are suitable:

- UL248-4 class CC fuses
- UL248-8 class J fuses
- UL248-12 class R fuses (RK1)
- UL248-15 class T fuses

The following max. fuse size and type have been tested:



## 6.2.4 Fuse Tables

| Enclosure type | Power (hp [kW]) | Recommended fuse size | Recommended Max. fuse | Recommended circuit breaker Moeller | Max trip level [A] |
|---|---|---|---|---|---|
| A2 | 1.5–3 [1.1–2.2] | gG-10 (1.5–2 [1.1–1.5])<br>gG-16 (3 [2.2]) | gG-25 | PKZM0-25 | 25 |
| A3 | 4–5 [3.0–3.7] | gG-16 (4 [3])<br>gG-20 (5 [3.7]) | gG-32 | PKZM0-25 | 25 |
| B3 | 7.5–15 [5.5–11] | gG-25 (7.5–10 [5.5–7.5])<br>gG-32 (15 [11]) | gG-63 | PKZM4-50 | 50 |
| B4 | 11–25 [15–18] | gG-50 (20 [15])<br>gG-63 (25 [18]) | gG-125 | NZMB1-A100 | 100 |
| C3 | 30–40 [22–30] | gG-80 (30 [22])<br>aR-125 (40 [30]) | gG-150 (22)<br>aR-160 (30) | NZMB2-A200 | 150 |
| C4 | 50–60 [37–45] | aR-160 (50 [37])<br>aR-200 (60 [45]) | aR-200 (50 [37])<br>aR-250 (60 [45]) | NZMB2-A250 | 250 |
| A4 | 1.5–3 [1.1–2.2] | gG-10 (1.5–2 [1.1–1.5])<br>gG-16 (3 [2.2]) | gG-32 | PKZM0-25 | 25 |
| A5 | 0.34–5 [0.25–3.7] | gG-10 (0.34–2 [0.25–1.5])<br>gG-16 (3–4 [2.2–3])<br>gG-20 (5 [3.7]) | gG-32 | PKZM0-25 | 25 |
| B1 | 7.5–15 [5.5–11] | gG-25 (7.5 [5.5])<br>gG-32 (10–15 [7.5–11]) | gG-80 | PKZM4-63 | 63 |
| B2 | 15 | gG-50 | gG-100 | NZMB1-A100 | 100 |
| C1 | 25–40 [18–30] | gG-63 (25 [18.5])<br>gG-80 (30 [22])<br>gG-100 (40 [30]) | gG-160 (25–30 [18.5–22])<br>aR-160 (40 [30]) | NZMB2-A200 | 160 |
| C2 | 50–60 [37–45] | aR-160 (50 [37])<br>aR-200 (60 [45]) | aR-200 (50 [37])<br>aR-250 (60 [45]) | NZMB2-A250 | 250 |

**Table 6.19 200–240 V, Enclosure Types A, B and C**

| Enclosure type | Power (hp [kW]) | Recommended fuse size | Recommended Max. fuse | Recommended circuit breaker Moeller | Max trip level [A] |
|---|---|---|---|---|---|
| A2 | 1.5–5 [1.1–4.0] | gG-10 (1.5–4 [1.1–3])<br>gG-16 (5 [4]) | gG-25 | PKZM0-25 | 25 |
| A3 | 7.5–10 [5.5–7.5] | gG-16 | gG-32 | PKZM0-25 | 25 |
| B3 | 15–25 [11–18] | gG-40 | gG-63 | PKZM4-50 | 50 |
| B4 | 30–50 [22–37] | gG-50 (30 [22])<br>gG-63 (40 [30])<br>gG-80 (50 [37]) | gG-125 | NZMB1-A100 | 100 |
| C3 | 60–75 [45–55] | gG-100 (60 [45])<br>gG-160 (75 [55]) | gG-150 (60 [45])<br>gG-160 (75 [55]) | NZMB2-A200 | 150 |
| C4 | 100–125 [75–90] | aR-200 (100 [75])<br>aR-250 (125 [90]) | aR-250 | NZMB2-A250 | 250 |
| A4 | 1.5–5 [1.1–4] | gG-10 (1.5–4 [1.1–3])<br>gG-16 (5 [4]) | gG-32 | PKZM0-25 | 82 [25] |
| A5 | 1.5–10 [1.1–7.5] | gG-10 (1.5–4 [1.1–3])<br>gG-16 (5–10 [4–7.5]) | gG-32 | PKZM0-25 | 25 |
| B1 | 15–25 [11–18.5] | gG-40 | gG-80 | PKZM4-63 | 63 |
| B2 | 30–40 [22–30] | gG-50 (30 [22])<br>gG-63 (40 [30]) | gG-100 | NZMB1-A100 | 100 |
| C1 | 50–75 [37–55] | gG-80 (50 [37])<br>gG-100 (60 [45])<br>gG-160 (75 [55]) | gG-160 | NZMB2-A200 | 160 |
| C2 | 100–125 [75–90] | aR-200 (100 [75])<br>aR-250 (125 [90]) | aR-250 | NZMB2-A250 | 250 |

**Table 6.20 380–480 V, Enclosure Types A, B and C**

| Enclosure type | Power (hp [kW]) | Recommended fuse size | Recommended Max. fuse | Recommended circuit breaker Moeller | Max trip level [A] |
|---|---|---|---|---|---|
| A3 | 7.5–10 [5.5–7.5] | gG-10 (7.5 [5.5])<br>gG-16 (10 [7.5]) | gG-32 | PKZM0-25 | 25 |
| B3 | 15–25 [11–18] | gG-25 (15 [11])<br>gG-32 (20–25 [15–18]) | gG-63 | PKZM4-50 | 50 |
| B4 | 30–50 [22–37] | gG-40 (30 [22])<br>gG-50 (40 [30])<br>gG-63 (50 [37]) | gG-125 | NZMB1-A100 | 100 |
| C3 | 60–75 [45–55] | gG-63 (60 [45])<br>gG-100 (75 [55]) | gG-150 | NZMB2-A200 | 150 |
| C4 | 100–125 [75–90] | aR-160 (100 [75])<br>aR-200 (125 [90]) | aR-250 | NZMB2-A250 | 250 |
| A5 | 1.5–10 [1.1–7.5] | gG-10 (1.5–7.5 [1.1–5.5])<br>gG-16 (10 [7.5]) | gG-32 | PKZM0-25 | 25 |
| B1 | 15–25 [11–18] | gG-25 (15 [11])<br>gG-32 (20 [15])<br>gG-40 (25 [18.5]) | gG-80 | PKZM4-63 | 63 |
| B2 | 30–40 [22–30] | gG-50 (30 [22])<br>gG-63 (40 [30]) | gG-100 | NZMB1-A100 | 100 |
| C1 | 50–75 [37–55] | gG-63 (50 [37])<br>gG-100 (60 [45])<br>aR-160 (75 [55]) | gG-160 (50–60 [37–45])<br>aR-250 (75 [55]) | NZMB2-A200 | 160 |
| C2 | 100–125 [75–90] | aR-200 (100–125 [75–90]) | aR-250 | NZMB2-A250 | 250 |

**Table 6.21 525–600 V, Enclosure Types A, B and C**

| Enclosure type | Power (hp [kW]) | Recommended fuse size | Recommended Max. fuse | Recommended circuit breaker Moeller | Max trip level [A] |
|---|---|---|---|---|---|
| A3 | 1.5 [1.1]<br>2 [1.5]<br>3 [2.2]<br>4 [3]<br>5 [4]<br>7.5 [5.5]<br>10 [7.5] | gG-6<br>gG-6<br>gG-6<br>gG-10<br>gG-10<br>gG-16<br>gG-16 | gG-25<br>gG-25<br>gG-25<br>gG-25<br>gG-25<br>gG-25<br>gG-25 | - | - |
| B2 | 15 [11]<br>20 [15]<br>25 [18]<br>30 [22]<br>40 [30] | gG-25 (15 [11])<br>gG-32 (20 [15])<br>gG-32 (25 [18])<br>gG-40 (30 [22])<br>gG-63 (40 [30]) | gG-63<br>gG-80 (40 [30]) | - | - |
| C2 | 50 [37]<br>60 [45]<br>75 [55]<br>100 [75] | gG-63 (50 [37])<br>gG-80 (60 [45])<br>gG-100 (75 [55])<br>gG-125 (100 [75]) | gG-100 (50 [37])<br>gG-125 (60 [45])<br>gG-160 (75–100 [55–75]) | - | - |
| C3 | 60 [45]<br>75 [55] | gG-80<br>gG-100 | gG-100<br>gG-125 | - | - |

**Table 6.22 525–690 V, Enclosure Types A, B and C**

**UL Compliance**

Fuses or circuit breakers are mandatory for compliance with NEC 2009. Danfoss recommends using a selection of the following

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 adjustable frequency drive voltage rating. With the proper fusing the adjustable frequency drive Short Circuit Current Rating (SCCR) is 100,000 Arms.

| | Recommended max. fuse | | | | | |
|---|---|---|---|---|---|---|
| Power (hp [kW]) | Bussmann Type RK1[1)] | Bussmann Type J | Bussmann Type T | Bussmann Type CC | Bussmann Type CC | Bussmann Type CC |
| 1.5 [1.1] | KTN-R-10 | JKS-10 | JJN-10 | FNQ-R-10 | KTK-R-10 | LP-CC-10 |
| 2 [1.5] | KTN-R-15 | JKS-15 | JJN-15 | FNQ-R-15 | KTK-R-15 | LP-CC-15 |
| 3 [2.2] | KTN-R-20 | JKS-20 | JJN-20 | FNQ-R-20 | KTK-R-20 | LP-CC-20 |
| 4 [3.0] | KTN-R-25 | JKS-25 | JJN-25 | FNQ-R-25 | KTK-R-25 | LP-CC-25 |
| 5 [3.7] | KTN-R-30 | JKS-30 | JJN-30 | FNQ-R-30 | KTK-R-30 | LP-CC-30 |
| 7.5 [5.5]-10 [7.5] | KTN-R-50 | KS-50 | JJN-50 | - | - | - |
| 15 [11] | KTN-R-60 | JKS-60 | JJN-60 | - | - | - |
| 15–18.5 | KTN-R-80 | JKS-80 | JJN-80 | - | - | - |
| 30 [22] | KTN-R-125 | JKS-125 | JJN-125 | - | - | - |
| 40 [30] | KTN-R-150 | JKS-150 | JJN-150 | - | - | - |
| 50 [37] | KTN-R-200 | JKS-200 | JJN-200 | - | - | - |
| 60 [45] | KTN-R-250 | JKS-250 | JJN-250 | - | - | - |

**Table 6.23 200–240 V, Enclosure Types A, B and C**

| | Recommended max. fuse | | | |
|---|---|---|---|---|
| Power (hp [kW]) | SIBA Type RK1 | Littelfuse Type RK1 | Ferraz-Shawmut Type CC | Ferraz-Shawmut Type RK1[3)] |
| 1.5 [1.1] | 5017906-010 | KLN-R-10 | ATM-R-10 | A2K-10-R |
| 2 [1.5] | 5017906-016 | KLN-R-15 | ATM-R-15 | A2K-15-R |
| 3 [2.2] | 5017906-020 | KLN-R-20 | ATM-R-20 | A2K-20-R |
| 4 [3.0] | 5017906-025 | KLN-R-25 | ATM-R-25 | A2K-25-R |
| 5 [3.7] | 5012406-032 | KLN-R-30 | ATM-R-30 | A2K-30-R |
| 7.5 [5.5]-10 [7.5] | 5014006-050 | KLN-R-50 | - | A2K-50-R |
| 15 [11] | 5014006-063 | KLN-R-60 | - | A2K-60-R |
| 15–18.5 | 5014006-080 | KLN-R-80 | - | A2K-80-R |
| 30 [22] | 2028220-125 | KLN-R-125 | - | A2K-125-R |
| 40 [30] | 2028220-150 | KLN-R-150 | - | A2K-150-R |
| 50 [37] | 2028220-200 | KLN-R-200 | - | A2K-200-R |
| 60 [45] | 2028220-250 | KLN-R-250 | - | A2K-250-R |

**Table 6.24 200–240 V, Enclosure Types A, B and C**

| | Recommended max. fuse | | | |
|---|---|---|---|---|
| Power (hp [kW]) | Bussmann Type JFHR2[2)] | Littelfuse JFHR2 | Ferraz-Shawmut JFHR2[4)] | Ferraz-Shawmut J |
| 1.5 [1.1] | FWX-10 | - | - | HSJ-10 |
| 2 [1.5] | FWX-15 | - | - | HSJ-15 |
| 3 [2.2] | FWX-20 | - | - | HSJ-20 |
| 4 [3.0] | FWX-25 | - | - | HSJ-25 |
| 5 [3.7] | FWX-30 | - | - | HSJ-30 |
| 7.5 [5.5]-10 [7.5] | FWX-50 | - | - | HSJ-50 |
| 15 [11] | FWX-60 | - | - | HSJ-60 |
| 20–25 [15–18.5] | FWX-80 | - | - | HSJ-80 |
| 30 [22] | FWX-125 | - | - | HSJ-125 |
| 40 [30] | FWX-150 | L25S-150 | A25X-150 | HSJ-150 |
| 50 [37] | FWX-200 | L25S-200 | A25X-200 | HSJ-200 |
| 60 [45] | FWX-250 | L25S-250 | A25X-250 | HSJ-250 |

**Table 6.25 200–240 V, Enclosure Types A, B and C**

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

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

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

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

| | Recommended max. fuse | | | | | |
|---|---|---|---|---|---|---|
| Power (hp [kW]) | Bussmann Type RK1 | Bussmann Type J | Bussmann Type T | Bussmann Type CC | Bussmann Type CC | Bussmann Type CC |
| 1.5 [1.1] | KTS-R-6 | JKS-6 | JJS-6 | FNQ-R-6 | KTK-R-6 | LP-CC-6 |
| 2–3 [1.5–2.2] | KTS-R-10 | JKS-10 | JJS-10 | FNQ-R-10 | KTK-R-10 | LP-CC-10 |
| 4 [3] | KTS-R-15 | JKS-15 | JJS-15 | FNQ-R-15 | KTK-R-15 | LP-CC-15 |
| 5 [4] | KTS-R-20 | JKS-20 | JJS-20 | FNQ-R-20 | KTK-R-20 | LP-CC-20 |
| 7.5 [5.5] | KTS-R-25 | JKS-25 | JJS-25 | FNQ-R-25 | KTK-R-25 | LP-CC-25 |
| 10 [7.5] | KTS-R-30 | JKS-30 | JJS-30 | FNQ-R-30 | KTK-R-30 | LP-CC-30 |
| 15 [11]-20 [15] | KTS-R-40 | JKS-40 | JJS-40 | - | - | - |
| 25 [18] | KTS-R-50 | JKS-50 | JJS-50 | - | - | - |
| 30 [22] | KTS-R-60 | JKS-60 | JJS-60 | - | - | - |
| 40 [30] | KTS-R-80 | JKS-80 | JJS-80 | - | - | - |
| 50 [37] | KTS-R-100 | JKS-100 | JJS-100 | - | - | - |
| 60 [45] | KTS-R-125 | JKS-125 | JJS-125 | - | - | - |
| 75 [55] | KTS-R-150 | JKS-150 | JJS-150 | - | - | - |
| 100 [75] | KTS-R-200 | JKS-200 | JJS-200 | - | - | - |
| 125 [0] | KTS-R-250 | JKS-250 | JJS-250 | - | - | - |

**Table 6.26 380–480 V, Enclosure Types A, B and C**

| | Recommended max. fuse | | | |
|---|---|---|---|---|
| Power (hp [kW]) | SIBA Type RK1 | Littelfuse Type RK1 | Ferraz-Shawmut Type CC | Ferraz-Shawmut Type RK1 |
| 1.5–3 [1.1–2.2] | 5017906-010 | KLS-R-10 | ATM-R-10 | A6K-10-R |
| 4 [3] | 5017906-016 | KLS-R-15 | ATM-R-15 | A6K-15-R |
| 5 [4] | 5017906-020 | KLS-R-20 | ATM-R-20 | A6K-20-R |
| 7.5 [5.5] | 5017906-025 | KLS-R-25 | ATM-R-25 | A6K-25-R |
| 10 [7.5] | 5012406-032 | KLS-R-30 | ATM-R-30 | A6K-30-R |
| 15 [11]-20 [15] | 5014006-040 | KLS-R-40 | - | A6K-40-R |
| 25 [18] | 5014006-050 | KLS-R-50 | - | A6K-50-R |
| 30 [22] | 5014006-063 | KLS-R-60 | - | A6K-60-R |
| 40 [30] | 2028220-100 | KLS-R-80 | - | A6K-80-R |
| 50 [37] | 2028220-125 | KLS-R-100 | - | A6K-100-R |
| 60 [45] | 2028220-125 | KLS-R-125 | - | A6K-125-R |
| 75 [55] | 2028220-160 | KLS-R-150 | - | A6K-150-R |
| 100 [75] | 2028220-200 | KLS-R-200 | - | A6K-200-R |
| 125 [90] | 2028220-250 | KLS-R-250 | - | A6K-250-R |

**Table 6.27 380–500 V, Enclosure Types A, B and C**

| | Recommended max. fuse | | | |
|---|---|---|---|---|
| Power (hp [kW]) | Bussmann JFHR2 | Ferraz- Shawmut J | Ferraz- Shawmut JFHR2[1)] | Littelfuse JFHR2 |
| 1.5–3 [1.1–2.2] | FWH-10 | HSJ-10 | - | - |
| 4 [3] | FWH-15 | HSJ-15 | - | - |
| 5 [4] | FWH-20 | HSJ-20 | - | - |
| 7.5 [5.5] | FWH-25 | HSJ-25 | - | - |
| 10 [7.5] | FWH-30 | HSJ-30 | - | - |
| 15 [11]-20 [15] | FWH-40 | HSJ-40 | - | - |
| 25 [18] | FWH-50 | HSJ-50 | - | - |
| 30 [22] | FWH-60 | HSJ-60 | - | - |
| 40 [30] | FWH-80 | HSJ-80 | - | - |
| 50 [37] | FWH-100 | HSJ-100 | - | - |
| 60 [45] | FWH-125 | HSJ-125 | - | - |
| 75 [55] | FWH-150 | HSJ-150 | - | - |
| 100 [75] | FWH-200 | HSJ-200 | A50-P-225 | L50-S-225 |
| 125 [90] | FWH-250 | HSJ-250 | A50-P-250 | L50-S-250 |

**Table 6.28 380–480 V, Enclosure Types A, B and C**

*1) Ferraz-Shawmut A50QS fuses may substitute for A50P fuses.*

| | Recommended max. fuse | | | | | |
|---|---|---|---|---|---|---|
| Power (hp [kW]) | Bussmann Type RK1 | Bussmann Type J | Bussmann Type T | Bussmann Type CC | Bussmann Type CC | Bussmann Type CC |
| 1.5 [1.1] | KTS-R-5 | JKS-5 | JJS-6 | FNQ-R-5 | KTK-R-5 | LP-CC-5 |
| 2–3 [1.5–2.2] | KTS-R-10 | JKS-10 | JJS-10 | FNQ-R-10 | KTK-R-10 | LP-CC-10 |
| 4 [3] | KTS-R15 | JKS-15 | JJS-15 | FNQ-R-15 | KTK-R-15 | LP-CC-15 |
| 5 [4] | KTS-R20 | JKS-20 | JJS-20 | FNQ-R-20 | KTK-R-20 | LP-CC-20 |
| 7.5 [5.5] | KTS-R-25 | JKS-25 | JJS-25 | FNQ-R-25 | KTK-R-25 | LP-CC-25 |
| 10 [7.5] | KTS-R-30 | JKS-30 | JJS-30 | FNQ-R-30 | KTK-R-30 | LP-CC-30 |
| 15 [11]-20 [15] | KTS-R-35 | JKS-35 | JJS-35 | - | - | - |
| 25 [18] | KTS-R-45 | JKS-45 | JJS-45 | - | - | - |
| 30 [22] | KTS-R-50 | JKS-50 | JJS-50 | - | - | - |
| 40 [30] | KTS-R-60 | JKS-60 | JJS-60 | - | - | - |
| 50 [37] | KTS-R-80 | JKS-80 | JJS-80 | - | - | - |
| 60 [45] | KTS-R-100 | JKS-100 | JJS-100 | - | - | - |
| 75 [55] | KTS-R-125 | JKS-125 | JJS-125 | - | - | - |
| 100 [75] | KTS-R-150 | JKS-150 | JJS-150 | - | - | - |
| 125 [90] | KTS-R-175 | JKS-175 | JJS-175 | - | - | - |

**Table 6.29 525–600 V, Enclosure Types A, B and C**

| | Recommended max. fuse | | | |
|---|---|---|---|---|
| Power (hp [kW]) | SIBA Type RK1 | Littelfuse Type RK1 | Ferraz-Shawmut Type RK1 | Ferraz-Shawmut J |
| 1.5 [1.1] | 5017906-005 | KLS-R-005 | A6K-5-R | HSJ-6 |
| 2–3 [1.5–2.2] | 5017906-010 | KLS-R-010 | A6K-10-R | HSJ-10 |
| 4 [3] | 5017906-016 | KLS-R-015 | A6K-15-R | HSJ-15 |
| 5 [4] | 5017906-020 | KLS-R-020 | A6K-20-R | HSJ-20 |
| 7.5 [5.5] | 5017906-025 | KLS-R-025 | A6K-25-R | HSJ-25 |
| 10 [7.5] | 5017906-030 | KLS-R-030 | A6K-30-R | HSJ-30 |
| 15 [11]-20 [15] | 5014006-040 | KLS-R-035 | A6K-35-R | HSJ-35 |
| 25 [18] | 5014006-050 | KLS-R-045 | A6K-45-R | HSJ-45 |
| 30 [22] | 5014006-050 | KLS-R-050 | A6K-50-R | HSJ-50 |
| 40 [30] | 5014006-063 | KLS-R-060 | A6K-60-R | HSJ-60 |
| 50 [37] | 5014006-080 | KLS-R-075 | A6K-80-R | HSJ-80 |
| 60 [45] | 5014006-100 | KLS-R-100 | A6K-100-R | HSJ-100 |
| 75 [55] | 2028220-125 | KLS-R-125 | A6K-125-R | HSJ-125 |
| 100[90] | 2028220-150 | KLS-R-150 | A6K-150-R | HSJ-150 |
| 125 [90] | 2028220-200 | KLS-R-175 | A6K-175-R | HSJ-175 |

**Table 6.30 525–600 V, Enclosure Types A, B and C**

*1) 170M fuses shown from Bussmann 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.*

| | Recommended max. fuse | | | | | |
|---|---|---|---|---|---|---|
| Power (hp [kW]) | Bussmann Type RK1 | Bussmann Type J | Bussmann Type T | Bussmann Type CC | Bussmann Type CC | Bussmann Type CC |
| (hp [kW]) | | | | | | |
| 1.5 [1.1] | KTS-R-5 | JKS-5 | JJS-6 | FNQ-R-5 | KTK-R-5 | LP-CC-5 |
| 2–3 [1.5–2.2] | KTS-R-10 | JKS-10 | JJS-10 | FNQ-R-10 | KTK-R-10 | LP-CC-10 |
| 4 [3] | KTS-R15 | JKS-15 | JJS-15 | FNQ-R-15 | KTK-R-15 | LP-CC-15 |
| 5 [4] | KTS-R20 | JKS-20 | JJS-20 | FNQ-R-20 | KTK-R-20 | LP-CC-20 |
| 7.5 [5.5] | KTS-R-25 | JKS-25 | JJS-25 | FNQ-R-25 | KTK-R-25 | LP-CC-25 |
| 10 [7.5] | KTS-R-30 | JKS-30 | JJS-30 | FNQ-R-30 | KTK-R-30 | LP-CC-30 |
| 15 [11]-20 [15] | KTS-R-35 | JKS-35 | JJS-35 | - | - | - |
| 25 [18] | KTS-R-45 | JKS-45 | JJS-45 | - | - | - |
| 30 [22] | KTS-R-50 | JKS-50 | JJS-50 | - | - | - |
| 40 [30] | KTS-R-60 | JKS-60 | JJS-60 | - | - | - |
| 50 [37] | KTS-R-80 | JKS-80 | JJS-80 | - | - | - |
| 60 [45] | KTS-R-100 | JKS-100 | JJS-100 | - | - | - |
| 75 [55] | KTS-R-125 | JKS-125 | JJS-125 | - | - | - |
| 100 [75] | KTS-R-150 | JKS-150 | JJS-150 | - | - | - |
| 125 [90] | KTS-R-175 | JKS-175 | JJS-175 | - | - | - |

**Table 6.31 525–690 V, Enclosure Types A, B and C**

| | Recommended max. fuse | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Power (hp [kW]) | Max. prefuse | Bussmann E52273 RK1/JDDZ | Bussmann E4273 J/JDDZ | Bussmann E4273 T/JDDZ | SIBA E180276 RK1/JDDZ | Littelfuse E81895 RK1/JDDZ | Ferraz-Shawmut E163267/E2137 RK1/JDDZ | Ferraz-Shawmut E2137 J/HSJ |
| 15 [11]-20 [15] | 30 A | KTS-R-30 | JKS-30 | JKJS-30 | 5017906-030 | KLS-R-030 | A6K-30-R | HST-30 |
| 20 [18.5] | 45 A | KTS-R-45 | JKS-45 | JJS-45 | 5014006-050 | KLS-R-045 | A6K-45-R | HST-45 |
| 40 [30] | 60 A | KTS-R-60 | JKS-60 | JJS-60 | 5014006-063 | KLS-R-060 | A6K-60-R | HST-60 |
| 50 [37] | 80 A | KTS-R-80 | JKS-80 | JJS-80 | 5014006-080 | KLS-R-075 | A6K-80-R | HST-80 |
| 60 [45] | 90 A | KTS-R-90 | JKS-90 | JJS-90 | 5014006-100 | KLS-R-090 | A6K-90-R | HST-90 |
| 75 [55] | 100 A | KTS-R-100 | JKS-100 | JJS-100 | 5014006-100 | KLS-R-100 | A6K-100-R | HST-100 |
| 100 [75] | 125 A | KTS-R-125 | JKS-125 | JJS-125 | 2028220-125 | KLS-150 | A6K-125-R | HST-125 |
| 125 [90] | 150 A | KTS-R-150 | JKS-150 | JJS-150 | 2028220-150 | KLS-175 | A6K-150-R | HST-150 |

**Table 6.32 *525–690 V, Enclosure Types B and C**

** UL compliance only 525–600 V*

## 6.3 Disconnectors and Contactors

### 6.3.1 Line Power Disconnectors

Assembling of IP55/NEMA Type 12 (enclosure type A5) with line power disconnector.

Line power switch is placed on left side on enclosure types B1, B2, C1 and C2. Line power switch on A5 enclosures is placed on right side.

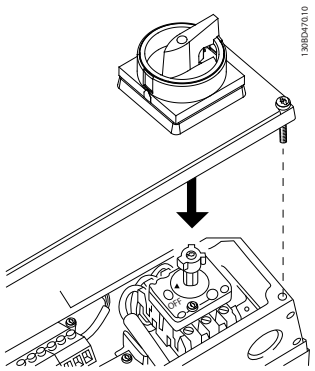



**Figure 6.39 Location of Line Power Switch**

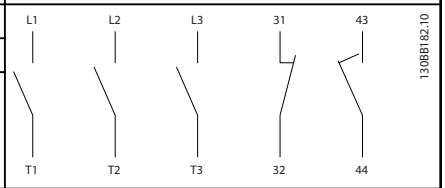
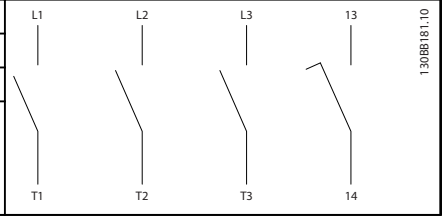
| Enclosure type | Type | Terminal connections |
|---|---|---|
| A5 | Kraus&Naimer KG20A T303 |   |
| B1 | Kraus&Naimer KG64 T303 | |
| B2 | Kraus&Naimer KG64 T303 | |
| C1 50 hp [37 kW] | Kraus&Naimer KG100 T303 |   |
| C1 60–75 hp [45–55 kW] | Kraus&Naimer KG105 T303 | |
| C2 100 hp [75 kW] | Kraus&Naimer KG160 T303 | |
| C2 125 hp [90 kW] | Kraus&Naimer KG250 T303 | |

**Table 6.33 Terminal Connections for Various Enclosure Types**

## 6.4 Additional Motor Information

### 6.4.1 Motor Cable

The motor must be connected to terminals U/T1/96, V/T2/97, W/T3/98. Ground to terminal 99. All types of three-phase asynchronous standard motors can be used with an adjustable frequency drive unit. The factory setting is for clockwise rotation with the adjustable frequency drive output connected as follows:

| Terminal No. | Function |
|---|---|
| 96, 97, 98, 99 | Line power U/T1, V/T2, W/T3<br>Ground |

**Table 6.34 Terminal Functions**

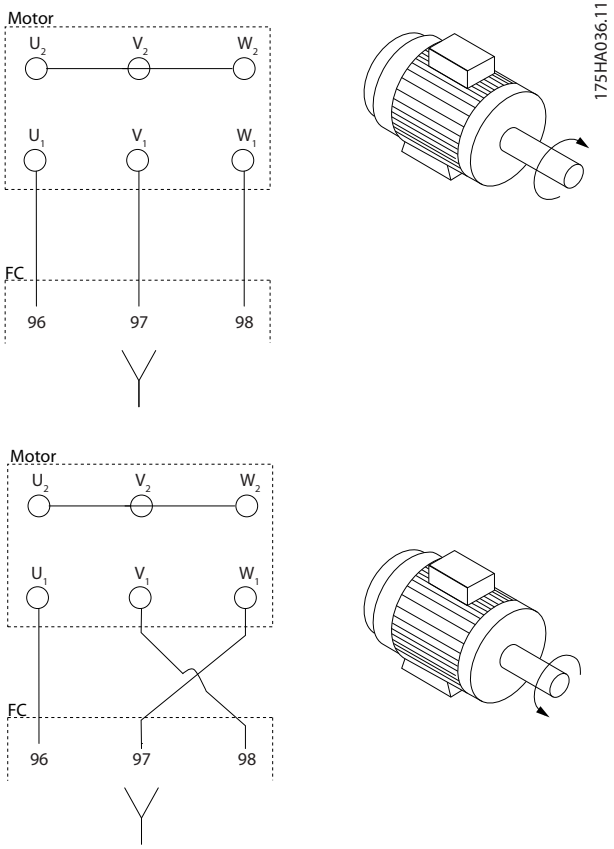



**Figure 6.40 Terminal Connection for Clockwise and Counter-clockwise Rotation**

- Terminal U/T1/96 connected to U-phase
- Terminal V/T2/97 connected to V-phase
- Terminal W/T3/98 connected to W-phase

The direction of rotation can be changed by switching two phases in the motor cable or by changing the setting of *4-10 Motor Speed Direction*.

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

***NOTICE!***

**If a retrofit application requires unequal amounts of wires per phase, consult the factory for requirements and documentation or use the top/bottom entry side cabinet option.**

### 6.4.2 Motor Thermal Protection

The electronic thermal relay in the adjustable frequency drive has received UL-approval for single motor protection, when *1-90 Motor Thermal Protection*is set for *ETR Trip* and *1-24 Motor Current* is set to the rated motor current (see the motor nameplate).
For thermal motor protection,it is also possible to use the PTC Thermistor Card option MCB 112. This card provides an ATEX certificate to protect motors in explosion hazard areas, Zone 1/21 and Zone 2/22. When *1-90 Motor Thermal Protection* is set to [20] ATEX ETR combined with the use of MCB 112, it is possible to control an Ex-e motor in explosion hazard areas. Consult the *Programming Guide* for details on how to set up the adjustable frequency drive for safe operation of Ex-e motors.



### 6.4.3 Parallel Connection of Motors

The adjustable frequency drive can control several motors connected in parallel. When using a parallel motor connection, the following must be observed:

- Recommended to run applications with parallel motors in U/F mode *1-01 Motor Control Principle*. Set the U/F graph in *1-55 U/f Characteristic - U* and *1-56 U/f Characteristic - F*.
- VCC$^{plus}$ mode may be used in some applications.
- The total current consumption of the motors must not exceed the rated output current $I_{INV}$ for the adjustable frequency drive.
- If motor sizes are widely different in winding resistance, starting problems may arise due to too low motor voltage at low speed.
- The electronic thermal relay (ETR) of the frequency inverter cannot be used as motor protection for the individual motor. Provide further motor protection, e.g., by thermistors in each motor winding or individual thermal relays. (Circuit breakers are not suitable as protection devices).

## NOTICE!

**Installations with cables connected using a common joint, as shown in the first example in the picture, are only recommended for short cable lengths.**

## NOTICE!

**When motors are connected in parallel, *1-02 Flux Motor Feedback Source* cannot be used, and *1-01 Motor Control Principle* must be set to *Special motor characteristics (U/f)*.**

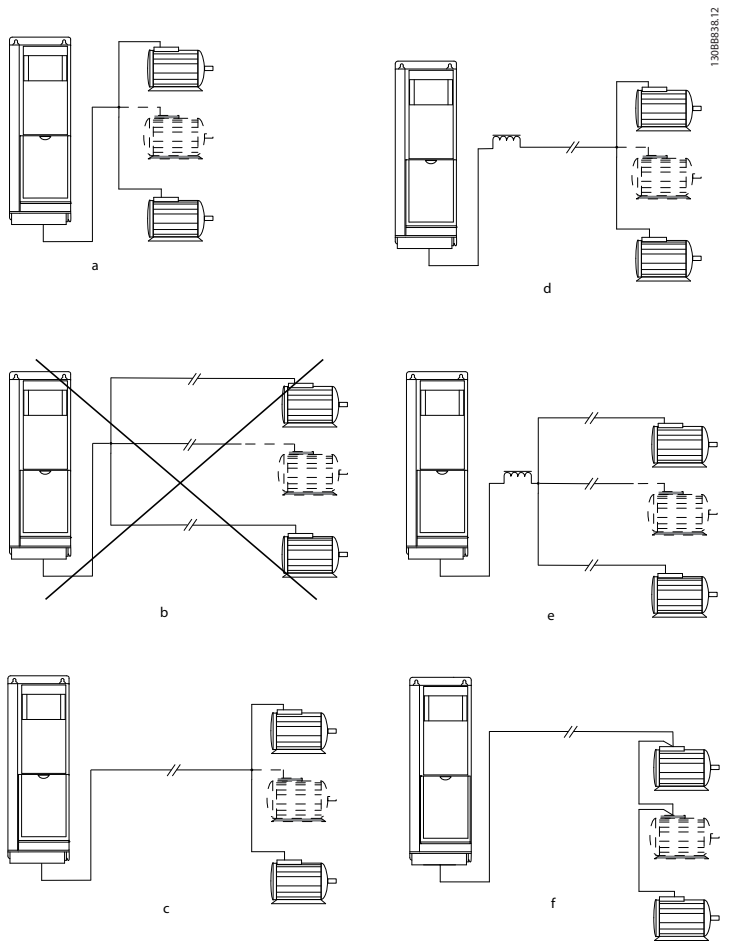



**Figure 6.41 Parallel Motor Connection**

c, d) The total motor cable length specified in section 4.5, *General Specifications*, is valid as long as the parallel cables are kept short (less than 33 ft [10 m] each).
d, e) Consider voltage drop across the motor cables.
e) Be aware of the maximum motor cable length specified in *Table 6.35*.
e) Use LC filter for long parallel cables.

| Enclosure Type | Power Size (hp [kW]) | Voltage [V] | 1 cable (ft [m]) | 2 cables (ft [m]) | 3 cables (ft [m]) | 4 cables (ft [m]) |
|---|---|---|---|---|---|---|
| A5 | 7.5 [5] | 400 | 492.13 [150] | 147.64 [45] | 26.25 [8] | 19.69 [6] |
| | | 500 | 492.13 [150] | 22.97 [7] | 13.12 [4] | 9.84 [3] |
| A2, A5 | 1.5–2 [1.1–1.5] | 400 | 492.13 [150] | 147.64 [45] | 65.62 [20] | 26.25 [8] |
| | | 500 | 492.13 [150] | 147.64 [45] | 16.4 [5] | 13.12 [4] |
| A2, A5 | 3–5 [2.2–4] | 400 | 492.13 [150] | 147.64 [45] | 65.62 [20] | 36.09 [11] |
| | | 500 | 492.13 [150] | 147.64 [45] | 65.62 [20] | 19.69 [6] |
| A3, A5 | 7.5–10 [5.5–7.5] | 400 | 492.13 [150] | 147.64 [45] | 65.62 [20] | 36.09 [11] |
| | | 500 | 492.13 [150] | 147.64 [45] | 65.62 [20] | 36.09 [11] |
| B1, B2, B3, B4, C1, C2, C3, C4 | 15–125 [11–90] | 400 | 492.13 [150] | 246.06 [75] | 164.04 [50] | 121.39 [37] |
| | | 500 | 492.13 [150] | 246.06 [75] | 164.04 [50] | 121.39 [37] |

**Table 6.35 Max. Cable Length for Each Parallel Cable, Depending on Quantity of Parallel Cables.**

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 suitable as protection).

## 6.4.4 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 *1-28 Motor Rotation Check* and following the steps shown in the display.

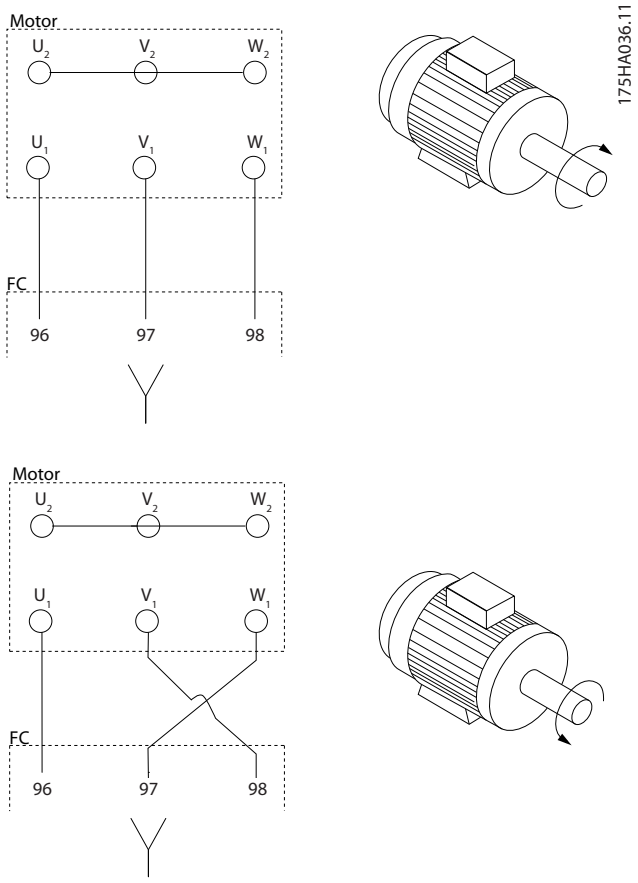



**Figure 6.42 Motor Rotation Check Steps**

## 6.4.5 Motor Insulation

For motor cable lengths ≤ the maximum cable length listed in *chapter 9 General Specifications and Trouble-shooting*, the motor insulation ratings listed in *Table 6.36* are recommended. If a motor has lower insulation rating, it is recommended to use a dU/dt or sine-wave filter.

| Nominal AC Line Voltage [V] | Motor Insulation [V] |
|---|---|
| $U_N \leq 420$ | Standard $U_{LL} = 1300$ |
| $420\ V < U_N \leq 500$ | Reinforced $U_{LL} = 1600$ |
| $500\ V < U_N \leq 600$ | Reinforced $U_{LL} = 1800$ |
| $600\ V < U_N \leq 690$ | Reinforced $U_{LL} = 2000$ |

**Table 6.36 Motor Insulation**

## 6.4.6 Motor Bearing Currents

All motors installed with FC 102 90 kW or higher power adjustable frequency drive should have NDE (Non-Drive End) insulated bearings installed to eliminate circulating bearing currents. To minimize DE (Drive End) bearing and shaft currents proper grounding of the adjustable frequency drive, motor, driven machine, and motor to the driven machine is required.

**Standard Mitigation Strategies**

1. Use an insulated bearing.
2. Apply rigorous installation procedures
   - 2a Ensure the motor and load motor are aligned.
   - 2b Strictly follow the EMC Installation guideline.
   - 2c Reinforce the PE so the high frequency impedance is lower in the PE than the input power leads.
   - 2d Provide a good high frequency connection between the motor and the adjustable frequency drive for instance by shielded cable which has a 360° connection in the motor and the adjustable frequency drive.
   - 2e Make sure that the impedance from adjustable frequency drive to building ground is lower that the grounding impedance of the machine. This can be difficult for pumps.
   - 2f Make a direct ground connection between the motor and load motor.
3. Lower the IGBT switching frequency.
4. Modify the inverter waveform, 60° AVM vs. SFAVM.
5. Install a shaft grounding system or use an isolating coupling.
6. Apply conductive lubrication.
7. Use minimum speed settings if possible.
8. Try to ensure the line voltage is balanced to ground. This can be difficult for IT, TT, TN-CS or Grounded leg systems.
9. Use a dU/dt or sinus filter.



## 6.5 Control Cables and Terminals

### 6.5.1 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 by means of a screwdriver (see *Figure 6.43*).

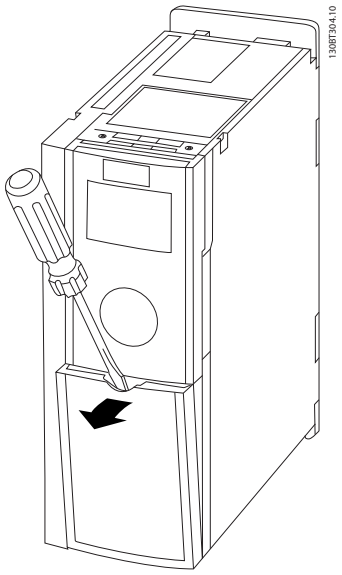



**Figure 6.43 Enclosure Types A1, A2, A3, B3, B4, C3 and C4**

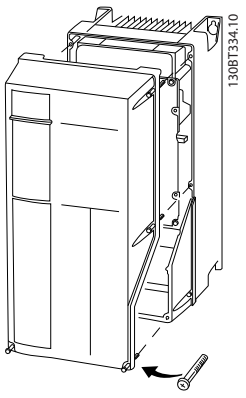



**Figure 6.44 Enclosure Types A5, B1, B2, C1 and C2**

### 6.5.2 Control Cable Routing

Tie down all control wires to the designated control cable routing as shown in the picture. Remember to connect the shields in a proper way to ensure optimum electrical immunity.

**Serial communication bus connection**
Connections are made to the relevant options on the control card. For details, see the relevant serial communication bus instructions. The cable must be placed in the provided path inside the adjustable frequency drive and tied down together with other control wires (see *Figure 6.45*).

In the chassis (IP00) and NEMA 1 units, it is also possible to connect the serial communication bus from the top of the unit as shown in *Figure 6.46* and *Figure 6.47*. On the NEMA 1 unit, remove a cover plate. Kit number for serial communication bus top connection: 176F1742.

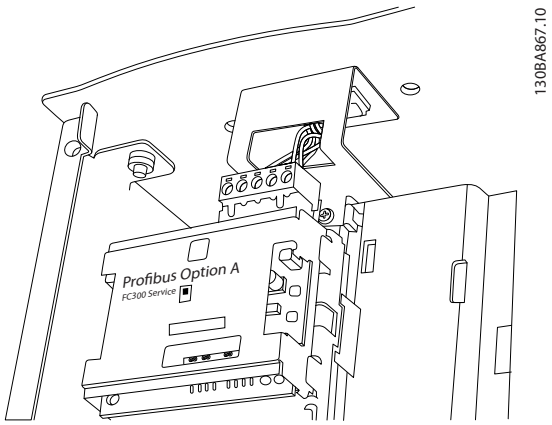



**Figure 6.45 Inside Location of Serial Communication Bus**

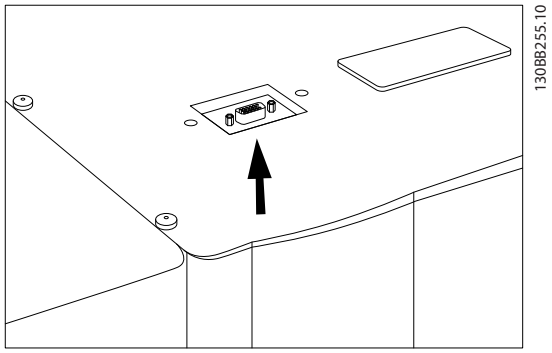



**Figure 6.46 Top Connection for Serial Communication Bus on IP00**

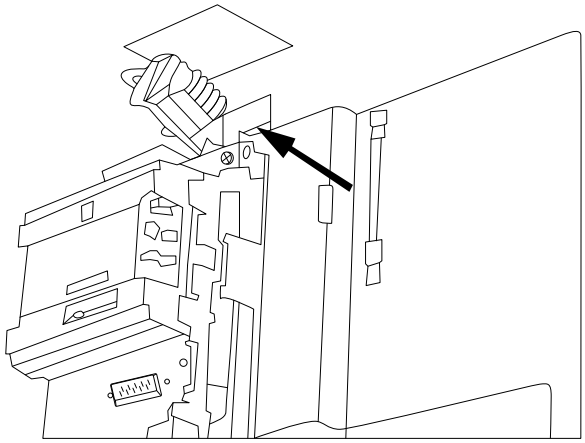



**Figure 6.47 Top Connection for Serial Communication Bus NEMA 1 Units**

**Installation of 24 V external DC Supply**
Torque: 0.5–0.6 Nm (5 in-lbs)
Screw size: M3

| No. | Function |
|---|---|
| 35 (-), 36 (+) | 24 V external DC supply |

**Table 6.37 24 V External DC Supply**

24 V DC external supply can be used as low-voltage supply to the control card and any option cards installed. This enables full operation of the LCP (including parameter setting) without connection to line power.

***NOTICE!***

**A warning of low voltage is given when 24 V DC has been connected; however, there is no tripping.**

**⚠WARNING**

**Use a 24 V DC supply of type PELV to ensure correct galvanic isolation (type PELV) on the control terminals of the adjustable frequency drive.**

## 6.5.3 Control Terminals

| Item | Description |
|---|---|
| 1 | 8-pole plug digital I/O |
| 2 | 3-pole plug RS-485 Bus |
| 3 | 6-pole analog I/O |
| 4 | USB Connection |

**Table 6.38 Legend Table to *Figure 6.48*, for FC 102**

| Item | Description |
|---|---|
| 1 | 10-pole plug digital I/O |
| 2 | 3-pole plug RS-485 Bus |
| 3 | 6-pole analog I/O |
| 4 | SB Connection |

**Table 6.39 Legend Table to *Figure 6.48*, for FC 102**

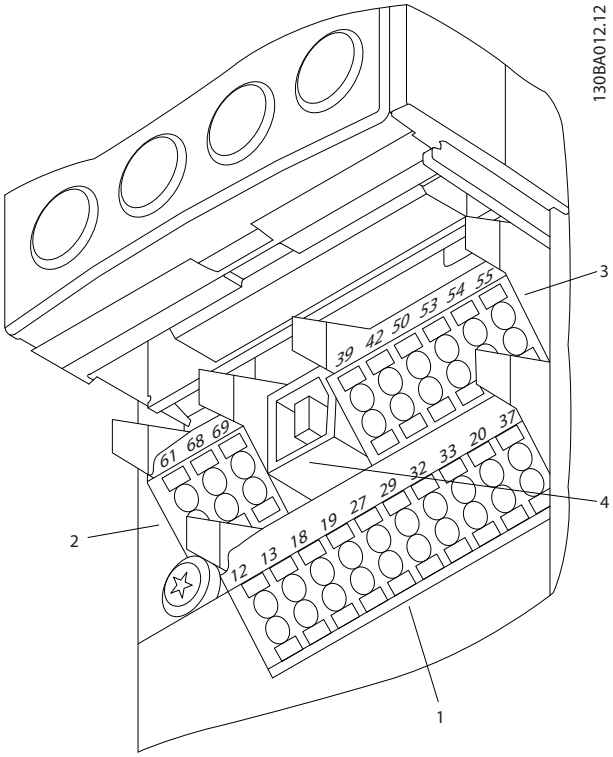



**Figure 6.48 Control Terminals (all Enclosure Types)**

6

## 6.5.4 Switches S201, S202, and S801

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

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

**Default setting**

S201 (A53) = OFF (voltage input)

S202 (A54) = OFF (voltage input)

S801 (Bus termination) = OFF

***NOTICE!***

**When changing the function of S201, S202 or S801, be careful not to force the switch over. Removing the LCP fixture (cradle) when operating the switches is recommended. The switches must not be operated while the adjustable frequency drive is powered.**

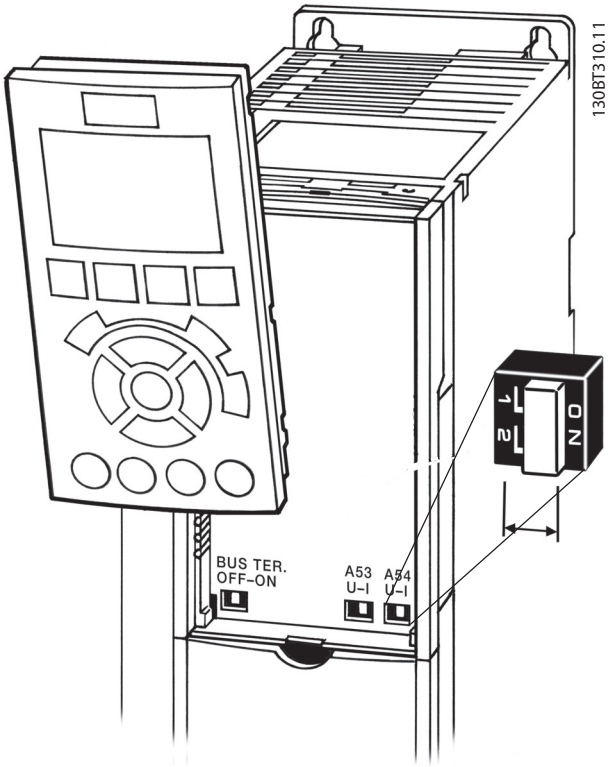



**Figure 6.49 Location of S201, S202 and S801 Switches**

## 6.5.5 Electrical Installation, Control Terminals

**To mount the cable to the terminal**

1. Strip insulation of 0.34–0.39 in [9–10 mm].

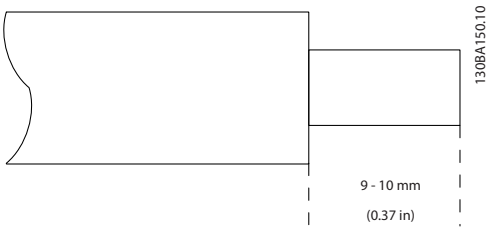



**Figure 6.50 Strip Cable**

2. Insert a screwdriver[1)] in the square hole.

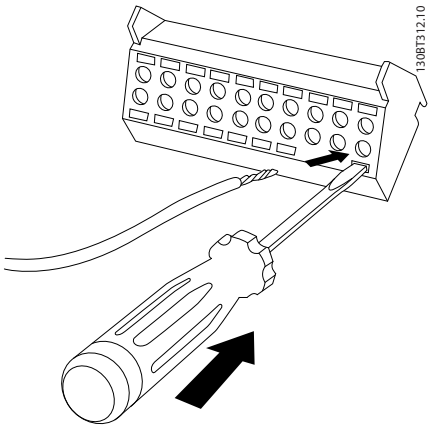



**Figure 6.51 Insert Screwdriver**

3. Insert the cable in the adjacent circular hole.

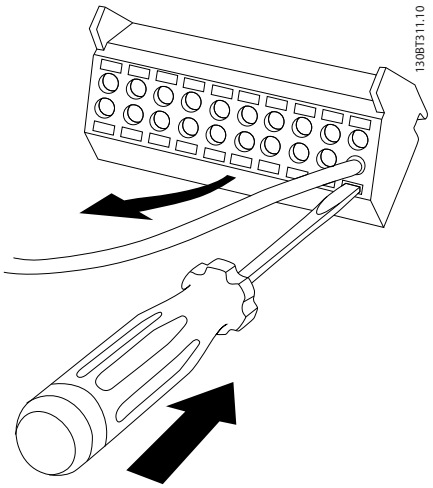



**Figure 6.52 Insert Cable**

4. Remove the screwdriver. The cable is now mounted to the terminal.

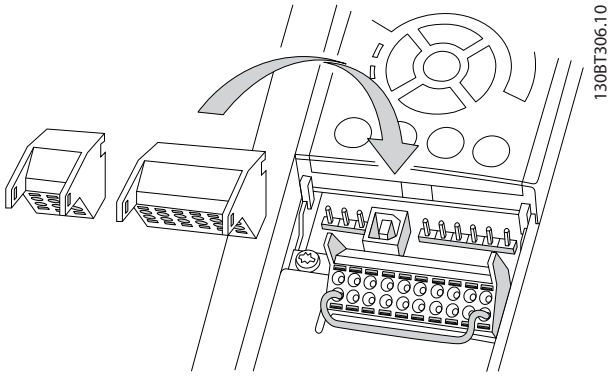



**Figure 6.53 Remove Screwdriver**

**To remove the cable from the terminal**

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

[1)] Max. 0.4 x 2.5 mm

## 6.5.6 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, *5-10 Terminal 18 Digital Input* [9]
27 = Stop inverse, *5-12 Terminal 27 Digital Input* [6]
37 = Safe Torque Off inverse

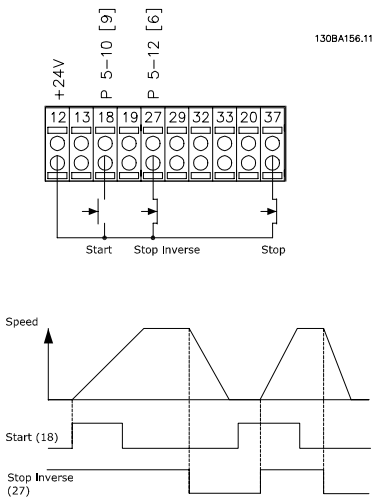



**Figure 6.54 Basic Wiring**

## 6.5.7 Electrical Installation, Control Cables

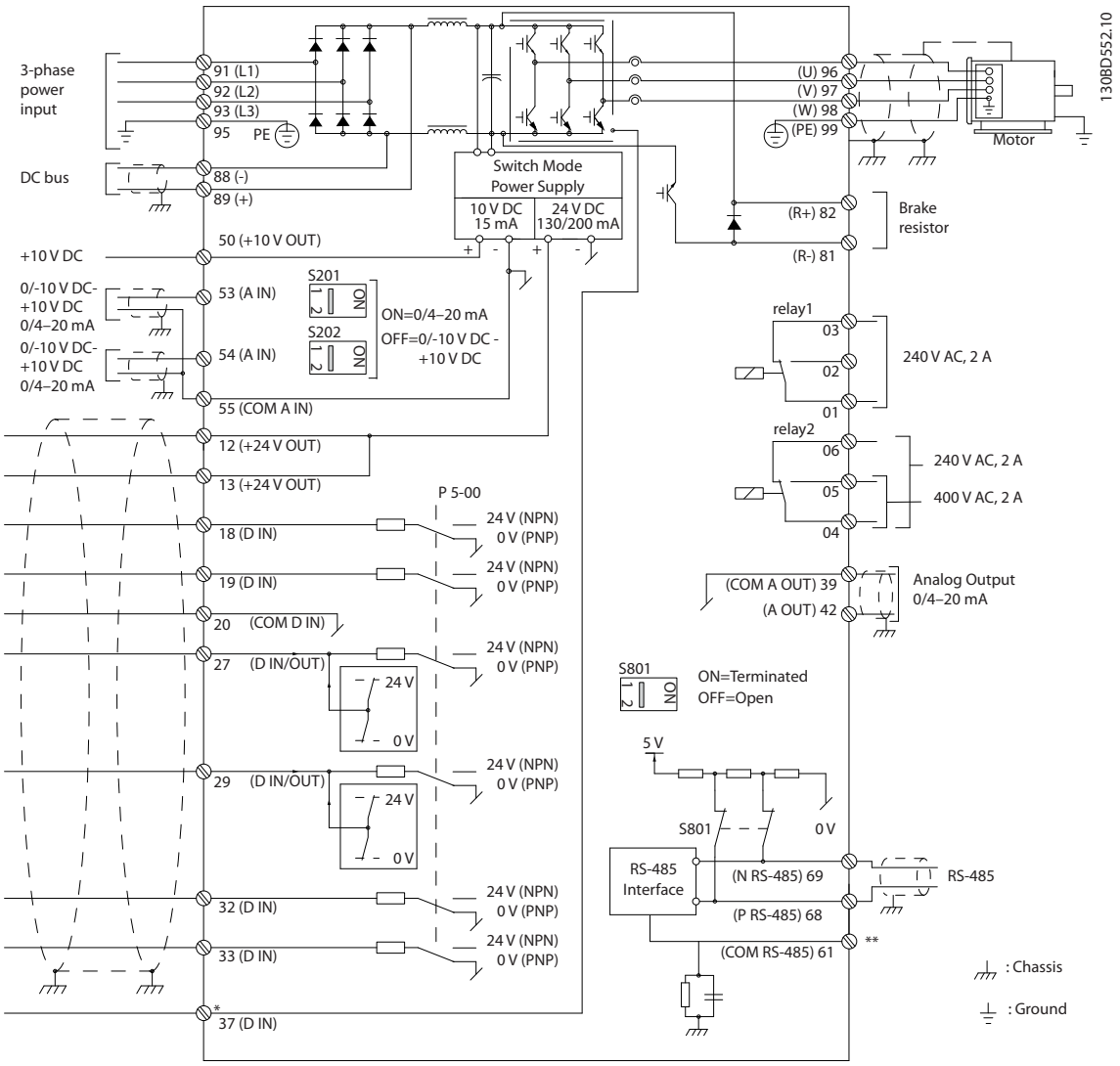



**Figure 6.55 Basic Wiring Schematic**

A=Analog, D=Digital

*Terminal 37 (optional) is used for Safe Torque Off. For Safe Torque Off installation instructions, refer to the *Safe Torque Off Instruction Manual for* Danfoss *VLT® Adjustable Frequency Drives*.

**Do not connect cable shield.

Very long control cables and analog signals may in rare cases and depending on installation, result in 50/60 Hz ground loops due to noise from line power supply cables. If this occurs, it may be necessary to break the shield or insert a 100 nF capacitor between shield and chassis. The digital and analog inputs and outputs must be connected separately to the common inputs (terminal 20, 55, 39) of the adjustable frequency drive to avoid ground currents from both groups affecting other groups. For example, switching on the digital input may disturb the analog input signal.

**Input polarity of control terminals**

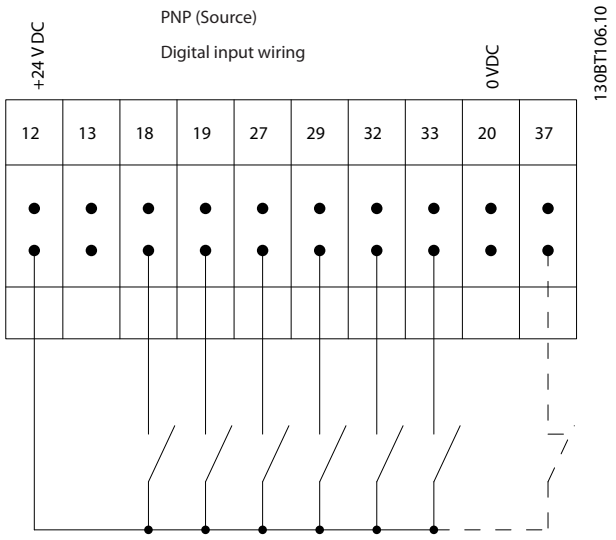



**Figure 6.56 Input Polarity PNP (Source)**

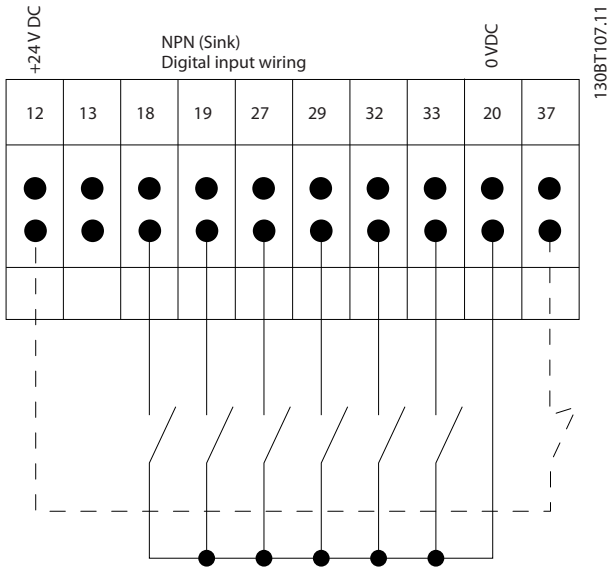



**Figure 6.57 Input Polarity NPN (Sink)**

***NOTICE!***

**To comply with EMC emission specifications, shielded/armored cables are recommended. If an non-shielded/unarmored cable is used, see *chapter 2.9.2 EMC Test Results*.**

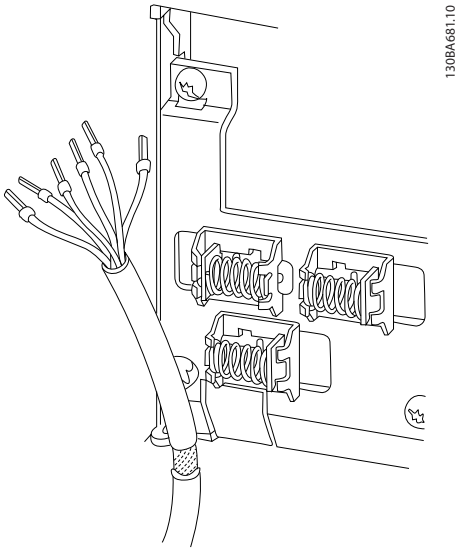



**Figure 6.58 Grounding of Shielded/Armored Control Cables**

## 6.5.8 Relay Output

**Relay 1**

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

**Relay 2 (Not FC 301)**

- 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 *5-40 Function Relay*, *5-41 On Delay, Relay* and *5-42 Off Delay, Relay*.

Additional relay outputs by using Relay Option Module MCB 105.

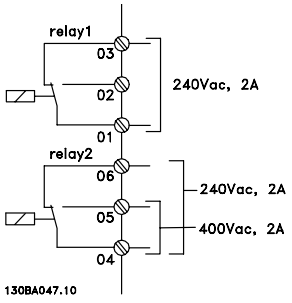



**Figure 6.59 Relay Outputs 1 and 2**

## 6.6 Additional Connections

### 6.6.1 DC Bus Connection

The DC bus terminal is used for DC backup, with the intermediate circuit being supplied from an external source. It uses terminals 88 and 89.

For further information, contact Danfoss.

### 6.6.2 Load Sharing

6

Use terminals 88 and 89 for load sharing.

The connection cable must be shielded and the max. length from the adjustable frequency drive to the DC bar is limited to 80 ft [25 m].
Load sharing enables the linking of the DC intermediate circuits of several adjustable frequency drives.

**⚠WARNING**

**Note that voltages up to 1099 V DC may occur on the terminals.**
**Load sharing calls for extra equipment and safety considerations. For further information, see load sharing Instructions.**

**⚠WARNING**

**Note that line power disconnect may not isolate the adjustable frequency drive due to DC link connection**

### 6.6.3 Installation of Brake Cable

The connection cable to the brake resistor must be shielded and the max. length from adjustable frequency drive to the DC bar is limited to 82 feet [25 m].

1. Connect the shield by means of cable clamps to the conductive backplate on the adjustable frequency drive and to the metal cabinet of the brake resistor.
2. Size the brake cable cross-section to match the brake torque.

Terminals 81 and 82 are brake resistor terminals.

See Brake instructions for more information about safe installation.

***NOTICE!***

**If a short circuit in the brake IGBT occurs, prevent power dissipation in the brake resistor by using a line switch or contactor to disconnect the line power from the adjustable frequency drive. Only the adjustable frequency drive should control the contactor.**

**⚠CAUTION**

**Note that voltages up to 1,099 V DC, depending on the supply voltage, may occur on the terminals.**

### 6.6.4 How to Connect a PC to the Adjustable Frequency Drive

To control 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.

USB is a serial bus utilizing four shielded wires with Ground pin 4 connected to the shield in the PC USB port. When connecting the PC to an adjustable frequency drive through the USB cable, there is a potential risk of damaging the PC USB host controller. All standard PCs are manufactured without galvanic isolation in the USB port. Any ground potential difference caused by not following the recommendations described in *AC Line Input Connection* in the *Instruction Manual* can damage the USB host controller through the shield of the USB cable.
It is recommended to use a USB isolator with galvanic isolation to protect the PC USB host controller from ground potential differences when connecting the PC to an adjustable frequency drive through a USB cable.
It is recommended not to use a PC power cable with a ground plug when the PC is connected to the adjustable frequency drive through a USB cable. It reduces the ground potential difference, but does not eliminate all potential differences due to the ground and shield connected in the PC USB port.

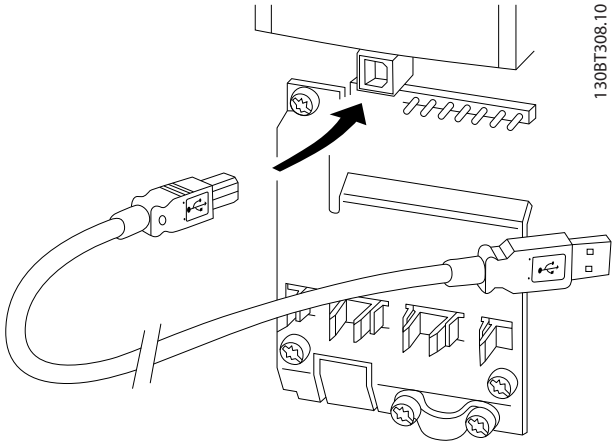



**Figure 6.60 USB Connection**

## 6.6.5 PC Software

**Data storage in PC via MCT 10 Set-up Software**

1. Connect a PC to the unit via the USB COM port.
2. Open MCT 10 Set-up Software.
3. Select the USB port in the *network* section.
4. Select *copy*.
5. Select the *project* section.
6. Select *paste*.
7. Select *Save as*.

All parameters are now stored.

**Data transfer from PC to adjustable frequency drive via MCT 10 Set-up Software**

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

All parameters are now transferred to the adjustable frequency drive.

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

## 6.6.6 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 additional harmonic reduction devices, such as Danfoss AHF filters and 12-18-pulse rectifiers, can be calculated.

**Ordering number:**
Order the CD containing the MCT 31 PC tool using code number 130B1031.

MCT 31 can also be downloaded from *www.danfoss.com/BusinessAreas/DrivesSolutions/Softwaredownload/*.

## 6.7 Safety

## 6.7.1 High Voltage Test

Carry out a high voltage test by short-circuiting terminals U, V, W, $L_1$, $L_2$ and $L_3$. Energize maximum 2.15 kV DC for 380–500 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.

**⚠WARNING**

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

## 6.7.2 Grounding

**The following basic issues need to be considered when installing an adjustable frequency drive, so as to obtain electromagnetic compatibility (EMC).**

- Safety grounding: The adjustable frequency drive has a high leakage current and must be grounded appropriately for safety reasons. Apply local safety regulations.
- High-frequency grounding: Keep the ground wire connections as short as possible.



Connect the different ground systems at the lowest possible conductor impedance. The lowest possible conductor impedance is obtained by keeping the conductor as short as possible and by using the greatest possible surface area.
The metal cabinets of the different devices are mounted on the cabinet rear plate using the lowest possible HF impedance. This prevents having different HF voltages for the individual devices and prevents the risk of radio interference currents running in connection cables that may be used between the devices, as The radio interference have been reduced.
To obtain a low HF impedance, use the fastening bolts of the devices as HF connection to the rear plate. It is necessary to remove insulating paint and the like from the fastening points.



## 6.7.3 Safety Ground Connection

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

**⚠WARNING**

**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 10 mm$^2$ or two rated ground wires terminated separately.**

## 6.7.4 ADN-compliant Installation

Units with ingress protection rating IP55 (NEMA 12) or higher prevent spark formation and are classified as limited explosion risk electrical apparatus in accordance with the European Agreement concerning International Carriage of Dangerous Goods by Inland Waterways (ADN).

For units with ingress protection rating IP20, IP21, or IP54, prevent risk of spark formation as follows:

- Do not install a line power switch.
- Ensure that *14-50 RFI 1* is set to *[1] On*.
- Remove all relay plugs marked “RELAY”. See *Figure 6.61*.
- Check which relay options are installed, if any. The only permitted relay option is Extended Relay Card MCB 113.

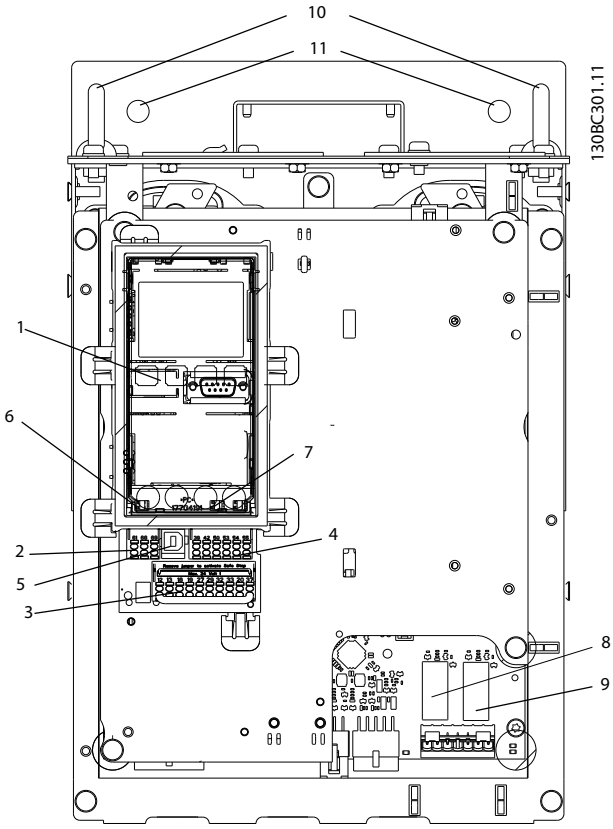



**Figure 6.61 Location of Relay Plugs, Pos. 8 and 9**

Manufacturer declaration is available upon request.

## 6.8 EMC-compatible Installation

### 6.8.1 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 *chapter 2.2 CE Labeling*, *chapter 2.9 General Aspects of EMC* and *chapter 2.9.2 EMC Test Results*.

**Good engineering practice to ensure EMC-compatible 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 a conduit separate from the control and line cables. Full connection of the conduit from the adjustable frequency drive to the motor is required. The EMC performance of flexible conduits varies a lot and information from the manufacturer must be obtained.
- Connect the 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 *chapter 6.8.3 Grounding of Shielded 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 non-shielded/unarmored motor or control cables inside cabinets housing the adjustable frequency drive(s).

Leave the shield as close to the connectors as possible.

*Figure 6.62* shows an example of an EMC-compatible electrical installation of an IP20 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 *chapter 2.9.2 EMC Test Results*.

6

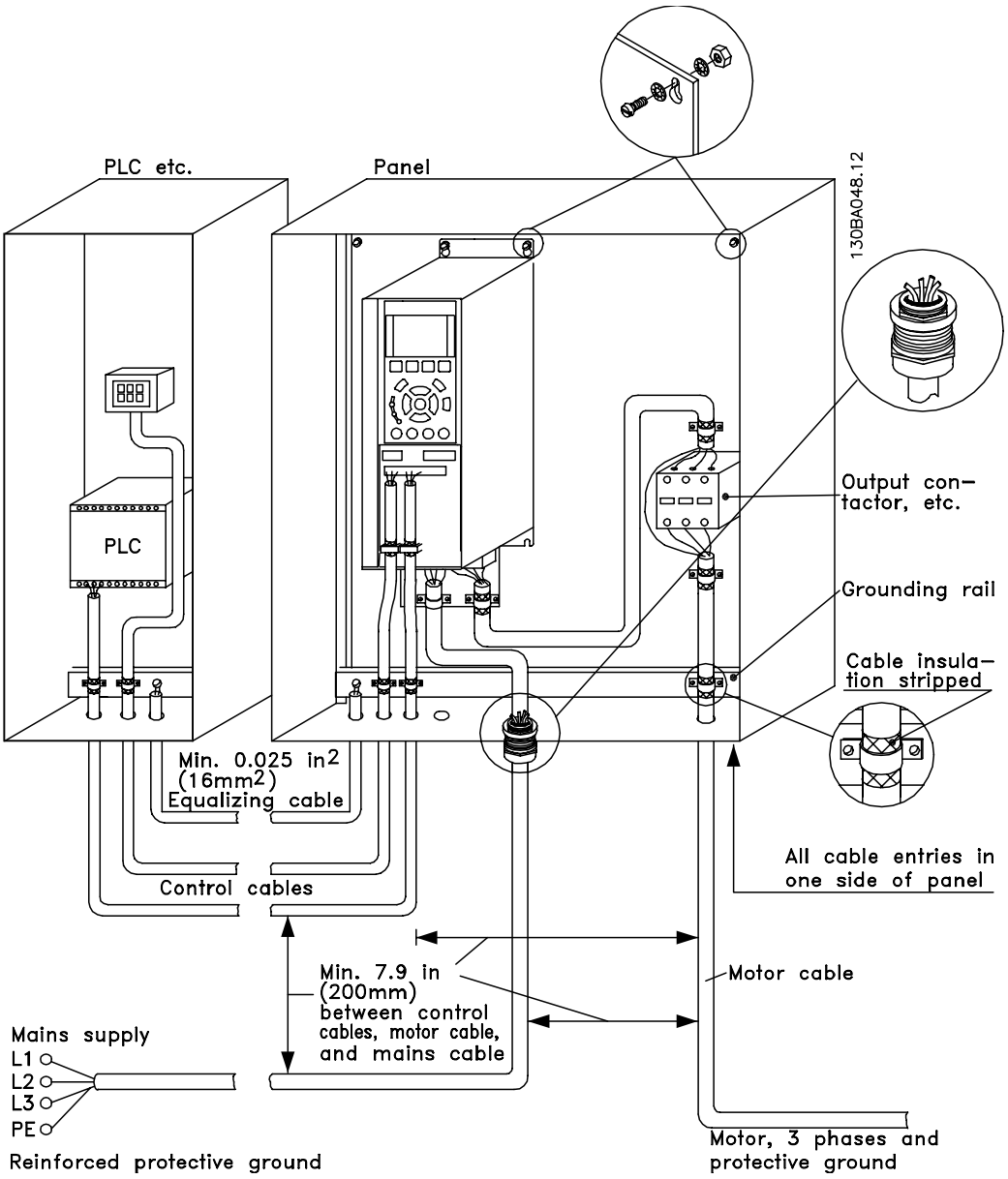



**Figure 6.62 EMC-compatible Electrical Installation of an Adjustable Frequency Drive in Cabinet**

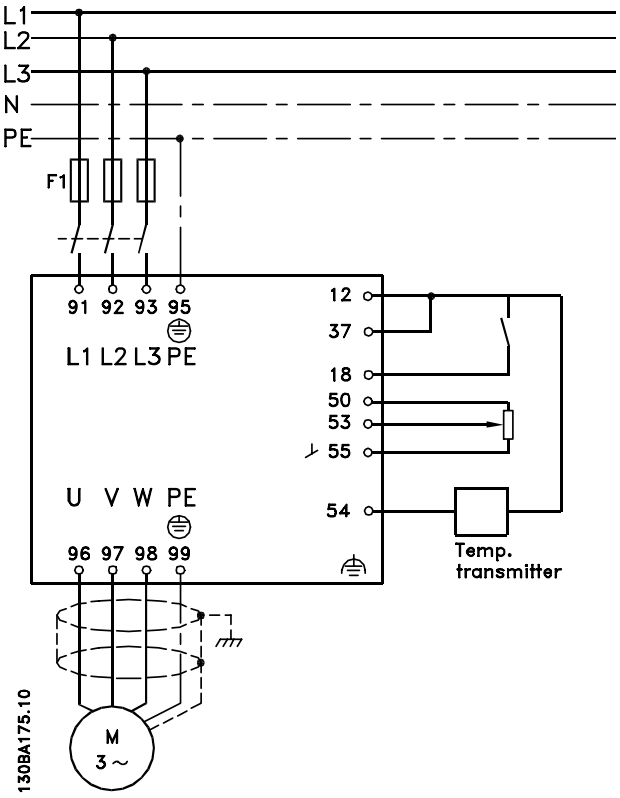



**Figure 6.63 Electrical Connection Diagram**

## 6.8.2 Use of EMC-Compatible 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 conductibility 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 0.043 in [1.1 mm] wall thickness

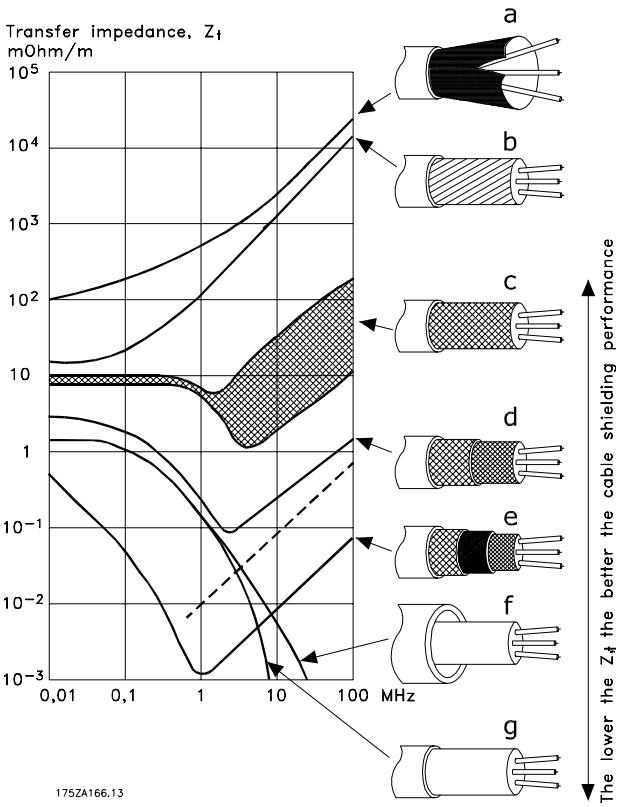



**Figure 6.64 Transfer Impedance**

## 6.8.3 Grounding of Shielded Control Cables

**Correct shielding**

The preferred method in most cases is to secure control and cables with shielding clamps provided at both ends to ensure best possible high frequency cable contact.
If the ground potential between the adjustable frequency drive and the PLC is different, electric noise may occur that disturbs the entire system. Solve this problem by fitting an equalizing cable next to the control cable. Minimum cable cross-section: 0.025 in$^2$ [16 mm$^2$].

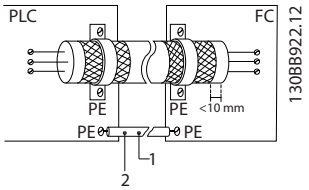



**Figure 6.65 Control Cable with Equalizing Cable**

| | |
|---|---|
| 1 | Min. 0.025 in$^2$ [16 mm$^2$] |
| 2 | Equalizing cable |

**Table 6.40 Legend to *Figure 6.65***

**50/60 Hz ground loops**

With very long control cables, ground loops may occur. To eliminate ground loops, connect one end of the shield-to-ground with a 100 nF capacitor (keeping leads short).

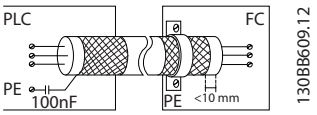



**Figure 6.66 Shield-to-ground Connected to a 100 nF Capacitor**

**Avoid EMC noise on serial communication**

This terminal is connected to ground via an internal RC link. Use twisted-pair cables to reduce interference between conductors.

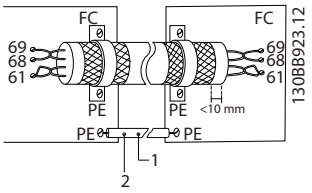



**Figure 6.67 Twisted-pair Cables**

| | |
|---|---|
| 1 | Min. 0.025 in$^2$ [16 mm$^2$] |
| 2 | Equalizing cable |

**Table 6.41 Legend to *Figure 6.67***

Alternatively, the connection to terminal 61 can be omitted:

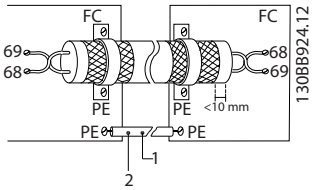



**Figure 6.68 Terminal 61 not Connected**

| | |
|---|---|
| 1 | Min. 0.025 in$^2$ [16 mm$^2$] |
| 2 | Equalizing cable |

**Table 6.42 Legend to *Figure 6.68***

### 6.8.4 RFI Switch

**Line power supply isolated from ground**
If the adjustable frequency drive is supplied from an isolated line power source (IT line power, floating delta) or TT/TN-S line power with grounded leg (grounded delta), turn off the RFI switch via *14-50 RFI 1*.
In OFF, the internal capacitors between the chassis (ground), the input RFI filter and the intermediate circuit are cut off. As the RFI switch is turned off, the adjustable frequency drive is not be able to meet optimum EMC performance.

By opening the RFI filter switch, the ground leakage currents are also reduced, but not the high-frequency leakage currents caused by the switching of the inverter. It is important to use isolation monitors that are capable for use with power electronics (IEC61557-8), e.g., Deif type SIM-Q, Bender type IRDH 275/375 or similar.
Also refer to the application note *VLT on IT line power*.

***NOTICE!***

**If the RFI switch is not turned off and the adjustable frequency drive is running on isolated grids, ground faults can potentially lead to charge-up of the intermediate circuit and cause DC capacitor damage or result in reduced product life.**

## 6.9 Residual Current Device

Use RCD relays, multiple protective 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, observe local regulations. Relays must be suitable for protection of three-phase equipment with a bridge rectifier and for a brief discharge on power-up, see *chapter 2.11 Ground Leakage Current* for further information.

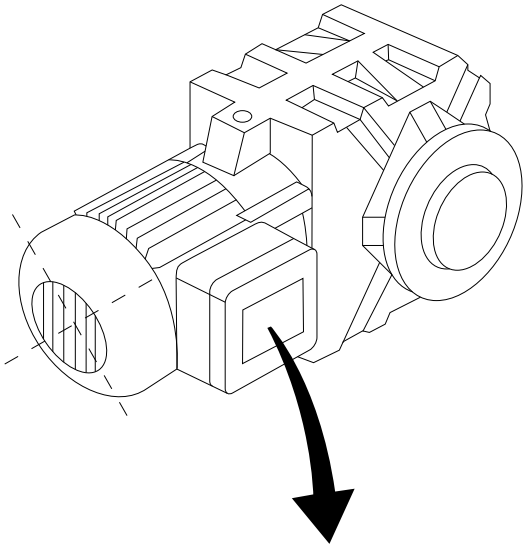
## 6.10 Final Set-up and Test

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

**Step 1. Locate the motor nameplate**

***NOTICE!***

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




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

**Figure 6.69 Motor Nameplate**

**Step 2. Enter the motor nameplate data in this parameter list.**
To access this list, press [Quick Menu] and select "Q2 Quick Set-up".

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

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

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

1. Connect terminal 37 to terminal 12 (if terminal 37 is available).
2. Connect terminal 27 to terminal 12 or set *5-12 Terminal 27 Digital Input* to *[0] No function*.
3. Activate the AMA *1-29 Automatic Motor Adaptation (AMA)*.
4. Select between complete or reduced AMA. If a sine-wave filter is mounted, run only the reduced AMA, or remove the sine-wave filter during the AMA procedure.
5. Press [OK]. The display shows *Press [Hand on] to start*.
6. Press [Hand On]. A progress bar indicates if the AMA is in progress.

**Stop the AMA during operation**

1. Press [Off] - the adjustable frequency drive enters 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 [OK] to exit the AMA state.

**Unsuccessful AMA**

1. The adjustable frequency drive enters alarm mode. A description of the alarm can be found in the *Warnings and Alarms* chapter in the product-related *Instruction Manual*.
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 assist in troubleshooting. If contacting Danfoss for service, make sure to mention number and alarm description.

***NOTICE!***

**Unsuccessful AMA is often caused by incorrectly registered motor nameplate data or a difference that is too large between the motor power size and the adjustable frequency drive power size.**

**Step 4. Set speed limit and ramp times**

**Set up the desired limits for speed and ramp time:**

*3-02 Minimum Reference*.

*3-03 Maximum Reference*.

*4-11 Motor Speed Low Limit [RPM]* or *4-12 Motor Speed Low Limit [Hz]*.

*4-13 Motor Speed High Limit [RPM]* or *4-14 Motor Speed High Limit [Hz]*.

*3-41 Ramp 1 Ramp-up Time*.

*3-42 Ramp 1 Ramp-down Time*.

# 7 Application Examples

## 7.1 Application Examples

### 7.1.1 Start/Stop

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

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

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

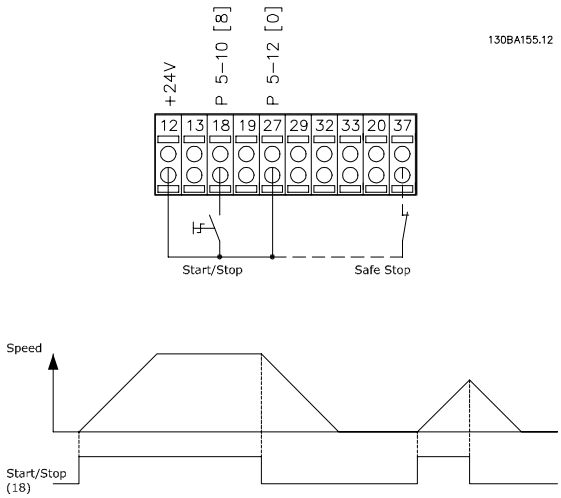



**Figure 7.1 Terminal 37: Available only with Safe Stop Function**

### 7.1.2 Pulse Start/Stop

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

*5-10 Terminal 18 Digital Input = Latched start*

*5-12 Terminal 27 Digital Input = Stop inverse*

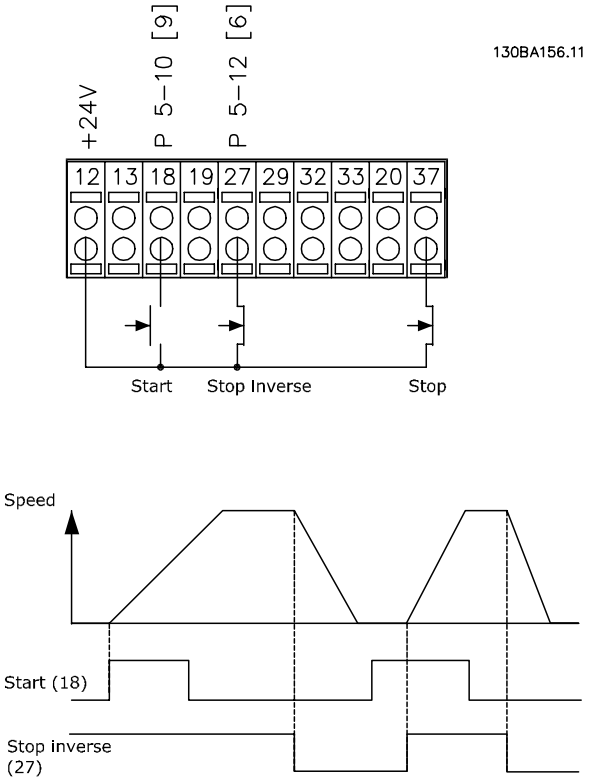



**Figure 7.2 Terminal 37: Available Only with Safe Torque Off Function**

7

## 7.1.3 Potentiometer Reference

Voltage reference via a potentiometer.

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

*6-10 Terminal 53 Low Voltage* = 0 V

*6-11 Terminal 53 High Voltage* = 10 V

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

*6-15 Terminal 53 High Ref./Feedb. Value* = 1500 RPM

Switch S201 = OFF (U)

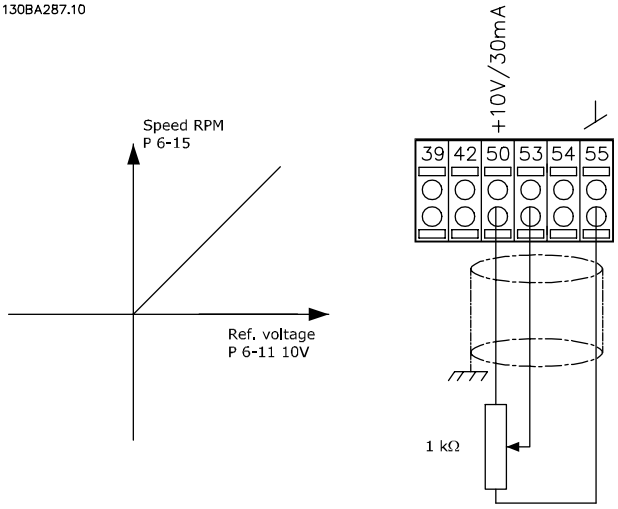



**Figure 7.3 Voltage Reference via a Potentiometer**

## 7.1.4 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. This feature is particularly used where the default setting does not apply to the connected motor.
*1-29 Automatic Motor Adaptation (AMA)* allows a choice of complete AMA with determination of all electrical motor parameters or reduced AMA with determination of the stator resistance Rs only.
The duration of a total AMA varies from a few minutes on small motors to more than 15 minutes on large motors.

**Limitations and preconditions:**

- For the AMA to determine the motor parameters optimally, enter the correct motor nameplate data in *1-20 Motor Power [kW]* to *1-28 Motor Rotation Check*.
- For the best adjustment of the adjustable frequency drive, carry out an AMA on a cold motor. Repeated AMA runs may lead to a heating of the motor, which results in an increase of the stator resistance, Rs. Normally, this is not critical.
- AMA can only be carried out if the rated motor current is minimum 35% of the rated output current of the 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 a 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 windmilling in ventilation systems, for example. This disturbs the AMA function.
- AMA cannot be activated when running a PM motor (when *1-10 Motor Construction* is set to *[1] PM non-salient SPM*).

## 7.1.5 Smart Logic Control

A useful facility in the adjustable frequency 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 generated in the adjustable frequency drive. The adjustable frequency drive then performs the pre-programmed action.

## 7.1.6 Smart Logic Control Programming

The Smart Logic Control (SLC) is essentially a sequence of user-defined actions (see *13-52 SL Controller Action*) executed by the SLC when the associated user-defined *event* (see *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]* is evaluated, and if evaluated TRUE, *action [2]* is 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* are 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 does the SLC execute *action [1]* and start 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]*.
*Figure 7.4* shows an example with three *events/actions*:

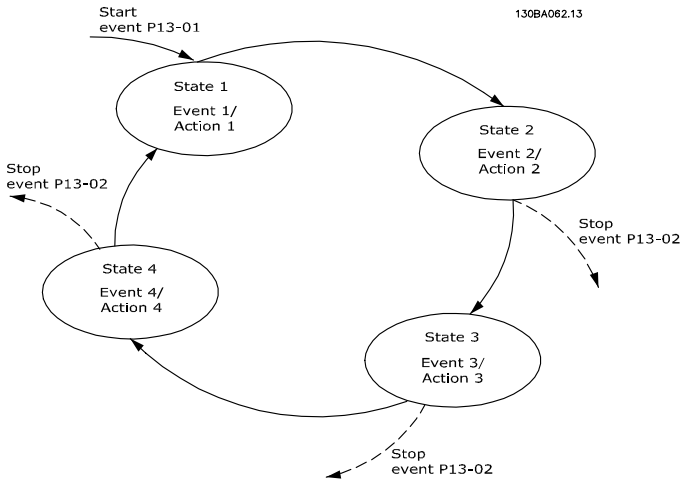



**Figure 7.4 An Example with Three Events/Actions**

## 7.1.7 SLC Application Example

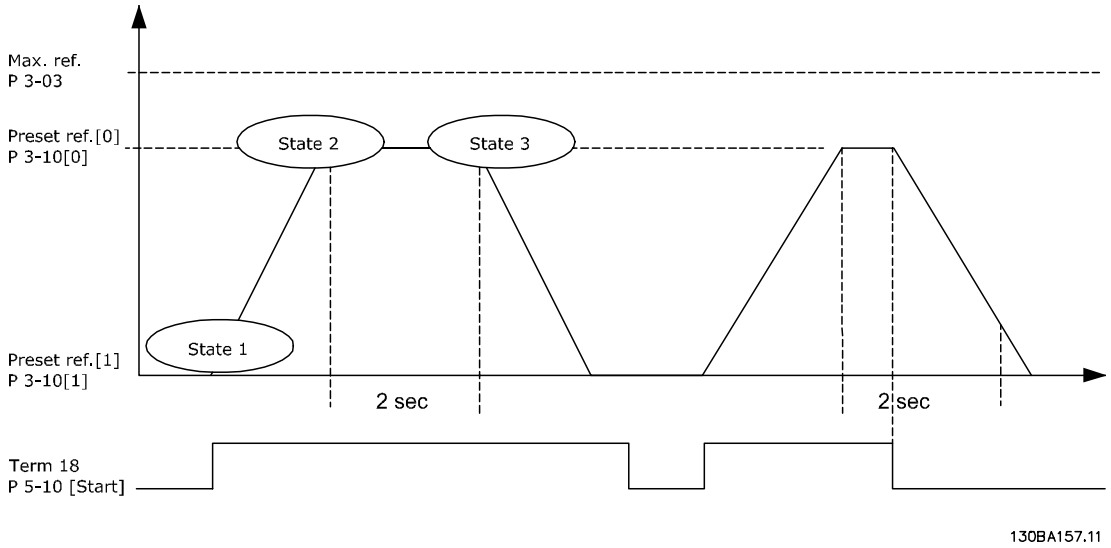



**Figure 7.5 One sequence 1: Start – ramp-up – run at reference speed 2 sec – ramp-down and hold shaft until stop.**

Set the ramping times in *3-41 Ramp 1 Ramp-up Time* and *3-42 Ramp 1 Ramp-down Time* to the desired times

$$tramp = \frac{tacc \times nnorm\,(par.\ 1-25)}{ref\,[RPM]}$$

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

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

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

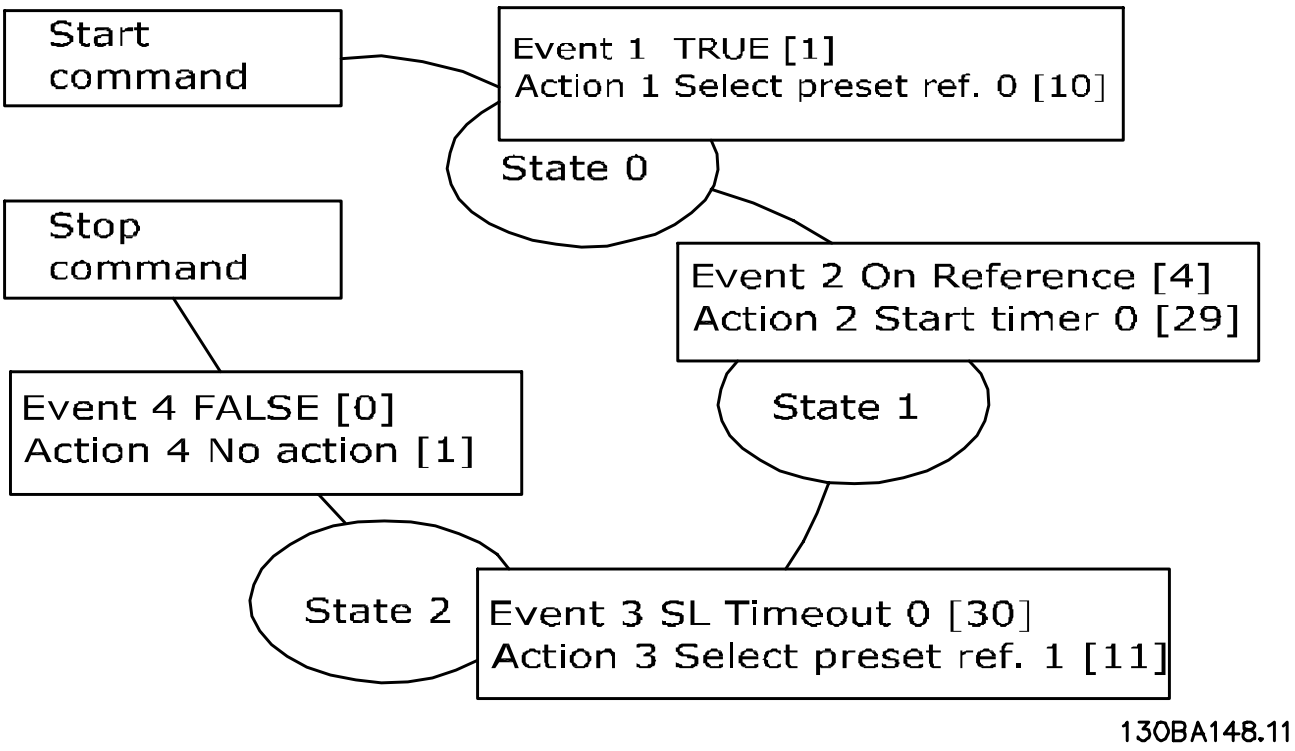



**Figure 7.6 Set Event and Action**

Set the Smart Logic Control in *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.

## 7.1.8 Cascade Controller

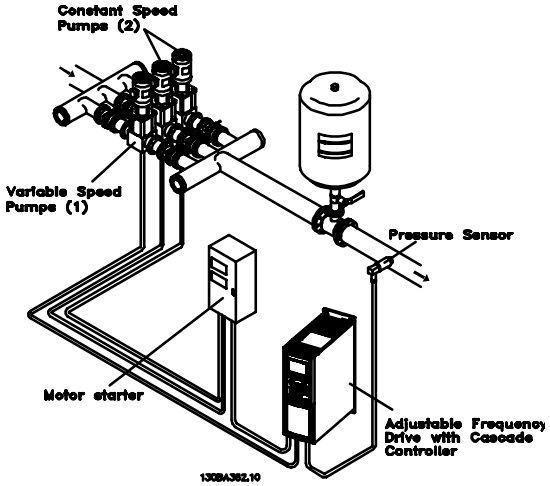



**Figure 7.7 A Pump Application**

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

In the Cascade Controller, the adjustable frequency drive controls a variable-speed motor as the variable-speed pump (lead) 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 Cascade Controller allows the adjustable frequency drive to control up to five equal size pumps using the adjustable frequency drives, two built-in relays and terminal 27, 29 (DI/DO). When the variable pump (lead) is connected directly to the adjustable frequency drive, the other four pumps are controlled by the two built-in relays and terminal 27, 29 (DI/DO). Lead pump alternation cannot be selected when lead pump is fixed.

**Lead Pump Alternation**
The motors must be of equal size. This function makes it possible to cycle the adjustable frequency drive between the pumps in the system (when *25-57 Relays per Pump* =1, maximum pump is 4. When *25-57 Relays per Pump* =2, maximum pump is 3). 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 lag 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, when the lead pump goes into sleep mode. Staging is determined by the actual system load.

*25-55 Alternate if Load* <= *50%*= 1, if load >50% alternation does not happen. If load <=50% Alternation happens. When *25-55 Alternate if Load* <= *50%* = 0, Alternation happens no matter with Load. Total pump capacity is determined as lead pump plus lag speed pumps capacities.

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

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

### 7.1.9 Pump Staging with Lead Pump Alternation

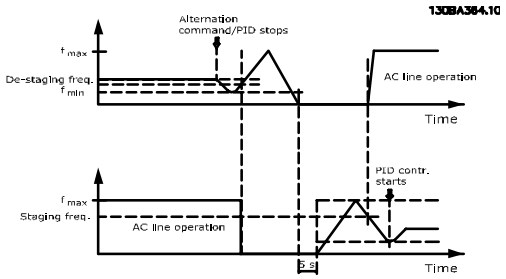



**Figure 7.8 Pump Staging with Lead Pump Alternation**

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

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

### 7.1.10 System Status and Operation

If the lead pump goes into Sleep Mode, the function is displayed on the LCP. 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 LCP. Information displayed includes:

- Pumps Status, is a readout 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, is a readout of the status for the Cascade Controller. The display shows the cascade controller is disabled, all pumps are off, and emergency has stopped all pumps, all pumps are running, fixed-speed pumps are being staged/de-staged and lead pump alternation is occurring.
- Destage at No-Flow ensures that all fixed-speed pumps are stopped individually until the no-flow status disappears.

### 7.1.11 Fixed Variable-speed Pump Wiring Diagram

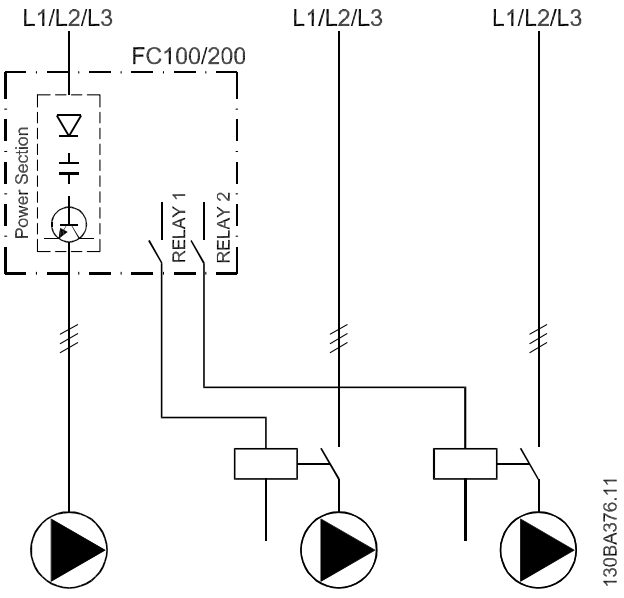



**Figure 7.9 Fixed Variable-speed Pump Wiring Diagram**

7

## 7.1.12 Lead Pump Alternation Wiring Diagram

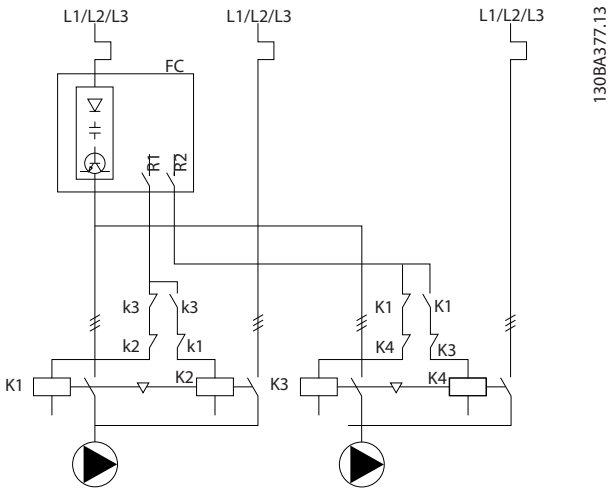



**Figure 7.10 Lead Pump Alternation Wiring Diagram**

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 cuts in the contactor corresponding to the pump controlled by the relay, e.g., RELAY 1 cuts in contactor K1, which becomes the lead pump.
- K1 blocks 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-energizes and now RELAY 2 is energized as the first relay.

## 7.1.13 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.

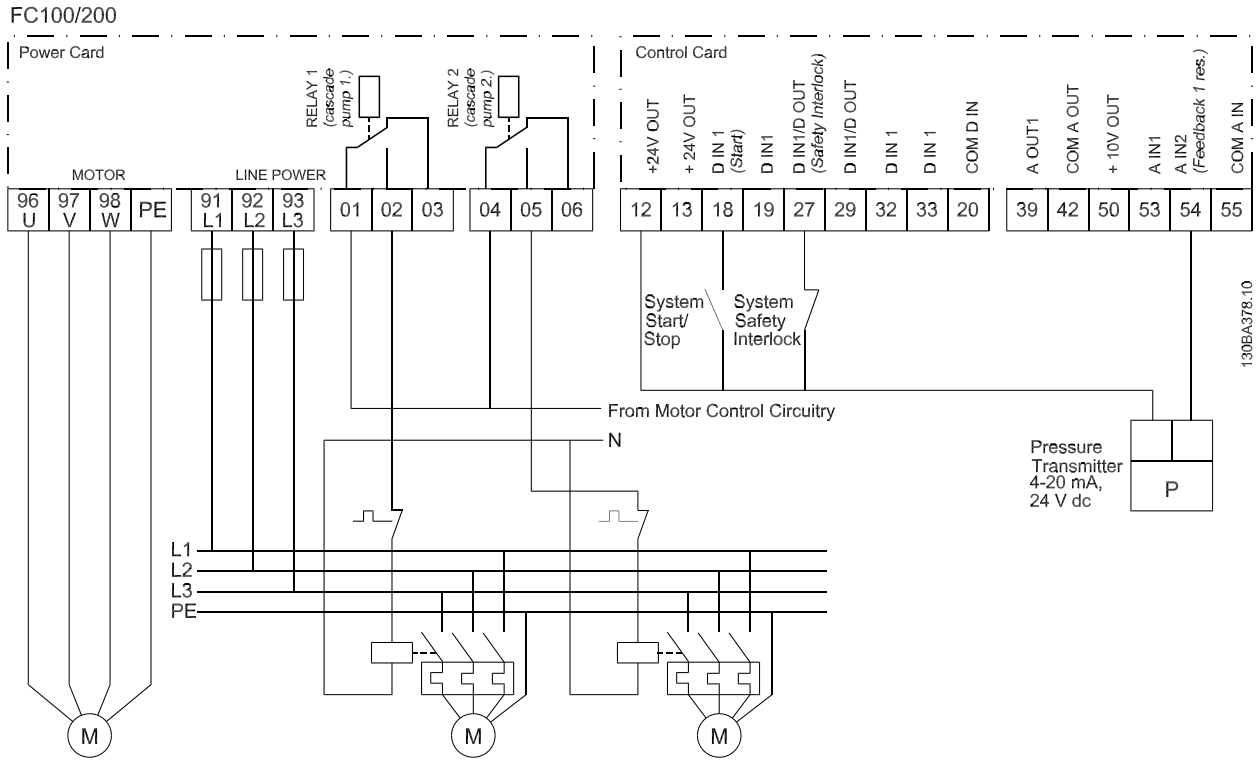



**Figure 7.11 Cascade Controller Wiring Diagram**

## 7.1.14 Start/Stop Conditions

See *5-1* Digital Inputs*.

| Digital input commands | Variable-speed pump (lead) | Fixed-speed pumps (lag) |
|---|---|---|
| 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 (corresponding relays, terminal 27/29 and 42/45) |
| External Interlock | Coast to stop | Cut out (built-in relays are de-energized) |

**Table 7.1 Commands Assigned to Digital Inputs**

| LCP keys | Variable-speed pump (lead) | Fixed-speed pumps (lag) |
|---|---|---|
| [Hand On] | Ramps up (if stopped by a normal stop command) or stays in operation if already running | Destaging (if running) |
| [Off] | Ramps down | Destaging |
| [Auto On] | Starts and stops according to commands via terminals or serial bus cascade controller only, can work when drive in "Auto ON" mode | Staging/Destaging |

**Table 7.2 LCP Key Functions**

# 8 Installation and Set-up

## 8.1 Installation and Set-up

### 8.1.1 Overview

RS-485 is a two-wire bus interface compatible with multi-drop network topology, that is, nodes can be connected as a bus, or via drop cables from a common trunk line.
A total of 32 nodes can be connected to one network segment. Repeaters divide network segments.

***NOTICE!***

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

Terminate each segment at both ends using either the termination switch (S801) of the 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 important, including at high frequencies. Thus, connect a large surface of the shield to ground, for example with a cable clamp or a conductive cable connector. It may be necessary to apply potential-equalizing cables to maintain the same ground potential throughout the network - particularly in installations with long cables.
To prevent impedance mismatch, always use the same type of cable throughout the entire network. When connecting a motor to the adjustable frequency drive, always use shielded motor cable.

| Cable | Shielded twisted pair (STP) |
|---|---|
| Impedance [Ω] | 120 |
| Cable length (ft [m]) | Max. 4,000 ft [1200 m] (including drop lines)<br>Max. 1,650 ft [500 m] station-to-station |

**Table 8.1 Cable Specifications**

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-). See drawings in *chapter 6.8.3 Grounding of Shielded Control Cables*.

If more than one adjustable frequency drive is connected to a master, use parallel connections.

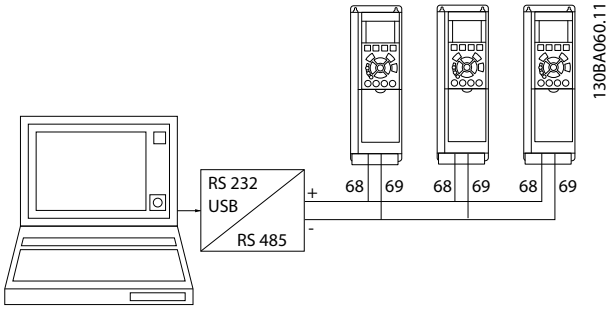



**Figure 8.1 Parallel Connections**

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

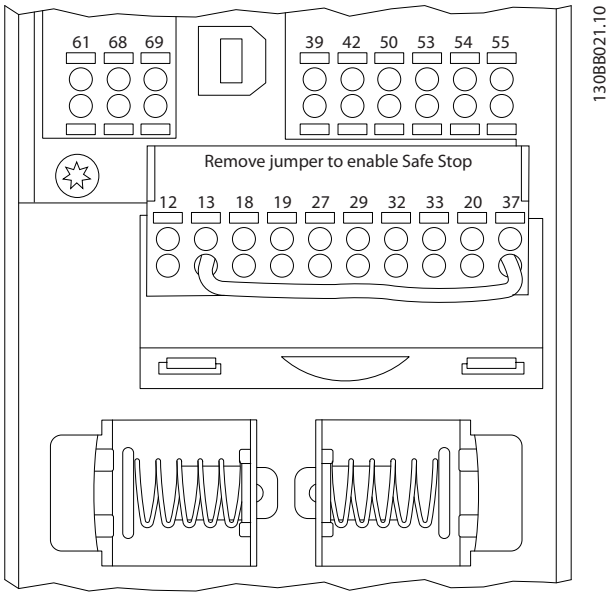



**Figure 8.2 Control Card Terminals**

## 8.1.2 Adjustable Frequency Drive Hardware Set-up

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

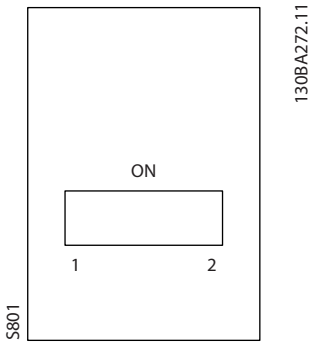



**Figure 8.3 Terminator Switch Factory Setting**

The factory setting for the dip switch is OFF.

## 8.1.3 Adjustable Frequency Drive Parameter Settings for Modbus Communication

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

| Parameter | 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 *8-30 Protocol* |
| 8-32 Baud Rate | Set the baud rate. Note: The default baud rate depends on the protocol selected in *8-30 Protocol* |
| 8-33 Parity / Stop Bits | Set the parity and number of stop bits. Note: The default selection depends on the protocol selected in *8-30 Protocol* |
| 8-35 Minimum Response Delay | Specify a minimum delay time between receiving a request and transmitting a response. This can be used for overcoming modem turnaround delays |
| 8-36 Maximum Response Delay | Specify a maximum delay time between transmitting a request and receiving a response |
| 8-37 Maximum Inter-Char Delay | Specify a maximum delay time between two received bytes to ensure timeout if transmission is interrupted |

**Table 8.2 Parameters Apply to the RS-485 Interface (FC port)**

### 8.1.4 EMC Precautions

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

Observe relevant national and local regulations, for example regarding protective ground connection. Keep the RS-485 communication cable 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 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°.

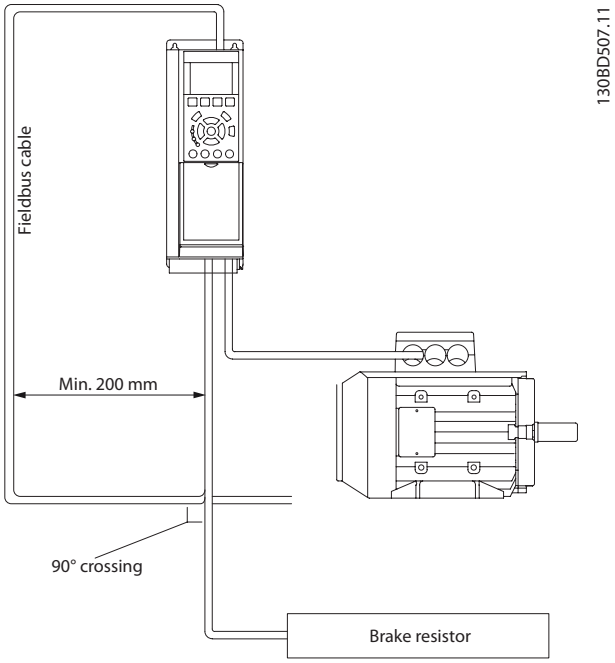



**Figure 8.4 Cable Routing**

## 8.2 Adjustable Frequency Protocol Overview

The FC protocol, also referred to as FC bus or Standard bus, is the Danfoss standard serial communication bus. It defines an access technique according to the master-follower principle for communications via a serial bus. One master and a maximum of 126 followers can be connected to the bus. The master selects the individual followers via an address character in the message.
A follower itself can never transmit without first being requested to do so, and direct message transfer between the individual followers 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 FC protocol supports different message formats:

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

### 8.2.1 FC with Modbus RTU

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

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.

## 8.3 Network Configuration

### 8.3.1 Adjustable Frequency Drive Set-up

Set the following parameters to enable the FC protocol for the adjustable frequency drive.

| Parameter Number | 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) |

**Table 8.3 Parameters Enable the FC Protocol**

8

## 8.4 FC Protocol Message Framing Structure

### 8.4.1 Content of a Character (byte)

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

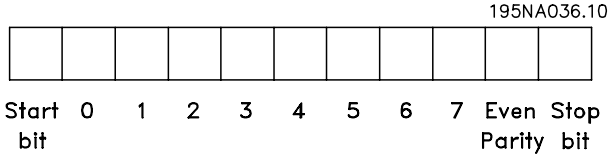



**Figure 8.5 Content of a Character**

### 8.4.2 Message Structure

Each message has the following structure:

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

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

A data control byte (BCC) completes the message.

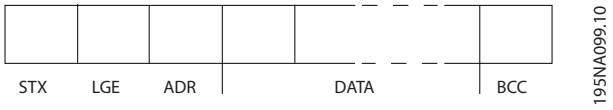



**Figure 8.6 Message Structure**

### 8.4.3 Message Length (LGE)

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

| | |
|---|---|
| 4 data bytes | LGE=4+1+1=6 bytes |
| 12 data bytes | LGE=12+1+1=14 bytes |
| Messages containing texts | 10[1)]+n bytes |

**Table 8.4 Length of Messages**

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

### 8.4.4 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 follower returns the address byte unchanged to the master in the response message.

### 8.4.5 Data Control Byte (BCC)

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



## 8.4.6 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⇒follower) and response messages (follower⇒master).

The three types of message are:

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

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


**Figure 8.7 Process Block**

8

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

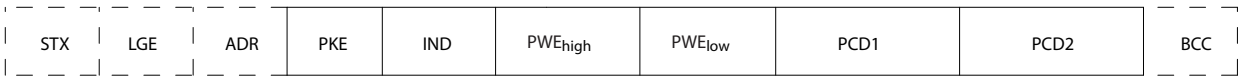



**Figure 8.8 Parameter Block**

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

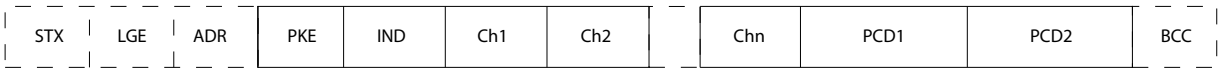



**Figure 8.9 Text Block**

## 8.4.7 The PKE Field

The PKE field contains two subfields: Parameter command and response AK, and parameter number PNU:

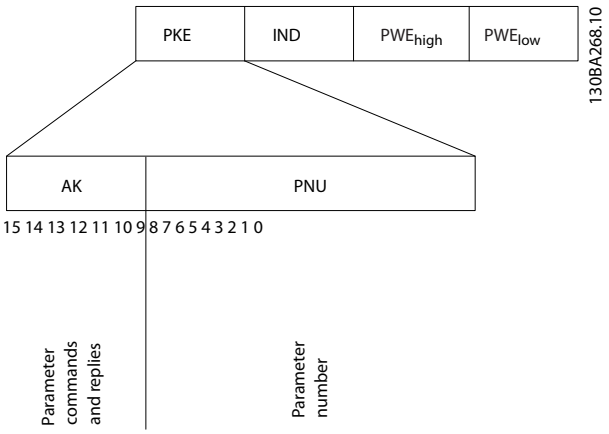



**Figure 8.10 PKE Field**

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

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

**Table 8.5 Parameter Commands Master ⇒ Follower**

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

**Table 8.6 Response Follower⇒ Master**

If the command cannot be performed, the follower 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 exist |
| 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 exist |
| 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 |

**Table 8.7 Parameter Value Fault Report**

## 8.4.8 Parameter Number (PNU)

Bits no. 0-11 transfer parameter numbers. The function of the relevant parameter is defined in the parameter description in *chapter 8.11.1 Control Word According to FC Profile (8-10 Control Profile = FC profile)*.

## 8.4.9 Index (IND)

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

Only the low byte is used as an index.

8

## 8.4.10 Parameter Value (PWE)

The parameter value block consists of two words (four 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 follower.

When a follower 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., *0-01 Language* where [0] is English, and [4] is 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).

*15-40 FC Type* to *15-53 Power Card Serial Number* contain data type 9.
For example, read the unit size and AC line voltage range in *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 characters high-byte must be "5".

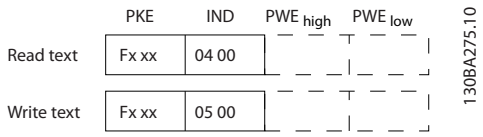



**Figure 8.11 Text via PWE Block**

## 8.4.11 Data Types Supported by the Adjustable Frequency Drive

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

| 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 |

**Table 8.8 Data Types and Description**

## 8.4.12 Conversion

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

*4-12 Motor Speed Low Limit [Hz]* has a conversion factor of 0.1. To preset the minimum frequency to 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 therefore read as 10.0.

Examples:
0 s ⇒ conversion index 0
0.00 s ⇒ conversion index -2
0 ms ⇒ conversion index -3
0.00 ms ⇒ conversion index -5

| Conversion index | Conversion factor |
|---|---|
| 100 | |
| 75 | |
| 74 | |
| 67 | |
| 6 | 1000000 |
| 5 | 100000 |
| 4 | 10000 |
| 3 | 1000 |
| 2 | 100 |
| 1 | 10 |
| 0 | 1 |
| -1 | 0.1 |
| -2 | 0.01 |
| -3 | 0.001 |
| -4 | 0.0001 |
| -5 | 0.00001 |
| -6 | 0.000001 |
| -7 | 0.0000001 |

**Table 8.9 Conversion Table**

### 8.4.13 Process Words (PCD)

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

| PCD 1 | PCD 2 |
|---|---|
| Control message (master ⇒ follower control word) | Reference value |
| Control message (follower ⇒ master) status word | Present output frequency |

**Table 8.10 Process Words (PCD)**

## 8.5 Examples

### 8.5.1 Writing a Parameter Value

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

PKE = E19E Hex - Write single word in *4-14 Motor Speed High Limit [Hz]*
IND = 0000 Hex
PWEHIGH = 0000 Hex
PWELOW = 03E8 Hex - Data value 1000, corresponding to 100 Hz, see *chapter 8.4.12 Conversion*.

The message looks like this:

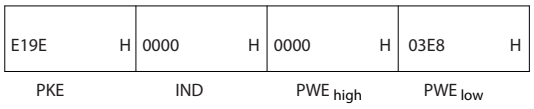



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**Figure 8.12 Write Data in EEPROM**

***NOTICE!***

***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 follower to the master is:

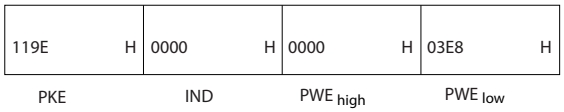


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**Figure 8.13 Response from Follower**

### 8.5.2 Reading a Parameter Value

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

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

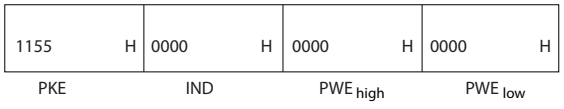


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**Figure 8.14 Parameter Value**

8

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

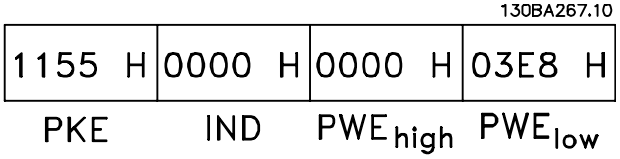



**Figure 8.15 Response from Follower**

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

## 8.6 Modbus RTU Overview

### 8.6.1 Assumptions

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

### 8.6.2 What the User Should Already Know

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

### 8.6.3 Modbus RTU Overview

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

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

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

Controllers communicate using a master-follower technique in which only the master can initiate transactions (called queries). Followers respond by supplying the requested data to the master, or by taking the action requested in the query.
The master can address individual followers, or initiate a broadcast message to all followers. Followers return a response to queries that are addressed to them individually. No responses are returned to broadcast queries from the master. The Modbus RTU protocol establishes the format for the master's query by providing the device (or broadcast) address, a function code defining the requested action, any data to be sent, and an error-checking field. The follower'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 follower is unable to perform the requested action, the follower constructs an error message, and send it in response, or a timeout occurs.

### 8.6.4 Adjustable Frequency Drive with Modbus RTU

The adjustable frequency drive communicates in Modbus RTU format over the built-in RS-485 interface. Modbus RTU provides access to the control word and bus reference of the adjustable frequency drive.

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 the active set-up
- Control the adjustable frequency drive's built-in relay

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

## 8.7 Network Configuration

To enable Modbus RTU on the adjustable frequency drive, set the following parameters

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

**Table 8.11 Modbus RTU Parameters**

## 8.8 Modbus RTU Message Framing Structure

### 8.8.1 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 in *Table 8.12*.

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

**Table 8.12 Format for Each Byte**

| | |
|---|---|
| Coding System | 8-bit binary, hexadecimal 0-9, A-F.<br>2 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) |

### 8.8.2 Modbus RTU Message Structure

The transmitting device places a Modbus RTU message into a frame with a known beginning and ending point. This allows receiving devices to begin at the start of the message, read the address portion, determine which device is addressed (or all devices, if the message is broadcast), and to 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 in *Table 8.13*.

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

**Table 8.13 Typical Modbus RTU Message Structure**

### 8.8.3 Start/Stop Field

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



### 8.8.4 Address Field

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

### 8.8.5 Function Field

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

### 8.8.6 Data Field

The data field is constructed using sets of 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 follower device contains additional information which the follower must use to take the action defined by the function code. This can include items such as coil or register addresses, the quantity of items to be handled and the count of actual data bytes in the field.

### 8.8.7 CRC Check Field

Messages include an error-checking field, operating based on 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.

### 8.8.8 Coil Register Addressing

In Modbus, all data are organized in coils and holding registers. Coils hold a single bit, whereas holding registers hold a 2-byte word (i.e., 16 bits). All data addresses in Modbus messages are referenced to zero. The first occurrence of a data item is addressed as item number zero. For example: The coil known as 'coil 1' in a programmable controller is addressed as coil 0000 in the data address field of a Modbus message. Coil 127 decimal is addressed as coil 007EHEX (126 decimal).
Holding register 40001 is addressed as register 0000 in the data address field of the message. The function code field already specifies a 'holding register' operation. Therefore, the '4XXXX' reference is implicit. Holding register 40108 is addressed as register 006BHEX (107 decimal).

| Coil number | Description | Signal direction |
|---|---|---|
| 1-16 | Adjustable frequency drive control word | Master to follower |
| 17-32 | Adjustable frequency driver speed or setpoint reference Range 0x0–0xFFFF (-200% ... ~200%) | Master to follower |
| 33-48 | Adjustable frequency drive status word (see *Table 8.16*) | Follower to master |
| 49-64 | Open-loop mode: Adjustable frequency drive output frequency closed-loop mode: Adjustable frequency drive feedback signal | Follower to master |
| 65 | Parameter write control (master to follower) | Master to follower |
| | 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 | |

**Table 8.14 Coil Descriptions**

| 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 |

**Table 8.15 Adjustable Frequency Drive Control Word (FC Profile)**

| 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 |

**Table 8.16 Adjustable Frequency Drive Status Word (FC Profile)**

| Register number | Description |
|---|---|
| 00001-00006 | Reserved |
| 00007 | Last error code from an FC 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). |

**Table 8.17 Holding Registers**

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



### 8.8.9 How to Control the Adjustable Frequency Drive

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

### 8.8.10 Function Codes Supported by Modbus RTU

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

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

**Table 8.18 Function Codes**

| 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 follower message count |

**Table 8.19 Function Codes**

### 8.8.11 Modbus Exception Codes

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

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

**Table 8.20 Modbus Exception Codes**

## 8.9 How to Access Parameters

### 8.9.1 Parameter Handling

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

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

For information on the parameters, size and converting index, consult the product relevant programming guide.

### 8.9.2 Storage of Data

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

### 8.9.3 IND

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

### 8.9.4 Text Blocks

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

### 8.9.5 Conversion Factor

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

### 8.9.6 Parameter Values

**Standard data types**
Standard data types are int 16, int 32, uint 8, uint 16 and uint 32. They are stored as 4x registers (40001–4FFFF). The parameters are read using function 03HEX "Read Holding Registers." Parameters are written using the function 6HEX "Preset Single Register" for 1 register (16 bits), and the function 10 HEX "Preset Multiple Registers" for 2 registers (32 bits). Readable sizes range from one register (16 bits) up to ten registers (20 characters).

**Non-standard data types**
Non-standard data types are text strings and are stored as 4x registers (40001–4FFFF). The parameters are read using function 03HEX "Read Holding Registers" and written using function 10HEX "Preset Multiple Registers." Readable sizes range from one register (two characters) up to ten registers (20 characters).

## 8.10 Examples

The following examples illustrate various Modbus RTU commands.

### 8.10.1 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, that is, coil 33 is addressed as 32.



Example of a request to read coils 33–48 (Status Word) from follower device 01.

| Field Name | Example (HEX) |
|---|---|
| Follower 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) | - |

**Table 8.21 Query**

**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 8, the remaining bits in the final data byte are 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) |
|---|---|
| Follower Address | 01 (adjustable frequency drive address) |
| Function | 01 (read coils) |
| Byte Count | 02 (two bytes of data) |
| Data (Coils 40-33) | 07 |
| Data (Coils 48-41) | 06 (STW=0607hex) |
| Error Check (CRC) | - |

**Table 8.22 Response**

***NOTICE!***

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

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

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

**Query**
The query message specifies the coil 65 (parameter write control) to be forced. Coil addresses start at zero, that is, coil 65 is addressed as 64. Force Data=00 00HEX (OFF) or FF 00HEX (ON).

| Field Name | Example (HEX) |
|---|---|
| Follower 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) | - |

**Table 8.23 Query**

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

| Field Name | Example (HEX) |
|---|---|
| Follower Address | 01 |
| Function | 05 |
| Force Data HI | FF |
| Force Data LO | 00 |
| Quantity of Coils HI | 00 |
| Quantity of Coils LO | 01 |
| Error Check (CRC) | - |

**Table 8.24 Response**

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

**Description**
This function forces each coil in a sequence of coils to either ON or OFF. When broadcasting the function forces the same coil references in all attached followers.

**Query**
The query message specifies the coils 17 to 32 (speed setpoint) to be forced.

| Field Name | Example (HEX) |
|---|---|
| Follower 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 (Coils 8-1) | 20 |
| Force Data LO (Coils 16-9) | 00 (ref.=2000 hex) |
| Error Check (CRC) | - |

**Table 8.25 Query**

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

| Field Name | Example (HEX) |
|---|---|
| Follower 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) | - |

**Table 8.26 Response**

### 8.10.4 Read Holding Registers (03 HEX)

**Description**
This function reads the contents of holding registers in the following.

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

| Field Name | Example (HEX) |
|---|---|
| Slave Address | 01 |
| Function | 03 (read holding registers) |
| Starting Address HI | 0B (Register address 3029) |
| Starting Address LO | D5 (Register address 3029) |
| No. of Points HI | 00 |
| No. of Points LO | 02 - (Par. 3-03 is 32 bits long, i.e., two registers) |
| Error Check (CRC) | - |

**Table 8.27 Example: Read *3-03 Maximum Reference*, register 03030**

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

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

**Table 8.28 Example: Hex 0016E360=1.500.000=1500 RPM**

8

### 8.10.5 Preset Single Register (06 HEX)

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

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

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

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

**Table 8.29 Query**

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

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

**Table 8.30 Response**

### 8.10.6 Preset Multiple Registers (10 HEX)

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

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

| Field Name | Example (HEX) |
|---|---|
| Slave Address | 01 |
| Function | 10 |
| Starting Address HI | 04 |
| Starting Address LO | D7 |
| No. of Registers HI | 00 |
| No. of registers LO | 02 |
| Byte Count | 04 |
| Write Data HI (Register 4: 1049) | 00 |
| Write Data LO (Register 4: 1049) | 00 |
| Write Data HI (Register 4: 1050) | 02 |
| Write Data LO (Register 4: 1050) | E2 |
| Error Check (CRC) | - |

**Table 8.31 Query**

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

| Field Name | Example (HEX) |
|---|---|
| Slave Address | 01 |
| Function | 10 |
| Starting Address HI | 04 |
| Starting Address LO | D7 |
| No. of Registers HI | 00 |
| No. of registers LO | 02 |
| Error Check (CRC) | - |

**Table 8.32 Response**

## 8.11 Danfoss FC Control Profile

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

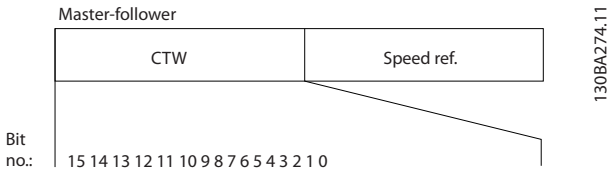



**Figure 8.16 Control Word**

| Bit | Bit value = 0 | Bit value = 1 |
|---|---|---|
| 00 | Reference value | External selection lsb |
| 01 | Reference value | External selection msb |
| 02 | DC brake | Ramp |
| 03 | Coasting | No coasting |
| 04 | Quick stop | Ramp |
| 05 | Hold output frequency | Use ramp |
| 06 | Ramp stop | Start |
| 07 | No function | Reset |
| 08 | No function | Jog |
| 09 | Ramp 1 | Ramp 2 |
| 10 | Data invalid | Data valid |
| 11 | 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 |

**Table 8.33 Control Word Bits**

**Explanation of the Control Bits**

**Bits 00/01**
Bits 00 and 01 are used to select between the four reference values, which are pre-programmed in *3-10 Preset Reference* according to *Table 8.34*.

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

**Table 8.34 Reference Values**

***NOTICE!***

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

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

**Bit 03, Coasting**
Bit 03 = '0': The 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.

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

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

**Bit 05, Hold output frequency**
Bit 05 = '0': The present output frequency (in Hz) freezes. Change the frozen output frequency only with the digital inputs (*5-10 Terminal 18 Digital Input* to *5-15 Terminal 33 Digital Input*) programmed to *Speed up* and *Slow-down*.

***NOTICE!***

**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 (*5-10 Terminal 18 Digital Input* to *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.

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

**Bit 07, Reset**
Bit 07 = '0': No reset. Bit 07 = '1': Resets a trip. Reset is activated on the 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 *3-19 Jog Speed [RPM]*.

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

**Bit 10, Data not valid/Data valid**
Tell the 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. Turn off the control word if it should not be used 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 selected in *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 selected in *5-40 Function Relay*.

**Bit 13/14, Selection of set-up**
Use bits 13 and 14 to select from the four menu set-ups according to *Table 8.35*.

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

**Table 8.35 Four Menu Set-ups**

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

Make a selection in *8-55 Set-up Select* to define how Bit 13/14 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 *8-54 Reverse Select*. Bit 15 causes reversing only when ser. communication, logic or OR logic and is selected.

## 8.11.2 Status Word According to FC Profile (STW) (*8-10 Control Profile* = FC profile)

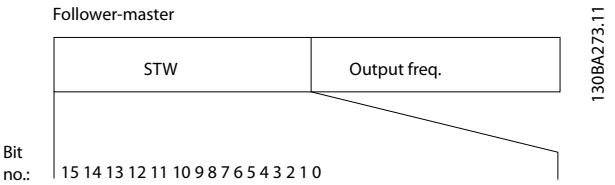



**Figure 8.17 Status Word**

| 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 | Trip lock |
| 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 |

**Table 8.36 Status Word Bits**

**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 activated on the control unit or *Local control* in *3-13 Reference Site* is selected. Control via serial communication is not possible. Bit 09 = '1' It is possible to control the adjustable frequency drive via the serial communication bus/serial communication.

**Bit 10, Out of frequency limit**
Bit 10 = '0': The output frequency has reached the value in *4-11 Motor Speed Low Limit [RPM]* or *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 resumes operation once the overtemperature 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 *4-18 Current Limit*. Bit 14 = '1': The torque limit in *4-18 Current Limit* is exceeded.

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

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.

## 8.11.3 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.

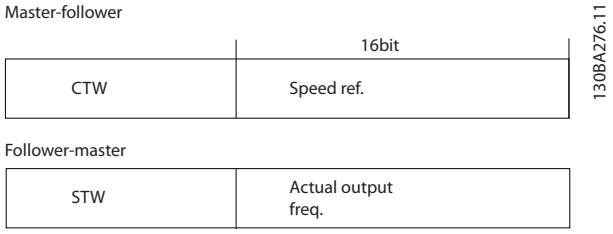



**Figure 8.18 Actual Output Frequency (MAV)**

The reference and MAV are scaled as follows:

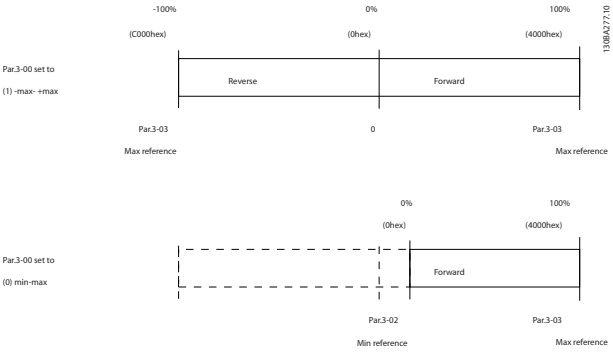



**Figure 8.19 Reference and MAV**

# 9 General Specifications and Troubleshooting

## 9.1 Line Power Supply Tables

**Line Power Supply 1x200–240 V AC**

| Line Power Supply 1 x 200–240 V AC - Normal overload 110% for 1 minute | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Adjustable frequency drive** | **P1K1** | **P1K5** | **P2K2** | **P3K0** | **P3K7** | **P5K5** | **P7K5** | **P15K** | **P22K** |
| **Typical Shaft Output [kW]** | **1.1** | **1.5** | **2.2** | **3.0** | **3.7** | **5.5** | **7.5** | **15** | **22** |
| Typical Shaft Output [HP] at 240 V | 1.5 | 2.0 | 2.9 | 4.0 | 4.9 | 7.5 | 10 | 20 | 30 |
| IP20/Chassis | A3 | - | - | - | - | - | - | - | - |
| IP21/NEMA 1 | - | B1 | B1 | B1 | B1 | B1 | B2 | C1 | C2 |
| IP55/NEMA 12 | A5 | B1 | B1 | B1 | B1 | B1 | B2 | C1 | C2 |
| IP66 | A5 | B1 | B1 | B1 | B1 | B1 | B2 | C1 | C2 |
| **Output current** | | | | | | | | | |
| Continuous (3 x 200–240 V) [A] | 6.6 | 7.5 | 10.6 | 12.5 | 16.7 | 24.2 | 30.8 | 59.4 | 88 |
| Intermittent (3 x 200–240 V) [A] | 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. input current** | | | | | | | | | |
| Continuous (1 x 200–240 V) [A] | 12.5 | 15 | 20.5 | 24 | 32 | 46 | 59 | 111 | 172 |
| Intermittent (1 x 200–240 V) [A] | 13.8 | 16.5 | 22.6 | 26.4 | 35.2 | 50.6 | 64.9 | 122.1 | 189.2 |
| Max. pre-fuses[1] [A] | 20 | 30 | 40 | 40 | 60 | 80 | 100 | 150 | 200 |
| **Additional specifications** | | | | | | | | | |
| Estimated power loss at rated max. load [W][4] | 44 | 30 | 44 | 60 | 74 | 110 | 150 | 300 | 440 |
| Max. cable size (line power, motor, brake) [mm²]/(AWG)[2] | [0.2–4]/(4–10) | | | | | [10]/(7) | [35]/(2) | [50]/(1)/0 | [95]/(4/0) |
| Weight enclosure IP20 (lb [kg]) | 10.8 [4.9] | - | - | - | - | - | - | - | - |
| Weight enclosure IP21 (lb [kg]) | - | 50.71 [23] | 50.71 [23] | 50.71 [23] | 50.71 [23] | 50.71 [23] | 59.53 [27] | 99.21 [45] | 143.3 [65] |
| Weight enclosure IP55 (lb [kg]) | - | 50.71 [23] | 50.71 [23] | 50.71 [23] | 50.71 [23] | 50.71 [23] | 59.53 [27] | 99.21 [45] | 143.3 [65] |
| Weight enclosure IP66 (lb [kg]) | - | 50.71 [23] | 50.71 [23] | 50.71 [23] | 50.71 [23] | 50.71 [23] | 59.53 [27] | 99.21 [45] | 143.3 [65] |
| Efficiency[3] | 0.968 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 |

**Table 9.1 Line Power Supply 1 x 200–240 V AC - Normal Overload 110% for 1 Minute**

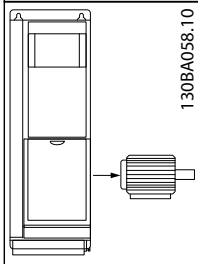
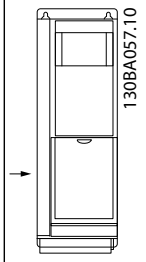
| Line power supply 3x200–240 V AC - Normal overload 110% for 1 minute | | | | | | |
|---|---|---|---|---|---|---|
| **Adjustable Frequency Drive** | | **P1K1** | **P1K5** | **P2K2** | **P3K0** | **P3K7** |
| **Typical Shaft Output [kW]** | | **1.1** | **1.5** | **2.2** | **3** | **3.7** |
| IP20/Chassis (A2+A3 may be converted to IP21 using a conversion kit) | | A2 | A2 | A2 | A3 | A3 |
| IP55/NEMA 12 | | A4/A5 | A4/A5 | A4/A5 | A5 | A5 |
| IP66/NEMA 12 | | A5 | A5 | A5 | A5 | A5 |
| Typical Shaft Output [hp] at 208 V | | 1.5 | 2.0 | 2.9 | 4.0 | 4.9 |
| **Output current** | | | | | | |
|  130BA058.10 | Continuous (3x200–240 V) [A] | 6.6 | 7.5 | 10.6 | 12.5 | 16.7 |
| | Intermittent (3x200–240 V) [A] | 7.3 | 8.3 | 11.7 | 13.8 | 18.4 |
| | Continuous kVA (208 V AC) [kVA] | 2.38 | 2.70 | 3.82 | 4.50 | 6.00 |
| | Max. cable size: | | | | | |
| | (line power, motor, brake) [mm²/AWG][2)] | 4/10 | | | | |
| **Max. input current** | | | | | | |
|  130BA057.10 | Continuous (3x200–240 V) [A] | 5.9 | 6.8 | 9.5 | 11.3 | 15.0 |
| | Intermittent (3x200–240 V) [A] | 6.5 | 7.5 | 10.5 | 12.4 | 16.5 |
| | Max. pre-fuses[1)] [A] | 20 | 20 | 20 | 32 | 32 |
| | Environment: | | | | | |
| | Estimated power loss at rated max. load [W][4)] | 63 | 82 | 116 | 155 | 185 |
| | Weight enclosure IP20 (lb [kg]) | 10.8 [4.9] | 10.8 [4.9] | 10.8 [4.9] | 14.6 [6.6] | 14.6 [6.6] |
| | Weight enclosure IP21 (lb [kg]) | 12.13 [5.5] | 12.13 [5.5] | 12.13 [5.5] | 16.54 [7.5] | 16.54 [7.5] |
| | Weight enclosure IP55 (lb [kg]) | 21.39/29.76 [9.7/13.5] | 21.39/29.76 [9.7/13.5] | 21.39/29.76 [9.7/13.5] | 29.76 [13.5] | 29.76 [13.5] |
| | Weight enclosure IP66 (lb [kg]) | 21.39/29.76 [9.7/13.5] | 21.39/29.76 [9.7/13.5] | 21.39/29.76 [9.7/13.5] | 29.76 [13.5] | 29.76 [13.5] |
| | Efficiency[3)] | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |

**Table 9.2 Line Power Supply 3x200–240 V AC**



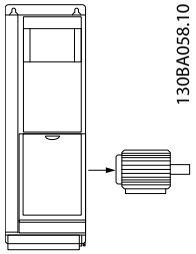
| Line power supply 3x200–240 V AC - Normal overload 110% for 1 minute | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **IP20/Chassis (B3+4 and C3+4 may be converted to IP21 using a conversion kit)** | | **B3** | **B3** | **B3** | **B4** | **B4** | **C3** | **C3** | **C4** | **C4** |
| IP21/NEMA 1 | | B1 | B1 | B1 | B2 | C1 | C1 | C1 | C2 | C2 |
| IP55/NEMA 12 | | B1 | B1 | B1 | B2 | C1 | C1 | C1 | C2 | C2 |
| IP66/NEMA 12 | | B1 | B1 | B1 | B2 | C1 | C1 | C1 | C2 | C2 |
| Typical Shaft Output [kW] | | P5K5 5.5 | P7K5 7.5 | P11K 11 | P15K 15 | P18K 18.5 | P22K 22 | P30K 30 | P37K 37 | P45K 45 |
| Typical Shaft Output [hp] at 208 V | | 7.5 | 10 | 15 | 20 | 25 | 30 | 40 | 50 | 60 |
| **Output current** | | | | | | | | | | |
|  130BA058.10 | Continuous (3x200–240 V) [A] | 24.2 | 30.8 | 46.2 | 59.4 | 74.8 | 88.0 | 115 | 143 | 170 |
| | | 16/6 | | | 35/2 | 35/2 | | | 70/3/0 | 185/ kcmil 350 |
| | Continuous (3x200–240 V) [A] | 22.0 | 28.0 | 42.0 | 54.0 | 68.0 | 80.0 | 104.0 | 130.0 | 154.0 |
| | Intermittent (3x200–240 V) [A] | 24.2 | 30.8 | 46.2 | 59.4 | 74.8 | 88.0 | 114.0 | 143.0 | 169.0 |
| | Max. pre-fuses[1] [A] | 63 | 63 | 63 | 80 | 125 | 125 | 160 | 200 | 250 |
| | Environment: | | | | | | | | | |
| | Estimated power loss at rated max. load [W][4] | 269 | 310 | 447 | 602 | 737 | 845 | 1140 | 1353 | 1636 |
| | Weight enclosure IP20 (lb [kg]) | 26.46 [12] | 26.46 [12] | 26.46 [12] | 52 [23.5] | 52 [23.5] | 77.2 [35] | 77.2 [35] | 164 [50] | 164 [50] |
| | Weight enclosure IP21 (lb [kg]) | 50.71 [23] | 50.71 [23] | 50.71 [23] | 59.53 [27] | 99.21 [45] | 99.21 [45] | 99.21 [45] | 143.3 [65] | 143.3 [65] |
| | Weight enclosure IP55 (lb [kg]) | 50.71 [23] | 50.71 [23] | 50.71 [23] | 59.53 [27] | 99.21 [45] | 99.21 [45] | 99.21 [45] | 143.3 [65] | 143.3 [65] |
| | Weight enclosure IP66 (lb [kg]) | 50.71 [23] | 50.71 [23] | 50.71 [23] | 59.53 [27] | 99.21 [45] | 99.21 [45] | 99.21 [45] | 143.3 [65] | 143.3 [65] |
| | Efficiency[3] | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.97 | 0.97 | 0.97 | 0.97 |
| | Intermittent (3x200–240 V) [A] | 26.6 | 33.9 | 50.8 | 65.3 | 82.3 | 96.8 | 127 | 157 | 187 |
| | Continuous kVA (208 V AC) [kVA] | 8.7 | 11.1 | 16.6 | 21.4 | 26.9 | 31.7 | 41.4 | 51.5 | 61.2 |
| | Max. cable size: | | | | | | | | | |
| | (line power, motor, brake) [mm²/AWG][2] | 10/7 | | | 35/2 | 50/1/0 (B4=35/2) | | | 95/4/0 | 120/ 250 MCM |

**Table 9.3 Line Power Supply 3x200–240 V AC**

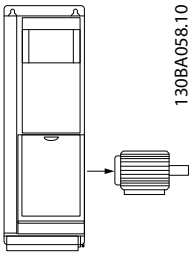
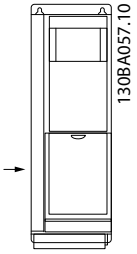
| Line Power Supply 3x380–480 V AC – Normal overload 110% for 1 minute | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Adjustable frequency drive** | | **P1K1** | **P1K5** | **P2K2** | **P3K0** | **P4K0** | **P5K5** | **P7K5** |
| **Typical Shaft Output [kW]** | | **1.1** | **1.5** | **2.2** | **3** | **4** | **5.5** | **7.5** |
| Typical Shaft Output [hp] at 460 V | | 1.5 | 2.0 | 2.9 | 4.0 | 5.0 | 7.5 | 10 |
| IP20/Chassis (A2+A3 may be converted to IP21 using a conversion kit) | | A2 | A2 | A2 | A2 | A2 | A3 | A3 |
| IP55/NEMA 12 | | A4/A5 | A4/A5 | A4/A5 | A4/A5 | A4/A5 | A5 | A5 |
| IP66/NEMA 12 | | A4/A5 | A4/A5 | A4/A5 | A4/A5 | A4/A5 | A5 | A5 |
| **Output current** | | | | | | | | |
|  130BA058.10 | Continuous (3x380-440 V) [A] | 3 | 4.1 | 5.6 | 7.2 | 10 | 13 | 16 |
| | Intermittent (3x380-440 V) [A] | 3.3 | 4.5 | 6.2 | 7.9 | 11 | 14.3 | 17.6 |
| | Continuous (3x441–480 V) [A] | 2.7 | 3.4 | 4.8 | 6.3 | 8.2 | 11 | 14.5 |
| | Intermittent (3x441–480 V) [A] | 3.0 | 3.7 | 5.3 | 6.9 | 9.0 | 12.1 | 15.4 |
| | Continuous kVA (400 V AC) [kVA] | 2.1 | 2.8 | 3.9 | 5.0 | 6.9 | 9.0 | 11.0 |
| | Continuous kVA (460 V AC) [kVA] | 2.4 | 2.7 | 3.8 | 5.0 | 6.5 | 8.8 | 11.6 |
| | Max. cable size: | | | | | | | |
| | (line power, motor, brake) [mm²/AWG][2)] | 4/10 | | | | | | |
| **Max. input current** | | | | | | | | |
| | Continuous (3x380–440 V) [A] | 2.7 | 3.7 | 5.0 | 6.5 | 9.0 | 11.7 | 14.4 |
| | Intermittent (3x380–440 V) [A] | 3.0 | 4.1 | 5.5 | 7.2 | 9.9 | 12.9 | 15.8 |
| | Continuous (3x441–480 V) [A] | 2.7 | 3.1 | 4.3 | 5.7 | 7.4 | 9.9 | 13.0 |
| | Intermittent (3x441–480 V) [A] | 3.0 | 3.4 | 4.7 | 6.3 | 8.1 | 10.9 | 14.3 |
| | Max. pre-fuses[1)] [A] | 10 | 10 | 20 | 20 | 20 | 32 | 32 |
|  130BA057.10 | Environment: | | | | | | | |
| | Estimated power loss at rated max. load [W][4)] | 58 | 62 | 88 | 116 | 124 | 187 | 255 |
| | Weight enclosure IP20 (lb [kg]) | 10.58 [4.8] | 10.8 [4.9] | 10.8 [4.9] | 10.8 [4.9] | 10.8 [4.9] | 14.6 [6.6] | 14.6 [6.6] |
| | Weight enclosure IP21 (lb [kg]) | | | | | | | |
| | Weight enclosure IP55 (lb [kg]) | 21.39/ 29.76 [9.7/13.5] | 21.39/ 29.76 [9.7/13.5] | 21.39/ 29.76 [9.7/13.5] | 21.39/ 29.76 [9.7/13.5] | 21.39/ 29.76 [9.7/13.5] | 31.31 [14.2] | 31.31 [14.2] |
| | Weight enclosure IP66 (lb [kg]) | 21.39/ 29.76 [9.7/13.5] | 21.39/ 29.76 [9.7/13.5] | 21.39/ 29.76 [9.7/13.5] | 21.39/ 29.76 [9.7/13.5] | 21.39/ 29.76 [9.7/13.5] | 31.31 [14.2] | 31.31 [14.2] |
| | Efficiency[3)] | 0.96 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 |

**Table 9.4 Line Power Supply 3x380–480 V AC**

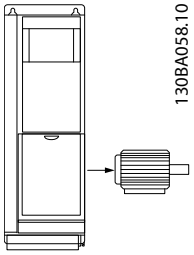
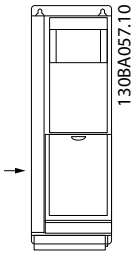
| Line Power Supply 3x380–480 V AC – Normal overload 110% for 1 minute | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Adjustable frequency drive** | | **P11K** | **P15K** | **P18K** | **P22K** | **P30K** | **P37K** | **P45K** | **P55K** | **P75K** | **P90K** |
| **Typical 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 |
| IP20/Chassis (B3+4 and C3+4 may be converted to IP21 using a conversion kit (Contact Danfoss) | | B3 | B3 | B3 | B4 | B4 | B4 | C3 | C3 | C4 | C4 |
| IP21/NEMA 1 | | B1 | B1 | B1 | B2 | B2 | C1 | C1 | C1 | C2 | C2 |
| IP55/NEMA 12 | | B1 | B1 | B1 | B2 | B2 | C1 | C1 | C1 | C2 | C2 |
| IP66/NEMA 12 | | B1 | B1 | B1 | B2 | B2 | C1 | C1 | C1 | C2 | C2 |
| **Output current** | | | | | | | | | | | |
|  130BA058.10 | Continuous (3x380–439 V) [A] | 24 | 32 | 37.5 | 44 | 61 | 73 | 90 | 106 | 147 | 177 |
| | Intermittent (3x380–439 V) [A] | 26.4 | 35.2 | 41.3 | 48.4 | 67.1 | 80.3 | 99 | 117 | 162 | 195 |
| | Continuous (3x440–480 V) [A] | 21 | 27 | 34 | 40 | 52 | 65 | 80 | 105 | 130 | 160 |
| | Intermittent (3x440–480 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) [mm²/ AWG][2)] | 10/7 | | | 35/2 | | 50/1/0 (B4=35/2) | | | 95/ 4/0 | 120/ MCM 250 |
| | With line power disconnect switch included: | 16/6 | | | | | 35/2 | 35/2 | | 70/3/0 | 185/ kcmil 350 |
| **Max. input current** | | | | | | | | | | | |
|  130BA057.10 | Continuous (3x380–439 V) [A] | 22 | 29 | 34 | 40 | 55 | 66 | 82 | 96 | 133 | 161 |
| | Intermittent (3x380–439 V) [A] | 24.2 | 31.9 | 37.4 | 44 | 60.5 | 72.6 | 90.2 | 106 | 146 | 177 |
| | Continuous (3x440–480 V) [A] | 19 | 25 | 31 | 36 | 47 | 59 | 73 | 95 | 118 | 145 |
| | Intermittent (3x440–480 V) [A] | 20.9 | 27.5 | 34.1 | 39.6 | 51.7 | 64.9 | 80.3 | 105 | 130 | 160 |
| | Max. pre-fuses[1)] [A] | 63 | 63 | 63 | 63 | 80 | 100 | 125 | 160 | 250 | 250 |
| | Environment: | | | | | | | | | | |
| | Estimated power loss at rated max. load [W][4)] | 278 | 392 | 465 | 525 | 698 | 739 | 843 | 1083 | 1384 | 1474 |
| | Weight enclosure IP20 (lb [kg]) | 26.5 [12] | 26.5 [12] | 26.5 [12] | 52 [23.5] | 52 [23.5] | 52 [23.5] | 77.2 [35] | 77.2 [35] | 164 [50] | 164 [50] |
| | Weight enclosure IP21 (lb [kg]) | 50.71 [23] | 50.71 [23] | 50.71 [23] | 59.53 [27] | 59.53 [27] | 99.21 [45] | 99.21 [45] | 99.21 [45] | 143.3 [65] | 143.3 [65] |
| | Weight enclosure IP55 (lb [kg]) | 50.71 [23] | 50.71 [23] | 50.71 [23] | 59.53 [27] | 59.53 [27] | 99.21 [45] | 99.21 [45] | 99.21 [45] | 143.3 [65] | 143.3 [65] |
| | Weight enclosure IP66 (lb [kg]) | 0.91 [23] | 0.91 [23] | 0.91 [23] | 59.53 [27] | 59.53 [27] | 99.21 [45] | 99.21 [45] | 99.21 [45] | 143.3 [65] | 143.3 [65] |
| | Efficiency[3)] | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.99 |

**Table 9.5 Line Power Supply 3x380–480 V AC**

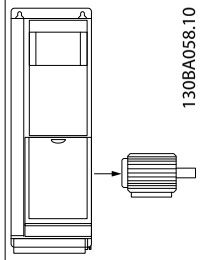
| Line power supply 3x525–600 VAC Normal overload 110% for 1 minute | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Size:** | | **P1K1** | **P1K5** | **P2K2** | **P3K0** | **P3K7** | **P4K0** | **P5K5** | **P7K5** | **P11K** | **P15K** | **P18K** | **P22K** | **P30K** | **P37K** | **P45K** | **P55K** | **P75K** | **P90K** |
| Typical Shaft Output [kW] | | 1.1 | 1.5 | 2.2 | 3 | 3.7 | 4 | 5.5 | 7.5 | 11 | 15 | 18.5 | 22 | 30 | 37 | 45 | 55 | 75 | 90 |
| IP20 / Chassis | | A3 | A3 | A3 | A3 | A2 | A3 | A3 | A3 | B3 | B3 | B3 | B4 | B4 | B4 | C3 | C3 | C4 | C4 |
| IP21 / NEMA 1 | | A3 | A3 | A3 | A3 | A2 | A3 | A3 | A3 | B1 | B1 | B1 | B2 | B2 | C1 | C1 | C1 | C2 | C2 |
| IP55 / NEMA 12 | | A5 | A5 | A5 | A5 | A5 | A5 | A5 | A5 | B1 | B1 | B1 | B2 | B2 | C1 | C1 | C1 | C2 | C2 |
| IP66 / NEMA 12 | | A5 | A5 | A5 | A5 | A5 | A5 | A5 | A5 | B1 | B1 | B1 | B2 | B2 | C1 | C1 | C1 | C2 | C2 |
| **Output current** | | | | | | | | | | | | | | | | | | | |
|  130BA058.10 | Continuous (3x525–550 V) [A] | 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 (3x525–550 V) [A] | 2.9 | 3.2 | 4.5 | 5.7 | - | 7.0 | 10.5 | 12.7 | 21 | 25 | 31 | 40 | 47 | 59 | 72 | 96 | 116 | 151 |
| | Continuous (3x525–600 V) [A] | 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 (3x525–600 V) [A] | 2.6 | 3.0 | 4.3 | 5.4 | - | 6.7 | 9.9 | 12.1 | 20 | 24 | 30 | 37 | 45 | 57 | 68 | 91 | 110 | 144 |
| | Continuous kVA (525 V AC) [kVA] | 2.5 | 2.8 | 3.9 | 5.0 | - | 6.1 | 9.0 | 11.0 | 18.1 | 21.9 | 26.7 | 34.3 | 41 | 51.4 | 61.9 | 82.9 | 100 | 130.5 |
| | Continuous kVA (575 V AC) [kVA] | 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, IP21/55/66 (line power, motor, brake) [mm$^2$]/[AWG][2)] | 4/10 | | | | | | | | 10/7 | | | 25/4 | | | 50/1/0 | | 95/ 4/0 | 120/ MCM 250 |
| | Max. cable size, IP20 (line power, motor, brake)[mm$^2$]/[AWG][2)] | 4/10 | | | | | | | | 16/6 | | | 35/2 | | | 50/1/0 | | 95/ 4/0 | 150/ MCM 250[5)] |
| | With line power disconnect switch included: | 4/10 | | | | | | | | 16/6 | | | | | 35/2 | | | 70/3/ 0 | 185/ kcmil 350 |

**Table 9.6** [5)] **With Brake and Load Sharing 95/4/0**

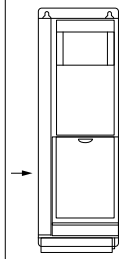
| Line power supply 3x525–600 VAC Normal overload 110% for 1 minute - continued | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Size:** | | **P1K1** | **P1K5** | **P2K2** | **P3K0** | **P3K7** | **P4K0** | **P5K5** | **P7K5** | **P11K** | **P15K** | **P18K** | **P22K** | **P30K** | **P37K** | **P45K** | **P55K** | **P75K** | **P90K** |
| **Max. input current** | | | | | | | | | | | | | | | | | | | |
|  130BA057.10 | Continuous (3x525–600 V) [A] | 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 (3x525–600 V) [A] | 2.7 | 3.0 | 4.5 | 5.7 | - | 6.4 | 9.5 | 11.5 | 19 | 23 | 28 | 36 | 43 | 54 | 65 | 87 | 105 | 137 |
| | Max. pre-fuses[1] [A] | 10 | 10 | 20 | 20 | - | 20 | 32 | 32 | 63 | 63 | 63 | 63 | 80 | 100 | 125 | 160 | 250 | 250 |
| | Environment: | | | | | | | | | | | | | | | | | | |
| | Estimated power loss at rated max. load [W][4] | 50 | 65 | 92 | 122 | - | 145 | 195 | 261 | 300 | 400 | 475 | 525 | 700 | 750 | 850 | 1100 | 1400 | 1500 |
| | Weight enclosure IP20 (lbs [kg]) | 14.33 [6.5] | 14.33 [6.5] | 14.33 [6.5] | 14.33 [6.5] | - | 14.33 [6.5] | 14.6 [6.6] | 14.6 [6.6] | 26.5 [12] | 26.5 [12] | 26.5 [12] | 52 [23.5] | 52 [23.5] | 52 [23.5] | 77.2 [35] | 77.2 [35] | 164 [50] | 164 [50] |
| | Weight enclosure IP21/55 (lbs [kg]) | 29.76 [13.5] | 29.76 [13.5] | 29.76 [13.5] | 29.76 [13.5] | 29.76 [13.5] | 29.76 [13.5] | 31.31 [14.2] | 31.31 [14.2] | 50.71 [23] | 50.71 [23] | 50.71 [23] | 59.53 [27] | 59.53 [27] | 59.53 [27] | 99.21 [45] | 99.21 [45] | 143.3 [65] | 143.3 [65] |
| | Efficiency[4] | 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 9.7 [5] With Brake and Load Sharing 95/ 4/0**

| Line Power Supply 3 x 525–690 V AC | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Adjustable Frequency Drive** | **P1K1** | **P1K5** | **P2K2** | **P3K0** | **P4K0** | **P5K5** | **P7K5** |
| **Typical Shaft Output [kW]** | **1.1** | **1.5** | **2.2** | **3** | **4** | **5.5** | **7.5** |
| Enclosure IP20 (only) | A3 | A3 | A3 | A3 | A3 | A3 | A3 |
| **Output current High overload 110% for 1 min** | | | | | | | |
| Continuous (3 x 525–550 V) [A] | 2.1 | 2.7 | 3.9 | 4.9 | 6.1 | 9 | 11 |
| Intermittent (3 x 525–550 V) [A] | 2.3 | 3.0 | 4.3 | 5.4 | 6.7 | 9.9 | 12.1 |
| Continuous kVA (3 x 551–690 V) [A] | 1.6 | 2.2 | 3.2 | 4.5 | 5.5 | 7.5 | 10 |
| Intermittent kVA (3 x 551–690 V) [A] | 1.8 | 2.4 | 3.5 | 4.9 | 6.0 | 8.2 | 11 |
| Continuous kVA 525 V AC | 1.9 | 2.6 | 3.8 | 5.4 | 6.6 | 9 | 12 |
| Continuous kVA 690 V AC | 1.9 | 2.6 | 3.8 | 5.4 | 6.6 | 9 | 12 |
| **Max. input current** | | | | | | | |
| Continuous (3 x 525–550 V) [A] | 1.9 | 2.4 | 3.5 | 4.4 | 5.5 | 8 | 10 |
| Intermittent (3 x 525–550 V) [A] | 2.1 | 2.6 | 3.8 | 8.4 | 6.0 | 8.8 | 11 |
| Continuous kVA (3 x 551–690 V) [A] | 1.4 | 2.0 | 2.9 | 4.0 | 4.9 | 6.7 | 9 |
| Intermittent kVA (3 x 551–690 V) [A] | 1.5 | 2.2 | 3.2 | 4.4 | 5.4 | 7.4 | 9.9 |
| **Additional specifications** | | | | | | | |
| IP20 max. cable cross-section[5] (line power, motor, brake and load sharing) [mm$^2$]/(AWG) | [0.2-4]/(24-10) | | | | | | |
| Estimated power loss at rated max. load [W][4] | 44 | 60 | 88 | 120 | 160 | 220 | 300 |
| Weight, enclosure IP20 (lb [kg]) | 14.6 [6.6] | 14.6 [6.6] | 14.6 [6.6] | 14.6 [6.6] | 14.6 [6.6] | 14.6 [6.6] | 14.6 [6.6] |
| Efficiency[4] | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |

**Table 9.8 Line Power Supply 3x525–690 V AC IP20**



| Normal overload 110% for 1 minute | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Adjustable frequency drive Typical Shaft Output [kW]** | **P11K 11** | **P15K 15** | **P18K 18.5** | **P22K 22** | **P30K 30** | **P37K 37** | **P45K 45** | **P55K 55** | **P75K 75** | **P90K 90** |
| Typical Shaft Output [HP] at 575 V | 10 | 16.4 | 20.1 | 24 | 33 | 40 | 50 | 60 | 75 | 100 |
| IP21/NEMA 1 | B2 | B2 | B2 | B2 | B2 | C2 | C2 | C2 | C2 | C2 |
| IP55/NEMA 12 | B2 | B2 | B2 | B2 | B2 | C2 | C2 | C2 | C2 | C2 |
| **Output current** | | | | | | | | | | |
| Continuous (3 x 525–550 V) [A] | 14 | 19 | 23 | 28 | 36 | 43 | 54 | 65 | 87 | 105 |
| Intermittent (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 (3x551–690 V) [A] | 13 | 18 | 22 | 27 | 34 | 41 | 52 | 62 | 83 | 100 |
| Intermittent (3x551–690 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. input current** | | | | | | | | | | |
| Continuous (3x525–690 V) [A] | 15 | 19.5 | 24 | 29 | 36 | 49 | 59 | 71 | 87 | 99 |
| Intermittent (3x525–690 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[1] [A] | 63 | 63 | 63 | 63 | 80 | 100 | 125 | 160 | 160 | 160 |
| **Additional specifications** | | | | | | | | | | |
| Estimated power loss at rated max. load [W][4] | 201 | 285 | 335 | 375 | 430 | 592 | 720 | 880 | 1200 | 1440 |
| Max. cable size (line power, motor, brake) [mm²]/(AWG)[2] | [35]/(1/0) | | | | [95]/(4/0) | | | | | |
| Weight IP21 (lb [kg]) | 59.53 [27] | 59.53 [27] | 59.53 [27] | 59.53 [27] | 59.53 [27] | 143.3 [65] | 143.3 [65] | 143.3 [65] | 143.3 [65] | 143.3 [65] |
| Weight IP55 (lb [kg]) | 59.53 [27] | 59.53 [27] | 59.53 [27] | 59.53 [27] | 59.53 [27] | 143.3 [65] | 143.3 [65] | 143.3 [65] | 143.3 [65] | 143.3 [65] |
| Efficiency[4] | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 |

**Table 9.9 Line Power Supply 3x525–690 V AC IP21-IP55/NEMA 1-NEMA 12**

| Normal overload 110% for 1 minute | | |
|---|---|---|
| **Adjustable frequency drive** | **P45K** | **P55K** |
| **Typical Shaft Output [kW]** | **45** | **55** |
| Typical Shaft Output [HP] at 575 V | 60 | 75 |
| IP20/Chassis | C3 | C3 |
| **Output current** | | |
| Continuous (3 x 525–550 V) [A] | 54 | 65 |
| Intermittent (3 x 525–550 V) [A] | 59.4 | 71.5 |
| Continuous (3x551–690 V) [A] | 52 | 62 |
| Intermittent (3x551–690 V) [A] | 57.2 | 68.2 |
| Continuous kVA (550 V AC) [kVA] | 51.4 | 62 |
| Continuous kVA (575 V AC) [kVA] | 62.2 | 74.1 |
| Continuous kVA (690 V AC) [kVA] | 62.2 | 74.1 |
| **Max. input current** | | |
| Continuous (3 x 525–550 V) [A] | 52 | 63 |
| Intermittent (3 x 525–550 V) [A] | 57.2 | 69.3 |
| Continuous (3x551–690 V) [A] | 50 | 60 |
| Intermittent (3x551–690 V) [A] | 55 | 66 |
| Max. pre-fuses[1)] [A] | 100 | 125 |
| **Additional specifications** | | |
| Estimated power loss at rated max. load [W][4)] | 592 | 720 |
| Max. cable size (line power, motor, brake) [mm$^2$]/(AWG)[2)] | 50 (1) | |
| Weight IP20 (lb [kg]) | 77.2 [35] | 77.2 [35] |
| Efficiency[4)] | 0.98 | 0.98 |

**Table 9.10 Line Power Supply 3x525–690 V IP20**

*1) For type of fuse, see chapter 6.2 Fuses and Circuit Breakers*

*2) American Wire Gauge*

*3) Measured using 16 ft [5 m] shielded motor cables at rated load and rated frequency*

*4) The typical power loss is at normal load conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions).*

*Values are based on a typical motor efficiency (IE1/IE2 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 consumption values 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%).*

*5) Motor and line cable: 300 MCM/150 mm$^2$*



## 9.2 General Specifications

| Line power supply (L1, L2, L3) | |
|---|---|
| Supply voltage | 200–240 V ±10%, 380–480 V ±10%, 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 ±5% |
| Max. imbalance temporary between line phases | 3.0% of rated supply voltage |
| True Power Factor () | ≥ 0.9 nominal at rated load |
| Displacement Power Factor (cos) near unity | (> 0.98) |
| Switching on input supply L1, L2, L3 (power-ups) ≤ enclosure type A | maximum twice/min. |
| Switching on input supply L1, L2, L3 (power-ups) ≥ enclosure type B, C | maximum once/min. |
| Switching on input supply L1, L2, L3 (power-ups) ≥ enclosure type D, E, F | maximum once/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, 480/600 V maximum.*

| Motor output (U, V, W) | |
|---|---|
| Output voltage | 0–100% of supply voltage |
| Output frequency | 0–590 Hz* |
| Switching on output | Unlimited |
| Ramp times | 1–3600 s |

** Dependent on power size.*

| Torque characteristics | |
|---|---|
| Starting torque (Constant torque) | Maximum 110% for 1 min.* |
| Starting torque | maximum 135% up to 0.5 s* |
| Overload torque (Constant torque) | Maximum 110% for 1 min.* |

** Percentage relates to the adjustable frequency drive's nominal torque.*

| Cable lengths and cross-sections | |
|---|---|
| Max. motor cable length, shielded/armored | VLT® HVAC Drive: 492 ft [150 m] |
| Max. motor cable length, non-shielded/unarmored | VLT® HVAC 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$^2$ [1.5 mm$^2$]/16 AWG (2 x 0.0012 in$^2$ [0.75 mm$^2$]) |
| Maximum cross-section to control terminals, flexible cable | 0.00016 in$^2$ [1 mm$^2$]/18 AWG |
| Maximum cross-section to control terminals, cable with enclosed core | 0.0008 in$^2$ [0.5 mm$^2$]/20 AWG |
| Minimum cross-section to control terminals | 0.00039 in$^2$ [0.25 mm$^2$] |

** See Line Power Supply tables for more information!*

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

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

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

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

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

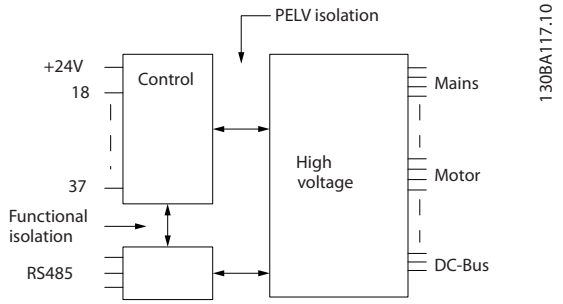



**Figure 9.1 PELV Isolation of Analog Inputs**

| 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 *chapter 9.2.1* |
| Maximum voltage on input | 28 V DC |
| Input resistance, $R_i$ | approx. 4 kΩ |
| Pulse input accuracy (0.1–1 kHz) | Max. error: 0.1% of full scale |
| 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.*

| 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 seated from other central circuits and galvanically isolated from the supply voltage (PELV).*

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

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

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

| Control card, 24 V DC output | |
|---|---|
| Terminal number | 12, 13 |
| Max. load | 200 mA |

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

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

*1) IEC 60947 parts 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 2 A*

| 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 0–590 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/Type12 |
| Enclosure type B1/B2 | IP 21/Type 1, IP55/Type12, IP 66/12 |
| Enclosure type B3/B4 | IP20/Chassis |
| Enclosure type C1/C2 | IP 21/Type 1, IP55/Type 12, IP66/12 |
| Enclosure type C3/C4 | IP20/Chassis |
| Enclosure kit available. | IP21/NEMA 1/IP $4_X$ on top of enclosure |
| Vibration test enclosure A, B, C | 1.0 g |
| Relative humidity | 5%–95% (IEC 721-3-3; Class 3K3 (non-condensing) during operation |
| Aggressive environment (IEC 60068-2-43) $H_2S$ test | class Kd |
| Test method according to IEC 60068-2-43 H2S (10 days) | |
| Ambient temperature (at 60 AVM switching mode) | |
| - with derating | max. 131 °F [55 °C][1)] |
| - with full output power of typical IE2 motors (up to 90% output current) | max. 122 °F [50 °C][1)] |
| - at full continuous FC output current | max. 113 °F [45 °C][1)] |

*1) For more information on derating see chapter 9.6 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 | 3300 ft [1000 m] |
| Maximum altitude above sea level with derating | 10,000 ft [3000 m] |

*Derating for high altitude, see chapter 9.6 Special Conditions*

| | |
|---|---|
| EMC standards, Emission | EN 61800-3, EN 61000-6-3/4, EN 55011, IEC 61800-3 |
| EMC standards, Immunity | EN 61800-3, EN 61000-6-1/2, EN 61000-4-2, EN 61000-4-3, EN 61000-4-4, EN 61000-4-5, EN 61000-4-6 |

*See chapter 9.6 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 |

# CAUTION

**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. Use only isolated laptop/PC as connection to the USB connector on or an isolated USB cable/drive.**

**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 ± 9 °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.). The has an auto derating function to avoid it's 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.

## 9.3 Efficiency

**Efficiency of the adjustable frequency drive ($\eta_{VLT}$)**
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 part 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.

**Adjustable frequency drive efficiency calculation**
Calculate the efficiency of the adjustable frequency drive at different loads based on *Figure 9.2*. The factor in this graph must be multiplied with the specific efficiency factor listed in the specification tables:

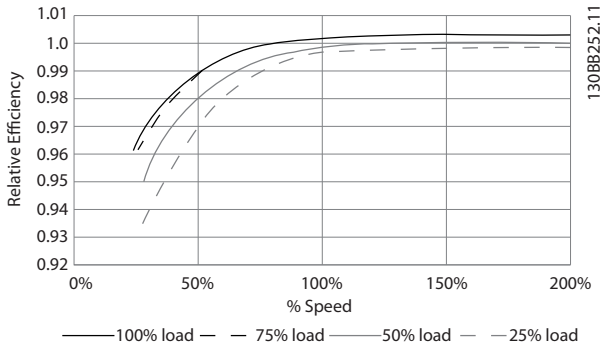



**Figure 9.2 Typical Efficiency Curves**

Example: Assume a 30 hp [22 kW], 380–480 V AC adjustable frequency drive runs at 25% load at 50% speed. The graph shows 0.97 - rated efficiency for a 30 hp [22 kW] adjustable frequency drive is 0.98. The actual efficiency is then: 0.97x0.98=0.95.

**Efficiency of the motor ($\eta_{MOTOR}$)**
The efficiency of a motor connected to the adjustable frequency drive depends on the magnetizing level. In general, the efficiency is just as good as with line power 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 the adjustable frequency drive ($\eta_{VLT}$) is multiplied by the efficiency of the motor ($\eta_{MOTOR}$):

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

## 9.4 Acoustic noise

**The acoustic noise from the adjustable frequency drive originates from three sources:**

- DC intermediate circuit coils.
- Integrated fan.
- RFI filter choke.

Typical values are measured at a distance of 3.3 ft. [1 m] from the unit:

| Enclosure type | At reduced fan speed (50%) [dBA] | Full fan speed [dBA] |
|---|---|---|
| A2 | 51 | 60 |
| A3 | 51 | 60 |
| A4 | 50 | 55 |
| 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 | - | - |

**Table 9.11 Measured values**

## 9.5 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 non-shielded)
- 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 (330 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. $U_{PEAK}$ = DC link voltage x 1.9
   (DC link voltage = AC line voltage x 1.35).
3. $dU/dt = \frac{0.8 \times UPEAK}{Rise\ time}$

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

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 120 [36] | 240 | 0.226 | 0.616 | 2.142 |
| 164 [50] | 240 | 0.262 | 0.626 | 1.908 |
| 330 [100] | 240 | 0.650 | 0.614 | 0.757 |
| 500 [150] | 240 | 0.745 | 0.612 | 0.655 |

**Table 9.12 Adjustable frequency drive, P5K5, T2**

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 16.4 [5] | 230 | 0.13 | 0.510 | 3.090 |
| 164 [50] | 230 | 0.23 | 0.590 | 2.034 |
| 330 [100] | 230 | 0.54 | 0.580 | 0.865 |
| 500 [150] | 230 | 0.66 | 0.560 | 0.674 |

**Table 9.13 Adjustable frequency drive, P7K5, T2**

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 120 [36] | 240 | 0.264 | 0.624 | 1.894 |
| 450 [136] | 240 | 0.536 | 0.596 | 0.896 |
| 500 [150] | 240 | 0.568 | 0.568 | 0.806 |

**Table 9.14 Adjustable frequency drive, P11K, T2**

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 100 [30] | 240 | 0.556 | 0.650 | 0.935 |
| 330 [100] | 240 | 0.592 | 0.594 | 0.807 |
| 500 [150] | 240 | 0.708 | 0.575 | 0.669 |

**Table 9.15 Adjustable frequency drive, P15K, T2**

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 120 [36] | 240 | 0.244 | 0.608 | 1.993 |
| 450 [136] | 240 | 0.568 | 0.580 | 0.832 |
| 500 [150] | 240 | 0.720 | 0.574 | 0.661 |

**Table 9.16 Adjustable frequency drive, P18K, T2**

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 120 [36] | 240 | 0.244 | 0.608 | 1.993 |
| 450 [136] | 240 | 0.560 | 0.580 | 0.832 |
| 500 [150] | 240 | 0.720 | 0.574 | 0.661 |

**Table 9.17 Adjustable frequency drive, P22K, T2**

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 50 [15] | 240 | 0.194 | 0.626 | 2.581 |
| 164 [50] | 240 | 0.252 | 0.574 | 1.929 |
| 500 [150] | 240 | 0.444 | 0.538 | 0.977 |

**Table 9.18 Adjustable frequency drive, P30K, T2**

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 100 [30] | 240 | 0.300 | 0.598 | 1.593 |
| 330 [100] | 240 | 0.536 | 0.566 | 0.843 |
| 500 [150] | 240 | 0.776 | 0.546 | 0.559 |

**Table 9.19 Adjustable frequency drive, P37K, T2**

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 100 [30] | 240 | 0.300 | 0.598 | 1.593 |
| 330 [100] | 240 | 0.536 | 0.566 | 0.843 |
| 500 [150] | 240 | 0.776 | 0.546 | 0.559 |

**Table 9.20 Adjustable frequency drive, P45K, T2**



| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 16.4 [5] | 400 | 0.640 | 0.690 | 0.862 |
| 164 [50] | 400 | 0.470 | 0.985 | 0.985 |
| 500 [150] | 400 | 0.760 | 1.045 | 0.947 |

**Table 9.21 Adjustable frequency drive, P1K5, T4**

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 16.4 [5] | 400 | 0.172 | 0.890 | 4.156 |
| 164 [50] | 400 | 0.310 | | 2.564 |
| 500 [150] | 400 | 0.370 | 1.190 | 1.770 |

**Table 9.22 Adjustable frequency drive, P4K0, T4**

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 16.4 [5] | 400 | 0.04755 | 0.739 | 8.035 |
| 164 [50] | 400 | 0.207 | 1.040 | 4.548 |
| 500 [150] | 400 | 0.6742 | 1.030 | 2.828 |

**Table 9.23 Adjustable frequency drive, P7K5, T4**

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 50 [15] | 400 | 0.408 | 0.718 | 1.402 |
| 330 [100] | 400 | 0.364 | 1.050 | 2.376 |
| 500 [150] | 400 | 0.400 | 0.980 | 2.000 |

**Table 9.24 Adjustable frequency drive, P11K, T4**

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 120 [36] | 400 | 0.422 | 1.060 | 2.014 |
| 330 [100] | 400 | 0.464 | 0.900 | 1.616 |
| 500 [150] | 400 | 0.896 | 1.000 | 0.915 |

**Table 9.25 Adjustable frequency drive, P15K, T4**

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 120 [36] | 400 | 0.344 | 1.040 | 2.442 |
| 330 [100] | 400 | 1.000 | 1.190 | 0.950 |
| 500 [150] | 400 | 1.400 | 1.040 | 0.596 |

**Table 9.26 Adjustable frequency drive, P18K, T4**

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 120 [36] | 400 | 0.232 | 0.950 | 3.534 |
| 330 [100] | 400 | 0.410 | 0.980 | 1.927 |
| 500 [150] | 400 | 0.430 | 0.970 | 1.860 |

**Table 9.27 Adjustable frequency drive, P22K, T4**

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 50 [15] | 400 | 0.271 | 1.000 | 3.100 |
| 330 [100] | 400 | 0.440 | 1.000 | 1.818 |
| 500 [150] | 400 | 0.520 | 0.990 | 1.510 |

**Table 9.28 Adjustable frequency drive, P30K, T4**

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 16.4 [5] | 480 | 0.270 | 1.276 | 3.781 |
| 164 [50] | 480 | 0.435 | 1.184 | 2.177 |
| 330 [100] | 480 | 0.840 | 1.188 | 1.131 |
| 500 [150] | 480 | 0.940 | 1.212 | 1.031 |

**Table 9.29 Adjustable frequency drive, P37K, T4**

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 120 [36] | 400 | 0.254 | 1.056 | 3.326 |
| 164 [50] | 400 | 0.465 | 1.048 | 1.803 |
| 330 [100] | 400 | 0.815 | 1.032 | 1.013 |
| 500 [150] | 400 | 0.890 | 1.016 | 0.913 |

**Table 9.30 Adjustable frequency drive, P45K, T4**

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 33 [10] | 400 | 0.350 | 0.932 | 2.130 |

**Table 9.31 Adjustable frequency drive, P55K, T4**

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 16.4 [5] | 480 | 0.371 | 1.170 | 2.466 |

**Table 9.32 Adjustable frequency drive, P75K, T4**

| Cable length (ft [m]) | AC linevoltage [V] | Rise time [µsec] | Vpeak [kV] | dU/dt [kV/µsec] |
|---|---|---|---|---|
| 16.4 [5] | 400 | 0.364 | 1.030 | 2.264 |

**Table 9.33 Adjustable frequency drive, P90K, T4**



## 9.6 Special Conditions

### 9.6.1 Purpose of Derating

Take derating into account when using the adjustable frequency drive at low air pressure (high altitudes), at low speeds, with long motor cables, cables with a large cross-section or at high ambient temperature. This section describes the actions required.

### 9.6.2 Derating for Ambient Temperature

90% adjustable frequency drive output current can be maintained up to max. 122 °F [50 °C] ambient temperature.

With a typical full load current of IE2 motors, full output shaft power can be maintained up to 122 °F [50 °C]. For more specific data and/or derating information for other motors or conditions, contact Danfoss.

### 9.6.3 Derating for Ambient Temperature, Enclosure Type A

**60° AVM - Pulse Width Modulation**

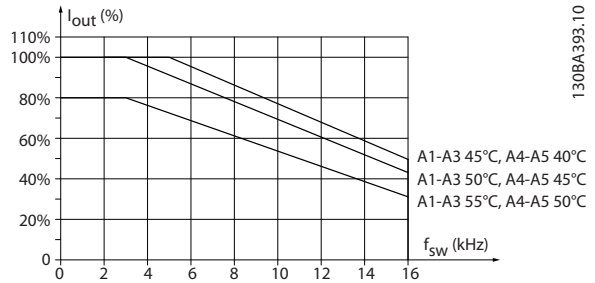



**Figure 9.3 Derating of $I_{out}$ for Different $T_{AMB, MAX}$ for Enclosure Type A, using 60° AVM**

**SFAVM - Stator Frequency Asyncron Vector Modulation**

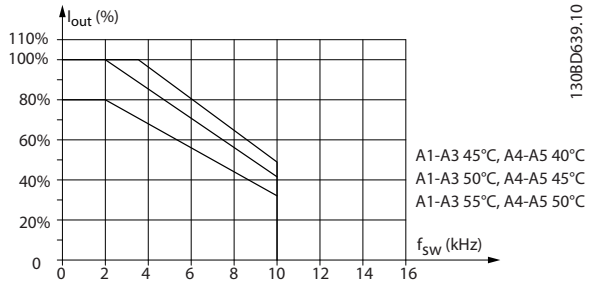



**Figure 9.4 Derating of $I_{out}$ for Different $T_{AMB, MAX}$ for Enclosures Type A, using SFAVM**

When using only 33 ft [10 m] motor cable or less in enclosure size A, less derating is necessary. This is due to the fact that the length of the motor cable has a relatively high impact on the recommended derating.

**60° AVM**

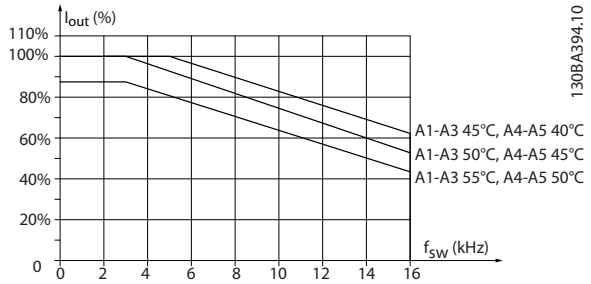



**Figure 9.5 Derating of $I_{out}$ for Different $T_{AMB, MAX}$ for Enclosures Type A, using 60° AVM and maximum 32 ft [10 m] motor cable**

**SFAVM**

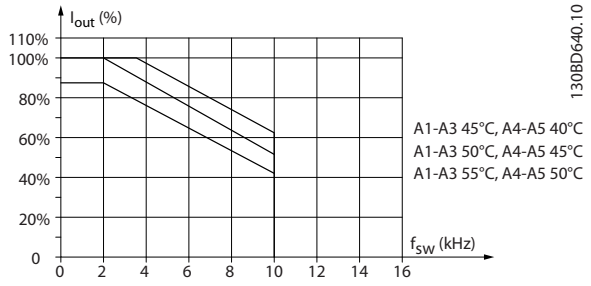



**Figure 9.6 Derating of $I_{out}$ for Different $T_{AMB, MAX}$ for Enclosures Type A, using SFAVM and maximum 32 ft [10 m] motor cable**

### 9.6.3.1 Enclosure Type A3, T7

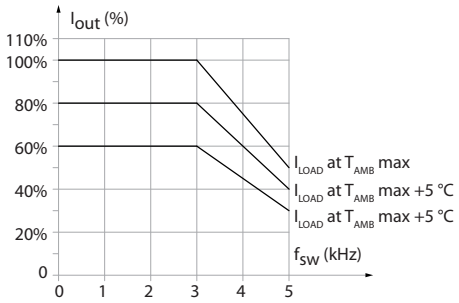



**Figure 9.7 Derating of $I_{out}$ for Different $T_{AMB, MAX}$ for Enclosure Type A3**

## 9.6.4 Derating for Ambient Temperature, Enclosure Type B

### 9.6.4.1 Enclosure Type B, T2, T4 and T5

For the B and C enclosure types, the derating also depends on the overload mode selected in *1-04 Overload Mode*

**60° AVM - Pulse Width Modulation**

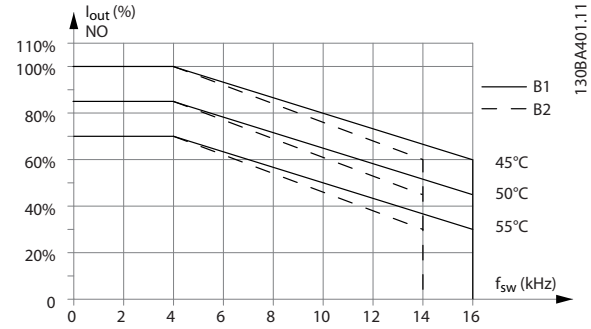



**Figure 9.8 Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure types B1 and B2, using 60° AVM in normal overload mode (110% over torque)**

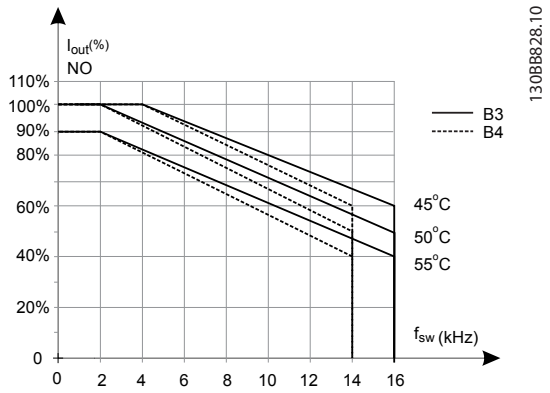



**Figure 9.9 Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure types B3 and B4, using 60° AVM in normal overload mode (110% over torque)**

**SFAVM - Stator Frequency Asyncron Vector Modulation**

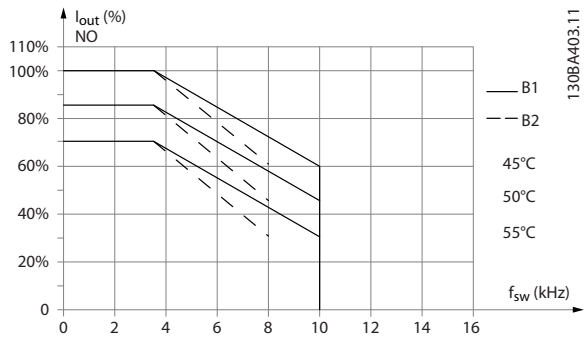



**Figure 9.10 Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure types B1 and B2, using SFAVM in normal overload mode (110% over torque)**

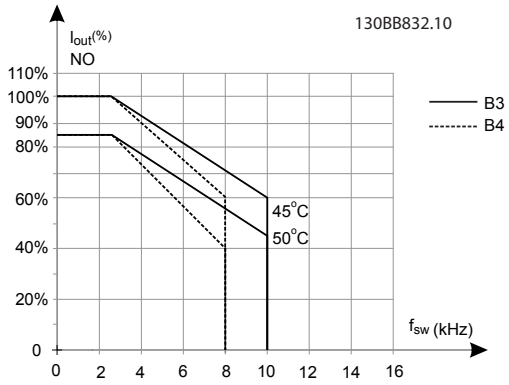



**Figure 9.11 Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure types B3 and B4, using SFAVM in normal overload mode (110% over torque)**

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## 9.6.4.2 Enclosure Type B, T6

**60° AVM - Pulse Width Modulation**

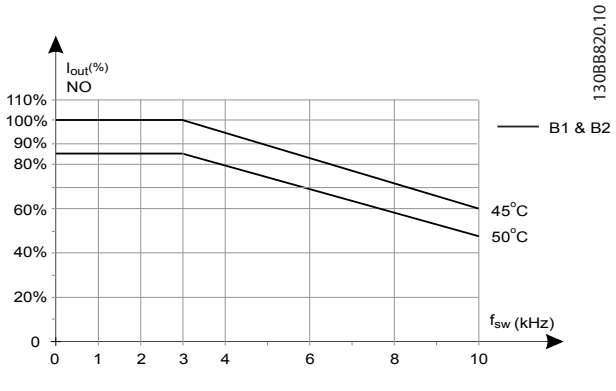


**Figure 9.12 Output current derating with switching frequency and ambient temperature for 600 V adjustable frequency drives, enclosure type B, 60° AVM, NO**

**SFAVM - Stator Frequency Asyncron Vector Modulation**

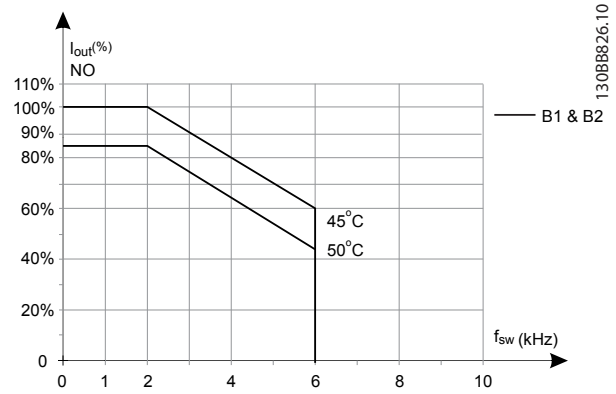


**Figure 9.13 Output current derating with switching frequency and ambient temperature for 600 V adjustable frequency drives, enclosure type B, SFAVM, NO**

## 9.6.4.3 Enclosure Type B, T7

**Enclosure Type B2, 525–690 V**
**60° AVM - Pulse Width Modulation**

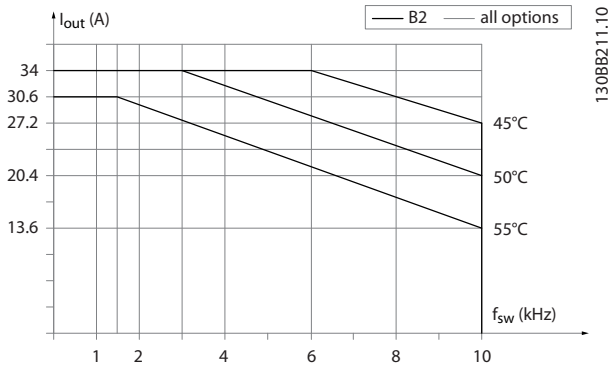


**Figure 9.14 Output current derating with switching frequency and ambient temperature for enclosure type B2, 60° AVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.**

**SFAVM - Stator Frequency Asyncron Vector Modulation**

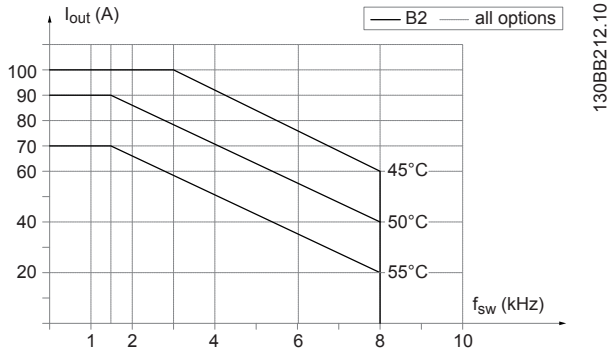


**Figure 9.15 Output current derating with switching frequency and ambient temperature for enclosure type B2, SFAVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.**

## 9.6.5 Derating for Ambient Temperature, Enclosure Type C

### 9.6.5.1 Enclosure Type C, T2, T4 and T5

**60° AVM - Pulse Width Modulation**

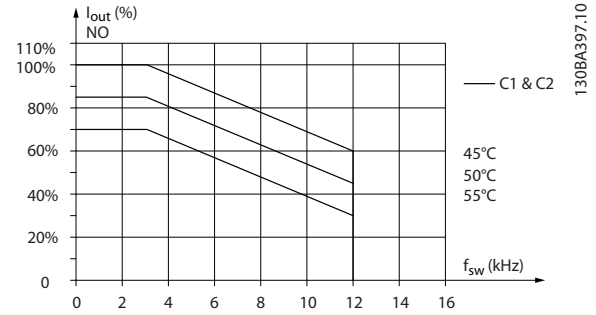


**Figure 9.16 Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure types C1 and C2, using 60° AVM in Normal overload mode (110% over torque)**

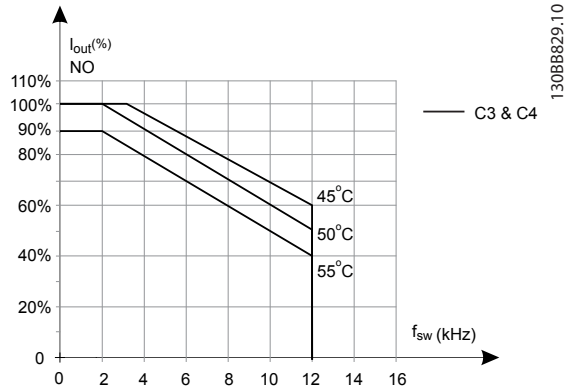


**Figure 9.17 Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure types C3 and C4, using 60° AVM in Normal overload mode (110% over torque)**

**SFAVM - Stator Frequency Asyncron Vector Modulation**

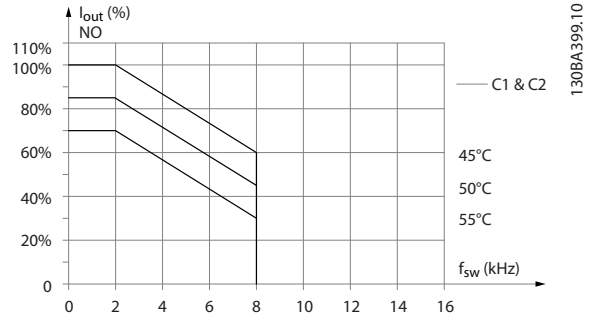


**Figure 9.18 Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure types C1 and C2, using SFAVM in normal overload mode (110% over torque)**

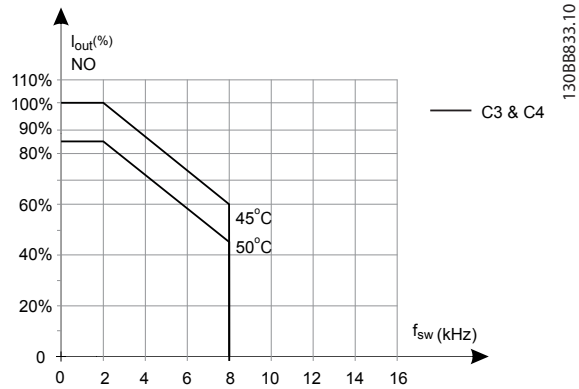


**Figure 9.19 Derating of $I_{out}$ for different $T_{AMB, MAX}$ for enclosure types C3 and C4, using SFAVM in normal overload mode (110% over torque)**

### 9.6.5.2 Enclosure Type C, T6

**60° AVM - Pulse Width Modulation**

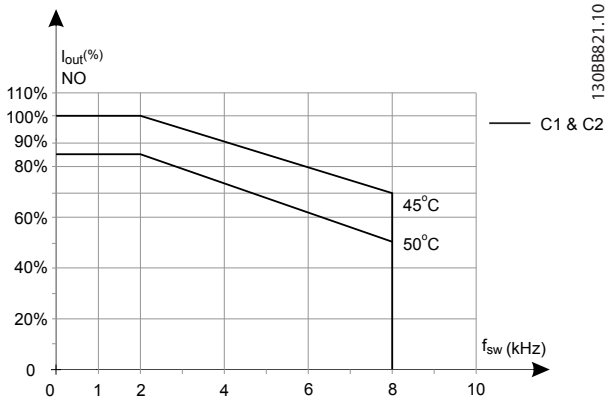


**Figure 9.20 Output current derating with switching frequency and ambient temperature for 600 V adjustable frequency drives, enclosure type C, 60° AVM, NO**

**SFAVM - Stator Frequency Asyncron Vector Modulation**

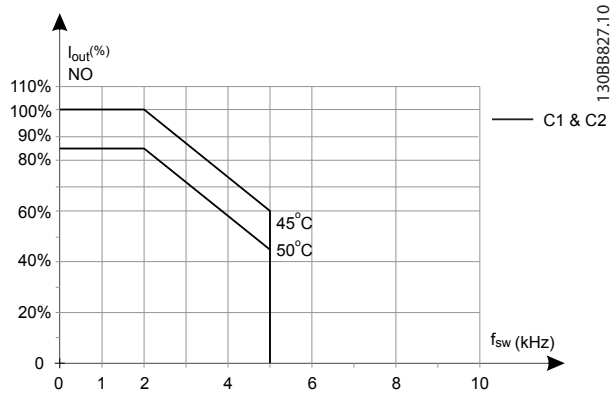


**Figure 9.21 Output current derating with switching frequency and ambient temperature for 600 V adjustable frequency drives, enclosure type C, SFAVM, NO**

## 9.6.5.3 Enclosure Type C, T7

**60° AVM - Pulse Width Modulation**

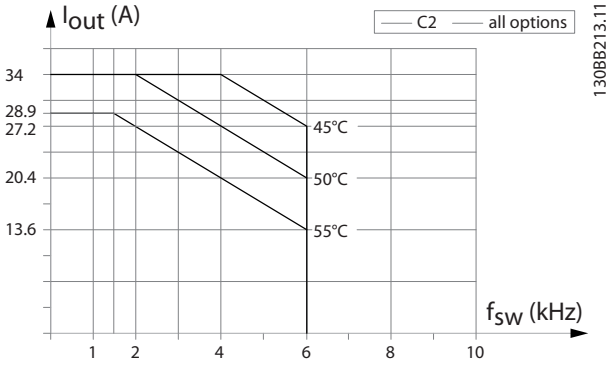


**Figure 9.22 Output current derating with switching frequency and ambient temperature for enclosure type C2, 60° AVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.**

**SFAVM - Stator Frequency Asyncron Vector Modulation**

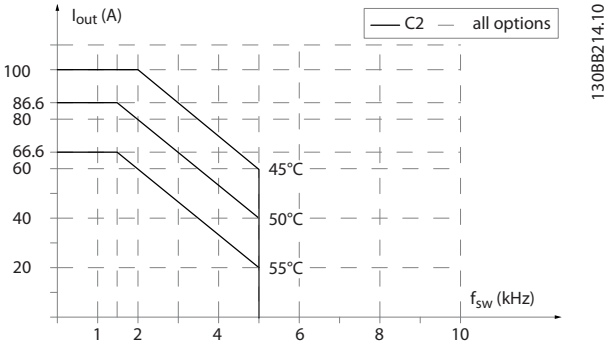


**Figure 9.23 Output current derating with switching frequency and ambient temperature for enclosure type C2, SFAVM. Note: The graph is drawn with the current as absolute value and is valid for both high and normal overload.**

## 9.6.6 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 to ensure the performance of the adjustable frequency drive. The capability for automatic output current reduction extends the acceptable operating conditions even further.

## 9.6.7 Derating for Low Air Pressure

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

Below 3,300 ft [1,000 m] altitude no derating is necessary, but above 3,300 ft [1,000 m] the ambient temperature ($T_{AMB}$) or max. output current ($I_{out}$) should be derated in accordance with the following diagram.

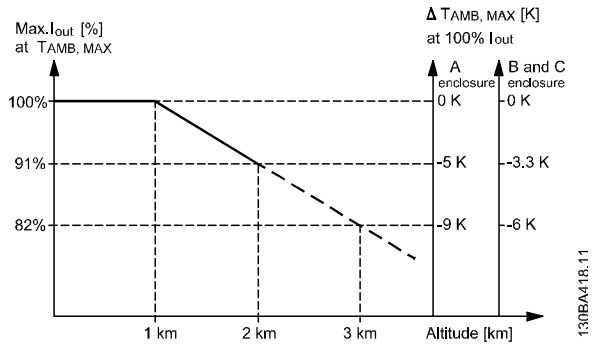


**Figure 9.24 Derating of output current versus altitude at $T_{AMB, MAX}$ for enclosure types A, B and C. At altitudes above 6,600 ft [2 km], contact Danfoss regarding PELV.**

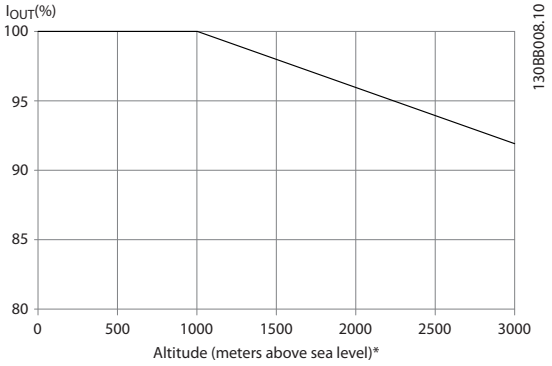


**Figure 9.25 An alternative is to lower the ambient temperature at high altitudes and thereby ensure 100% output current at high altitudes**

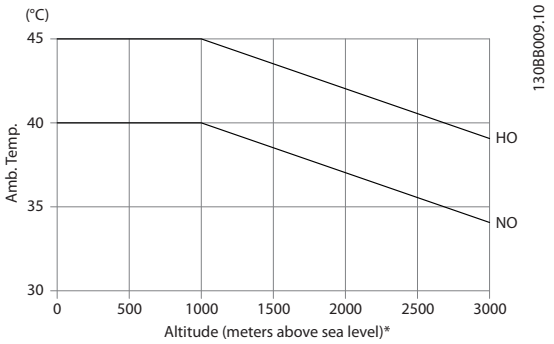


**Figure 9.26 Example: At an altitude of 6,600 ft [2 km] and a temperature of 113 °F [45 °C] ($T_{AMB, MAX}$ - 3.3 K), 91% of the rated output current is available. At a temperature of 107 °F [41.7 °C], 100% of the rated output current is available**

Derating of output current versus altitude at $T_{AMB, MAX}$ for enclosure types D, E and F.

## 9.6.8 Derating for Running at Low Speed

When a motor is connected to an adjustable frequency drive, it is necessary to make sure 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 selecting 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.

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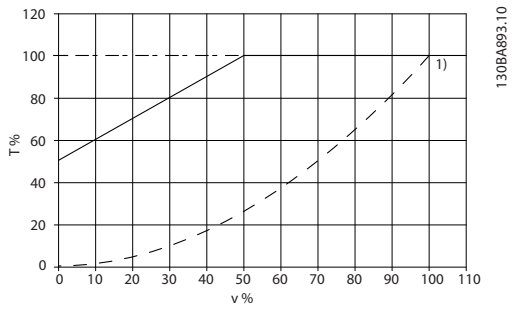
In the graphs shown below, the typical VT curve is below the maximum torque with derating and maximum torque with forced cooling at all speeds.




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

Note 1) Oversynchronous speed operation results in the available motor torque decreasing inversely proportional with the increase in speed. This must be considered during the design phase to avoid overloading the motor.

**Table 9.34 Maximum load for a standard motor at 104 °F [40 °C]**

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## 9.7 Troubleshooting

A warning or an alarm is signaled by the relevant LED on the front of the 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 trips. Alarms must be reset to restart operation once their cause has been rectified.

**This may be done in four ways:**

1. By resetting the [RESET] on the LCP.
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® HVAC Drive, see *14-20 Reset Mode* in the *FC 102 Programming Guide*

***NOTICE!***

**After a manual reset pressing [RESET] on the LCP, press [Auto On] or [Hand On] to restart the motor.**

If an alarm cannot be reset, the reason may be that its cause has not been rectified, or the alarm is trip-locked (see also *Table 9.35*).

**⚠CAUTION**

**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 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 *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 *1-90 Motor Thermal Protection*. After an alarm or trip, the motor carries on coasting, and the alarm and warning flash on the . Once the problem has been rectified, only the alarm continues flashing.**

***NOTICE!***

**No missing motor phase detection (no 30-32) and no stall detection is active when *1-10 Motor Construction* is set to [1] PM non-salient SPM.**

  

| No. | Description | Warning | Alarm/ Trip | Alarm/Trip Lock | Parameter Reference |
|---|---|---|---|---|---|
| 1 | 10 V 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 overtemp. | (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 |
| 18 | Start failed | | X | | |
| 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 over temperature | 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 communication fault | X | X | | |
| 35 | Out of frequency range | 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 Term. 27 | (X) | | | 5-00, 5-01 |
| 41 | Overload of Digital Output Term. 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 | (X) | | 1-86 |
| 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 | | |



  

| No. | Description | Warning | Alarm/ Trip | Alarm/Trip Lock | Parameter Reference |
|---|---|---|---|---|---|
| 56 | AMA interrupted by user | | X | | |
| 57 | AMA timeout | | X | | |
| 58 | AMA internal fault | X | X | | |
| 59 | Current limit | X | | | |
| 60 | External Interlock | X | | | |
| 62 | Output Frequency at Maximum Limit | X | | | |
| 64 | Voltage Limit | X | | | |
| 65 | Control Board Over temperature | X | X | X | |
| 66 | Heatsink Temperature Low | X | | | |
| 67 | Option Configuration has Changed | | X | | |
| 68 | Safe Stop | (X) | X[1)] | | 5-19 |
| 69 | Pwr. Card Temp | | X | X | |
| 70 | Illegal FC configuration | | | X | |
| 71 | PTC 1 Safe Stop | X | X[1)] | | |
| 72 | Dang. failure | | | X[1)] | |
| 73 | Safe Stop Auto Restart | | | | |
| 76 | Pwr Unit Set-up | X | | | |
| 79 | Illegal PS config | | X | X | |
| 80 | Drive Initialized to Default Value | | X | | |
| 91 | Analog input 54 wrong settings | | | X | |
| 92 | No-Flow | 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* |
| 201 | Fire M was Active | | | | |
| 202 | Fire M Limits Exceeded | | | | |
| 203 | Missing Motor | | | | |
| 204 | Locked Rotor | | | | |
| 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 parts | | | X | |
| 251 | New Type Code | | X | X | |

**Table 9.35 Alarm/Warning Code List**

*(X) Dependent on parameter*

*1) Cannot be Auto reset via 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 [Reset] or make a reset by a digital input (parameter group 5-1* [1]). The original event that caused an alarm cannot damage the or cause dangerous conditions. A trip lock is an action when an alarm occurs, which may cause damage to or connected parts. A trip lock situation can only be reset by power cycling.

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

**Table 9.36 LED Indication**

| 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 power ph. Loss | Line power 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 | Serial communication bus fault | Serial communication bus fault | |
| 23 | 00800000 | 8388608 | 24 V Supply Low | 24 V 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 | |
| 31 | 80000000 | 2147483648 | Mech. brake low (A63) | Extended Status Word | |

**Table 9.37 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 *16-90 Alarm Word*, *16-92 Warning Word* and *16-94 Ext. Status Word*.



  

## 9.7.1 Alarm Words

| Bit (Hex) | Alarm Word (16-90 Alarm Word) |
|---|---|
| 00000001 | |
| 00000002 | Power card over temperature |
| 00000004 | Ground fault |
| 00000008 | |
| 00000010 | Control word timeout |
| 00000020 | Overcurrent |
| 00000040 | |
| 00000080 | Motor thermistor overtemp. |
| 00000100 | Motor ETR overtemperature |
| 00000200 | Inverter overloaded |
| 00000400 | DC link undervoltage |
| 00000800 | DC link overvoltage |
| 00001000 | Short-circuit |
| 00002000 | |
| 00004000 | Line phase loss |
| 00008000 | AMA not OK |
| 00010000 | Live zero error |
| 00020000 | Internal fault |
| 00040000 | |
| 00080000 | Motor phase U is missing |
| 00100000 | Motor phase V is missing |
| 00200000 | Motor phase W is missing |
| 00800000 | Control Voltage Fault |
| 01000000 | |
| 02000000 | VDD, supply low |
| 04000000 | Brake resistor short-circuit |
| 08000000 | Brake chopper fault |
| 10000000 | Ground fault DESAT |
| 20000000 | Drive initialized |
| 40000000 | Safe Stop [A68] |
| 80000000 | |

**Table 9.38 16-90 Alarm Word**

| Bit (Hex) | Alarm Word 2 (16-91 Alarm Word 2) |
|---|---|
| 00000001 | |
| 00000002 | Reserved |
| 00000004 | Service Trip, Type code / Spare part |
| 00000008 | Reserved |
| 00000010 | Reserved |
| 00000020 | |
| 00000040 | |
| 00000080 | |
| 00000100 | Broken Belt |
| 00000200 | Not used |
| 00000400 | Not used |
| 00000800 | Reserved |
| 00001000 | Reserved |
| 00002000 | Reserved |
| 00004000 | Reserved |
| 00008000 | Reserved |
| 00010000 | Reserved |
| 00020000 | Not used |
| 00040000 | Fans error |
| 00080000 | ECB error |
| 00100000 | Reserved |
| 00200000 | Reserved |
| 00400000 | Reserved |
| 00800000 | Reserved |
| 01000000 | Reserved |
| 02000000 | Reserved |
| 04000000 | Reserved |
| 08000000 | Reserved |
| 10000000 | Reserved |
| 20000000 | Reserved |
| 40000000 | PTC 1 Safe Stop [A71] |
| 80000000 | Dangerous Failure [A72] |

**Table 9.39 16-91 Alarm Word 2**

## 9.7.2 Warning Words

| Bit (Hex) | Warning Word (16-92 Warning Word) |
|---|---|
| 00000001 | |
| 00000002 | Power card over temperature |
| 00000004 | Ground fault |
| 00000008 | |
| 00000010 | Control word timeout |
| 00000020 | Overcurrent |
| 00000040 | |
| 00000080 | Motor thermistor overtemp. |
| 00000100 | Motor ETR overtemperature |
| 00000200 | Inverter overloaded |
| 00000400 | DC link undervoltage |
| 00000800 | DC link overvoltage |
| 00001000 | |
| 00002000 | |
| 00004000 | Line phase loss |
| 00008000 | No motor |
| 00010000 | Live zero error |
| 00020000 | |
| 00040000 | |
| 00080000 | |
| 00100000 | |
| 00200000 | |
| 00400000 | |
| 00800000 | |
| 01000000 | |
| 02000000 | Current limit |
| 04000000 | |
| 08000000 | |
| 10000000 | |
| 20000000 | |
| 40000000 | Safe Stop [W68] |
| 80000000 | Not used |

**Table 9.40 16-92 Warning Word**

| Bit (Hex) | Warning Word 2 (16-93 Warning Word 2) |
|---|---|
| 00000001 | |
| 00000002 | |
| 00000004 | Clock Failure |
| 00000008 | Reserved |
| 00000010 | Reserved |
| 00000020 | |
| 00000040 | |
| 00000080 | End of Curve |
| 00000100 | Broken Belt |
| 00000200 | Not used |
| 00000400 | Reserved |
| 00000800 | Reserved |
| 00001000 | Reserved |
| 00002000 | Reserved |
| 00004000 | Reserved |
| 00008000 | Reserved |
| 00010000 | Reserved |
| 00020000 | Not used |
| 00040000 | Fans warning |
| 00080000 | |
| 00100000 | Reserved |
| 00200000 | Reserved |
| 00400000 | Reserved |
| 00800000 | Reserved |
| 01000000 | Reserved |
| 02000000 | Reserved |
| 04000000 | Reserved |
| 08000000 | Reserved |
| 10000000 | Reserved |
| 20000000 | Reserved |
| 40000000 | PTC 1 Safe Stop [W71] |
| 80000000 | Reserved |

**Table 9.41 16-93 Warning Word 2**

## 9.7.3 Extended Status Words

| Bit (Hex) | Extended Status Word (16-94 Ext. Status Word) |
|---|---|
| 00000001 | Ramping |
| 00000002 | AMA tuning |
| 00000004 | Start CW/CCW |
| 00000008 | Not used |
| 00000010 | Not used |
| 00000020 | Feedback high |
| 00000040 | Feedback low |
| 00000080 | Output current high |
| 00000100 | Output current low |
| 00000200 | Output frequency high |
| 00000400 | Output frequency low |
| 00000800 | Brake check OK |
| 00001000 | Braking max |
| 00002000 | Braking |
| 00004000 | Out of speed range |
| 00008000 | OVC active |
| 00010000 | AC brake |
| 00020000 | Password Timelock |
| 00040000 | Password Protection |
| 00080000 | Reference high |
| 00100000 | Reference low |
| 00200000 | Local Ref./Remote Ref. |
| 00400000 | Reserved |
| 00800000 | Reserved |
| 01000000 | Reserved |
| 02000000 | Reserved |
| 04000000 | Reserved |
| 08000000 | Reserved |
| 10000000 | Reserved |
| 20000000 | Reserved |
| 40000000 | Reserved |
| 80000000 | Reserved |

**Table 9.42 Extended Status Word, 16-94 Ext. Status Word**

| Bit (Hex) | Extended Status Word 2 (16-95 Ext. Status Word 2) |
|---|---|
| 00000001 | Off |
| 00000002 | Hand / Auto |
| 00000004 | Not used |
| 00000008 | Not used |
| 00000010 | Not used |
| 00000020 | Relay 123 active |
| 00000040 | Start Prevented |
| 00000080 | Control ready |
| 00000100 | Drive ready |
| 00000200 | Quick Stop |
| 00000400 | DC Brake |
| 00000800 | Stop |
| 00001000 | Standby |
| 00002000 | Freeze Output Request |
| 00004000 | Freeze Output |
| 00008000 | Jog Request |
| 00010000 | Jog |
| 00020000 | Start Request |
| 00040000 | Start |
| 00080000 | Start Applied |
| 00100000 | Start Delay |
| 00200000 | Sleep |
| 00400000 | Sleep Boost |
| 00800000 | Running |
| 01000000 | Bypass |
| 02000000 | Fire Mode |
| 04000000 | Reserved |
| 08000000 | Reserved |
| 10000000 | Reserved |
| 20000000 | Reserved |
| 40000000 | Reserved |
| 80000000 | Reserved |

**Table 9.43 Extended Status Word 2, 16-95 Ext. Status Word 2**

The warning/alarm information below defines each warning/alarm condition, provides the probable cause for the condition, and details a remedy or troubleshooting procedure.

**WARNING 1, 10 Volts low**
The control card voltage is below 10 V from terminal 50. Remove some of the load from terminal 50, as the 10 V supply is overloaded. Max. 15 mA or minimum 590 Ω.

A short circuit in a connected potentiometer or improper wiring of the potentiometer can cause this condition.

**Troubleshooting**

Remove the wiring from terminal 50. If the warning clears, the problem is with the wiring. If the warning does not clear, replace the control card.

**WARNING/ALARM 2, Live zero error**
This warning or alarm only appears if programmed in *6-01 Live Zero Timeout Function*. The signal on one of the analog inputs is less than 50% of the minimum value programmed for that input. Broken wiring or faulty device sending the signal can cause this condition.

**Troubleshooting**

Check connections on all the analog input terminals. Control card terminals 53 and 54 for signals, terminal 55 common. MCB 101 terminals 11 and 12 for signals, terminal 10 common. MCB 109 terminals 1, 3, 5 for signals, terminals 2, 4, 6 common).

Check that the frequency converter programming and switch settings match the analog signal type.

Perform Input Terminal Signal Test.

**WARNING/ALARM 4, Line phase loss**
A phase is missing on the supply side, or the line voltage imbalance is too high. This message also appears for a fault in the input rectifier on the adjustable frequency drive. Options are programmed at *14-12 Function at Mains Imbalance*.

**Troubleshooting**

Check the supply voltage and supply currents to the adjustable frequency drive.

**WARNING 5, DC link voltage high**
The intermediate circuit voltage (DC) is higher than the high-voltage warning limit. The limit is dependent on the adjustable frequency drive voltage rating. The unit is still active.

**WARNING 6, DC link voltage low**
The intermediate circuit voltage (DC) is lower than the low-voltage warning limit. The limit is dependent on the frequency converter voltage rating. The unit is still active.

**WARNING/ALARM 7, DC overvoltage**
If the intermediate circuit voltage exceeds the limit, the adjustable frequency drive trips after a time.

**Troubleshooting**

Connect a brake resistor

Extend the ramp time

Change the ramp type

Activate the functions in *2-10 Brake Function*

Increase *14-26 Trip Delay at Inverter Fault*

If the alarm/warning occurs during a power sag, use kinetic backup (*14-10 Line Failure*)

**WARNING/ALARM 8, DC undervoltage**
If the DC link voltage drops below the undervoltage limit, the adjustable frequency drive checks if a 24 V DC backup supply is connected. If no 24 V DC backup supply is connected, the adjustable frequency drive trips after a fixed time delay. The time delay varies with unit size.

**Troubleshooting**

Make sure that the supply voltage matches the adjustable frequency drive voltage.

Perform input voltage test.

Perform soft charge circuit test.

**WARNING/ALARM 9, Inverter overload**
The frequency converter is about to cut out because of an overload (too high current for too long). The counter for electronic, thermal inverter protection issues a warning at 98% and trips at 100%, while giving an alarm. The frequency converter *cannot* be reset until the counter is below 90%.
The fault is that the frequency converter has run with more than 100% overload for too long.

**Troubleshooting**

Compare the output current shown on the LCP with the frequency converter rated current.

Compare the output current shown on the LCP with measured motor current.

Display the Thermal Drive Load on the LCP and monitor the value. When running above the frequency converter continuous current rating, the counter increases. When running below the frequency converter continuous current rating, the counter decreases.

**WARNING/ALARM 10, Motor overload temperature**
According to the electronic thermal protection (ETR), the motor is too hot. Select whether the adjustable frequency drive issues a warning or an alarm when the counter reaches 100% in *1-90 Motor Thermal Protection*. The fault occurs when the motor runs with more than 100% overload for too long.



  

**Troubleshooting**

Check for motor overheating.

Check if the motor is mechanically overloaded.

Check that the motor current set in *1-24 Motor Current* is correct.

Ensure that Motor data in parameters 1-20 to 1-25 are set correctly.

If an external fan is in use, check in *1-91 Motor External Fan* that it is selected.

Running AMA in *1-29 Automatic Motor Adaptation (AMA)* tunes the adjustable frequency drive to the motor more accurately and reduces thermal loading.

**WARNING/ALARM 11, Motor thermistor over-temp**

Check whether the thermistor is disconnected. Select whether the adjustable frequency drive issues a warning or an alarm in *1-90 Motor Thermal Protection*.

**Troubleshooting**

Check for motor overheating.

Check if the motor is mechanically overloaded.

When using terminal 53 or 54, check that the thermistor is connected correctly between either terminal 53 or 54 (analog voltage input) and terminal 50 (+10 V supply). Also check that the terminal switch for 53 or 54 is set for voltage. Check *1-93 Thermistor Source* selects terminal 53 or 54.

When using digital inputs 18 or 19, check that the thermistor is connected correctly between either terminal 18 or 19 (digital input PNP only) and terminal 50. Check *1-93 Thermistor Source* selects terminal 18 or 19.

**WARNING/ALARM 12, Torque limit**

The torque has exceeded the value in *4-16 Torque Limit Motor Mode* or the value in *4-17 Torque Limit Generator Mode*. *14-25 Trip Delay at Torque Limit* can change this warning from a warning-only condition to a warning followed by an alarm.

**Troubleshooting**

If the motor torque limit is exceeded during ramp-up, extend the ramp-up time.

If the generator torque limit is exceeded during ramp-down, extend the ramp-down time.

If torque limit occurs while running, possibly increase the torque limit. Make sure that the system can operate safely at a higher torque.

Check the application for excessive current draw on the motor.

**WARNING/ALARM 13, Overcurrent**

The inverter peak current limit (approximately 200% of the rated current) is exceeded. The warning lasts about 1.5 s, then the adjustable frequency drive trips and issues an alarm. Shock loading or quick acceleration with high inertia loads can cause this fault. If the acceleration during ramp up is quick, the fault can also appear after kinetic backup. If extended mechanical brake control is selected, trip can be reset externally.

**Troubleshooting**

Remove power and check if the motor shaft can be turned.

Make sure that the motor size matches the adjustable frequency drive.

Check parameters 1-20 to 1-25 for correct motor data.

**ALARM 14, Ground fault**

There is current from the output phases to ground, either in the cable between the adjustable frequency drive and the motor or in the motor itself.

**Troubleshooting**

Remove power to the adjustable frequency drive and repair the ground fault.

Check for ground faults in the motor by measuring the resistance to ground of the motor leads and the motor with a megohmmeter.

**ALARM 15, Hardware mismatch**

A fitted option is not operational with the present control board hardware or software.

Record the value of the following parameters and contact your Danfoss supplier:

*15-40 FC Type*

*15-41 Power Section*

*15-42 Voltage*

*15-43 Software Version*

*15-45 Actual Typecode String*

*15-49 SW ID Control Card*

*15-50 SW ID Power Card*

*15-60 Option Mounted*

*15-61 Option SW Version* (for each option slot)

**ALARM 16, Short-circuit**

There is short-circuiting in the motor or motor wiring.

Remove power to the adjustable frequency drive and repair the short circuit.

  

**WARNING/ALARM 17, Control word timeout**
There is no communication to the adjustable frequency drive.
The warning is only active when *8-04 Control Word Timeout Function* is NOT set to *[0] Off*.
If *8-04 Control Word Timeout Function* is set to *[5] Stop and Trip*, a warning appears and the adjustable frequency drive ramps down until it stops then displays an alarm.

**Troubleshooting**

Check connections on the serial communication cable.

Increase *8-03 Control Word Timeout Time*

Check the operation of the communication equipment.

Verify a proper installation based on EMC requirements.

**ALARM 18, Start failed**
The speed has not been able to exceed *1-77 Compressor Start Max Speed [RPM]* during start within the allowed time. (set in *1-79 Compressor Start Max Time to Trip*). This may be caused by a blocked motor.

**WARNING 23, Internal fan fault**
The fan warning function is an extra protective function that checks if the fan is running/mounted. The fan warning can be disabled in *14-53 Fan Monitor* (*[0] Disabled*).

For the D, E, and F Frame filters, the regulated voltage to the fans is monitored.

**Troubleshooting**

Check for proper fan operation.

Cycle power to the adjustable frequency drive and check that the fan operates briefly at start-up.

Check the sensors on the heatsink and control card.

**WARNING 24, External fan fault**
The fan warning function is an extra protective function that checks if the fan is running/mounted. The fan warning can be disabled in *14-53 Fan Monitor* (*[0] Disabled*).

**Troubleshooting**

Check for proper fan operation.

Cycle power to the adjustable frequency drive and check that the fan operates briefly at start-up.

Check the sensors on the heatsink and control card.

**WARNING 25, Brake resistor short-circuit**
The brake resistor is monitored during operation. If a short circuit occurs, the brake function is disabled and the warning appears. The adjustable frequency drive is still operational but without the brake function. Remove power to the adjustable frequency drive and replace the brake resistor (see *2-15 Brake Check*).

**WARNING/ALARM 26, Brake resistor power limit**
The power transmitted to the brake resistor is calculated as a mean value over the last 120 seconds of run time. The calculation is based on the intermediate circuit voltage and the brake resistance value set in *2-16 AC Brake Max. Current*. The warning is active when the dissipated braking energy is higher than 90% of the brake resistance power. If *[2] Trip* is selected in *2-13 Brake Power Monitoring*, the adjustable frequency drive trips when the dissipated braking energy reaches 100%.

**WARNING/ALARM 27, Brake chopper fault**
The brake transistor is monitored during operation and if a short circuit occurs, the brake function is disabled and a warning is issued. The adjustable frequency drive is still operational but, since the brake transistor has short-circuited, substantial power is transmitted to the brake resistor, even if it is inactive.
Remove power to the adjustable frequency drive and remove the brake resistor.

**WARNING/ALARM 28, Brake check failed**
The brake resistor is not connected or not working.
Check *2-15 Brake Check*.

**ALARM 29, Heatsink temp**
The maximum temperature of the heatsink has been exceeded. The temperature fault does not reset until the temperature falls below a defined heatsink temperature. The trip and reset points are different based on the adjustable frequency drive power size.

**Troubleshooting**

Check for the following conditions.

Ambient temperature too high.

Motor cable too long.

Incorrect airflow clearance above and below the adjustable frequency drive.

Blocked airflow around the adjustable frequency drive.

Damaged heatsink fan.

Dirty heatsink.



  

**ALARM 30, Motor phase U missing**
Motor phase U between the adjustable frequency drive and the motor is missing.

Remove power from the adjustable frequency drive and check motor phase U.

**ALARM 31, Motor phase V missing**
Motor phase V between the adjustable frequency drive and the motor is missing.

Remove power from the adjustable frequency drive and check motor phase V.

**ALARM 32, Motor phase W missing**
Motor phase W between the adjustable frequency drive and the motor is missing.

Remove power from the adjustable frequency drive and check motor phase W.

**ALARM 33, Soft-charge fault**
Too many power-ups have occurred within a short time period. Let the unit cool to operating temperature.

**WARNING/ALARM 34, Serial communication bus communication fault**
The serial communication bus on the communication option card is not working.

**WARNING/ALARM 36, Line failure**
This warning/alarm is only active if the supply voltage to the frequency converter is lost and *14-10 Mains Failure* is NOT set to *[0] No Function*. Check the fuses to the frequency converter and mains supply to the unit.

**ALARM 38, Internal fault**
When an internal fault occurs, a code number defined in *Table 9.44* is displayed.

**Troubleshooting**

Cycle power

Check that the option is properly installed

Check for loose or missing wiring

It may be necessary to contact your Danfoss supplier or service department. Note the code number for further troubleshooting directions.

| No. | Text |
|---|---|
| 0 | Serial port cannot be initialized. Contact your Danfoss supplier or Danfoss Service Department |
| 256-258 | Power EEPROM data is defective or too old. Replace power card |
| 512-519 | Internal fault. Contact your Danfoss supplier or Danfoss Service Department |
| 783 | Parameter value outside of min/max limits |
| 1024-1284 | Internal fault. Contact your Danfoss supplier or the Danfoss Service Department. |
| 1299 | Option SW in slot A is too old |
| 1300 | Option SW in slot B is too old |
| 1302 | Option SW in slot C1 is too old |
| 1315 | Option SW in slot A is not supported (not allowed) |
| 1316 | Option SW in slot B is not supported (not allowed) |
| 1318 | Option SW in slot C1 is not supported (not allowed) |
| 1379-2819 | Internal fault. Contact your Danfoss supplier or Danfoss Service Department |
| 1792 | HW reset of DSP |
| 1793 | Motor-derived parameters not transferred correctly to DSP |
| 1794 | Power data not transferred correctly at power-up to DSP |
| 1795 | The DSP has received too many unknown SPI messages |
| 1796 | RAM copy error |
| 2561 | Replace control card |
| 2820 | LCP stack overflow |
| 2821 | Serial port overflow |
| 2822 | USB port overflow |
| 3072-5122 | Parameter value is outside its limits |
| 5123 | Option in slot A: Hardware incompatible with control board hardware |
| 5124 | Option in slot B: Hardware incompatible with control board hardware |
| 5125 | Option in slot C0: Hardware incompatible with control board hardware |
| 5126 | Option in slot C1: Hardware incompatible with control board hardware |
| 5376-6231 | Internal fault. Contact your Danfoss supplier or Danfoss Service Department |

**Table 9.44 Internal Fault Codes**

**ALARM 39, Heatsink sensor**
No feedback from the heatsink temperature sensor.

The signal from the IGBT thermal sensor is not available on the power card. The problem could be on the power card, on the gate drive card, or the ribbon cable between the power card and gate drive card.

**WARNING 40, Overload of digital output terminal 27**
Check the load connected to terminal 27 or remove short-circuit connection. Check *5-00 Digital I/O Mode* and *5-01 Terminal 27 Mode*.

**WARNING 41, Overload of digital output terminal 29**
Check the load connected to terminal 29 or remove short-circuit connection. Check *5-00 Digital I/O Mode* and *5-02 Terminal 29 Mode*.

  

**WARNING 42, Overload of digital output on X30/6 or overload of digital output on X30/7**
For X30/6, check the load connected to X30/6 or remove the short-circuit connection. Check *5-32 Term X30/6 Digi Out (MCB 101)*.

For X30/7, check the load connected to X30/7 or remove the short-circuit connection. Check *5-33 Term X30/7 Digi Out (MCB 101)*.

**ALARM 45, Ground fault 2**
Ground fault.

**Troubleshooting**

Check for proper grounding and loose connections.

Check for proper wire size.

Check motor cables for short-circuits or leakage currents.

**ALARM 46, Power card supply**
The supply on the power card is out of range.

There are three power supplies generated by the switch mode power supply (SMPS) on the power card: 24 V, 5 V, ±18 V. When powered with 24 V DC with the MCB 107 option, only the 24 V and 5 V supplies are monitored. When powered with three-phase AC line voltage, all three supplies are monitored.

**Troubleshooting**

Check for a defective power card.

Check for a defective control card.

Check for a defective option card.

If a 24 V DC power supply is used, verify proper supply power.

**WARNING 47, 24 V supply low**
The 24 V DC is measured on the control card. The external 24 V DC backup power supply may be overloaded; otherwise, contact the Danfoss supplier.

**WARNING 48, 1.8 V supply low**
The 1.8 V DC supply used on the control card is outside of allowable limits. The power supply is measured on the control card. Check for a defective control card. If an option card is present, check for an overvoltage condition.

**WARNING 49, Speed limit**
When the speed is not within the specified range in *4-11 Motor Speed Low Limit [RPM]* and *4-13 Motor Speed High Limit [RPM]*, the adjustable frequency drive shows a warning. When the speed is below the specified limit in *1-86 Trip Speed Low [RPM]* (except when starting or stopping), the adjustable frequency drive trips.

**ALARM 50, AMA calibration failed**
Contact your Danfoss supplier or Danfoss Service Department.

**ALARM 51, AMA check $U_{nom}$ and $I_{nom}$**
The settings for motor voltage, motor current and motor power are wrong. Check the settings in parameters 1-20 to 1-25.

**ALARM 52, AMA low $I_{nom}$**
The motor current is too low. Check the settings.

**ALARM 53, AMA motor too big**
The motor is too big for the AMA to operate.

**ALARM 54, AMA motor too small**
The motor is too small for the AMA to operate.

**ALARM 55, AMA parameter out of range**
The parameter values of the motor are outside of the acceptable range. AMA cannot run.

**ALARM 56, AMA interrupted by user**
The user has interrupted the AMA.

**ALARM 57, AMA internal fault**
Try to restart AMA again. Repeated restarts can overheat the motor.

**ALARM 58, AMA Internal fault**
Contact your Danfoss supplier.

**WARNING 59, Current limit**
The current is higher than the value in *4-18 Current Limit*. Ensure that Motor data in parameters 1-20 to 1-25 are set correctly. Possibly increase the current limit. Be sure that the system can operate safely at a higher limit.

**WARNING 60, External interlock**
A digital input signal is indicating a fault condition external to the frequency converter. An external interlock has commanded the frequency converter to trip. Clear the external fault condition. To resume normal operation, apply 24 V DC to the terminal programmed for external interlock. Reset the frequency converter.

**WARNING 62, Output frequency at maximum limit**
The output frequency has reached the value set in *4-19 Max Output Frequency*. Check the application to determine the cause. Possibly increase the output frequency limit. Be sure the system can operate safely at a higher output frequency. The warning will clear when the output drops below the maximum limit.

**WARNING/ALARM 65, Control card over temperature**
The cut-out temperature of the control card is 176 °F [80 °C].



  

**Troubleshooting**

- Check that the ambient operating temperature is within limits.
- Check for clogged filters.
- Check fan operation.
- Check the control card.

**WARNING 66, Heatsink temperature low**
The frequency converter is too cold to operate. This warning is based on the temperature sensor in the IGBT module.
Increase the ambient temperature of the unit. Also, a trickle amount of current can be supplied to the frequency converter whenever the motor is stopped by setting *2-00 DC Hold/Preheat Current* at 5% and *1-80 Function at Stop*

**ALARM 67, Option module configuration has changed**
One or more options have either been added or removed since the last power-down. Check that the configuration change is intentional and reset the unit.

**ALARM 68, Safe Stop activated**
Safe Torque Off has been activated. To resume normal operation, apply 24 V DC to terminal 37, then send a reset signal (via bus, digital I/O, or by pressing [Reset]).

**ALARM 69, Power card temperature**
The temperature sensor on the power card is either too hot or too cold.

**Troubleshooting**

Check that the ambient operating temperature is within limits.

Check for clogged filters.

Check fan operation.

Check the power card.

**ALARM 70, Illegal FC configuration**
The control card and power card are incompatible. To check compatibility, contact your supplier with the type code of the unit from the nameplate and the part numbers of the cards.

**ALARM 71, PTC 1 safe stop**
Safe Torque Off has been activated from the PTC Thermistor Card MCB 112 (motor too warm). Normal operation can be resumed when the MCB 112 applies 24 V DC to Terminal 37 again (when the motor temperature reaches an acceptable level) and when the Digital Input from the MCB 112 is deactivated. When that happens, a reset signal must be sent (via Bus, Digital I/O, or by pressing [Reset]).

**ALARM 72, Dangerous failure**
Safe Torque Off with trip lock. An unexpected combination of Safe Torque Off commands has occurred:

- VLT PTC Thermistor Card enables X44/10 but safe stop is not enabled.
- MCB 112 is the only device using Safe Torque Off (specified through selection [4] or [5] in *5-19 Terminal 37 Safe Stop*), Safe Torque Off is activated, and X44/10 is not activated.

**ALARM 80, Drive initialized to default value**
Parameter settings are initialized to default settings after a manual reset. To clear the alarm, reset the unit.

**ALARM 92, No-Flow**
A no-flow condition has been detected in the system. *22-23 No-Flow Function* is set for alarm. Troubleshoot the system and reset the adjustable frequency drive after the fault has been cleared.

**ALARM 93, Dry pump**
A no-flow condition in the system with the adjustable frequency drive operating at high speed may indicate a dry pump. *22-26 Dry Pump Function* is set for alarm. Troubleshoot the system and reset the adjustable frequency drive after the fault has been cleared.

**ALARM 94, End of curve**
Feedback is lower than the setpoint. This may indicate leakage in the system. *22-50 End of Curve Function* is set for alarm. Troubleshoot the system and reset the adjustable frequency drive after the fault has been cleared.

**ALARM 95, Broken belt**
Torque is below the torque level set for no load, indicating a broken belt. *22-60 Broken Belt Function* is set for alarm. Troubleshoot the system and reset the adjustable frequency drive after the fault has been cleared.

**ALARM 96, Start delayed**
Motor start has been delayed due to short-cycle protection. *22-76 Interval between Starts* is enabled. Troubleshoot the system and reset the adjustable frequency drive after the fault has been cleared.

**WARNING 97, Stop delayed**
Stopping the motor has been delayed due to short cycle protection. *22-76 Interval between Starts* is enabled. Troubleshoot the system and reset the adjustable frequency drive after the fault has been cleared.

**WARNING 98, Clock fault**
Time is not set or the RTC clock has failed. Reset the clock in *0-70 Date and Time*.

  

**WARNING 200, Fire mode**
This warning indicates the adjustable frequency drive is operating in Fire mode. The warning clears when fire mode is removed. See the fire mode data in the alarm log.

**WARNING 201, Fire Mode was Active**
This indicates the adjustable frequency drive had entered fire mode. Cycle power to the unit to remove the warning. See the fire mode data in the alarm log.

**WARNING 202, Fire mode limits exceeded**
While operating in fire mode one or more alarm conditions have been ignored which would normally trip the unit. Operating in this condition voids unit warranty. Cycle power to the unit to remove the warning. See the fire mode data in the alarm log.

**WARNING 203, Missing motor**
With an adjustable frequency drive operating multi-motors, an underload condition was detected. This could indicate a missing motor. Inspect the system for proper operation.

**WARNING 204, Locked rotor**
With an adjustable frequency drive operating multi-motors, an overload condition was detected. This could indicate a locked rotor. Inspect the motor for proper operation.

**WARNING 250, New spare part**
A component in the adjustable frequency drive has been replaced. Reset the adjustable frequency drive for normal operation.

**WARNING 251, New type code**
The power card or other components have been replaced and the type code changed. Reset to remove the warning and resume normal operation.

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## O



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