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1. How to Read this Design Guide

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1.1.1. Copyright, Limitation of Liability and Revision Rights

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

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

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

This design guide will introduce all aspects of your VLT AQUA Drive.

Available literature for the VLT AQUA Drive

- The Instruction Manual MG.20.MX.YY provides the necessary information for getting the drive up and running.
- Drive Design Guide MG.20.NX.YY contains all the technical information about the drive, customer design and applications.
- Programming Guide MG.20.OX.YY provides information on how to program and includes complete parameter descriptions.

X = Revision number

YY = Language code

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

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1.1.2. Approvals



1.1.3. Symbols

Symbols used in this guide.

	NOTE Indicates something to be noted by the reader.
--	---

	Indicates a general warning.
--	------------------------------

	Indicates a high-voltage warning.
--	-----------------------------------

*	Indicates default setting
---	---------------------------

1.1.4. Abbreviations

Alternating current	AC
American wire gauge	AWG
Ampere/AMP	A
Automatic Motor Adaptation	AMA
Current limit	I _{LIM}
Degrees Celsius	°C
Direct current	DC
Drive Dependent	D-TYPE
Electro Magnetic Compatibility	EMC
Electronic Thermal Relay	ETR
drive	FC
Gram	g
Hertz	Hz
Kilohertz	kHz
Local Control Panel	LCP
Meter	m
Milli Henry Inductance	mH
Milliampere	mA
Millisecond	ms
Minute	min
Motion Control Tool	MCT
Nanofarad	nF
Newton Meters	Nm
Nominal motor current	I _{M,N}
Nominal motor frequency	f _{M,N}
Nominal motor power	P _{M,N}
Nominal motor voltage	U _{M,N}
Parameter	par.
Protective Extra Low Voltage	PELV
Printed Circuit Board	PCB
Rated Inverter Output Current	I _{INV}
Revolutions Per Minute	RPM
Second	s
Torque limit	T _{LIM}
Volt	V

1.1.5. Definitions

Drive:

I_{VLT,MAX}
The maximum output current.

I_{VLT,N}
The rated output current supplied by the adjustable frequency drive.

U_{VLT, MAX}
The maximum output voltage.

Input:

<p><u>Control command</u> You can start and stop the connected motor using the LCP and the digital inputs. Functions are divided into two groups. Functions in group 1 have higher priority than functions in group 2.</p>	<p>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</p>
--	---

1**Motor:** f_{JOG}

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

 f_M

The motor frequency.

 f_{MAX}

The maximum motor frequency.

 f_{MIN}

The minimum motor frequency.

 $f_{M,N}$

The rated motor frequency (nameplate data).

 I_M

The motor current.

 $I_{M,N}$

The rated motor current (nameplate data).

 $n_{M,N}$

The rated motor speed (nameplate data).

 $P_{M,N}$

The rated motor power (nameplate data).

 $T_{M,N}$

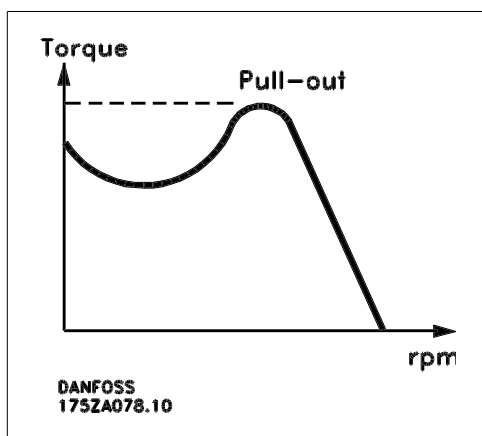
The rated torque (motor).

 U_M

The instantaneous motor voltage.

 $U_{M,N}$

The rated motor voltage (nameplate data).



η_{VLT}

The efficiency of the adjustable frequency drive is defined as the ratio between the power output and the power input.

Start-disable command

A stop command belonging to the group 1 control commands - see this group.

Stop command

See Control commands.

References:

Analog Reference

A signal transmitted to the analog inputs 53 or 54 can be voltage or current.

Bus Reference

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

Preset Reference

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

Pulse Reference

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

Ref_{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 par. 3-03.

Ref_{MIN}

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

Miscellaneous:Analog Inputs

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

There are two types of analog inputs:

Current input, 0-20 mA and 4-20 mA

Voltage input, 0-10 V DC.

Analog Outputs

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

Automatic Motor Adaptation, AMA

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

Brake Resistor

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

CT Characteristics

Constant torque characteristics used for positive displacement pumps and blowers.

Digital Inputs

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

Digital Outputs

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

DSP

Digital Signal Processor.

Relay Outputs:

The adjustable frequency drive features two programmable relay outputs.

ETR

Electronic Thermal Relay is a thermal load calculation based on present load and time. Its purpose is to estimate the motor temperature.

GLCP:

Graphical Local Control Panel (LCP102)

Initializing

If initializing is carried out (par. 14-22), the programmable parameters of the adjustable frequency drive return to their default settings.

Intermittent Duty Cycle

An intermittent duty rating refers to a sequence of duty cycles. Each cycle consists of an on-load and an off-load period. The operation can be either periodic duty or non-periodic duty.

LCP

The Local Control Panel (LCP) makes up a complete interface for control and programming of the adjustable frequency drive. The control panel is detachable and can be installed up to 9.8 ft (3 meters) from the adjustable frequency drive, i.e. in a front panel by means of the installation kit option.

The local control panel is available in two versions:

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

lsb

Least significant bit.

MCM

Short for Mille Circular Mil, an American measuring unit for cable cross-section. 1 MCM \equiv 0.00079 in.² (0.5067 mm²).

msb

Most significant bit.

NLCP

Numerical Local Control Panel LCP101

Online/Offline Parameters

Changes to online parameters are activated immediately after the data value is changed. Changes to offline parameters are not activated until you enter [OK] on the LCP.

PID Controller

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

RCD

Residual Current Device.

Set-up

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

SFAVM

Switching pattern called Stator Flux oriented Aynchronous Vector Modulation (par. 14-00).

Slip Compensation

The adjustable frequency drive compensates for the motor slip by giving the frequency a supplement that follows the measured motor load, thus 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, such as when 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 cancelled by activating reset or, in some cases, by being programmed to reset automatically. Trip may not be used for personal safety.

Trip-Locked

A state entered in fault situations when the adjustable frequency drive is protecting itself and requires physical intervention, such as when it is subject to a short circuit on the output. A locked trip can only be cancelled by cutting off AC line power, removing the cause of the fault, and reconnecting the adjustable frequency drive. Restart is prevented until the trip state is cancelled 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.

VVCplus

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

60° AVM

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

1.1.6. Power Factor

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

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

The power factor for 3-phase control:

$$= \frac{I_1 \times \cos\varphi_1}{I_{RMS}} = \frac{I_1}{I_{RMS}} \text{ since } \cos\varphi_1 = 1$$

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

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

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

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.

2. Introduction to the VLT AQUA Drive

2.1. Safety

2.1.1. Safety note



The voltage of the adjustable frequency drive is dangerous whenever connected to line power. Incorrect installation of the motor, adjustable frequency drive or serial communication bus may cause damage to the equipment, serious personal injury or death. Consequently, the instructions in this manual, as well as national and local rules and safety regulations, must be followed.

Safety Regulations

1. The adjustable frequency drive must be disconnected from line power if repair work is to be carried out. Make sure that the line supply has been disconnected and that the necessary time has passed before removing motor and line plugs.
2. The [STOP/RESET] key on the control panel of the adjustable frequency drive does not disconnect the equipment from line power and is thus not to be used as a safety switch.
3. Correct protective grounding of the equipment must be established, the user must be protected against supply voltage, and the motor must be protected against overload in accordance with applicable national and local regulations.
4. The ground leakage currents are higher than 3.5 mA.
5. Protection against motor overload is set by par. 1-90 *Motor Thermal Protection*. If this function is desired, set par. 1-90 to data value [ETR trip] (default value) or data value [ETR warning]. Note: The function is initialized at 1.16 x rated motor current and rated motor frequency. For the North American market: The ETR functions provide class 20 motor overload protection in accordance with NEC.
6. Do not remove the plugs for the motor and line supply while the adjustable frequency drive is connected to line power. Make sure that the line supply has been disconnected and that the necessary time has passed before removing motor and line plugs.
7. Please note that the adjustable frequency drive has more voltage inputs than L1, L2 and L3 when load sharing (linking of DC intermediate circuit) and external 24 V DC have been installed. Make sure that all voltage inputs have been disconnected and that the necessary time has passed before commencing repair work.

Installation at High Altitudes




At altitudes higher than 6,600 feet [2 km], please contact Danfoss Drives regarding PELV.

Warning against Unintended Start

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

2


quency drive, or if a temporary overload or a fault in the supply line 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 **VLT® AQUA Drive Instruction Manual MG.20.MX.YY** for further safety guidelines.


2.1.2. Caution

 The adjustable frequency drive DC link capacitors remain charged after power has been disconnected. To avoid the risk of electric shock, disconnect the adjustable frequency drive from line power before performing maintenance procedures. Wait at least as long as follows before servicing the adjustable frequency drive:

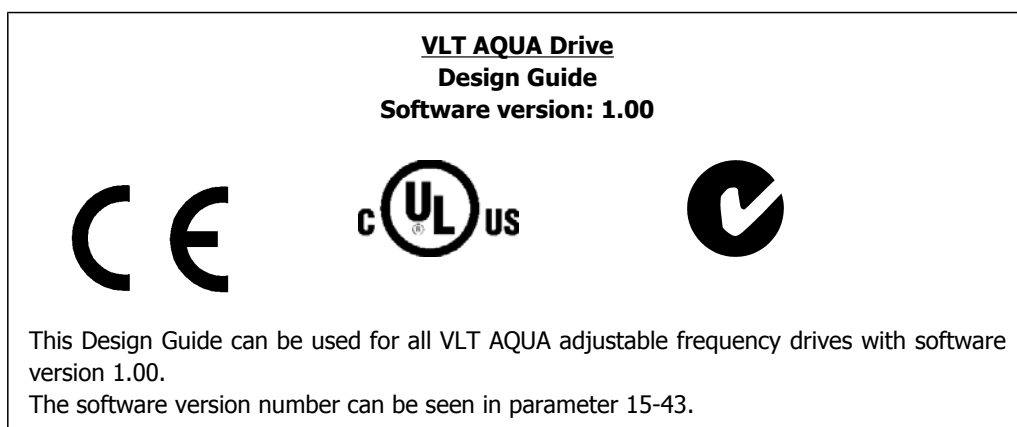
Voltage	Min. Waiting Time	
	4 min.	15 min.
200 - 240 V	1.5-4 hp [1.1-3.7 kW]	7.5-60 hp [5.5-45 kW]
380 - 480 V	1.5-10 hp [1.1-7.5 kW]	15-125 hp [11-90 kW]

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

2.1.3. Disposal Instructions

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

2.2. Software Version



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2.3. CE labeling

2.3.1. CE Conformity and Labeling

What is CE Conformity and Labeling?

The purpose of CE labeling is to avoid technical trade obstacles within the EFTA and the EU. The EU has introduced the CE label as a simple way of showing whether a product complies with the relevant EU directives. The CE label says nothing about the specifications or quality of the product. Adjustable frequency drives are regulated by three EU directives:

The machinery directive (98/37/EEC)

All machines with critical moving parts are covered by the Machinery Directive of January 1, 1995. Since an adjustable frequency drive is largely electrical, it does not fall under the Machinery Directive. However, if an adjustable frequency drive is supplied for use in a machine, we provide information on its safety aspects in the manufacturer's declaration.

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

Adjustable frequency drives must be CE-labeled in accordance with the Low-voltage Directive of January 1, 1997. The directive applies to all electrical equipment and appliances used in the 50-1000 V AC and the 75-1500 V DC voltage ranges. Danfoss uses CE labels in accordance with the directive and will issue a declaration of conformity upon request.

The EMC directive (89/336/EEC)

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

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

The adjustable frequency drive is most often used by professionals of the trade as a complex component forming part of a larger appliance, system or installation. It must be noted that the responsibility for the final EMC properties of the appliance, system or installation rests with the installer.

2.3.2. What Is Covered

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

1. The adjustable frequency drive is sold directly to the end-consumer. For example, it may be sold to a DIY market. The end-consumer is a layman. He installs the adjustable frequency drive himself for use with a hobby machine, a kitchen appliance, etc. For such applications, the adjustable frequency drive must be CE-labeled in accordance with the EMC directive.
2. The adjustable frequency drive is sold for installation in a plant. The plant is built up by professionals of the trade. It could be a production plant or a heating/ventilation plant designed and installed by professionals of the trade. Neither the adjustable frequency drive nor the finished plant must be CE-labeled under the EMC directive. However, the unit must comply with the basic EMC requirements of the directive. This is ensured by using components, appliances and systems that are CE-labeled under the EMC directive.
3. The adjustable frequency drive is sold as part of a complete system. The system is being marketed as complete and could, for example, be an air-conditioning system. The complete system must be CE-labeled in accordance with the EMC directive. The manufacturer can ensure CE-labeling under the EMC directive either by using CE-labeled components or by testing the EMC of the system. If he chooses to use only CE-labeled components, he does not have to test the entire system.

2.3.3. Danfoss VLT Adjustable Frequency Drive and CE Labeling

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

However, CE labeling may cover many different specifications. Thus, you must 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 sense of security when using an adjustable frequency drive as a component in a system or an appliance.

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

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

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

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

2.3.4. Compliance with EMC Directive 89/336/EEC

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

2.4. 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].

2.5. Aggressive Environments

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



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

Liquids can be carried through the air and condense in the adjustable frequency drive and may cause corrosion of components and metal parts. Steam, oil and salt water may cause corrosion of components and metal parts. In such environments, use equipment with enclosure rating IP 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 55 or a cabinet for IP 00/IP 20/TYP 1 equipment.

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

Such chemical reactions will rapidly affect and damage the electronic components. In such environments, mount the equipment in a cabinet with fresh air ventilation, keeping aggressive gases away from the adjustable frequency drive.

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

**NOTE**

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

Before installing the adjustable frequency drive, check the ambient air for liquids, particles and gases. This is done by observing existing installations in this environment. A typical indicator of harmful airborne liquids is the presence of water or oil on metal parts, or the 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.

2.6. Vibration and shock

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

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

IEC/EN 60068-2-6:
IEC/EN 60068-2-64:

Vibration (sinusoidal) - 1970
Vibration, broad-band random

2.7. Advantages

2.7.1. Why use an adjustable frequency drive for controlling fans and pumps?

An adjustable frequency drive takes advantage of the fact that centrifugal fans and pumps follow the laws of proportionality for such fans and pumps. For further information, see *The Laws of Proportionality* text.

2.7.2. The clear advantage - energy savings

The very clear advantage of using an adjustable frequency drive for controlling the speed of fans or pumps lies in the electricity savings.

Compared to alternative control systems and technologies, an adjustable frequency drive is the optimum energy control system for controlling fan and pump systems.

2.7.3. Example of energy savings

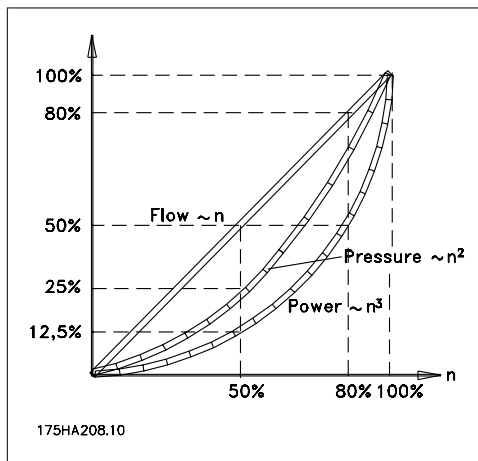
As can be seen from the figure (the laws of proportionality), the flow is controlled by changing the rpm. By reducing the rated speed by only 20%, the flow is also reduced by 20%. This is because the flow is directly proportional to the rpm. The consumption of electricity, however, is reduced by 50%.

If the system in question only needs to be able to supply a flow corresponding to 100% a few days each year, while the average is below 80% of the rated flow for the remainder of the year, the amount of energy saved is even greater than 50%.

The laws of proportionality

This figure 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



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

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

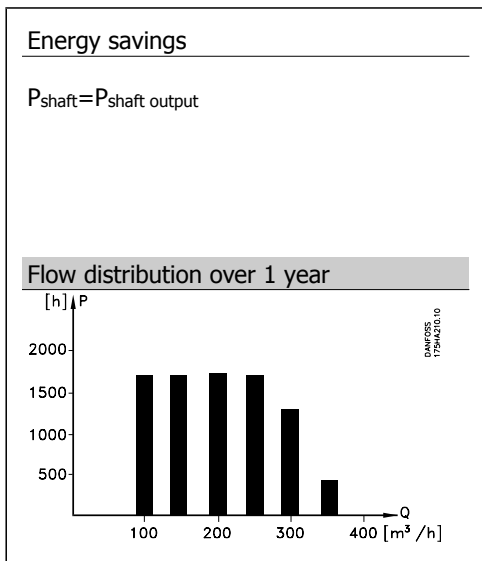
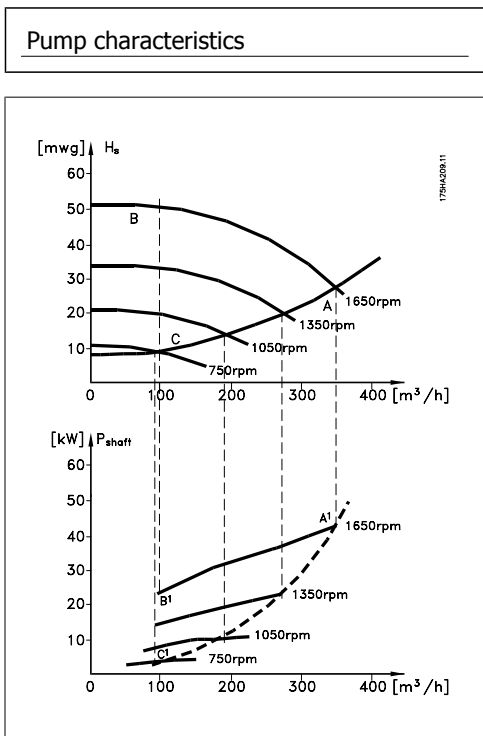
$$\text{Power} : \frac{P_1}{P_2} = \left(\frac{n_1}{n_2}\right)^3$$

2.7.4. Example with varying flow over 1 year

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

The result obtained shows energy savings in excess of 50% at the given flow distribution over a year. The pay back period depends on the price per kwh and the price of the adjustable frequency drive. In this example, it is less than a year when compared with valves and constant speed.

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m³/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

2.7.5. Better control

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

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

Furthermore, an adjustable frequency drive can quickly adapt the speed of the fan or pump to new flow or pressure conditions in the system.

Simple control of process (flow, level or pressure) utilizing the built-in PID control.

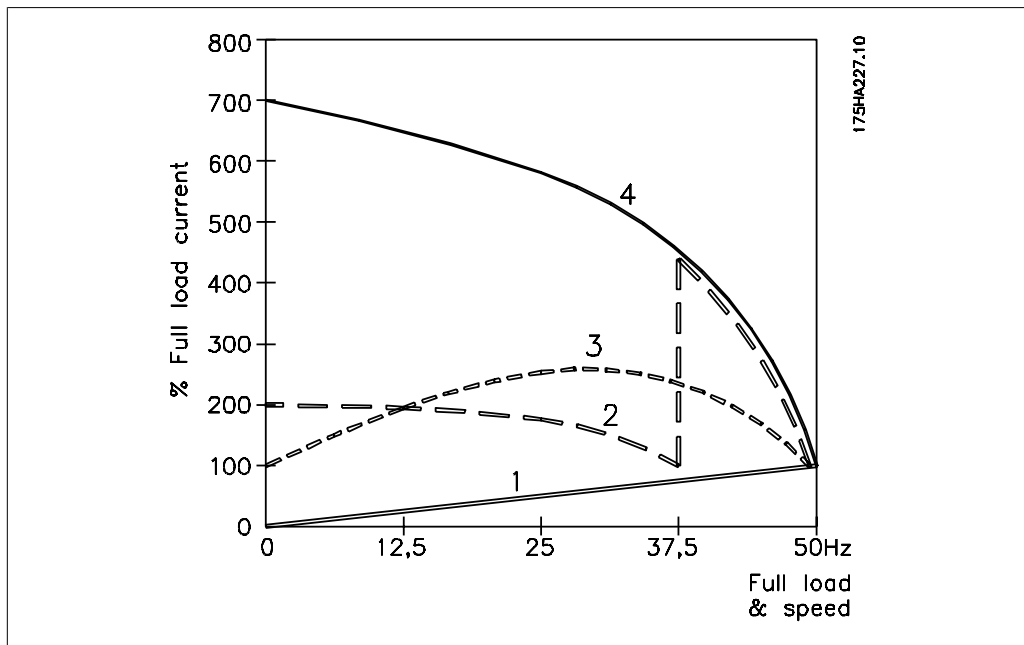
2.7.6. Cos φ compensation

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

2.7.7. Star/delta starter or soft-starter not required

When larger motors are started, it is necessary in many countries to use equipment that limits the start-up current. In more traditional systems, a star/delta starter or soft-starter is widely used. Such motor starters are not required if an adjustable frequency drive is used.

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



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

2.8. VLT AQUA Controls

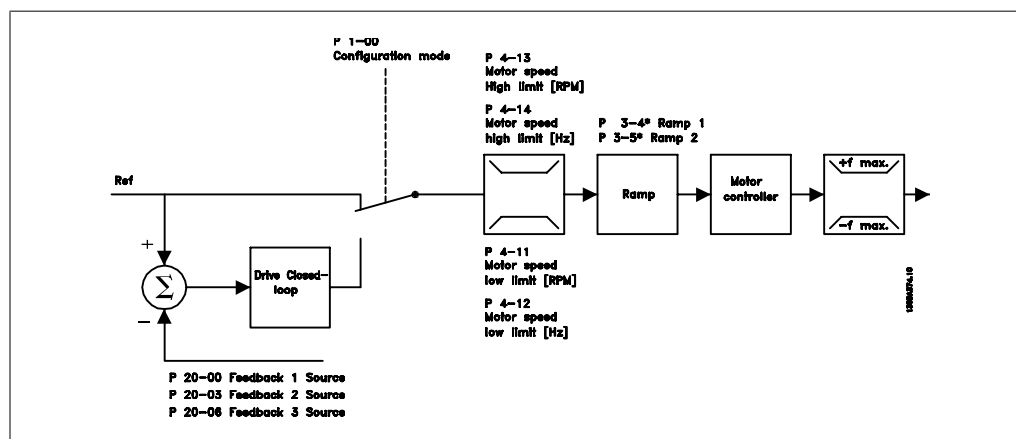
2.8.1. Control Principle

An adjustable frequency drive rectifies AC voltage from line into DC voltage, after which DC voltage is converted into an AC current with a variable amplitude and frequency.

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

2.8.2. Control Structure

Control structure in open-loop and closed-loop configurations:



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

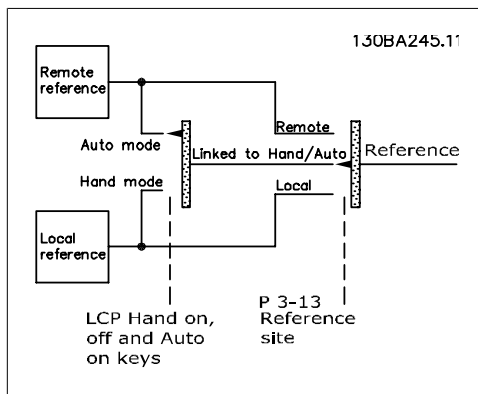
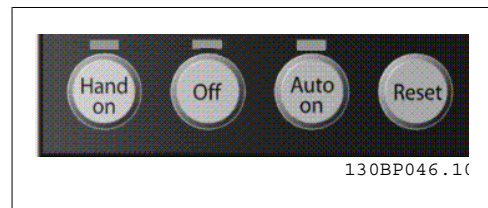
Select *Closed-loop* [3] in par. 1-00 to use the PID controller for closed-loop control of, e.g., flow, level or pressure in the controlled application. The PID parameters are located in par. group 20-**. .

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

The adjustable frequency drive can be operated manually via the local control panel (LCP) or remotely via analog and digital inputs and serial bus.

If allowed in par. 0-40, 0-41, 0-42, and 0-43, it is possible to start and stop the adjustable frequency drive via the LCP using the [Hand ON] and [Off] keys. Alarms can be reset via the [RESET] key. After pressing the [Hand On] key, the adjustable frequency drive goes into hand mode and follows (as default) the local reference set by using the LCP arrow keys.

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



Active Reference and Configuration Mode

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

In par. 3-13 *Reference Site*, the local reference can be permanently selected by selecting *Local* [2].

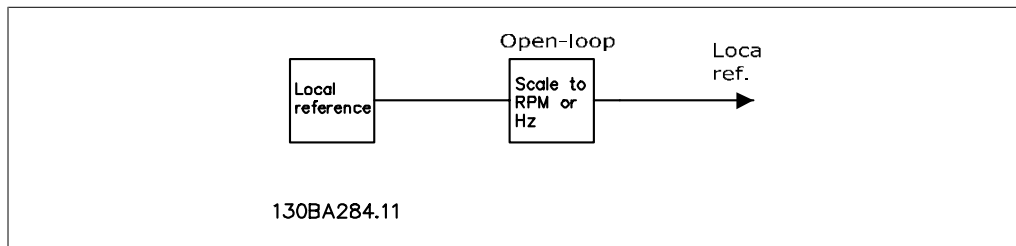
To permanently select the remote reference, select *Remote* [1]. By selecting *Linked to Hand/Auto* [0] (default), the reference site will depend on which mode is active. (Hand Mode or Auto Mode).

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

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

Par. 1-00 *Configuration Mode* determines what kind of application control principle (i.e., open-loop or closed-loop) is used when the remote reference is active (see table above for the conditions).

Reference Handling - Local Reference

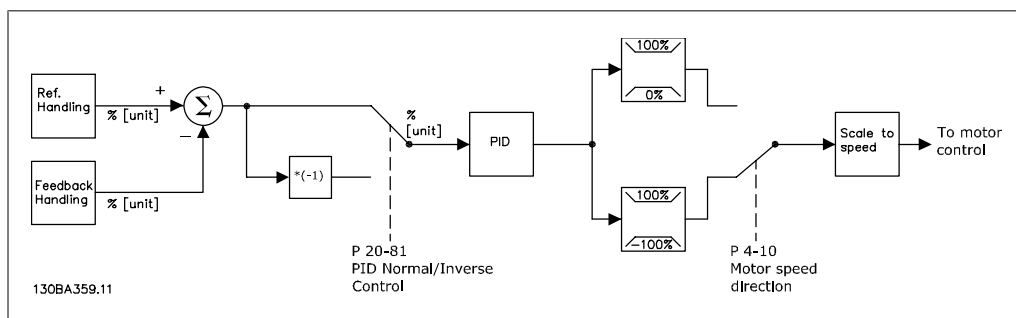


2.9. PID

2.9.1. Closed-loop (PID) Controller

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

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



NOTE
 While the default values for the drive’s closed-loop controller will often provide satisfactory performance, the control of the system can often be optimized by adjusting some of the closed-loop controller’s parameters. It is also possible to autotune the PI constants.

The figure is a block diagram of the drive’s closed-loop controller. The details of the reference handling block and feedback handling block are described in their respective sections below.

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

Parameter	Description of function
Feedback 1 Source par. 20-00	Select the source for Feedback 1. This is most commonly an analog input, but other sources are also available. Use the scaling of this input to provide the appropriate values for this signal. By default, Analog Input 54 is the default source for Feedback 1.
Reference/Feedback Unit par 20-12	Select the unit for the setpoint reference and feedback for the drive's closed-loop controller. Note: Because a conversion can be applied to the feedback signal before it is used by the closed-loop controller, the reference/feedback unit (par. 20-12) may not be the same as the feedback source unit (par. 20-02, 20-05 and 20-08).
PID Normal/Inverse Control par. 20-81	Select <i>Normal</i> [0] if the speed of the motor should decrease when the feedback is greater than the setpoint reference. Select <i>Inverse</i> [1] if the speed of the motor should increase when the feedback is greater than the setpoint reference.
PID Proportional Gain par. 20-93	This parameter adjusts the output of the drive's closed-loop control based on the error between the feedback and the setpoint reference. Quick controller response is obtained when this value is large. However, if a value that is too large is used, the drive's output frequency may become unstable.
PID Integral Time par. 20-94	Over time, the integrator adds (integrates) the error between the feedback and the setpoint reference. This is required to ensure that the error approaches zero. Quick controller response is obtained when this value is small. However, if a value that is too small is used, the drive's output frequency may become unstable. A setting of 10,000 s disables the integrator.

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

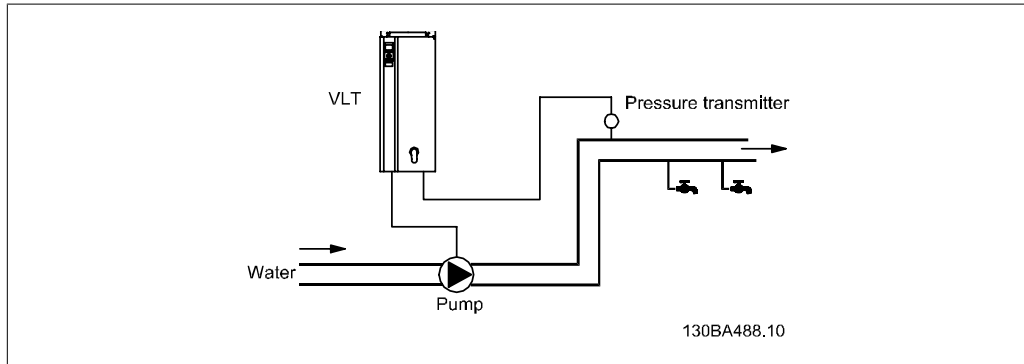
2.9.2. Closed-loop Control Relevant Parameters

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

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

2.9.3. Example of Closed-loop PID Control

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



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

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

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

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

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

2.9.4. Programming Order

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

2.9.5. Tuning the Drive Closed-loop Controller

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

2.9.6. Manual PID Adjustment

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

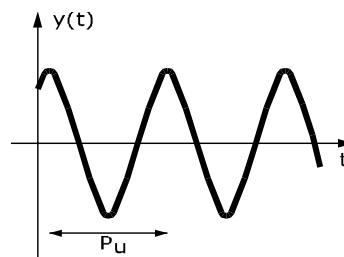
2.9.7. Ziegler Nichols Tuning Method

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



NOTE

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



2.1: Figure 1: Marginally stable system

1. Select proportional control only. That is, PID Integral Time (par. 20-94) is set to Off (10,000 s), and the PID Differentiation Time (par. 20-95) is also set to Off (0 s in this case).
2. Increase the value of the PID Proportional Gain (par 20-93) until the point of instability is reached, as indicated by sustained oscillations of the feedback signal. The PID Proportional Gain that causes sustained oscillations is called the critical gain, K_u .
3. Measure the period of oscillation, P_u .

NOTE: P_u should be measured when the amplitude of oscillation is relatively small. The output must not saturate (i.e., the maximum or minimum feedback signal must not be reached during the test).

- Use the table below to calculate the necessary PID control parameters.

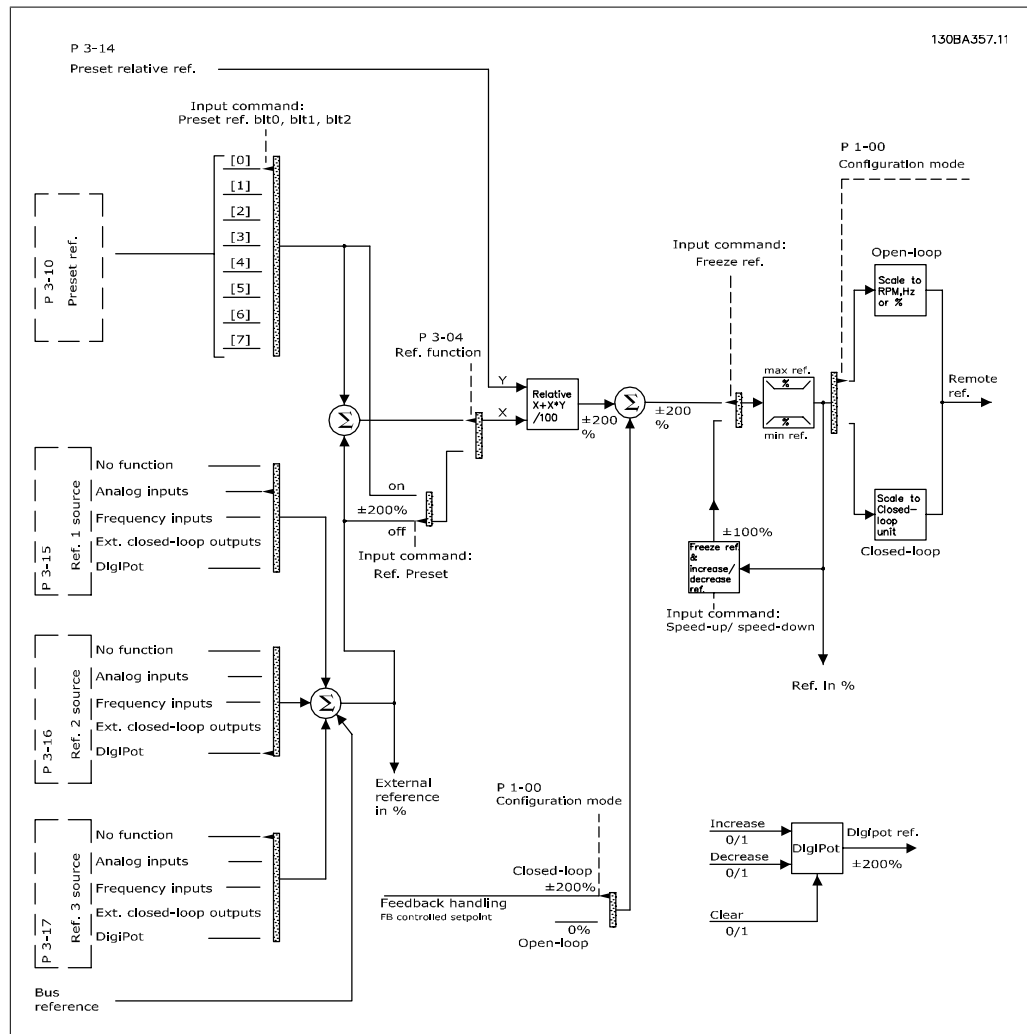
Type of Control	Proportional Gain	Integral Time	Differentiation Time
PI-control	$0.45 * K_u$	$0.833 * P_u$	-
PID tight control	$0.6 * K_u$	$0.5 * P_u$	$0.125 * P_u$
PID some overshoot	$0.33 * K_u$	$0.5 * P_u$	$0.33 * P_u$

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

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

2.9.8. Reference Handling

A block diagram of how the drive produces the remote reference is shown below.



The Remote Reference is comprised of:

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

Up to 8 preset references can be programmed in the drive. The active preset reference can be selected using digital inputs or the serial communications bus. The reference can also be supplied externally, most commonly from an analog input. This external source is selected by one of the 3 reference source parameters (par. 3-15, 3-16 and 3-17). 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 the preset relative reference (par. 3-14).

The scaled reference is calculated as follows:

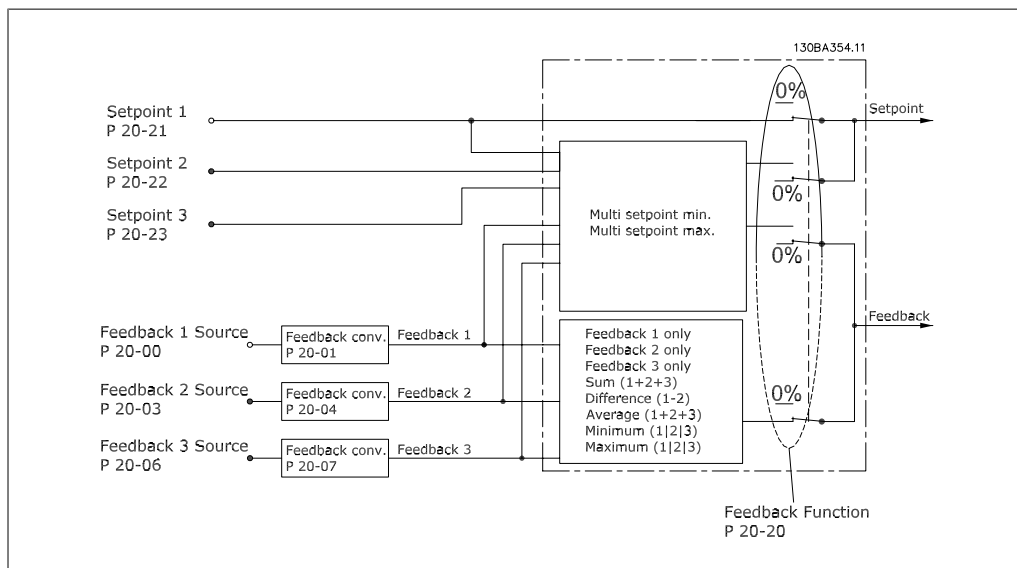
$$Reference = X + X \times \left(\frac{Y}{100}\right)$$

Where X is the external reference, the preset reference or the sum of these, and Y is the preset relative reference (par. 3-14) in [%].

NOTE
If Y, the preset relative reference (par. 3-14), is set to 0%, the reference will not be affected by the scaling

2.9.9. Feedback Handling

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



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

Single Zone, Single Setpoint

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

Multi-zone, Single Setpoint

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

Multi-zone, Multi-setpoint

applies an individual setpoint reference to each feedback. The drive’s closed-loop controller chooses one pair to control the drive based on the user’s selection in par. 20-20. If *Multi-setpoint Max* [14] is selected, the setpoint/feedback pair with the smallest difference controls the speed of the drive. (Note that a negative value is always smaller than a positive value).

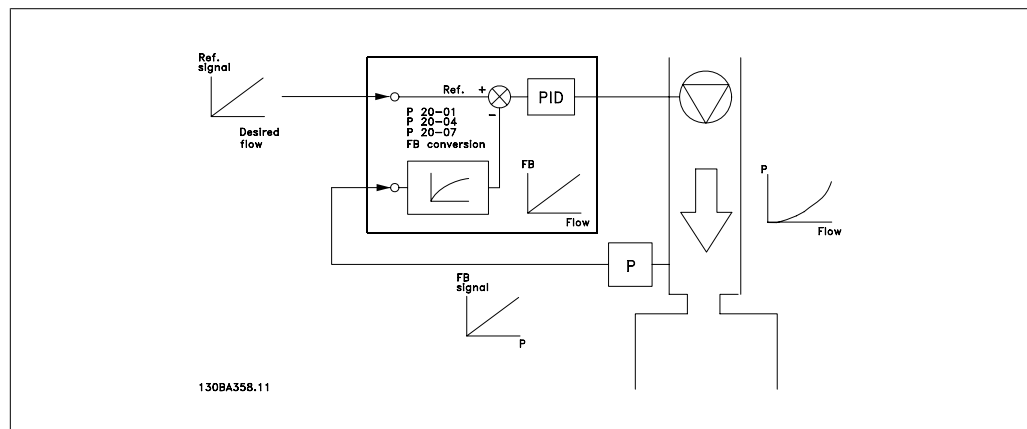
If *Multi-setpoint Min* [13] is selected, the setpoint/feedback pair with the largest difference controls the speed of the drive. *Multi-setpoint Maximum* [14] attempts to keep all zones at or below their respective setpoints, while *Multi-setpoint Min* [13] attempts to keep all zones at or above their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

Example:

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

2.9.10. Feedback Conversion

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



2.10. General aspects of EMC

2.10.1. General Aspects of EMC Emissions

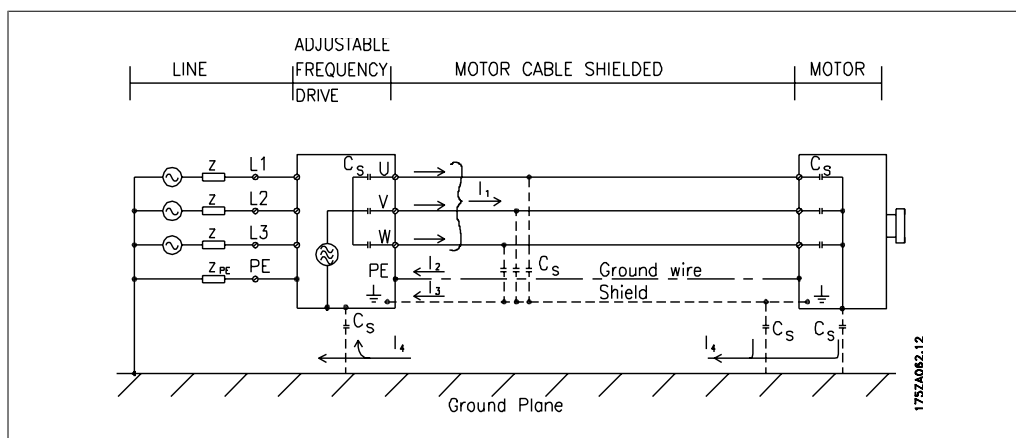
Electrical interference is usually conducted at frequencies in the range of 150 kHz to 30 MHz. Airborne interference from the drive system in the range of 30 MHz to 1 GHz is generated from the inverter, motor cable and motor.

As shown in the illustration below, capacitive currents in the motor cable coupled with a high dV/dt from the motor voltage generate leakage currents.

The use of a shielded motor cable increases the leakage current (see illustration below), because shielded cables have higher capacitance to ground than non-shielded cables. If the leakage current is not filtered, it will cause greater interference on the line power supply in the radio frequency range below approximately 5 MHz. Because the leakage current (I_1) is carried back to the unit through the shield (I_3), there will in principle only be a small electro-magnetic field (I_4) from the shielded motor cable according to the below figure.

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

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



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



NOTE

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

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

2.10.2. EMC Test Results (Emission, Immunity)

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

RFI filter type	Conducted emission			Radiated emission	
	Industrial environment		Housing, trades, and light industries	Industrial environment	Housing, trades, and light industries
Set-up	EN 55011 Class A2	EN 55011 Class A1	EN 55011 Class B	EN 55011 Class A1	EN 55011 Class B
H1					
0.34-60 hp [0.25-45 kW] 200-240 V	492 ft [150 m]	492 ft [150 m] 1)	164 ft [50 m]	Yes	No
0.34-125 hp [0.25-90 kW] 380-480 V	492 ft [150 m]	492 ft [150 m]	164 ft [50 m]	Yes	No
H2					
0.34-4 hp [0.25-3.7 kW] 200-240 V	16 ft [5 m]	No	No	No	No
7.5-60 hp [5.5-45 kW] 200-240 V	82 ft [25 m]	No	No	No	No
0.34-10 hp [0.25-7.5 kW] 380-480 V	16 ft [5 m]	No	No	No	No
15-125 hp [11-90 kW] 380-480 V	82 ft [25 m]	No	No	No	No
H3					
0.34-60 hp [0.25-45 kW] 200-240 V	246 ft [75 m]	164 ft [50 m] 1)	33 ft [10 m]	Yes	No
0.34-125 hp [0.25-90 kW] 380-480 V	246 ft [75 m]	164 ft [50 m]	33 ft [10 m]	Yes	No

2.1: EMC Test Results (Emission, Immunity)

- 1) 15 hp [11 kW]200 V, H1 and H2 performance is delivered in enclosure type B1.
- 15 hp [11 kW] 200 V, H3 performance is delivered in enclosure type B2.

2.10.3. Required Compliance Levels

Standard / environment	Housing, trades, and light industries		Industrial environment	
	Conducted	Radiated	Conducted	Radiated
IEC 61000-6-3 (generic)	Class B	Class B		
IEC 61000-6-4			Class A1	Class A1
EN 61800-3 (restricted)	Class A1	Class A1	Class A1	Class A1
EN 61800-3 (unrestricted)	Class B	Class B	Class A2	Class A2

EN 55011:	Threshold values and measuring methods for radio interference from industrial, scientific and medical (ISM) high-frequency equipment.
Class A1:	Equipment used in a public supply network. Restricted distribution.
Class A2:	Equipment used in a public supply network.
Class B1:	Equipment used in areas with a public supply network (residential, commerce, and light industries). Unrestricted distribution.

2.10.4. EMC Immunity

In order to document immunity against interference from electrical phenomena, the following immunity tests have been performed on a system consisting of an adjustable frequency drive (with options, if relevant), a shielded control cable and a control box with potentiometer, motor cable and motor.

The tests were performed in accordance with the following basic standards:

- **EN 61000-4-2 (IEC 61000-4-2): Electrostatic discharges (ESD)** Simulation of electrostatic discharges from human beings.
- **EN 61000-4-3 (IEC 61000-4-3): Incoming electromagnetic field radiation, amplitude modulated** Simulation of the effects of radar and radio communication equipment as well as mobile communications.
- **EN 61000-4-4 (IEC 61000-4-4): Electrical interference** Simulation of interference caused by switching with a contactor, relays, or similar devices.
- **EN 61000-4-5 (IEC 61000-4-5): Surge transients** Simulation of transients caused, e.g., by lightning strikes near installations.
- **EN 61000-4-6 (IEC 61000-4-6): RF Common mode** Simulation of the effect from radio-transmitting equipment connected to connection cables.

See following EMC immunity form.

VLT AQUA; 200-240 V, 380-480 V					
Basic standard	Burst IEC 61000-4-4	Surge IEC 61000-4-5	ESD IEC 61000-4-2	Radiated electromagnetic field IEC 61000-4-3	RF common mode voltage IEC 61000-4-6
Acceptance criterion	B	B	B	A	A
Line	4 kV CM	2 kV/2 Ω DM 4 kV/12 Ω CM	—	—	10 V _{RMS}
Motor	4 kV CM	4 kV/2 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 kV CM	0.5 kV/2 Ω DM 1 kV/12 Ω CM	—	—	10 V _{RMS}
Enclosure	—	—	8 kV AD 6 kV CD	10 V/m	—

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

2.2: Immunity

2.11. Galvanic isolation (PELV)

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

All control terminals and relay terminals 01-03/04-06 comply with PELV (Protective Extra Low Voltage - does not apply to 525-600 V units and at grounded Delta leg above 300 V).

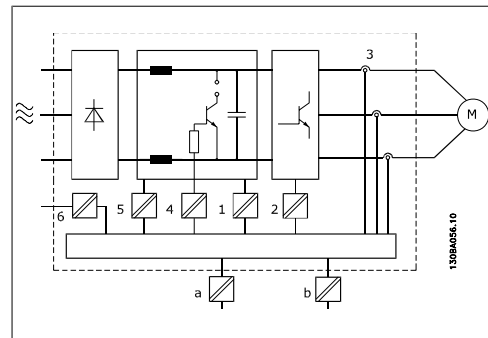
Galvanic (ensured) isolation is obtained by fulfilling requirements for higher isolation and by providing the relevant creepage/clearance distances. These requirements are described in the EN 61800-5-1 standard.

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

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

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

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



2.2: 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.

At altitudes higher than 6,600 feet [2 km], please contact Danfoss Drives regarding PELV.

2.12. Ground leakage current

2



Warning:

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

Also make sure that other voltage inputs have been disconnected, such as load sharing (linkage of DC intermediate circuit), as well as the motor connection for kinetic backup.

Before touching any electrical parts, wait at least 15 minutes.

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



Leakage Current

The ground leakage current from the adjustable frequency drive exceeds 3.5 mA. To ensure that the ground cable has a good mechanical connection to the ground connection (terminal 95), the cable cross-section must be at least 0.016 in.² [10 mm²] or have 2 rated ground wires terminated separately.

Residual Current Device

This product can cause DC current in the protective conductor. Where a residual current device (RCD) is used for extra protection, only an RCD of Type B (time delayed) shall be used on the supply side of this product. See also RCD Application Note MN.90.Gx.yy.

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

2.13. Control with brake function

2.13.1. Selection of Brake Resistor

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

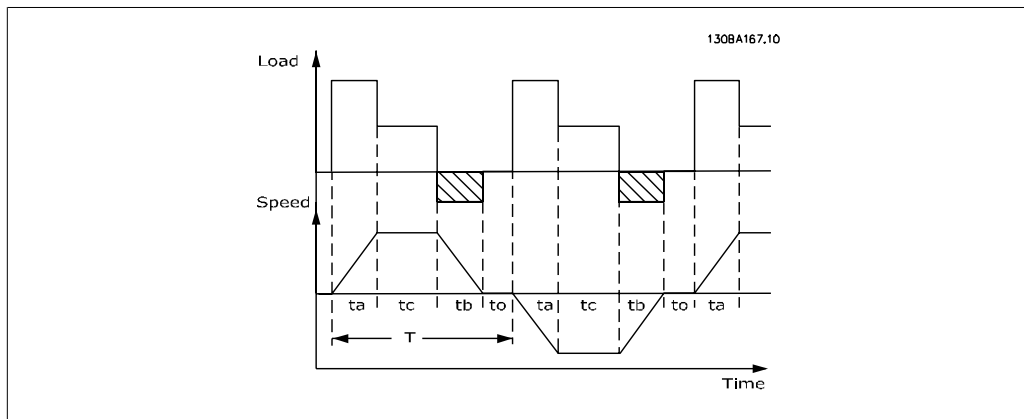
If the amount of kinetic energy transferred to the resistor in each braking period is not known, the average power can be calculated on the basis of the cycle time and braking time, also known as the intermitted duty cycle. The resistor intermittent duty cycle is an indication of the duty cycle at which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

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

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

T = cycle time in seconds

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



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

For further selection advice, please contact Danfoss.

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

2.13.2. Control with Brake Function

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

Placing the brake resistor externally offers the following advantages:

- The brake resistor can be selected on the basis of the application in question.
- The braking energy can be dissipated outside the control panel, i.e., where the energy can be utilized.
- The electronics of the adjustable frequency drive will not overheat if the brake resistor is overloaded.

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

In addition, the brake makes it possible to read out the momentary power and the mean power for the last 120 seconds. The brake can also monitor the power energizing and ensure that it does not exceed a limit set in par. 2-12. In par. 2-13, select the function to carry out when the power transmitted to the brake resistor exceeds the limit set in par. 2-12.

**NOTE**

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

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

2.14. Mechanical brake control

2.14.1. Cabling

EMC (twisted cables/shielding)

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

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

2.15. Extreme running conditions

Short Circuit (Motor Phase – Phase)

The adjustable frequency drive is protected against short circuits by means of current measurement in each of the three motor phases or in the DC link. A short circuit between two output phases will cause an overcurrent in the inverter. The inverter will be turned off individually when the short circuit current exceeds the permitted value (Alarm 16 Trip Lock).

To protect the drive against a short circuit at the load sharing and brake outputs, please see the design guidelines.

Switching on the Output

Switching on the output between the motor and the adjustable frequency drive is fully permitted. You cannot damage the adjustable frequency drive in any way by switching on the output. However, fault messages may appear.

Motor-generated Overvoltage

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

1. The load drives the motor, i.e., the load generates energy.
2. During deceleration ("ramp-down"), if the moment of inertia is high the friction is low and the ramp-down time is too short for the energy to be dissipated as a loss in the adjustable frequency drive, the motor and the installation.
3. Incorrect slip compensation setting may cause higher DC link voltage.

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

High Temperature

High ambient temperature may overheat the adjustable frequency drive.

Line Drop-out

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

The 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

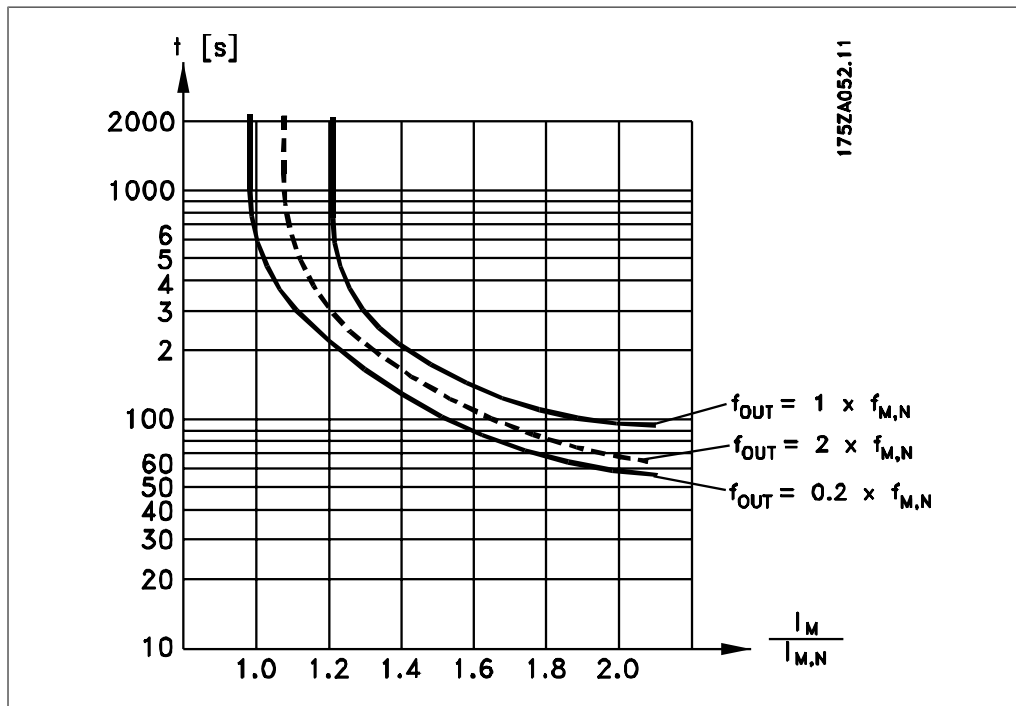
When the adjustable frequency drive is overloaded (the torque limit in par. 4-16/4-17 is reached), the control reduces the output frequency to reduce the load.

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

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

2.15.1. Motor Thermal Protection

The motor temperature is calculated on the basis of motor current, output frequency, and time or thermistor. See par. 1-90 in the chapter *How to Program*.



2.15.2. Safe Stop Operation

The FC 202 can perform the Safety Function “Uncontrolled Stopping by removal of power” (as defined by draft IEC 61800-5-2) or Stop Category 0 (as defined in EN 60204-1).

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

Prior to integration and use of the FC 202 Safe Stop in an installation, a thorough risk analysis on the installation must be carried out in order to determine whether the FC 202 Safe Stop functionality and safety category are appropriate and sufficient.

The safe stop function is activated by removing the voltage at Terminal 37 of the safe inverter. By connecting the safe inverter to external safety devices providing a safe relay, an installation for a safe Stop Category 1 can be obtained. The safe stop function of the FC 202 can be used for asynchronous and synchronous motors.

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

**NOTE**

The safe stop function of the FC 202 can be used for asynchronous and synchronous motors. It may happen that two faults occur in the adjustable frequency drive's power semiconductor. When using synchronous motors, this may cause a residual rotation. The rotation can be calculated to $\text{Angle} = 360 / (\text{Number of Poles})$. The application using synchronous motors must take this into consideration and ensure that this is not a safety-critical issue. This situation is not relevant for asynchronous motors.

**NOTE**

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

**NOTE**

The adjustable frequency drive does not provide safety-related protection against unintended or malicious voltage supply to terminal 37 and subsequent reset. Provide this protection via the interrupt device, at the application level, or organizational level.

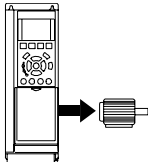
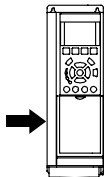
For more information - see section *Safe Stop Installation*.

3. VLT AQUA Selection

3.1. General Specifications

3.1.1. Line Supply 3 x 200-240 V AC

3

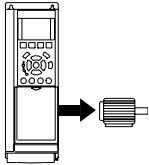
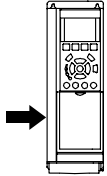
Normal overload 110% for 1 minute						
Line supply 200-240 V AC.						
	PK25	PK37	PK55	PK75		
Adjustable frequency drive	PK25	PK37	PK55	PK75		
Typical Shaft Output [kW]	0.25	0.37	0.55	0.75		
Typical Shaft Output [HP] at 208 V	0.3	0.5	0.75	1.0		
Encapsulation						
IP 20	A2	A2	A2	A2		
IP 55	A5	A5	A5	A5		
IP 66	A5	A5	A5	A5		
Output current						
	Continuous (3 x 200-240 V) [A]	1.8	2.4	3.5	4.6	
	Intermittent (3 x 200-240 V) [A]	2.9	3.8	5.6	7.4	
	Continuous kVA (208 V AC) [kVA]	0.65	0.86	1.26	1.66	
	Max. cable size: (line, motor, brake) [mm ² /AWG]	24 - 10 AWG				
		0.00031-0.0062 in. [0.2-4 mm] ²				
Max. input current						
	Continuous (3 x 200-240 V) [A]	1.6	2.2	3.2	4.1	
	Intermittent (3 x 200-240 V) [A]	2.6	3.5	5.1	6.6	
	Max. pre-fuses ¹⁾ [A]	10	10	10	10	
	Environment					
	Estimated power loss at rated max. load [W] ⁴⁾	21	29	42	54	
Weight enclosure IP 20 [kg]	4.7	4.7	4.8	4.8		
Efficiency ⁴⁾	0.94	0.94	0.95	0.95		

1. For type of fuse, see section Fuses.
2. American Wire Gauge
3. Measured using 16.4 ft. [5 m] shielded motor cables at rated load and rated frequency.
4. The typical power loss is at nominal load conditions and expected to be within +/-15% (tolerance relates to variety in voltage and cable conditions).
 Values are based on a typical motor efficiency (eff2/eff3 border line). Lower efficiency motors will also add to the power loss in the adjustable frequency drive and vice versa. If the switching frequency is raised from nominal, the power losses may rise significantly. LCP and typical control card power consumption values are included. Further options and customer load may add up to 30W to the losses (though typically only 4W extra for a fully loaded control card, or options for slot A or slot B, each).
 Although measurements are made with state of the art equipment, some measurement inaccuracy must be allowed for (+/- 5%).

3

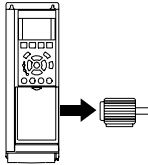
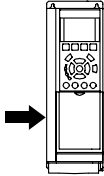
Normal overload 110% for 1 minute						
Line supply 200-240 V AC.						
Adjustable frequency drive	P1K1	P1K5	P2K2	P3K0	P3K7	
Typical Shaft Output [kW]	1.1	1.5	2.2	3	3.7	
Typical Shaft Output [HP] at 208 V	1.5	2	3	4	5	
Encapsulation						
IP 20	A2	A2	A2	A3	A3	
IP 55	A5	A5	A5	A5	A5	
IP 66	A5	A5	A5	A5	A5	
Output current						
	Continuous (3 x 200-240 V) [A]	6.6	7.5	10.6	12.5	16.7
	Intermittent (3 x 200-240 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, motor, brake) [mm ² /AWG]	4/10				
	Max. input current					
	Continuous (3 x 200-240 V) [A]	5.9	6.8	9.5	11.3	15.0
	Intermittent (3 x 200-240 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 IP 20 [kg]	4.9	4.9	4.9	6.6	6.6
	Weight enclosure IP 21 [kg]	5.5	5.5	5.5	7.5	7.5
Weight enclosure IP 55 [kg]	13.5	13.5	13.5	13.5	13.5	
Weight enclosure IP 66 [kg]	13.5	13.5	13.5	13.5	13.5	
Efficiency ⁴⁾	0.96	0.96	0.96	0.96	0.96	

1. For type of fuse, see section Fuses.
2. American Wire Gauge
3. Measured using 16.4 ft. [5 m] shielded motor cables at rated load and rated frequency.
4. The typical power loss is at nominal load conditions and expected to be within +/-15% (tolerance relates to variety in voltage and cable conditions).
 Values are based on a typical motor efficiency (eff2/eff3 border line). Lower efficiency motors will also add to the power loss in the adjustable frequency drive and vice versa. If the switching frequency is raised from nominal, the power losses may rise significantly. LCP and typical control card power consumption values are included. Further options and customer load may add up to 30W to the losses (though typically only 4W extra for a fully loaded control card, or options for slot A or slot B, each).
 Although measurements are made with state of the art equipment, some measurement inaccuracy must be allowed for (+/- 5%).

Normal overload 110% for 1 minute					
Line supply 200-240 V AC.					
Adjustable frequency drive	P5K5	P7K5	P11K	P15K	
Typical Shaft Output [kW]	5.5	7.5	11	15	
Typical Shaft Output [HP] at 208 V	7.5	10	15	20	
Encapsulation					
IP 21	B1	B1	B2	B2	
IP 55	B1	B1	B2	B2	
IP 66	B1	B1	B2	B2	
Output current					
	Continuous (3 x 200-240 V) [A]	24.2	30.8	46.2	59.4
	Intermittent (3 x 200-240 V) [A]	26.6	33.9	50.8	65.3
	Continuous kVA (208 V AC) [kVA]	8.7	11.1	16.6	21.4
	Max. cable size: (line, motor, brake) [mm ² /AWG]		10/7		35/2
	Max. input current				
	Continuous (3 x 200-240 V) [A]	22.0	28.0	42.0	54.0
	Intermittent (3 x 200-240 V) [A]	24.2	30.8	46.2	59.4
	Max. pre-fuses ¹⁾ [A]	63	63	63	80
	Environment				
	Estimated power loss at rated max. load [W] ⁴⁾	269	310	447	602
	Weight enclosure IP 20 [kg]				
	Weight enclosure IP 21 [kg]	23	23	23	27
	Weight enclosure IP 55 [kg]	23	23	23	27
Weight enclosure IP 66 [kg]	23	23	23	27	
Efficiency ⁴⁾	0.96	0.96	0.96	0.96	

1. For type of fuse, see section Fuses.
2. American Wire Gauge
3. Measured using 16.4 ft. [5 m] shielded motor cables at rated load and rated frequency.
4. The typical power loss is at nominal load conditions and expected to be within +/-15% (tolerance relates to variety in voltage and cable conditions).
 Values are based on a typical motor efficiency (eff2/eff3 border line). Lower efficiency motors will also add to the power loss in the adjustable frequency drive and vice versa. If the switching frequency is raised from nominal, the power losses may rise significantly. LCP and typical control card power consumption values are included. Further options and customer load may add up to 30W to the losses (though typically only 4W extra for a fully loaded control card, or options for slot A or slot B, each).
 Although measurements are made with state of the art equipment, some measurement inaccuracy must be allowed for (+/- 5%).

3

Normal overload 110% for 1 minute						
Line supply 200-240 V AC.						
Adjustable frequency drive	P18K	P22K	P30K	P37K	P45K	
Typical Shaft Output [kW]	18.5	22	30	37	45	
Typical Shaft Output [HP] at 208 V	25	30	40	50	60	
Encapsulation						
IP 21	C1	C1	C2	C2	C2	
IP 55	C1	C1	C2	C2	C2	
IP 66	C1	C1	C2	C2	C2	
Output current						
	Continuous (3 x 200-240 V) [A]	74.8	88.0	115	143	170
	Intermittent (3 x 200-240 V) [A]	82.3	96.8	127	157	187
	Continuous kVA (208 V AC) [kVA]	26.9	31.7	41.4	51.5	61.2
	Max. cable size: (line, motor, brake) [mm ² /AWG]	50/1/0		95/4/0		120/250 MCM
	Max. input current					
		Continuous (3 x 200-240 V) [A]	68.0	80.0	104.0	130.0
Intermittent (3 x 200-240 V) [A]		74.8	88.0	114.0	143.0	169.0
Max. pre-fuses ¹⁾ [A]		125	125	160	200	250
Environment						
Estimated power loss at rated max. load [W] ⁴⁾		737	845	1140	1353	1636
Weight enclosure IP 20 [kg]						
Weight enclosure IP 21 [kg]		45	45	65	65	65
Weight enclosure IP 55 [kg]		45	45	65	65	65
Weight enclosure IP 66 [kg]		45	45	65	65	65
Efficiency ⁴⁾		0.96	0.97	0.97	0.97	0.97

1. For type of fuse, see section Fuses.
2. American Wire Gauge
3. Measured using 16.4 ft. [5 m] shielded motor cables at rated load and rated frequency.
4. The typical power loss is at nominal load conditions and expected to be within +/-15% (tolerance relates to variety in voltage and cable conditions).
 Values are based on a typical motor efficiency (eff2/eff3 border line). Lower efficiency motors will also add to the power loss in the adjustable frequency drive and vice versa. If the switching frequency is raised from nominal, the power losses may rise significantly. LCP and typical control card power consumption values are included. Further options and customer load may add up to 30W to the losses (though typically only 4W extra for a fully loaded control card, or options for slot A or slot B, each).
 Although measurements are made with state of the art equipment, some measurement inaccuracy must be allowed for (+/- 5%).

3.1.2. Line Supply 3 x 380-480 V AC

Normal overload 110% for 1 minute							
Line Supply 3 x 380-480 V AC							
Adjustable frequency drive	PK37	PK55	PK75	P1K1	P1K5		
Typical Shaft Output [kW]	0.37	0.55	0.75	1.1	1.5		
Typical Shaft Output [HP] at 460 V	0.5	0.75	1	1.5	2		
Encapsulation							
IP 20	A2	A2	A2	A2	A2		
IP 21							
IP 55	A5	A5	A5	A5	A5		
IP 66	A5	A5	A5	A5	A5		
Output current							
	Continuous (3 x 380-440 V) [A]	1.3	1.8	2.4	3	4.1	
	Intermittent (3 x 380-440 V) [A]	2.1	2.9	3.8	3.3	4.5	
	Continuous (3 x 440-480 V) [A]	1.2	1.6	2.1	2.7	3.4	
	Intermittent (3 x 440-480 V) [A]	1.9	2.6	3.4	3.0	3.7	
	Continuous kVA (400 V AC) [kVA]	0.9	1.3	1.7	2.1	2.8	
	Continuous kVA (460 V AC) [kVA]	0.9	1.3	1.7	2.4	2.7	
	Max. cable size: (line, motor, brake) [[mm ² / AWG]	4/10					
	Max. input current						
		Continuous (3 x 380-440 V) [A]	1.2	1.6	2.2	2.7	3.7
		Intermittent (3 x 380-440 V) [A]	1.9	2.6	3.5	3.0	4.1
		Continuous (3 x 440-480 V) [A]	1.0	1.4	1.9	2.7	3.1
		Intermittent (3 x 440-480 V) [A]	1.6	2.2	3.0	3.0	3.4
Max. pre-fuses ¹⁾ [A]		10	10	10	10	10	
Environment							
Estimated power loss at rated max. load [W] ⁴⁾		35	42	46	58	62	
Weight enclosure IP 20 [kg]		4.7	4.7	4.8	4.8	4.9	
Weight enclosure IP 55 [kg]		13.5	13.5	13.5	13.5	13.5	
Efficiency ⁴⁾		0.93	0.95	0.96	0.96	0.97	

1. For type of fuse, see section Fuses.
2. American Wire Gauge
3. Measured using 16.4 ft. [5 m] shielded motor cables at rated load and rated frequency.
4. The typical power loss is at nominal load conditions and expected to be within +/-15% (tolerance relates to variety in voltage and cable conditions).
Values are based on a typical motor efficiency (eff2/eff3 border line). Lower efficiency motors will also add to the power loss in the adjustable frequency drive and vice versa. If the switching frequency is raised from nominal, the power losses may rise significantly. LCP and typical control card power consumption values are included. Further options and customer load may add up to 30W to the losses (though typically only 4W extra for a fully loaded control card, or options for slot A or slot B, each).
Although measurements are made with state of the art equipment, some measurement inaccuracy must be allowed for (+/- 5%).

Normal overload 110% for 1 minute							
Line Supply 3 x 380-480 V AC							
Adjustable frequency drive	P2K2	P3K0	P4K0	P5K5	P7K5		
Typical Shaft Output [kW]	2.2	3	4	5.5	7.5		
Typical Shaft Output [HP] at 460 V	3	4	5	7	10		
Encapsulation							
IP 20	A2	A2	A2	A3	A3		
IP 21							
IP 55	A5	A5	A5	A5	A5		
IP 66	A5	A5	A5	A5	A5		
Output current							
	Continuous (3 x 380-440 V) [A]	5.6	7.2	10	13	16	
	Intermittent (3 x 380-440 V) [A]	6.2	7.9	11	14.3	17.6	
	Continuous (3 x 440-480 V) [A]	4.8	6.3	8.2	11	14.5	
	Intermittent (3 x 440-480 V) [A]	5.3	6.9	9.0	12.1	15.4	
	Continuous kVA (400 V AC) [kVA]	3.9	5.0	6.9	9.0	11.0	
	Continuous kVA (460 V AC) [kVA]	3.8	5.0	6.5	8.8	11.6	
	Max. cable size: (line, motor, brake) [mm ² /AWG]						
	Max. input current						
		Continuous (3 x 380-440 V) [A]	5.0	6.5	9.0	11.7	14.4
		Intermittent (3 x 380-440 V) [A]	5.5	7.2	9.9	12.9	15.8
Continuous (3 x 440-480 V) [A]		4.3	5.7	7.4	9.9	13.0	
Intermittent (3 x 440-480 V) [A]		4.7	6.3	8.1	10.9	14.3	
Max. pre-fuses ¹⁾ [A]		20	20	20	32	32	
Environment							
Estimated power loss at rated max. load [W] ⁴⁾		88	116	124	187	255	
Weight enclosure IP 20 [kg]		4.9	4.9	4.9	6.6	6.6	
Weight enclosure IP 21 [kg]							
Weight enclosure IP 55 [kg]		13.5	13.5	13.5	14.2	14.2	
Weight enclosure IP 66 [kg]	13.5	13.5	13.5	14.2	14.2		
Efficiency ⁴⁾	0.97	0.97	0.97	0.97	0.97		

1. For type of fuse, see section Fuses.
2. American Wire Gauge
3. Measured using 16.4 ft. [5 m] shielded motor cables at rated load and rated frequency.
4. The typical power loss is at nominal load conditions and expected to be within +/-15% (tolerance relates to variety in voltage and cable conditions).
 Values are based on a typical motor efficiency (eff2/eff3 border line). Lower efficiency motors will also add to the power loss in the adjustable frequency drive and vice versa. If the switching frequency is raised from nominal, the power losses may rise significantly. LCP and typical control card power consumption values are included. Further options and customer load may add up to 30W to the losses (though typically only 4W extra for a fully loaded control card, or options for slot A or slot B, each).
 Although measurements are made with state of the art equipment, some measurement inaccuracy must be allowed for (+/- 5%).

Normal overload 110% for 1 minute						
Line Supply 3 x 380-480 V AC						
Adjustable frequency drive	P11K	P15K	P18K	P22K	P30K	
Typical Shaft Output [kW]	11	15	18.5	22	30	
Typical Shaft Output [HP] at 460 V	15	20	25	30	40	
Encapsulation						
IP 20						
IP 21	B1	B1	B1	B2	B2	
IP 55	B1	B1	B1	B2	B2	
IP 66	B1	B1	B1	B2	B2	
Output current						
	Continuous (3 x 380-440 V) [A]	24	32	37.5	44	61
	Intermittent (3 x 380-440 V) [A]	26.4	35.2	41.3	48.4	67.1
	Continuous (3 x 440-480 V) [A]	21	27	34	40	52
	Intermittent (3 x 440-480 V) [A]	23.1	29.7	37.4	44	61.6
	Continuous kVA (400 V AC) [kVA]	16.6	22.2	26	30.5	42.3
	Continuous kVA (460 V AC) [kVA]	16.7	21.5	27.1	31.9	41.4
	Max. cable size:					
	(line, motor, brake) [mm ² / AWG]		10/7		35/2	
	Max. input current					
		Continuous (3 x 380-440 V) [A]	22	29	34	40
Intermittent (3 x 380-440 V) [A]		24.2	31.9	37.4	44	60.5
Continuous (3 x 440-480 V) [A]		19	25	31	36	47
Intermittent (3 x 440-480 V) [A]		20.9	27.5	34.1	39.6	51.7
Max. pre-fuses ¹⁾ [A]		63	63	63	63	80
Environment						
Estimated power loss at rated max. load [W] ⁴⁾		278	392	465	525	739
Weight enclosure IP 20 [kg]						
Weight enclosure IP 21 [kg]		23	23	23	27	27
Weight enclosure IP 55 [kg]		23	23	23	27	27
Weight enclosure IP 66 [kg]	23	23	23	27	27	
Efficiency ⁴⁾	0.98	0.98	0.98	0.98	0.98	

1. For type of fuse, see section Fuses.
2. American Wire Gauge
3. Measured using 16.4 ft. [5 m] shielded motor cables at rated load and rated frequency.
4. The typical power loss is at nominal load conditions and expected to be within +/-15% (tolerance relates to variety in voltage and cable conditions).
 Values are based on a typical motor efficiency (eff2/eff3 border line). Lower efficiency motors will also add to the power loss in the adjustable frequency drive and vice versa. If the switching frequency is raised from nominal, the power losses may rise significantly. LCP and typical control card power consumption values are included. Further options and customer load may add up to 30W to the losses (though typically only 4W extra for a fully loaded control card, or options for slot A or slot B, each).
 Although measurements are made with state of the art equipment, some measurement inaccuracy must be allowed for (+/- 5%).

Normal overload 110% for 1 minute							
Line Supply 3 x 380-480 V AC							
Adjustable frequency drive	P37K	P45K	P55K	P75K	P90K		
Typical Shaft Output [kW]	37	45	55	75	90		
Typical Shaft Output [HP] at 460 V	50	60	75	100	125		
Encapsulation							
IP 20							
IP 21	C1	C1	C1	C2	C2		
IP 55	C1	C1	C1	C2	C2		
IP 66	C1	C1	C1	C2	C2		
Output current							
	Continuous (3 x 380-440 V) [A]	73	90	106	147	177	
	Intermittent (3 x 380-440 V) [A]	80.3	99	117	162	195	
	Continuous (3 x 440-480 V) [A]	65	80	105	130	160	
	Intermittent (3 x 440-480 V) [A]	71.5	88	116	143	176	
	Continuous kVA (400 V AC) [kVA]	50.6	62.4	73.4	102	123	
	Continuous kVA (460 V AC) [kVA]	51.8	63.7	83.7	104	128	
	Max. cable size: (line, motor, brake) [[mm ² /AWG]		50/1/0		104	128	
	Max. input current						
		Continuous (3 x 380-440 V) [A]	66	82	96	133	161
		Intermittent (3 x 380-440 V) [A]	72.6	90.2	106	146	177
Continuous (3 x 440-480 V) [A]		59	73	95	118	145	
Intermittent (3 x 440-480 V) [A]		64.9	80.3	105	130	160	
Max. pre-fuses ¹⁾ [A]		100	125	160	250	250	
Environment Estimated power loss at rated max. load [W] ⁴⁾		698	843	1083	1384	1474	
Weight enclosure IP 20 [kg]							
Weight enclosure IP 21 [kg]		45	45	45	65	65	
Weight enclosure IP 55 [kg]		45	45	45	65	65	
Weight enclosure IP 66 [kg]		45	45	45	-	-	
Efficiency ⁴⁾	0.98	0.98	0.98	0.98	0.99		

1. For type of fuse, see section Fuses.
2. American Wire Gauge
3. Measured using 16.4 ft. [5 m] shielded motor cables at rated load and rated frequency.
4. The typical power loss is at nominal load conditions and expected to be within +/-15% (tolerance relates to variety in voltage and cable conditions).
 Values are based on a typical motor efficiency (eff2/eff3 border line). Lower efficiency motors will also add to the power loss in the adjustable frequency drive and vice versa. If the switching frequency is raised from nominal, the power losses may rise significantly. LCP and typical control card power consumption values are included. Further options and customer load may add up to 30W to the losses (though typically only 4W extra for a fully loaded control card, or options for slot A or slot B, each).
 Although measurements are made with state of the art equipment, some measurement inaccuracy must be allowed for (+/- 5%).

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°C ± 9°C [70°C ± 5°C] (Guideline - these temperatures may vary for different power sizes, enclosures, etc.). The VLT AQUA Drive has an auto-derating function to prevent its heatsink from reaching 203°F [95°C].
- The adjustable frequency drive is protected against short-circuits on motor terminals U, V, W.
- If a line phase is missing, the adjustable frequency drive trips or issues a warning (depending on the load).
- Monitoring of the intermediate circuit voltage ensures that the adjustable frequency drive trips if the intermediate circuit voltage is too low or too high.
- The adjustable frequency drive is protected against ground faults on motor terminals U, V, W.

Line power supply (L1, L2, L3):

Supply voltage	200-240 V ±10%
Supply voltage	380-480 V ±10%
Supply voltage	525-600 V ±10%
Supply frequency	50/60 Hz
Max. imbalance temporary between line phases	3.0% of rated supply voltage
True Power Factor (λ)	≥ 0.9 nominal at rated load
Displacement Power Factor ($\cos\phi$) near unity	(> 0.98)
Switching on input supply L1, L2, L3 (power-ups) ≤ enclosure type A	maximum twice/min.
Switching on input supply L1, L2, L3 (power-ups) ≥ enclosure type B, C	maximum once/min.
Environment according to EN60664-1	overvoltage category III/pollution degree 2

The unit is suitable for use on a circuit capable of delivering not more than 100,000 RMS symmetrical Amperes, 240/480 V maximum.

Motor output (U, V, W):

Output voltage	0 - 100% of supply voltage
Output frequency	0 - 1000 Hz
Switching on output	Unlimited
Ramp times	1 - 3600 sec.

Torque characteristics:

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

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

Cable lengths and cross-sections:

Max. motor cable length, shielded/armored	VLT AQUA Drive: 492 ft [150 m]
Max. motor cable length, unshielded/unarmored	VLT AQUA Drive: 984 ft [300 m]
Max. cross-section to motor, line power, load sharing and brake *	
Maximum cross-section to control terminals, rigid wire	0.0023 in. ² [1.5 mm ²]/16 AWG (2 x 0.0012 in. ² [2 x 0.75 mm ²])
Maximum cross-section to control terminals, flexible cable	0.0016 in. ² [1 mm ²]/18 AWG
Maximum cross-section to control terminals, cable with enclosed core	0.00078 in. ² [0.5 mm ²]/20 AWG
Minimum cross-section to control terminals	0.00039 in. ² [0.25 mm ²]

* See Line Supply tables for more information!

Control card, RS-485 serial communication:

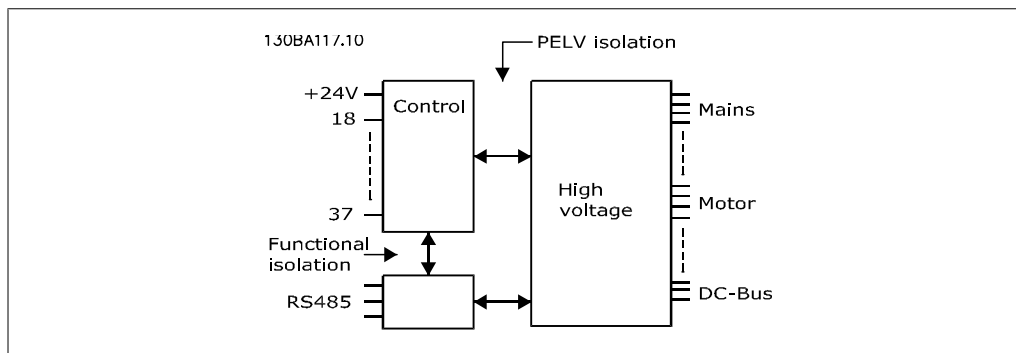
Terminal number	68 (P,TX+, RX+), 69 (N,TX-, RX-)
Terminal number 61	Common for terminals 68 and 69

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

Analog inputs:

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

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



Analog output:

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

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

Digital inputs:

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

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

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

Digital output:

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

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

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

Pulse inputs:

Programmable pulse inputs	2
Terminal number pulse	29, 33
Max. frequency at terminal, 29, 33	110 kHz (push-pull driven)
Max. frequency at terminal, 29, 33	5 kHz (open collector)
Min. frequency at terminal 29, 33	4 Hz
Voltage level	see section on Digital input
Maximum voltage on input	28 V DC

Input resistance, R_i	approx. 4 k Ω
Pulse input accuracy (0.1-1 kHz)	Max. error: 0.1% of full scale

Control card, 24 V DC output:

Terminal number	12, 13
Max. load	: 200 mA

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

Relay outputs:

Programmable relay outputs	2
Relay 01 Terminal number	1-3 (break), 1-2 (make)
Max. terminal load (AC-1) ¹⁾ on 1-3 (NC), 1-2 (NO) (Resistive load)	240 V AC, 2 A
Max. terminal load (AC-15) ¹⁾ (Inductive load @ $\cos\phi$ 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)	240 V AC, 2 A
Max. terminal load (AC-15) ¹⁾ on 4-5 (NO) (Inductive load @ $\cos\phi$ 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 @ $\cos\phi$ 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 part 4 and 5

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

Control card, 10 V DC output:

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

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

Control characteristics:

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

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

Surroundings:

Enclosure ≤ enclosure type A	IP 20, IP 55, IP 66
Enclosure ≥ enclosure type B	IP 21, IP 55, IP 66
Enclosure kit available ≤ enclosure type A	IP 21/TYPE 1/IP 4X top
Vibration test	1.0 g
Max. relative humidity	5% - 95% (IEC 721-3-3); Class 3K3 (non-condensing) during operation
Aggressive environment (IEC 721-3-3), uncoated	class 3C2
Aggressive environment (IEC 721-3-3), coated	class 3C3
Test method according to IEC 60068-2-43 H2S (10 days)	
Ambient temperature	Max. 122°F [50°C]

Derating for high ambient temperature, see section on special conditions

Minimum ambient temperature during full-scale operation	32°F [0°C]
Minimum ambient temperature at reduced performance	14°F [-10°C]
Temperature during storage/transport	-193° - +149°/158°F [-25° - +65°/70°C]
Maximum altitude above sea level without derating	3,280 ft [1,000 m]
Maximum altitude above sea level with derating	9,842.5 ft [3,000 m]

Derating for high altitude, see section on special conditions.

EMC standards, Emission	EN 61800-3, EN 61000-6-3/4, EN 55011, IEC 61800-3 EN 61800-3, EN 61000-6-1/2, EN 61000-4-2, EN 61000-4-3, EN 61000-4-4, EN 61000-4-5, EN
EMC standards, Immunity	61000-4-6

See section on Special conditions

Control card performance:

Scan interval	: 5 ms
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Control card, USB serial communication:

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



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

3.2. Efficiency

Efficiency of VLT AQUA (η_{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% 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 line voltage is 480 V, or if the motor cable is longer than 98.43 ft. [30 m].

Efficiency of the motor (η_{MOTOR})

The efficiency of a motor connected to the adjustable frequency drive depends on magnetizing level. In general, the efficiency is just as good as with line operation; however, it 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 (η_{SYSTEM})

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

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

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

3.3. Acoustic noise

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

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

Typical values are measured at a distance of 3.28 ft. [1 m] from the unit:

Encapsulation	At reduced fan speed (50%)	Full fan speed [dBA]
	[dBA]	
A2	51	60
A3	51	60
A5	-	54
B1	61	67
B2	58	70
C1	52	62
C2	55	65

3.4. Peak voltage on motor

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

- the motor cable (type, cross-section, length, shielded or unshielded)
- inductance

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

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

In motors without phase insulation paper or other insulation reinforcement suitable for operation with voltage supply (such as an adjustable frequency drive), fit a sine-wave filter on the output of the FC 300.

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

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

Data are measured according to IEC 60034-17.
Cable lengths are in meters/feet.

FC 202, P11KT5				
Cable length [m]	AC line voltage	Rise time [μ sec]	Vpeak [kV]	dU/dt [kV/ μ sec]
10	400 V	0.22	0.470	1.573
150	400 V	0.52	0.512	0.846
10	480 V	0.34	0.580	1.394
150	480 V	0.36	0.598	1.328

FC 202, P18KT5

Cable length [m]	AC line voltage	Rise time [μ sec]	Vpeak [kV]	dU/dt [kV/ μ sec]
25	400 V	0.276	1.040	2.717
50	400 V	0.236	1.070	2.775
150	400 V	0.284	1.020	2.025
25	480 V	0.316	1.220	2.880
50	480 V	0.328	1.260	2.591
150	480 V	0.28	1.210	2.304

FC 202, P7K5T2

Cable length [m]	AC line voltage	Rise time [μ sec]	Vpeak [kV]	dU/dt [kV/ μ sec]
5	230 V	0.13	0.510	3.090
50	230 V	0.23	0.590	2.034
100	230 V	0.54	0.580	0.865
150	230 V	0.66	0.560	0.674

FC 202, P11KT2

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

FC 202, P11KT2

Cable length [m]	AC line voltage	Rise time [μ sec]	Vpeak [kV]	dU/dt [kV/ μ sec]
36	240 V	0.15	0.624	1.664
136	240 V	0.168	0.596	1.419
150	240 V	0.156	0.568	1.456

FC 202, P22KT5

Cable length [m]	AC line voltage	Rise time [μ sec]	Vpeak [kV]	dU/dt [kV/ μ sec]
25	400 V	0.320	0.930	2.547
150	400 V	0.330	1.000	2.121
25	480 V	0.312	1.150	2.965
150	480 V	0.550	1.250	1.582

FC 202, P30KT5

Cable length [m]	AC line voltage	Rise time [μ sec]	Vpeak [kV]	dU/dt [kV/ μ sec]
25	400 V	0.216	1.000	3.773
150	400 V	0.250	1.000	2.000
25	480 V	0.264	1.150	3.788
150	480 V	0.400	1.225	1.750

FC 202, P30KT5

Cable length [m]	AC line voltage	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
25	400 V	0.216	1.000	3.773
150	400 V	0.250	1.000	2.000
25	480 V	0.264	1.150	3.788
150	480 V	0.400	1.225	1.750

FC 202, P15KT2

Cable length [m]	AC line voltage	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
36	240 V	0.296	0.574	1.551
136	240 V	0.696	0.580	0.666
150	240 V	0.832	0.576	0.553

FC 202, P15KT2

Cable length [m]	AC line voltage	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
36	240 V	0.188	0.574	1.221
136	240 V	0.256	0.580	0.906
150	240 V	0.26	0.576	0.886

FC 202, P37KT5

Cable length [m]	AC line voltage	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
5	400 V	0.376	1.090	2.380
50	400 V	0.576	1.040	1.450
100	400 V	0.544	1.020	1.471
150	400 V	0.832	1.010	0.962
5	480 V	0.368	1.270	2.853
50	480 V	0.536	1.290	1.978
100	480 V	0.680	1.240	1.426
150	480 V	0.712	1.200	1.334

FC 202, P55KT5

Cable length [m]	AC line voltage	Rise time [μsec]	Vpeak [kV]	dU/dt [kV/μsec]
15	400 V	0.232	1.000	3.362
50	400 V	0.384	1.000	2.096
100	400 V	0.496	1.000	1.612
150	400 V	0.752	0.980	1.070
15	480 V	0.256	1.230	3.847
50	480 V	0.328	1.200	2.957
100	480 V	0.456	1.200	2.127
150	480 V	0.960	1.150	1.052

FC 202, P30KT2				
Cable length [m]	AC line voltage	Rise time [μ sec]	Vpeak [kV]	dU/dt [kV/ μ sec]
15	240 V	0.194	0.626	2.581
50	240 V	0.252	0.574	1.822
150	240 V	0.488	0.538	0.882

FC 202, P30KT2				
Cable length [m]	AC line voltage	Rise time [μ sec]	Vpeak [kV]	dU/dt [kV/ μ sec]
15	240 V	0.117	0.626	2.410
50	240 V	0.150	0.574	1.531
150	240 V	0.184	0.538	1.170

FC 202, P90KT5				
Cable length [m]	AC line voltage	Rise time [μ sec]	Vpeak [kV]	dU/dt [kV/ μ sec]
5	400 V	0.240	1.030	1.683
5	480 V	0.184	1.170	2.652

3.5. Special Conditions

3.5.1. Purpose of derating

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

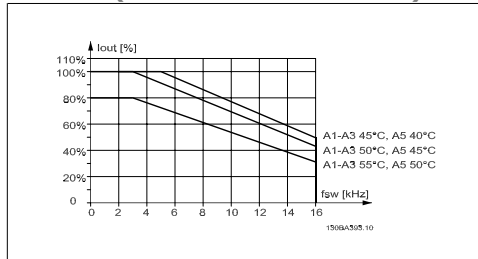
3.5.2. Derating for Ambient Temperature

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

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

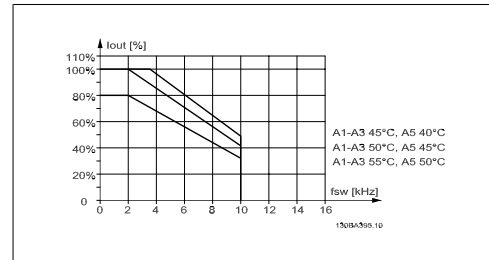
The derating depends on the switching pattern, which can be set to 60 PWM or SFAVM in parameter 14-00.

A enclosures
60 PWM (Pulse Width Modulation)



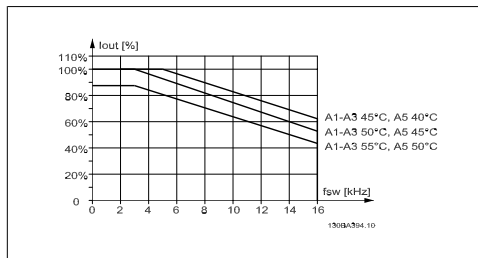
3.1: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure A, using 60 PWM

SFAVM - Stator Frequency Asyncon Vector Modulation

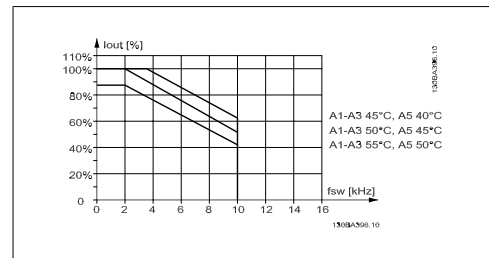


3.2: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure A, using SFAVM

In enclosure A, the length of the motor cable has a relatively high impact on the recommended derating. Therefore, the recommended derating for an application with max. 32 ft. [10 m] motor cable is also shown.

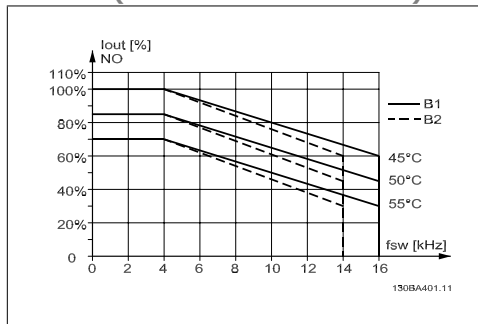


3.3: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure A, using 60 PWM and a maximum of 32 ft. [10 m] motor cable



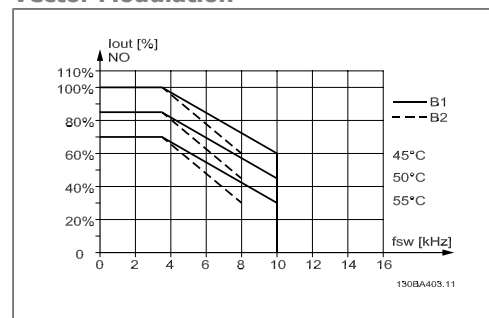
3.4: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure A, using SFAVM and a maximum of 32 ft. [10 m] motor cable

B enclosures
60 PWM (Pulse Width Modulation)



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

SFAVM - Stator Frequency Asyncon Vector Modulation

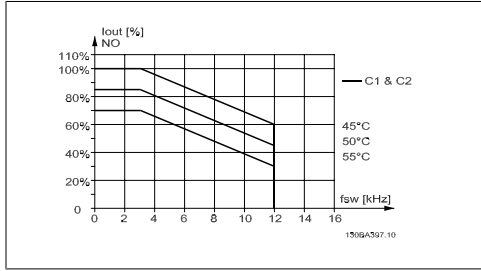


3.6: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure B, using SFAVM in normal torque mode (110% over-torque)

3

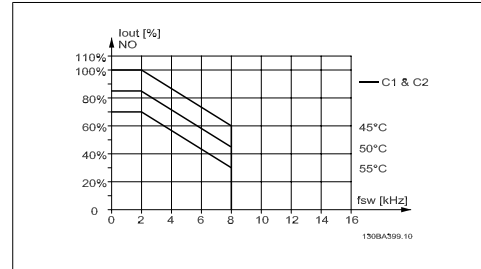
C enclosures

60 PWM (Pulse Width Modulation)



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

SFAVM - Stator Frequency Asynchron Vector Modulation



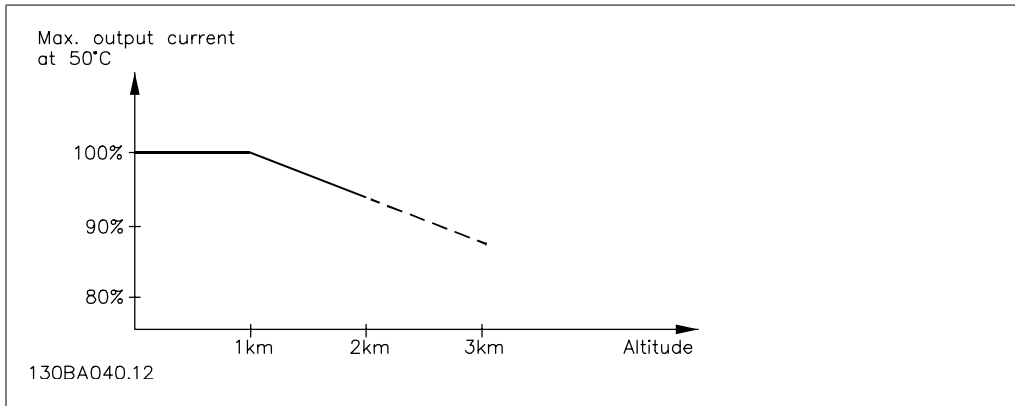
3.8: Derating of I_{out} for different $T_{AMB, MAX}$ for enclosure C, using SFAVM in normal torque mode (110% over-torque)

3.5.3. Derating for Low Air Pressure

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

At altitudes higher than 6,600 feet [2 km], please contact Danfoss Drives regarding PELV.

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



3.9: Derating of output current versus altitude at $T_{AMB, MAX}$. At altitudes higher than 6,600 feet [2 km], please contact Danfoss Drives regarding PELV.

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

3.5.4. 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.

A problem may occur at low RPM values in constant torque applications. The motor fan may not be able to supply the required volume of air for cooling, which limits the torque that can be supported. Therefore, if the motor is to be run continuously at an RPM value lower than half of the rated value, the motor must be supplied with additional air-cooling (or a motor designed for this type of operation may be used).

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

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

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

The adjustable frequency drive has been designed to work using a motor cable with a rated cross-section. If a cable with a larger cross-section is used, reduce the output current by 5% for every step the cross-section is increased.

(Increased cable cross-section leads to increased capacity to ground, and thus an increased ground leakage current).

3.5.6. Automatic adaptations to ensure performance

The adjustable frequency drive constantly checks for critical levels of internal temperature, load current, high voltage on the intermediate circuit and low motor speeds. As a response to a critical level, the adjustable frequency drive can adjust the switching frequency and/or change the switching pattern in order to ensure the performance of the drive. The capability to automatically reduce the output current extends the acceptable operating conditions even further.

3.6. Mechanical Dimension

3

Mechanical dimensions						
Frame size		A2		A3		A5
		0.33-4 hp [0.25-3 kW] (200-240 V) 0.5-5 hp [0.37-4 kW] (380-480 V)		4 hp [3.7 kW] (200-240 V) 7.5-10 hp [5.5-7.5 kW] (380-480 V)		0.33-5 hp [0.25-3.7 kW] (200-240 V) 0.5-10 hp [0.37-7.5 kW] (380-480 V)
IP NEMA		20 Chassis	21 Type 1	20 Chassis	21 Type 1	55/66 Type 12
Height						
Backplate	A	10.53 in [267.5 mm]	14.6 in [370 mm]	10.53 in [267.5 mm]	14.6 in [370 mm]	16.5 in [420 mm]
With de-coupling plate	A	373.79	-	373.79	-	-
Distance between mounting holes	a	10.1 in [257 mm]	13.8 in [350 mm]	10.1 in [257 mm]	13.8 in [350 mm]	15.8 in [402 mm]
Width						
Backplate	B	3.5 in [90 mm]	3.5 in [90 mm]	5.1 in [130 mm]	5.1 in [130 mm]	9.5 in [242 mm]
Backplate with one C option	B	5.1 in [130 mm]	5.1 in [130 mm]	6.7 in [170 mm]	6.7 in [170 mm]	9.5 in [242 mm]
Backplate with two C options	B	5.9 in [150 mm]	5.9 in [150 mm]	7.5 in [190 mm]	7.5 in [190 mm]	9.5 in [242 mm]
Distance between mounting holes	b	2.8 in [70 mm]	2.8 in [70 mm]	4.3 in [110 mm]	4.3 in [110 mm]	8.5 in [215 mm]
Depth						
Without option A/B	C	8.1 in [205 mm]	8.1 in [205 mm]	8.1 in [205 mm]	8.1 in [205 mm]	7.9 in [200 mm]
With option A/B	C	8.6 in [219 mm]	8.7 in [220 mm]	8.6 in [219 mm]	8.6 in [219 mm]	7.9 in [200 mm]
Without option A/B	D		8.2 in [207 mm]		8.2 in [207 mm]	-
With option A/B	D		8.7 in [222 mm]		8.7 in [222 mm]	-
Screw holes						
	c	0.32 in [8.0 mm]	0.32 in [8.0 mm]	0.32 in [8.0 mm]	0.32 in [8.0 mm]	0.33 in [8.25 mm]
	d	ø0.43 in [11 mm]	ø0.43 in [11 mm]	ø0.43 in [11 mm]	ø0.43 in [11 mm]	ø0.47 in [12 mm]
	e	ø0.22 in [5.5 mm]	ø0.22 in [5.5 mm]	ø0.22 in [5.5 mm]	ø0.22 in [5.5 mm]	ø0.26 in (6.5 mm)
	f	0.35 in [9 mm]	0.35 in [9 mm]	0.35 in [9 mm]	0.35 in [9 mm]	0.35 in [9 mm]
Max weight		10.8 lbs [4.9 kg]	11.7 lbs [5.3 kg]	14.6 lbs [6.6 kg]	15.4 lbs [7.0 kg]	29.8/31.3 lbs [13.5/14.2 kg]

Mechanical dimensions					
Frame size		B1	B2	C1	C2
		7.5-10 hp [5.5-7.5 kW] (200-240 V) 15-25 hp [11-18.5 kW] (380-480 V)	15-20 hp [11-15 kW] (200-240 V) 30-40 hp [22-30 kW] (380-480 V)	25-30 hp [18.5-22 kW] (200-240 V) 50-75 hp [37-55 kW] (380-480 V)	40-60 hp [30-45 kW] (200-240 V) 100-125 hp [75-90 kW] (380-480 V)
IP		21/ 55/66	21/55/66	21/55/66	21/55/66
NEMA		Type 1/ Type 12	Type 1/ Type 12	Type 1/ Type 12	Type 1/ Type 12
Height					
Backplate	A	18.93 in [480.8 mm]	25.6 in [650 mm]	26.8 in [680 mm]	30.3 in [770 mm]
With de-coupling plate	A	-	-	-	-
Distance between mounting holes	a	17.9 in [454 mm]	24.6 in [624 mm]	25.5 in [648 mm]	29.1 in [739 mm]
Width					
Backplate	B	9.5 in [242 mm]	9.5 in [242 mm]	12.1 in [308 mm]	14.6 in [370 mm]
Backplate with one C option	B	9.5 in [242 mm]	9.5 in [242 mm]	12.1 in [308 mm]	14.6 in [370 mm]
Backplate with two C options	B	9.5 in [242 mm]	9.5 in [242 mm]	12.1 in [308 mm]	14.6 in [370 mm]
Distance between mounting holes	b	8.3 in [210 mm]	8.3 in [210 mm]	10.7 in [272 mm]	13.2 in [334 mm]
Depth					
Without option A/B	C	10.26 in [260.5 mm]	10.26 in [260.5 mm]	12.2 in [310 mm]	13.2 in [335 mm]
With option A/B	C	10.26 in [260.5 mm]	10.26 in [260.5 mm]	12.2 in [310 mm]	13.2 in [335 mm]
Without option A/B	D	-	-	-	-
With option A/B	D	-	-	-	-
Screw holes					
	c	0.47 in [12 mm]	0.47 in [12 mm]	0.47 in [12 mm]	0.47 in [12 mm]
	d	ø0.75 in [19 mm]	ø0.75 in [19 mm]	ø0.75 in [19 mm]	ø0.75 in [19 mm]
	e	ø0.35 in [9 mm]	ø0.35 in [9 mm]	ø0.39 in [9.8 mm]	ø0.39 in [9.8 mm]
	f	0.35 in [9 mm]	0.35 in [9 mm]	0.69 in [17.6 mm]	0.71 in [18 mm]
Max weight		50.7 lbs [23 kg]	59.5 lbs [27 kg]	94.8 lbs [43 kg]	134.5 lbs [61 kg]

3.7. Options and Accessories

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

3.7.1. Mounting Option Modules in Slot B

The power to the adjustable frequency drive must be disconnected.

For A2 and A3 enclosures:

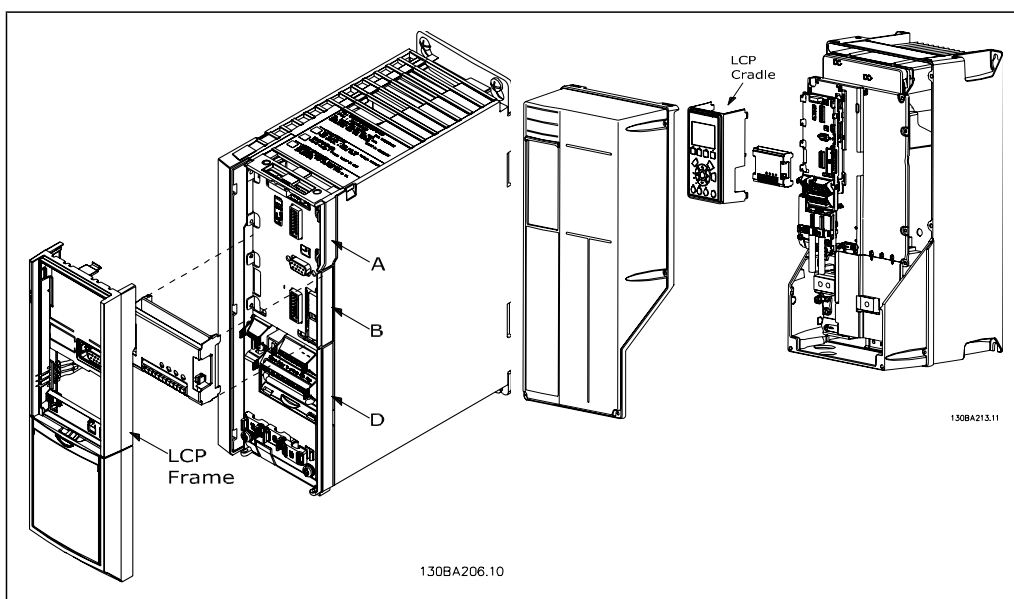
- Remove the LCP (Local Control Panel), the terminal cover and the LCP frame from the adjustable frequency drive.
- Insert the MCB10x option card into slot B.
- Connect the control cables and fasten the cables with the enclosed cable strips.

Remove the knock-out in the extended LCP frame delivered in the option set, so that the option will fit under the extended LCP frame.

- Fit the extended LCP frame and terminal cover.
- Fit the LCP or blind cover in the extended LCP frame.
- Connect power to the adjustable frequency drive.
- Set up the input/output functions in the corresponding parameters, as mentioned in the section *General Technical Data*.

For B1, B2, C1 and C2 enclosures:

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



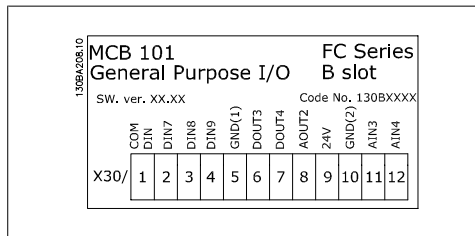
A2 and A3 enclosures	A5, B1, B2, C1 and C2 enclosures
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3.7.2. General Purpose Input Output Module MCB 101

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

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

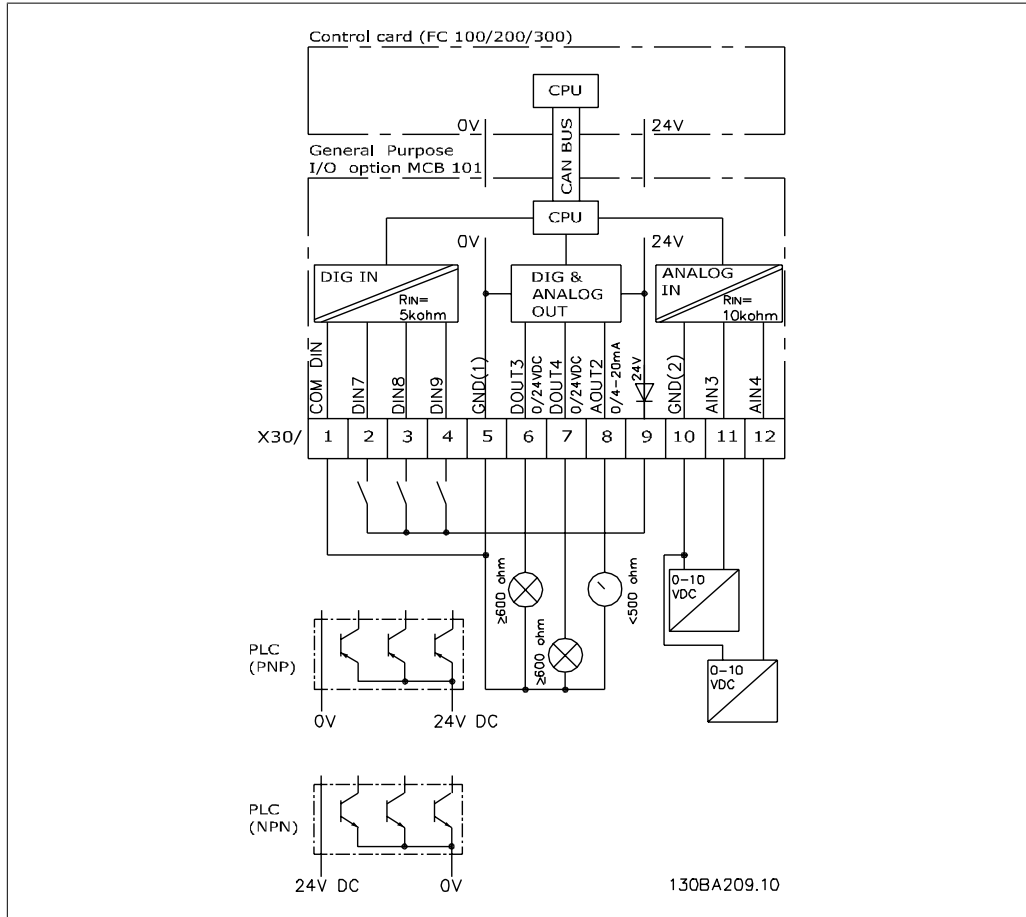
- MCB 101 option module
- Extended LCP frame
- Terminal cover



Galvanic Isolation in the MCB 101

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

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



3.10: Principle Diagram

3.7.3. Digital inputs - Terminal X30/1-4

Parameters for set-up: 5-16, 5-17 and 5-18				
Number of digital inputs	Voltage level	Voltage levels	Input impedance	Max. load
3	0-24 V DC	PNP type: Common = 0 V Logic "0": Input < 5 V DC Logic "1": Input > 10 V DC NPN type: Common = 24 V Logic "0": Input > 19 V DC Logic "1": Input < 14 V DC	Approximately 5 K ohm	± 28 V continuous ± 37 V in minimum 10 sec.

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

Parameters for set-up: 6-3*, 6-4* and 16-76				
Number of analog voltage inputs	Standardized input signal	Input impedance	Resolution	Max. load
2	0-10 V DC	Approximately 5 K ohm	10 bits	± 20 V continuously

3.7.5. Digital outputs - Terminal X30/5-7

Parameters for set-up: 5-32 and 5-33			
Number of digital outputs	Output level	Tolerance	Max. load
2	0 or 24 V DC	± 4 V	≥ 600 ohm

3.7.6. Analog outputs - Terminal X30/5+8

Parameters for set-up: 6-6* and 16-77			
Number of analog outputs	Output signal level	Tolerance	Max. load
1	0/4 - 20 mA	± 0.1 mA	< 500 ohm

3.7.7. Relay Option MCB 105

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

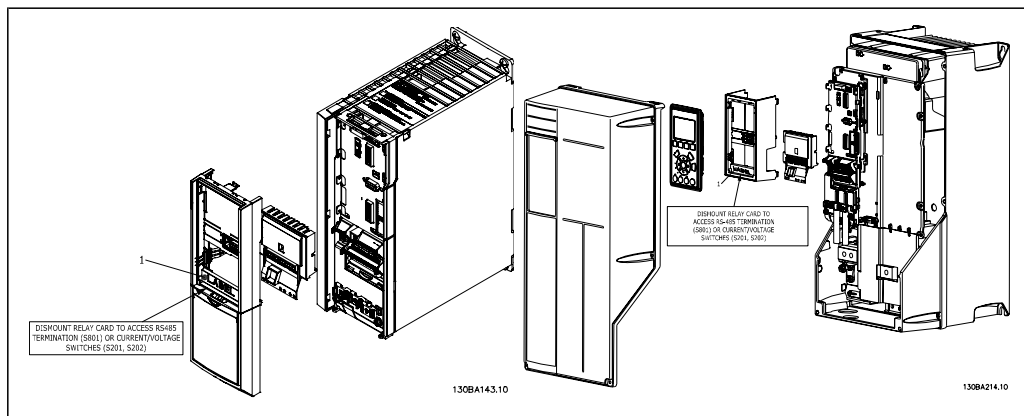
Electrical Data:

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

1) IEC 947 part 4 and 5

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

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



A2-A3 A5-C2

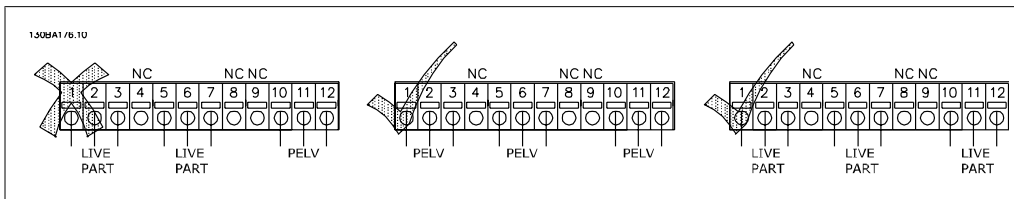
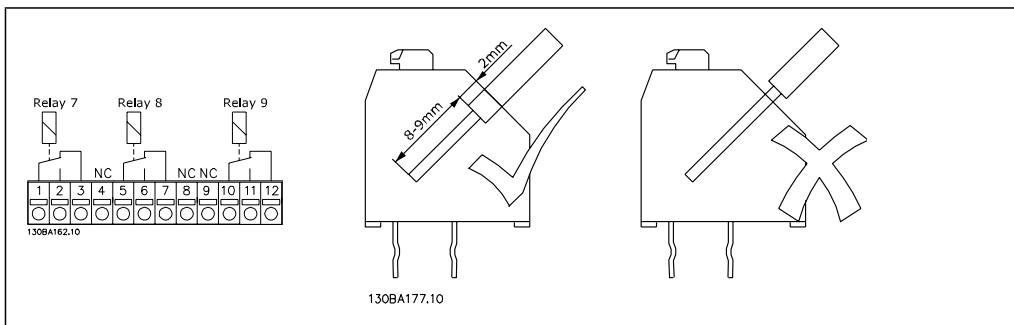
IMPORTANT 1. The label **MUST** be placed on the LCP frame as shown (UL-approved).

Warning Dual supply

How to add the MCB 105 option:

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

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



Do not combine low voltage parts and PELV systems.

3.7.8. 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.

External 24 V DC supply specification:

Input voltage range	24 V DC ±15% (max. 37 V in 10 s)
Max. input current	2.2 A
Average input current for the adjustable frequency drive	0.9 A
Max. cable length	246 ft [75 m]
Input capacitance load	< 10 uF
Power-up delay	< 0.6 s
The inputs are protected.	

Terminal numbers:

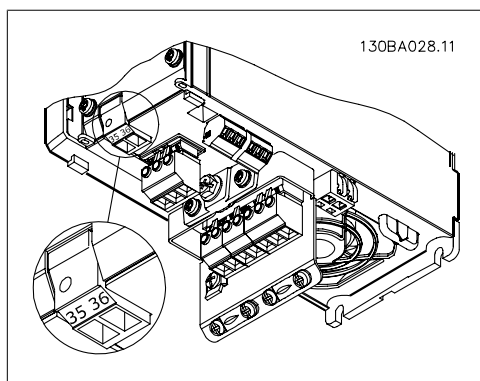
Terminal 35: - external 24 V DC supply.

Terminal 36: + external 24 V DC supply.

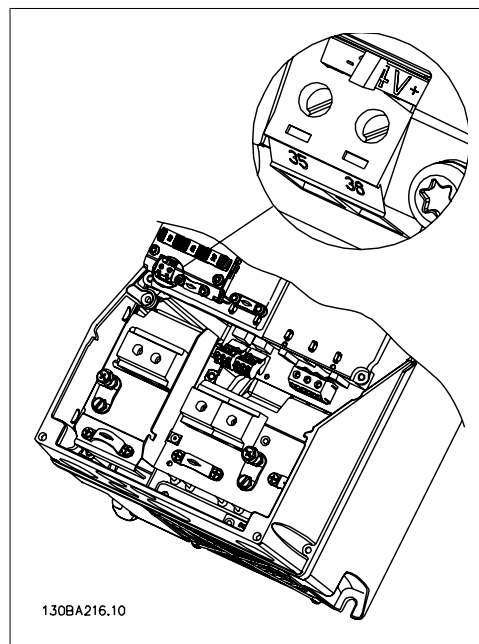
Follow these steps:

1. Remove the LCP or blind cover.
2. Remove the terminal cover.
3. Remove the cable 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 decoupling plate.
6. Attach the terminal cover and the LCP or blind cover.

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



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

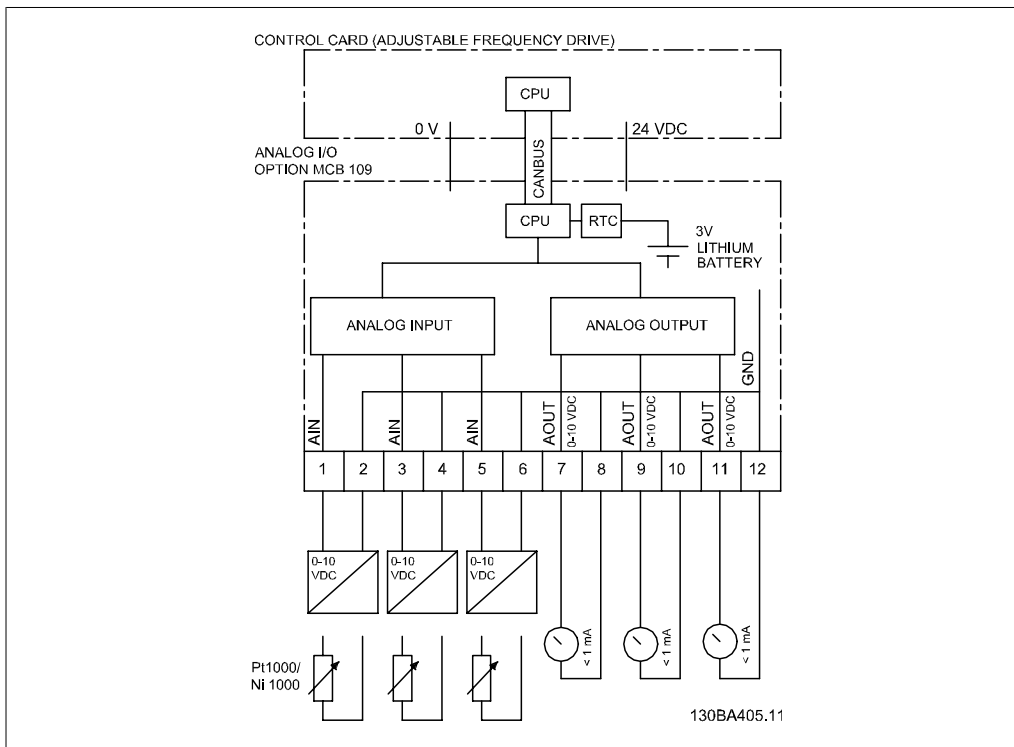


3.12: Connection to 24 V back-up supplier (A5-C2).

3.7.9. Analog I/O option MCB 109

The Analog I/O card should be used for the following:

- Providing battery back-up of clock function on control card
- As a general extension of analog I/O selection available on a control card, such as for multi-zone control with three pressure transmitters.
- Turning the adjustable frequency drive into a decentral I/O block supporting the Building Management System with inputs for sensors and outputs for operating dampers and valve switches.
- Support Extended PID controllers with I/Os for set point inputs, transmitter/sensor inputs and outputs for switches.



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

Analog I/O configuration

3 x analog inputs, capable of handling following:

- 0-10 V DC

OR

- 0-20 mA (voltage input 0-10V) by mounting a 510Ω resistor across terminals (see NB!)
- 4-20 mA (voltage input 2-10 V) by mounting a 510Ω resistor across terminals (see NB!)
- Ni1000 temperature sensor of 1000 Ω at 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.

NOTE

Please note the values available within the different standard groups of resistors:

E12: Closest standard value is 470Ω, creating an input of 449.9Ω and 8.997 V.

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

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

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

Analog inputs - terminal X42/1-6

Parameter group for read out: 18-3* See also VLT® AQUA Drive Programming Guide, MG200XY

Parameter groups for set-up: 26-0*, 26-1*, 26-2* and 26-3* See also **VLT® AQUA Drive Programming Guide, MG200XY**

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

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

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

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

When operating with temperature sensors, the maximum cable length to connect sensors is 262 ft [80 m] with non-shielded/non-twisted wires.

Analog outputs - terminal X42/7-12

Parameter group for read out and write: 18-3* See also **VLT® AQUA Drive Programming Guide, MG200XY**

Parameter groups for set-up: 26-4*, 26-5* and 26-6* See also **VLT® AQUA Drive Programming Guide, MG200XY**

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

Analog outputs are scalable by parameters for each output.

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

For a more detailed description of parameters, please refer to the **VLT® AQUA Drive Programming Guide, MG200XY**

Real-time clock (RTC) with back-up

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

Accuracy of clock is better than ± 20 ppm at 77° F [25° C].

On average, the built-in lithium back-up battery lasts a minimum of 10 years when the adjustable frequency drive is operating at an ambient temperature of 104° F [40° C]. If the battery back-up pack fails, the analog I/O option must be replaced.

3.7.10. Brake Resistors

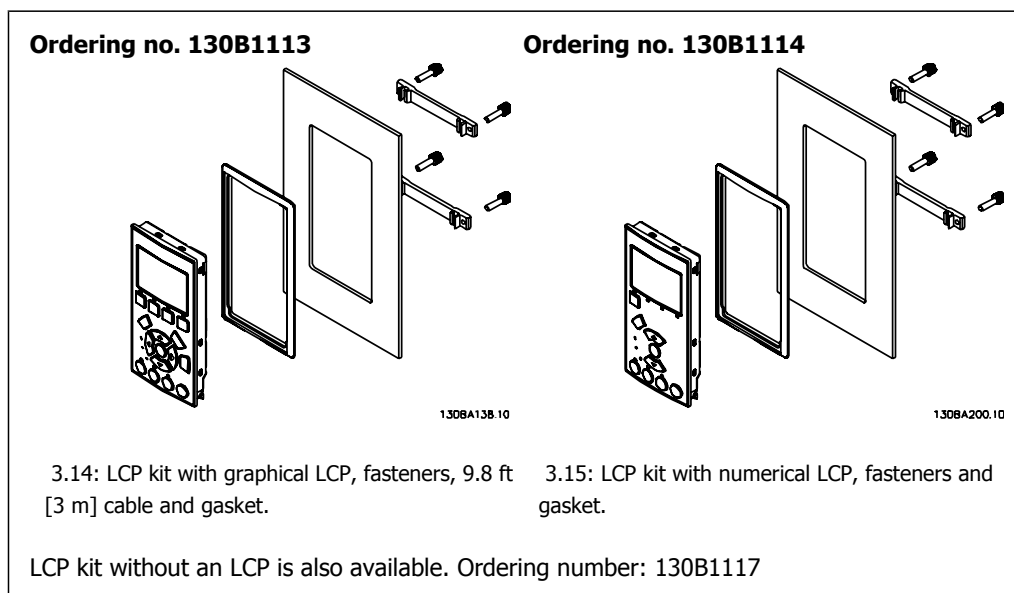
In applications where the motor is used as a brake, energy is generated in the motor and sent back into the adjustable frequency drive. If the energy cannot be transported back to the motor, it will increase the voltage in the drive DC line. In applications with frequent braking and/or high inertia loads,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

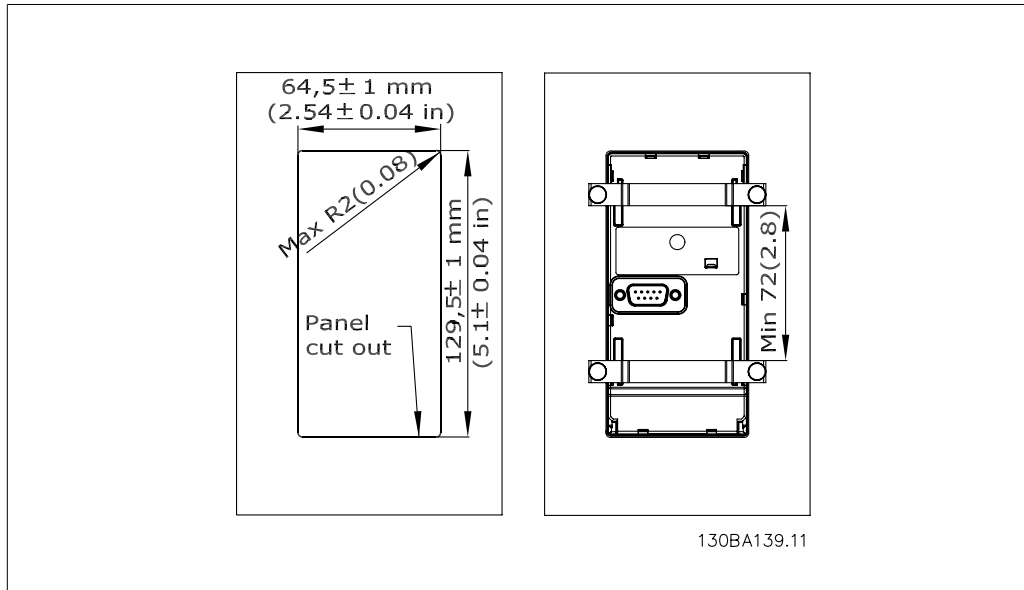
3.7.11. Remote mounting kit for LCP

The local control panel can be moved to the front of a cabinet by using the remote built-in kit. The enclosure is the IP 65. The fastening screws must be tightened with a torque of max. 1 Nm.

Technical data

Enclosure:	IP 65 front
Max. cable length between VLT and unit:	9.8 ft [3 m]
Communication std:	RS 485





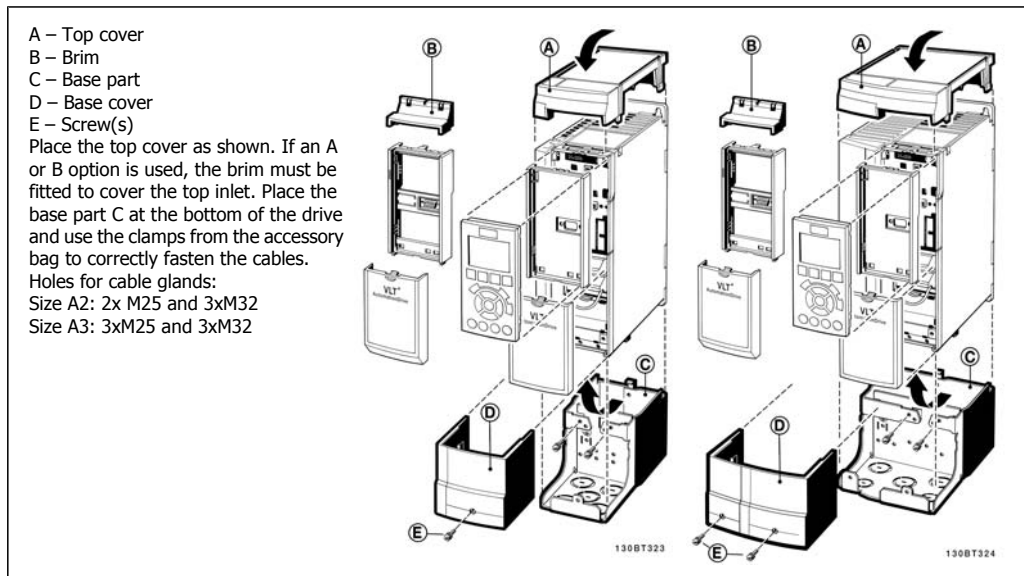
3.7.12. IP 21/IP 4X/ TYPE 1 Enclosure Kit

IP 20/IP 4X top/ TYPE 1 is an optional enclosure element available for IP 20 Compact units, enclosure size A2-A3.

If the enclosure kit is used, an IP 20 unit is upgraded to comply with enclosure IP 21/ 4X top/ TYPE 1.

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

3.7.13. IP 21/Type 1 Enclosure Kit



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

Sine-wave filters

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

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

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

4. How to Order

4.1. Ordering form

4.1.1. Drive Configurator

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

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

FC-202P18KT4E21H1XGCXXXSXXXAGBKCXXXDX

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

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

Use the Internet-based drive configurator to configure the right drive for the right application and generate the type code string. The drive configurator will automatically generate an eight-digit sales number to be delivered to your local sales office.

Furthermore, you can establish a project list with several products and send it to a Danfoss sales representative.

The drive configurator can be found on the Danfoss homepage: www.danfoss.com/drives.

4.1.2. Type Code String

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
FC	-	2	0	2	P					T						H						X	X	S	X	X	X	X	A	B	C							D

130BA484.10

Description	Pos	Possible choice
Product group & VLT Series	1-6	FC 202
Power rating	8-10	0.33-125 hp [0.25-90 kW]
Number of phases	11	Three phases (T)
AC line voltage	11-12	T 2: 200-240 V AC T 4: 380-480 V AC
Enclosure	13-15	E20: IP 20 E21: IP 21/NEMA Type 1 E55: IP 55/NEMA Type 12 E66: IP 66 P21: IP 21/NEMA Type 1 w/backplate P55: IP 55/NEMA Type 12 w/backplate
RFI filter	16-17	H1: RFI filter class A1/B H2: Class A2 H3: RFI filter A1/B (reduced cable length)
Brake	18	X: No brake chopper included B: Brake chopper included T: Safe Stop U: Safe + brake
Display	19	G: Graphical Local Control Panel (GLCP) N: Numeric Local Control Panel (NLCP) X: No Local Control Panel
Coating PCB	20	X: No coated PCB C: Coated PCB
Line option	21	X: No line power disconnect switch 1: With line power disconnect switch (IP55 only)
Adaptation	22	Reserved
Adaptation	23	Reserved
Software release	24-27	Current software
Software language	28	
A options	29-30	AX: No options A0: MCA 101 Profibus DP V1 A4: MCA 104 DeviceNet AG: MCA 108 LON works
B options	31-32	BX: No option BK: MCB 101 General purpose I/O option BP: MCB 105 Relay option BY: MCO 101 Extended Cascade Control
C0 options MCO	33-34	CX: No options
C1 options	35	X: No options
C option software	36-37	XX: Standard software
D options	38-39	DX: No option D0: DC backup

4.1: Type code description.

The various options are described further in the **VLT AQUA Drive Design Guide**.

4.2. Ordering Numbers

4.2.1. Ordering Numbers: Options and Accessories

Type	Description	Ordering no.	
Miscellaneous hardware			
DC link connector	Terminal block for DC link connection on frame size A2/A3	130B1064	
IP 21/4X top/TYPE 1 kit	Enclosure, frame size A2: IP 21/IP 4X Top/TYPE 1	130B1122	
IP 21/4X top/TYPE 1 kit	Enclosure, frame size A3: IP 21/IP 4X Top/TYPE 1	130B1123	
Profibus D-Sub 9	Connector kit for IP 20	130B1112	
Profibus top entry kit	Top entry kit for Profibus connection - only A enclosures	130B0524 ¹⁾	
Terminal blocks	Screw terminal blocks for replacing spring loaded terminals 1 x 10-pin, 1 x 6-pin and 1 x 3-pin connectors	130B1116	
LCP			
LCP 101	Numerical Local Control Panel (NLCP)	130B1124	
LCP 102	Graphical Local Control Panel (GLCP)	130B1107	
LCP cable	Separate LCP cable, 9.8 ft. [3 m]	175Z0929	
LCP kit	Panel mounting kit including graphical LCP, fasteners, 9.8 ft. [3 m] cable and gasket	130B1113	
LCP kit	Panel mounting kit including numerical LCP, fasteners and gasket	130B1114	
LCP kit	Panel mounting kit for all LCPs including fasteners, 9.8 ft. [3 m] cable and gasket	130B1117	
Options for Slot A Uncoated/Coated		Uncoated	Coated
MCA 101	Profibus option DP V0/V1	130B1100	130B1200
MCA 104	DeviceNet option	130B1102	130B1202
MCA 108	LON works	130B1106	130B1206
Options for Slot B			
MCB 101	General purpose Input Output option	130B1125	
MCB 105	Relay option	130B1110	
MCB 109	Analog I/O option	130B1143	130B1243
MCO 101	Extended Cascade Control	130B1118	130B1218
Option for Slot C			
MCO 102	Advanced Cascade Control	130B1154	130B1254
Option for Slot D			
MCB 107	24 V DC back-up	130B1108	130B1208
External Options			
Ethernet IP	Ethernet master	175N2584	
Spare Parts			
Control board VLT AQUA Drive	With Safe Stop Function	130B1150	
Control board VLT AQUA Drive	Without Safe Stop Function	130B1151	
Fan A2	Fan, frame size A2	130B1009	
Fan A3	Fan, frame size A3	130B1010	
Fan A5	Fan, frame size A3	130B1017	
Fan B1	Fan external, frame size B1	130B1013	
Fan B2	Fan external, frame size B2	130B1015	
Fan C1	Fan external, frame size C1	130B3865	
Fan C2	Fan external, frame size C2	130B3867	
Accessory bag A2	Accessory bag, frame size A2	130B0509	
Accessory bag A3	Accessory bag, frame size A3	130B0510	
Accessory bag A5	Accessory bag, frame size A5	130B1023	
Accessory bag B1	Accessory bag, frame size B1	130B2060	
Accessory bag B2	Accessory bag, frame size B2	130B2061	
Accessory bag C1	Accessory bag, frame size C1	130B0046	
Accessory bag C2	Accessory bag, frame size C2	130B0047	
1) Only IP 21 / > 14.75 HP [11 kW]			

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

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

4.2.2. Ordering Numbers: Harmonic Filters

Harmonic filters are used to reduce line harmonics.

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


380-415 V, 50 Hz				
I _{AHF,N}	Typical Motor Used [kW]	Danfoss ordering number		Adjustable frequency drive size
		AHF 005	AHF 010	
10 A	4, 5.5	175G6600	175G6622	P4K0, P5K5
19 A	7.5	175G6601	175G6623	P5K5 - P7K5
26 A	11	175G6602	175G6624	P11K
35 A	15, 18.5	175G6603	175G6625	P15K, P18K
43 A	22	175G6604	175G6626	P22K
72 A	30, 37	175G6605	175G6627	P30K - P37K
101A	45, 55	175G6606	175G6628	P45K - P55K
144A	75	175G6607	175G6629	P75K
180A	90	175G6608	175G6630	P90K

440-480 V, 60 Hz				
I _{AHF,N}	Typical Motor Used [HP]	Danfoss ordering number		Adjustable frequency drive size
		AHF 005	AHF 010	
19 A	10, 15	175G6612	175G6634	P7K5
26 A	20	175G6613	175G6635	P15K
35 A	25, 30	175G6614	175G6636	P18K, P22K
43 A	40	175G6615	175G6637	P30K
72A	50, 60	175G6616	175G6638	P30K - P37K
101A	75	175G6617	175G6639	P45K - P55K
144A	100, 125	175G6618	175G6640	P75K - P90K

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.

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

Adjustable frequency drive size			Minimum switching frequency	Maximum output frequency	Part No. IP 20	Part No. IP 00	Rated filter current at 50 Hz
200-240 V	380-440 V	440-500 V					
PK25	PK37	PK37	5 kHz	120 Hz	130B2439	130B2404	2.5 A
PK37	PK55	PK55	5 kHz	120 Hz	130B2439	130B2404	2.5 A
	PK75	PK75	5 kHz	120 Hz	130B2439	130B2404	2.5 A
PK55	P1K1	P1K1	5 kHz	120 Hz	130B2441	130B2406	4.5 A
	P1K5	P1K5	5 kHz	120 Hz	130B2441	130B2406	4.5 A
PK75	P2K2	P2K2	5 kHz	120 Hz	130B2443	130B2408	8 A
P1K1	P3K0	P3K0	5 kHz	120 Hz	130B2443	130B2408	8 A
P1K5			5 kHz	120 Hz	130B2443	130B2408	8 A
	P4K0	P4K0	5 kHz	120 Hz	130B2444	130B2409	10 A
P2K2	P5K5	P5K5	5 kHz	120 Hz	130B2446	130B2411	17 A
P3K0	P7K5	P7K5	5 kHz	120 Hz	130B2446	130B2411	17 A
P4K0			5 kHz	120 Hz	130B2446	130B2411	17 A
P5K5	P11K	P11K	4 kHz	60 Hz	130B2447	130B2412	24 A
P7K5	P15K	P15K	4 kHz	60 Hz	130B2448	130B2413	38 A
	P18K	P18K	4 kHz	60 Hz	130B2448	130B2413	38 A
P11K	P22K	P22K	4 kHz	60 Hz	130B2307	130B2281	48 A
P15K	P30K	P30K	3 kHz	60 Hz	130B2308	130B2282	62 A
P18K	P37K	P37K	3 kHz	60 Hz	130B2309	130B2283	75 A
P22K	P45K	P55K	3 kHz	60 Hz	130B2310	130B2284	115 A
P30K	P55K	P75K	3 kHz	60 Hz	130B2310	130B2284	115 A
P37K	P75K	P90K	3 kHz	60 Hz	130B2311	130B2285	180 A
P45K	P90K	P110	3 kHz	60 Hz	130B2311	130B2285	180 A
	P110	P132	3 kHz	60 Hz	130B2312	130B2286	260 A
	P132	P160	3 kHz	60 Hz	130B2312	130B2286	260 A
	P160	P200	3 kHz	60 Hz	130B2313	130B2287	410 A
	P200	P250	3 kHz	60 Hz	130B2313	130B2287	410 A
	P250	P315	3 kHz	60 Hz	130B2314	130B2288	480 A
	P315	P355	2 kHz	60 Hz	130B2315	130B2289	660 A
	P355	P400	2 kHz	60 Hz	130B2315	130B2289	660 A
	P400	P450	2 kHz	60 Hz	130B2316	130B2290	750 A
	P450	P500	2 kHz	60 Hz	130B2317	130B2291	880 A
	P500	P560	2 kHz	60 Hz	130B2317	130B2291	880 A
	P560	P630	2 kHz	60 Hz	130B2318	130B2292	1200 A
	P630	P710	2 kHz	60 Hz	130B2318	130B2292	1200 A

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

4.2.4. Ordering Numbers:du/dt Filters

Line supply 3x380 to 3x500 V

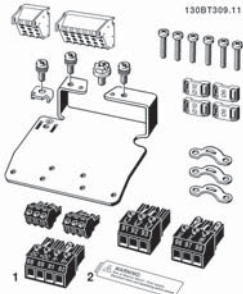
Adjustable frequency drive size		Minimum switching frequency	Maximum output frequency	Part No. IP 20	Part No. IP 00	Rated filter current at 50 Hz
380-440 V	441-500 V					
15 hp [11 kW]	15 hp [11 kW]	4 kHz	60 Hz	130B2396	130B2385	24 A
20 hp [15 kW]	20 hp [15 kW]	4 kHz	60 Hz	130B2397	130B2386	45 A
25 hp [18.5 kW]	25 hp [18.5 kW]	4 kHz	60 Hz	130B2397	130B2386	45 A
30 hp [22 kW]	30 hp [22 kW]	4 kHz	60 Hz	130B2397	130B2386	45 A
40 hp [30 kW]	40 hp [30 kW]	3 kHz	60 Hz	130B2398	130B2387	75 A
50 hp [37 kW]	50 hp [37 kW]	3 kHz	60 Hz	130B2398	130B2387	75 A
60 hp [45 kW]	75 hp [55 kW]	3 kHz	60 Hz	130B2399	130B2388	110 A
75 hp [55 kW]	100 hp [75 kW]	3 kHz	60 Hz	130B2399	130B2388	110 A
100 hp [75 kW]	125 hp [90 kW]	3 kHz	60 Hz	130B2400	130B2389	182 A
125 hp [90 kW]	150 hp [110 kW]	3 kHz	60 Hz	130B2400	130B2389	182 A
150 hp [110 kW]	200 hp [132 kW]	3 kHz	60 Hz	130B2401	130B2390	280 A
200 hp [132 kW]	250 hp [160 kW]	3 kHz	60 Hz	130B2401	130B2390	280 A
250 hp [160 kW]	300 hp [200 kW]	3 kHz	60 Hz	130B2402	130B2391	400 A
300 hp [200 kW]	350 hp [250 kW]	3 kHz	60 Hz	130B2402	130B2391	400 A
350 hp [250 kW]	450 hp [315 kW]	3 kHz	60 Hz	130B2277	130B2275	500 A
450 hp [315 kW]	500 hp [355 kW]	2 kHz	60 Hz	130B2278	130B2276	750 A
500 hp [355 kW]	550 hp [400 kW]	2 kHz	60 Hz	130B2278	130B2276	750 A
550 hp [400 kW]	600 hp [450 kW]	2 kHz	60 Hz	130B2278	130B2276	750 A
600 hp [450 kW]	670 hp [500 kW]	2 kHz	60 Hz	130B2405	130B2393	910 A
670 hp [500 kW]	750 hp [560 kW]	2 kHz	60 Hz	130B2405	130B2393	910 A
750 hp [560 kW]	845 hp [630 kW]	2 kHz	60 Hz	130B2407	130B2394	1500 A
845 hp [630 kW]	950 hp [710 kW]	2 kHz	60 Hz	130B2407	130B2394	1500 A
950 hp [710 kW]	1070 hp [800 kW]	2 kHz	60 Hz	130B2407	130B2394	1500 A
1070 hp [800 kW]	1340 hp [1000 kW]	2 kHz	60 Hz	130B2407	130B2394	1500 A
1340 hp [1000 kW]	1475 hp [1100 kW]	2 kHz	60 Hz	130B2410	130B2395	2300 A

5. How to Install

5.1. Mechanical Installation

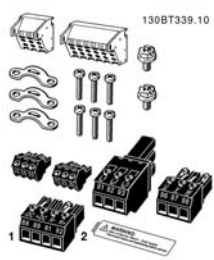
5.1.1. Accessory Bag

The following parts are included in the FC 100/200/300 Accessory Bag.




130BT309.11

Frame sizes A1, A2 and A3
IP20/Chassis



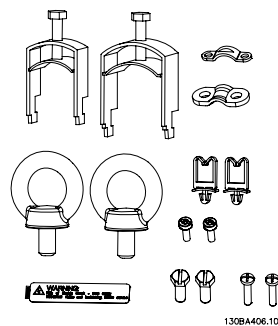
130BT339.10

Frame size A5
IP55/Type 12



130BT330.11

Frame sizes B1 and B2
IP21/IP55/Type 1/Type 12



130BA406.10

Frame sizes C1 and C2
IP55/66/Type 1/Type 12

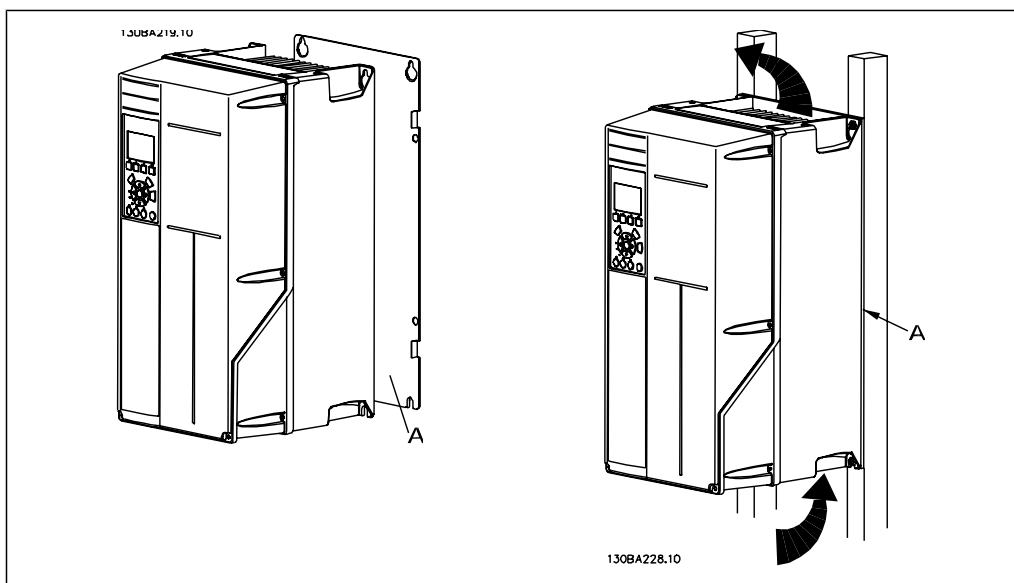
1 + 2 only available in units with brake chopper. Only one relay connector is included for FC 101/202/301 units. For DC link connection (Load sharing), the connector 1 can be ordered separately (Code no 130B1064).
An eight pole connector is included in accessory bag for the FC 101/202/301 without Safe Stop.

5.1.2. Mechanical mounting

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

The adjustable frequency drive allows side-by-side installation. Because of the need for cooling, allow for a minimum of 3.9 in [100 mm] free air passage above and below the adjustable frequency drive.

The back wall must always be solid.



5.1.3. Safety Requirements of Mechanical Installation



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

The adjustable frequency drive is cooled by air circulation.

To protect the unit from overheating, it must be ensured that the ambient temperature *does not exceed the maximum temperature stated for the adjustable frequency drive*, and that the 24-hour average temperature *is not exceeded*. Locate the maximum temperature and 24-hour average in the paragraph *Derating for Ambient Temperature*.

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

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

5.1.4. Field Mounting

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

5.2. Electrical Installation

5.2.1. Cables General


NOTE

Cables General

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

Details of terminal tightening torques.

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

5.1: Tightening of terminals.

5.2.2. Removal of Knockouts for Extra Cables

1. Remove the cable entry from the adjustable frequency drive (avoid foreign parts entering the adjustable frequency drive when removing knockouts).
2. The cable entry must be supported around the knockout you intend to remove.
3. The knockout can now be removed with a strong mandrel and a hammer.
4. Remove burrs from the hole.
5. Mount cable entry on adjustable frequency drive.

5.2.3. Connection to Line Power and Grounding


NOTE

The plug connector for power can be removed.

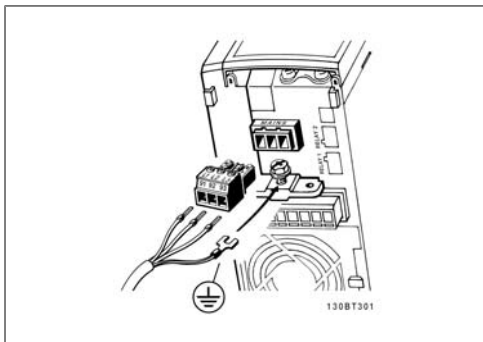
1. Make sure the adjustable frequency drive is properly grounded. Connect to ground connection (terminal 95). Use the screw from the accessory bag.

2. Place plug connector 91, 92, 93 from the accessory bag onto the terminals labeled LINE at the bottom of the adjustable frequency drive.
3. Connect line power wires to the line plug connector.

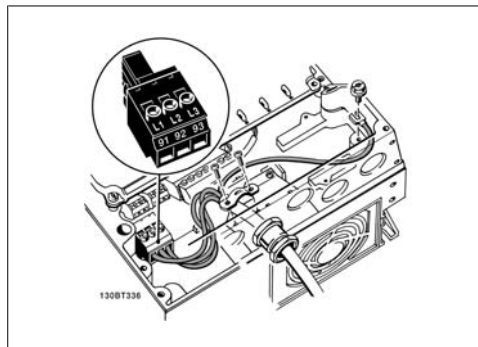
! The ground connection cable cross-section must be at least 0.016 in.² [10 mm²] or have 2 rated line supply wires terminated separately according to EN 50178.

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

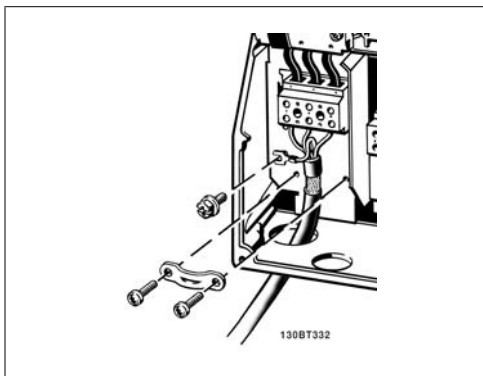
5



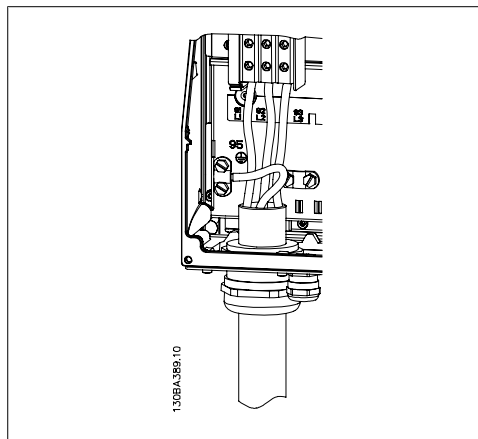
5.1: How to connect to the line supply and grounding (A2 and A3 enclosure).



5.2: How to connect to the line supply and grounding (A5 enclosure).




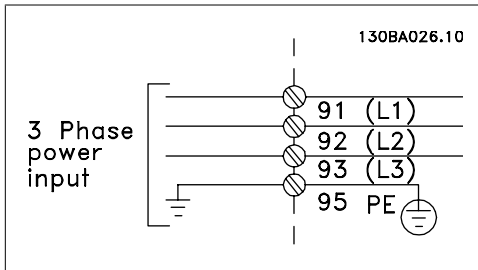
5.3: How to connect to the line supply and grounding (B1 and B2 enclosure).



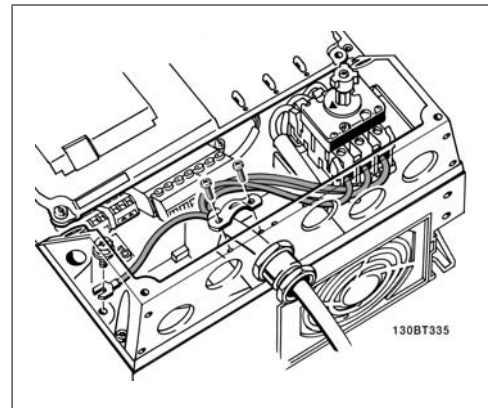
5.4: How to connect to the line supply and grounding (C1 and C2 enclosure).

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

 **IT Line**
 Do not connect 400 V adjustable frequency drives with RFI filters to line supplies with a voltage between phase and ground of more than 440 V. For IT lines and delta ground (grounded leg), line voltage may exceed 440 V between phase and ground.




5.5: Terminals for line supply and grounding.

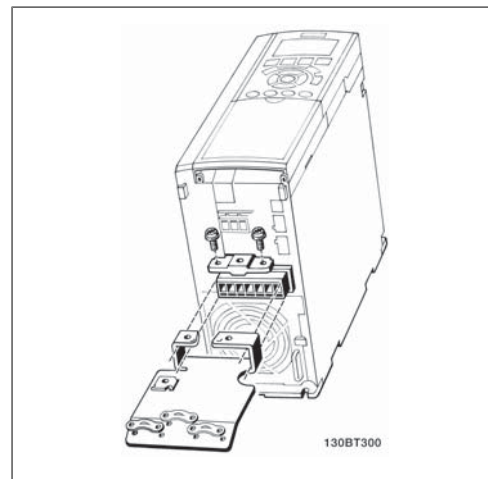


5.6: How to connect to the line supply and grounding with disconnecter (A5 enclosure).

5.2.4. Motor Connection

 **NOTE**
 Motor cable must be shielded/armored. The use of an unshielded/unarmored cable is against EMC requirements. For more information, see *EMC specifications*.

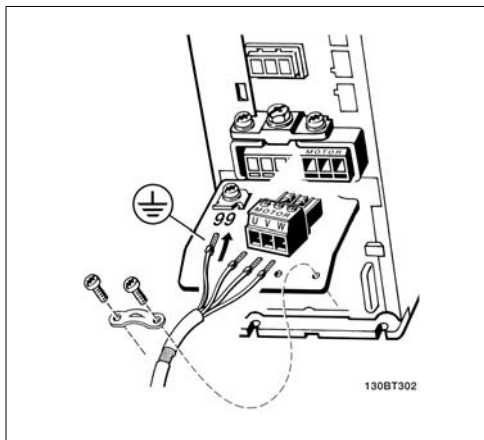
1. Fasten a decoupling plate to the bottom of the adjustable frequency drive with screws and washers from the accessory bag.



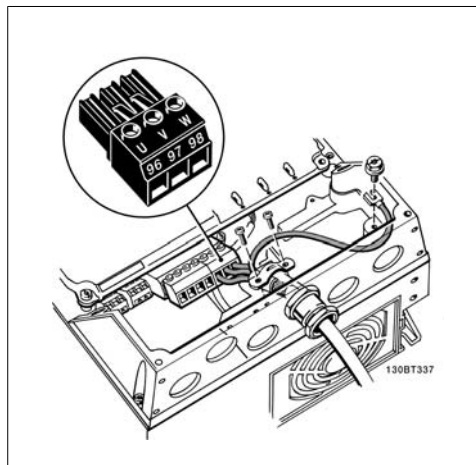
5.7: Mounting of decoupling plate

2. Attach the motor cable to terminals 96 (U), 97 (V), 98 (W).
3. Connect to ground connection (terminal 99) on decoupling plate with screws from the accessory bag.

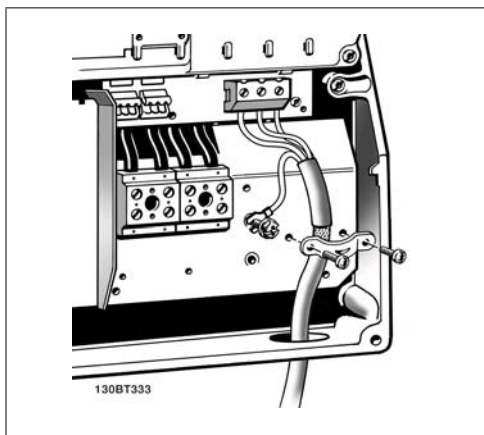
4. Insert terminals 96 (U), 97 (V), 98 (W) and motor cable to terminals labeled MOTOR.
5. Fasten shielded cable to the decoupling plate with screws and washers from the accessory bag.



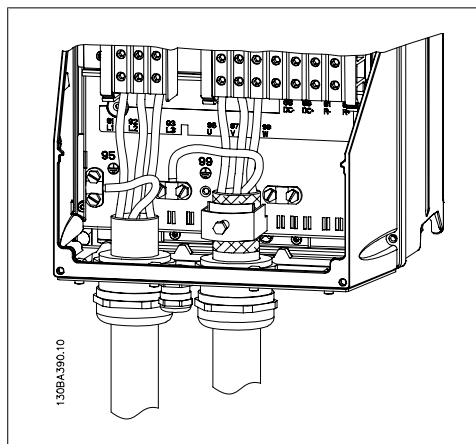
5.8: Motor connection for enclosures A2 and A3



5.9: Motor connection for enclosure A5

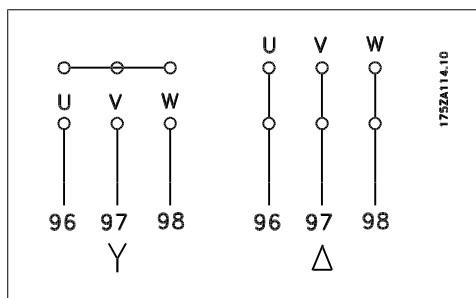


5.10: Motor connection for enclosure B1 and B2



5.11: Motor connection for enclosure C1 and C2

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



NOTE
 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.

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

5.2.5. Motor Cables

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

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

5.2.6. Electrical Installation of Motor Cables

Shielding of cables

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

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

Cable length and cross-section

The adjustable frequency drive has been tested with a given length of cable and a given cross-section of that cable. If the cross-section is increased, the cable capacitance - and thus the leakage current - may increase, thereby requiring that the cable length is reduced accordingly.

Switching frequency

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

Aluminum conductors

Aluminum conductors are not recommended. Terminals can accept aluminum conductors, but the conductor surface has to be clean, oxidation must be removed, and the area must be sealed by neutral acid-free Vaseline grease before the conductor is connected.

Furthermore, the terminal screw must be retightened after two days due to the softness of the aluminum. It is crucial to keep the connection a gas-tight joint, otherwise the aluminum surface will oxidize again.

5.2.7. Fuses

Branch circuit protection:

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

Short circuit protection:

The adjustable frequency drive must be protected against short circuit in order to prevent electrical or fire hazard. Danfoss recommends using the fuses mentioned in tables 4.3 and 4.4 in order to protect service personnel and equipment in case of an internal failure in the unit. The adjustable frequency drive provides full short circuit protection in case of a short circuit in the motor output.

Overcurrent protection:

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

Non-UL compliance

If UL/cUL is not to be complied with, Danfoss recommends using the fuses mentioned in table 4.2, which will ensure compliance with EN50178:

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

VLT AQUA	Max. fuse size	Voltage	Type
200-240 V			
K25-1K1	16A ¹	200-240 V	type gG
1K5	16A ¹	200-240 V	type gG
2K2	25A ¹	200-240 V	type gG
3K0	25A ¹	200-240 V	type gG
3K7	35A ¹	200-240 V	type gG
5K5	50A ¹	200-240 V	type gG
7K5	63A ¹	200-240 V	type gG
11K	63A ¹	200-240 V	type gG
15K	80A ¹	200-240 V	type gG
18K5	125A ¹	200-240 V	type gG
22K	125A ¹	200-240 V	type gG
30K	160A ¹	200-240 V	type gG
37K	200A ¹	200-240 V	type aR
45K	250A ¹	200-240 V	type aR
380-500 V			
11K	63A ¹	380-480 V	type gG
15K	63A ¹	380-480 V	type gG
18K	63A ¹	380-480 V	type gG
22K	63A ¹	380-480 V	type gG
30K	80A ¹	380-480 V	type gG
37K	100A ¹	380-480 V	type gG
45K	125A ¹	380-480 V	type gG
55K	160A ¹	380-480 V	type gG
75K	250A ¹	380-480 V	type aR
90K	250A ¹	380-480 V	type aR

5.2: Non-UL fuses 200 V to 500 V

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

UL Compliance

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

5.3: UL fuses 200-240 V

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

5.4: UL fuses 380-600 V

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

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

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

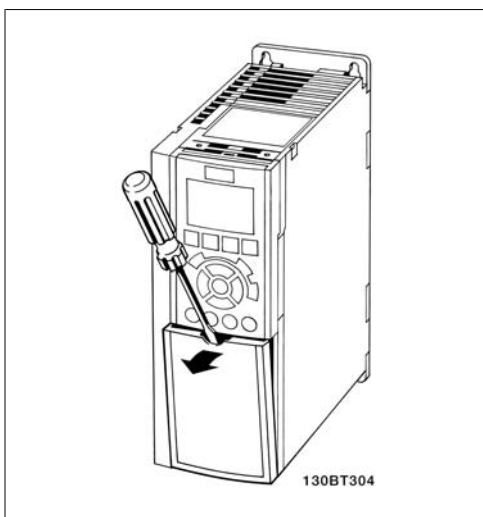
L50S fuses from LITTEL FUSE may substitute for L50S fuses in 240 V adjustable frequency drives.

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

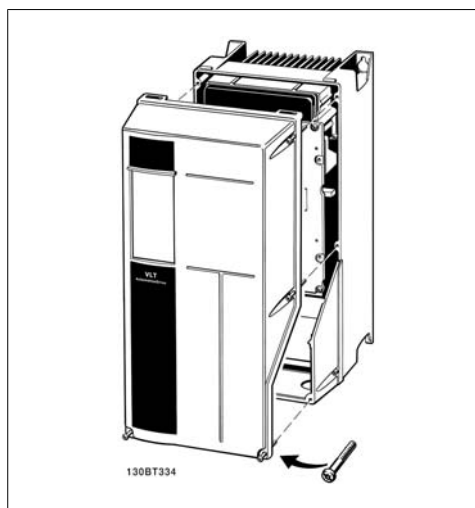
A50X fuses from FERRAZ SHAWMUT may substitute for A25X in 240 V adjustable frequency drives.

5.2.8. Access to Control Terminals

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



5.12: A1, A2 and A3 enclosures

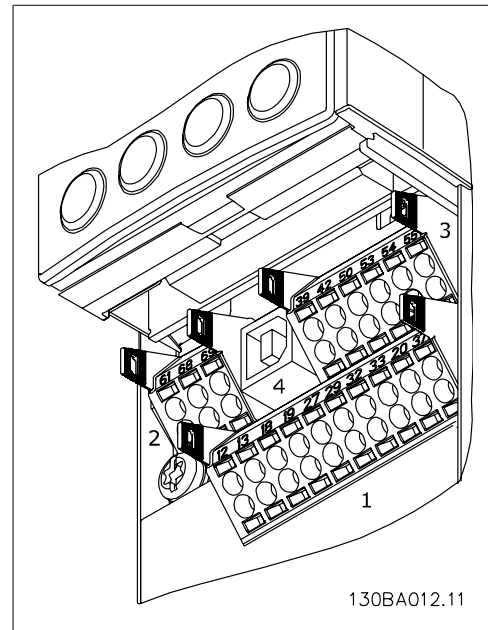


5.13: A5, B1, B2, C1 and C2 enclosures

5.2.9. Control Terminals

Drawing reference numbers:

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



5.14: Control terminals (all enclosures)

5.2.10. Electrical Installation, Control Terminals

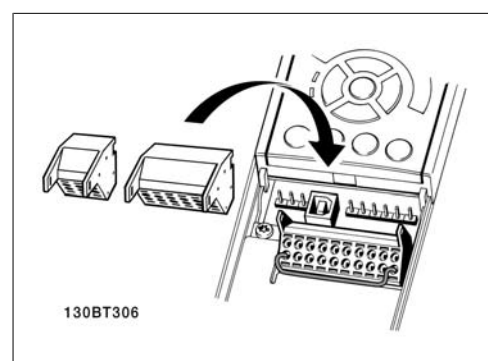
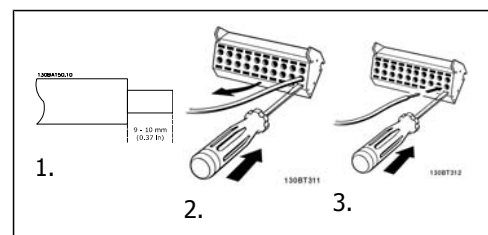
To mount the cable to the terminal:

1. Strip isolation of 0.34-0.39 in [9-10 mm]
2. Insert a screw driver¹⁾ in the square hole.
3. Insert the cable in the adjacent circular hole.
4. Remove the screwdriver. The cable is now mounted to the terminal.

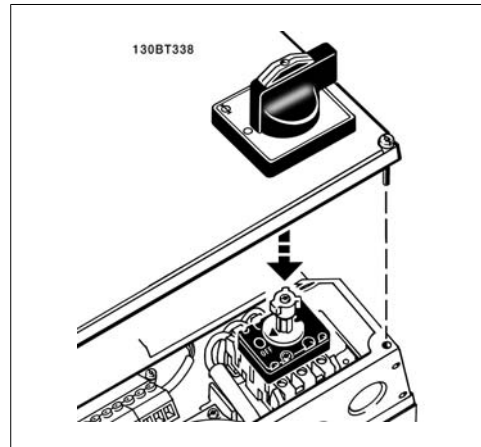
To remove the cable from the terminal:

1. Insert a screw driver¹⁾ in the square hole.
2. Pull out the cable.

¹⁾ Max. 0.015 x 0.1 in. [0.4 x 2.5 mm]



Assembling of IP55 / NEMA TYPE 12 housing with line power disconnector

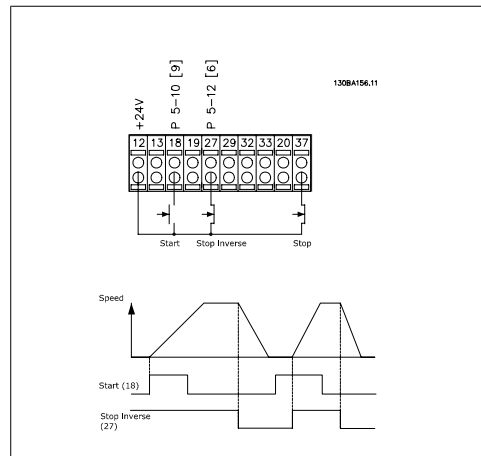


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5.2.11. Basic Wiring Example

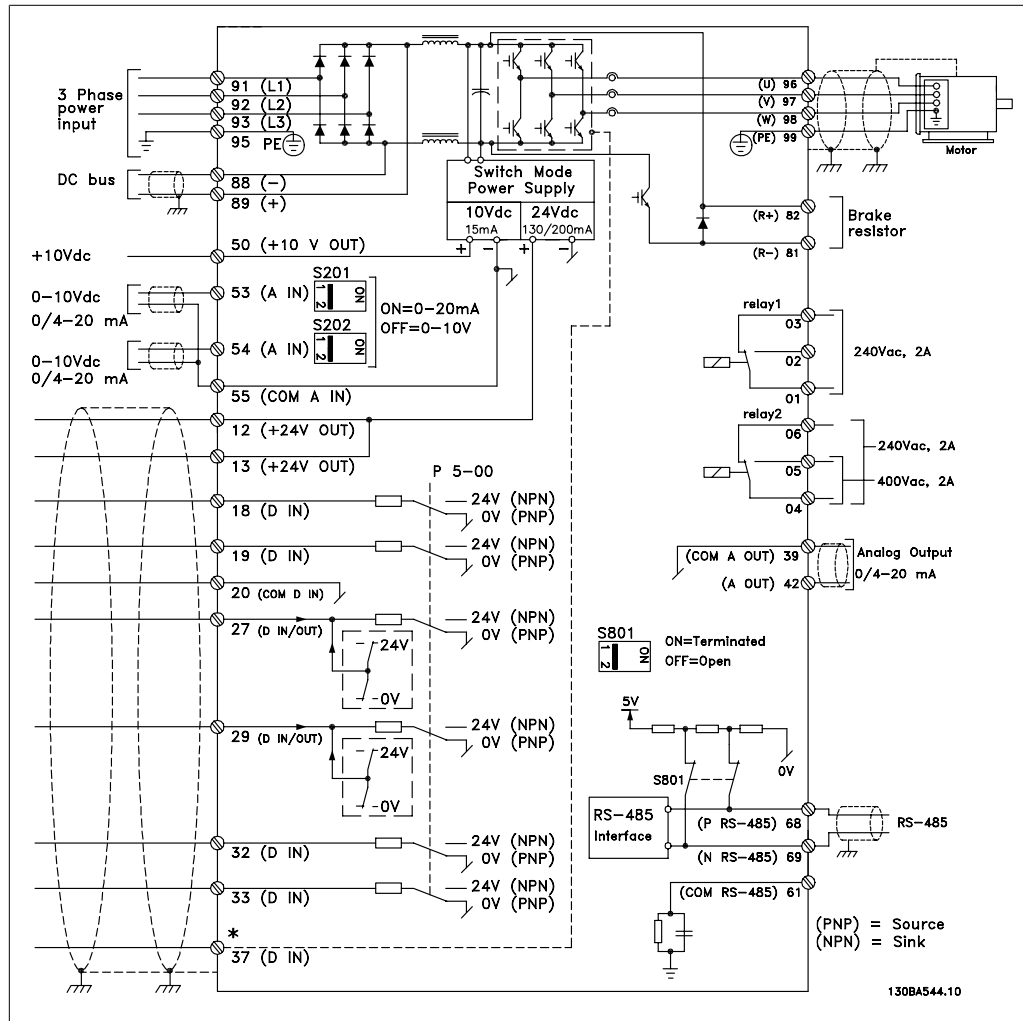
1. Mount terminals from the accessory bag to the front of the adjustable frequency drive.
2. Connect terminals 18 and 27 to +24 V (terminal 12/13)

Default settings:
 18 = Start
 27 = stop inverse



5.15: Terminal 37 available with Safe Stop Function only!

5.2.12. Electrical Installation, Control Cables



5.16: Terminal 37: Safe Stop input available with Safe Stop Function only!

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

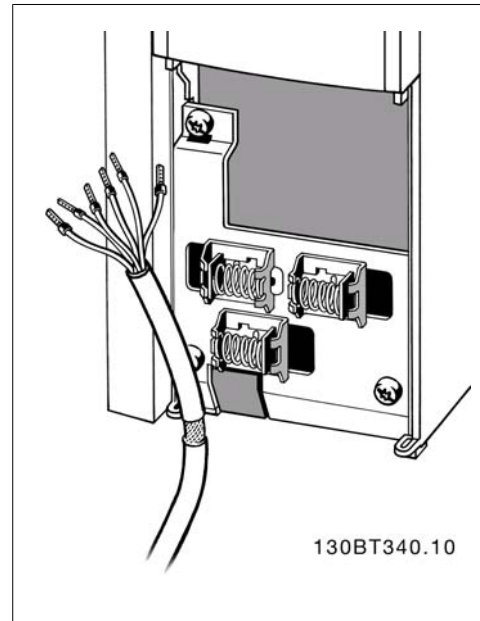
If this occurs, you may have to break the shield or insert a 100 nF capacitor between shield and chassis.

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

NOTE
Control cables must be shield/armored.

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

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



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5.2.13. Switches S201, S202, and S801

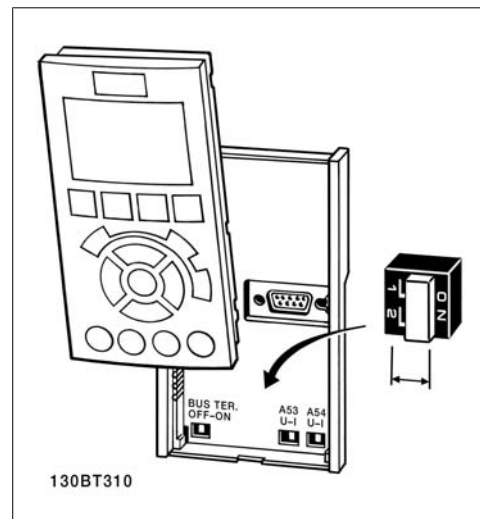
Switches S201 (A53) and S202 (A54) are used to select a current (0-20 mA) or a voltage (0 to 10 V) configuration for the analog input terminals 53 and 54, respectively.

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

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

Default setting:

- S201 (A53) = OFF (voltage input)
- S202 (A54) = OFF (voltage input)
- S801 (Bus termination) = OFF



5.3. Final Set-Up and Test

5.3.1. Final Set-Up and Test

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

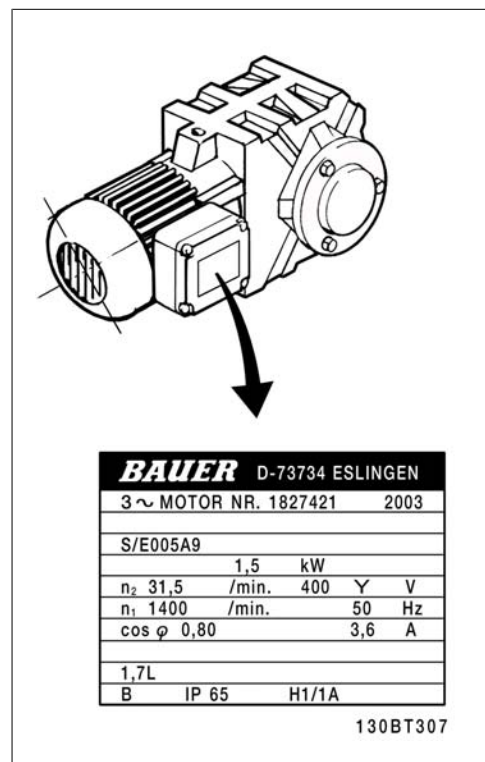
Step 1. Locate the motor nameplate.

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

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

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

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



Step 3. Activate the Automatic Motor Adaptation (AMA)

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

1. Connect terminal 27 to terminal 12, or set par. 5-12 to 'No function' (par. 5-12 [0])
2. Activate the AMA par. 1-29.
3. Choose between complete or reduced AMA. If an LC filter is mounted, run only the reduced AMA, or remove the LC filter during the AMA procedure.
4. Press the [OK] key. The display shows "Press [Hand on] to start."

5. Press the [Hand on] key. A progress bar indicates if the AMA is in progress.

Stop the AMA during operation.

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

Successful AMA

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

Unsuccessful AMA

1. The adjustable frequency drive enters into alarm mode. A description of the alarm can be found in the *Troubleshooting* section.
2. "Report Value" in the [Alarm Log] shows the last measuring sequence carried out by the AMA before the adjustable frequency drive entered alarm mode. This number, along with the description of the alarm, will assist you in troubleshooting. If you contact Danfoss Service, make sure to mention both the number and the alarm description.

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

Step 4. Set speed limit and ramp time

Set up the desired limits for speed and ramp time.

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

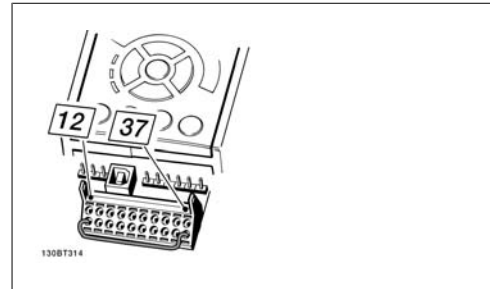
Motor Speed Low Limit	par. 4-11 or 4-12
Motor Speed High Limit	par. 4-13 or 4-14

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

5.4.1. Safe Stop Installation

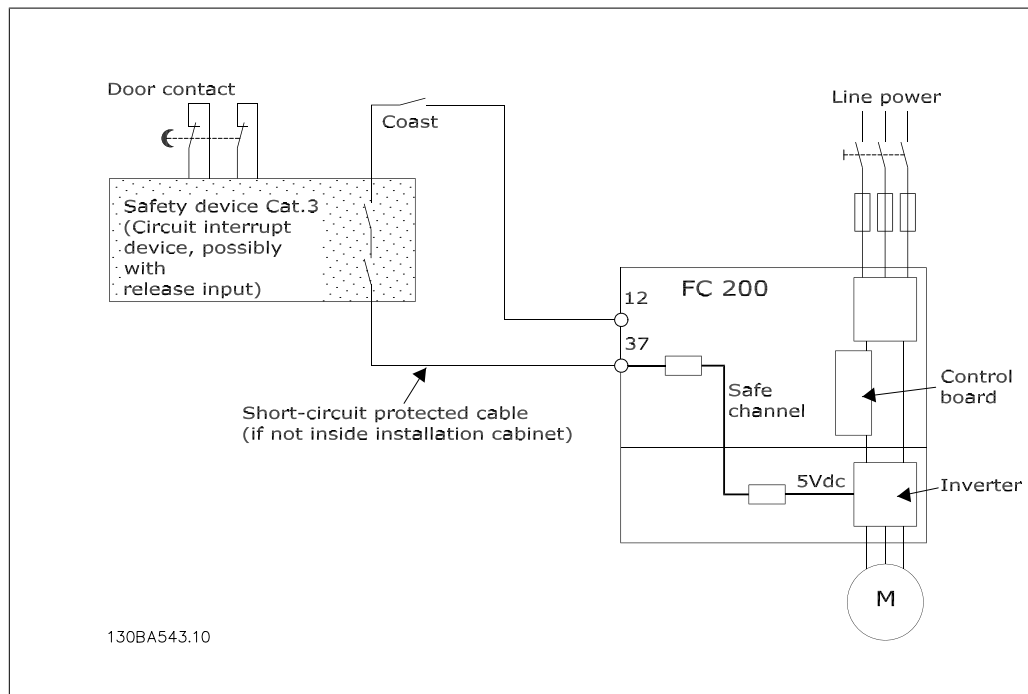
To carry out an installation of a Category 0 Stop (EN60204) in accordance with Safety Category 3 (EN954-1), follow these instructions:

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



5.17: Bridge jumper between terminal 37 and 24 V DC.

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



5.18: Illustration of the essential aspects of an installation to achieve a stopping category 0 (EN 60204-1) with safety cat. 3 (EN 954-1).

5.4.2. Safe Stop Commissioning Test

After installation and before first operation, perform a commissioning test of an installation or application making use of the FC 200 Safe Stop.

Moreover, perform the test after each modification of the installation or application, which the FC 200 Safe Stop is part of.

The commissioning test:

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

5.5. Additional Connections

5.5.1. DC bus connection

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

Terminal numbers: 88, 89

Please contact Danfoss if you require further information.

5.5.2. Brake Connection Option

The connection cable to the brake resistor must be shielded/armored.


No	81	82	Brake resistor
	R-	R	terminals
		+	




NOTE

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

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



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

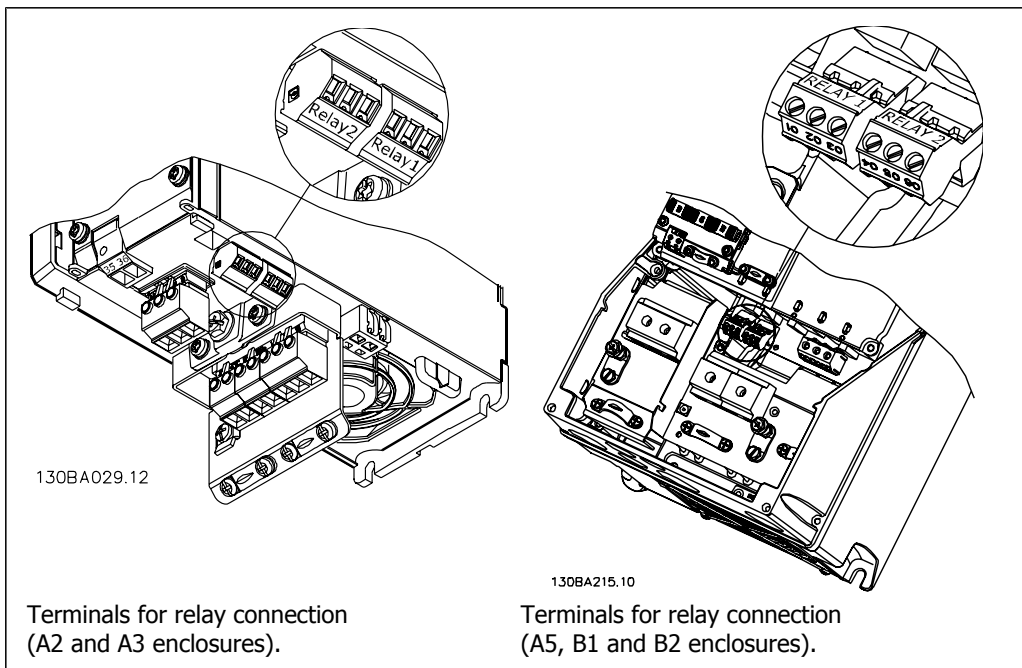


NOTE
 If a short circuit in the brake IGBT occurs, prevent power dissipation in the brake resistor by using a line switch or contactor to disconnect the line power from the adjustable frequency drive. Only the adjustable frequency drive should control the contactor.

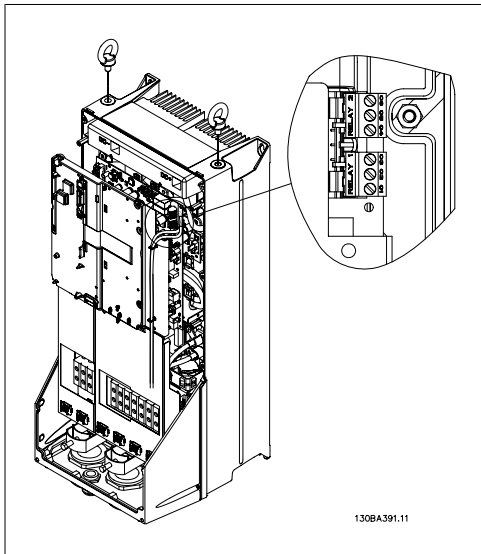
5.5.3. Relay Connection

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

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



5



(C1 and C2 enclosures).

5.19: Terminals for relay connection

5.5.4. Relay Output

Relay 1

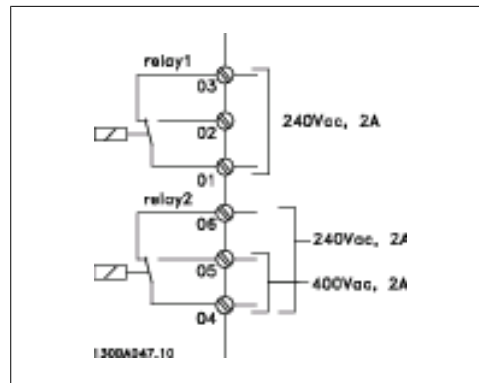
- Terminal 01: common
- Terminal 02: normal open 240 V AC
- Terminal 03: normal closed 240 V AC

Relay 2

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


Relay 1 and relay 2 are programmed in par. 5-40, 5-41, and 5-42.

Additional relay outputs by using option module MCB 105.



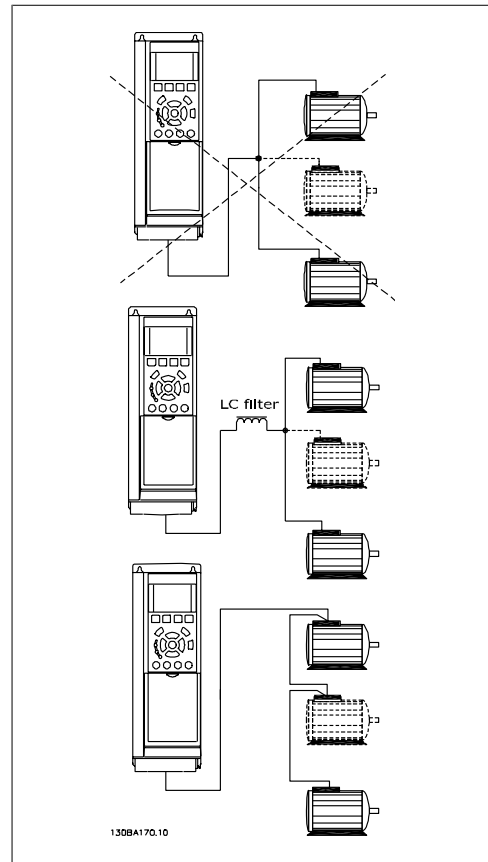
5.5.5. Parallel Connection of Motors

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

NOTE
 When motors are connected in parallel, par. 1-02 *Automatic Motor Adaptation (AMA)* cannot be used.

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

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

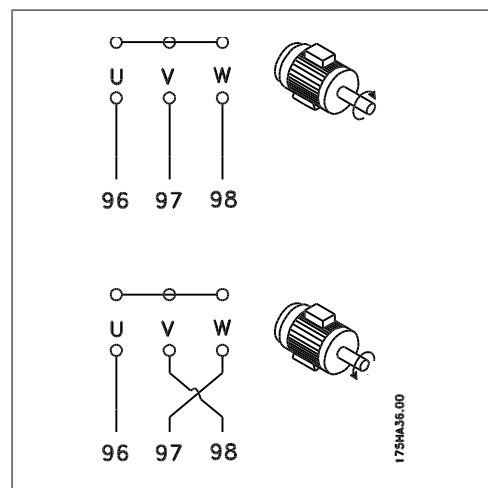


5.5.6. Direction of Motor Rotation

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.



5.5.7. Motor Thermal Protection

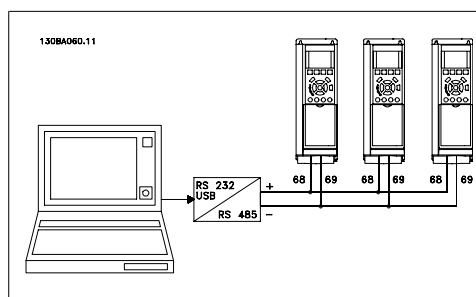
The electronic thermal relay in the adjustable frequency drive has received UL approval for single motor protection, when par. 1-90 *Motor Thermal Protection* is set for *ETR Trip* and par. 1-24 *Motor current*, $I_{M,N}$ is set to the rated motor current (see motor nameplate).

5.6. Installation of misc. connections

5.6.1. RS-485 Bus Connection

One or more adjustable frequency drives can be connected to a control (or master) using the RS-485 standardized interface. Terminal 68 is connected to the P signal (TX+, RX+), while terminal 69 is connected to the N signal (TX-, RX-).

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



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

Bus termination

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

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



NOTE

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

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

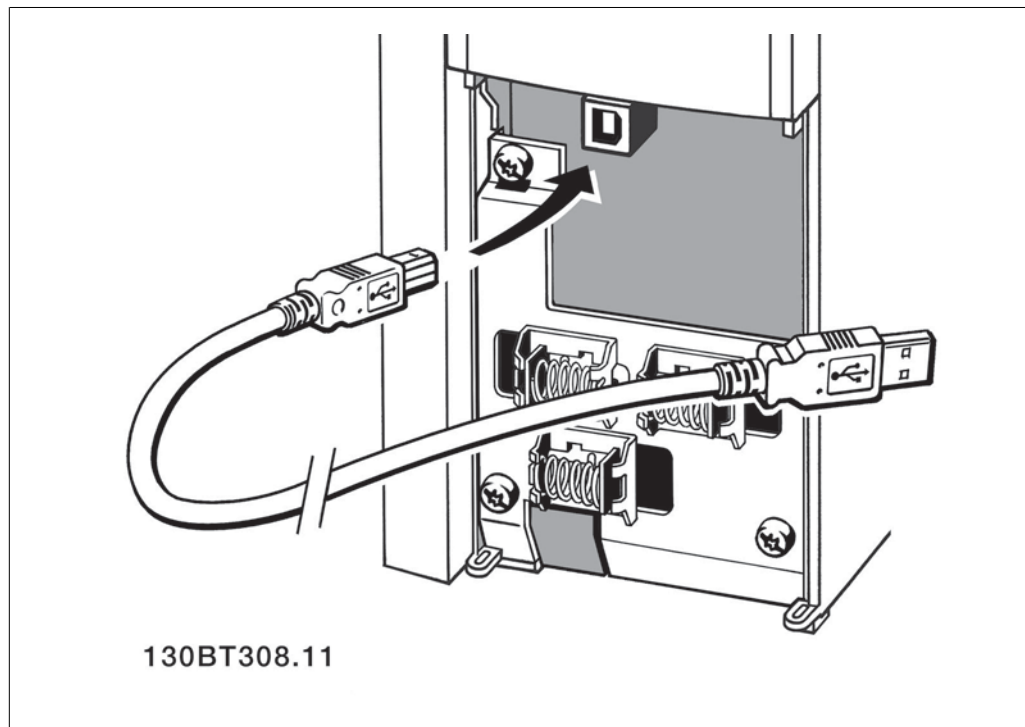
To control or program the adjustable frequency drive from a PC, install the MCT 10 Set-up software.

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



NOTE

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

**PC Software - MCT 10**

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

MCT 10 Set-up Software

MCT 10 has been designed as an easy-to-use interactive tool for setting parameters in our adjustable frequency drives.

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

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

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

Save Drive Settings:

1. Connect a PC to the unit via the USB com port.
2. Open MCT 10 Set-up software
3. Choose "Read from drive".
4. Choose "Save as".

All parameters are now stored on the PC.

Load Drive Settings:

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

All parameter settings are now transferred to the drive.

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

The MCT 10 Set-up Software Modules

The following modules are included in the software package:



MCT 10 Set-up Software

Setting parameters

Copy to and from adjustable frequency drives

Documentation and print-out of parameter settings incl. diagrams

Ext. User Interface

Preventive Maintenance Schedule

Clock settings

Timed Action Programming

Smart Logic Controller Set-up

Cascade Control Config. Tool

Ordering number:

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

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

MCT 31

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

Ordering number:

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

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

5.7. Safety

5.7.1. High Voltage Test

Carry out a high voltage test by short circuiting terminals U, V, W, L₁, L₂ and L₃. Energize by max. 2.15 kV DC for one second between this short circuit and the chassis.

**NOTE**

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

5.7.2. Safety Ground Connection

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



The ground leakage current from the adjustable frequency drive exceeds 3.5 mA. To ensure a good mechanical connection from the ground cable to the ground connection (terminal 95), the cable cross-section must be at least 0.39 in² [10 mm²] or 2 rated ground wires terminated separately.

5.8. EMC-correct Installation

5.8.1. Electrical Installation -

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

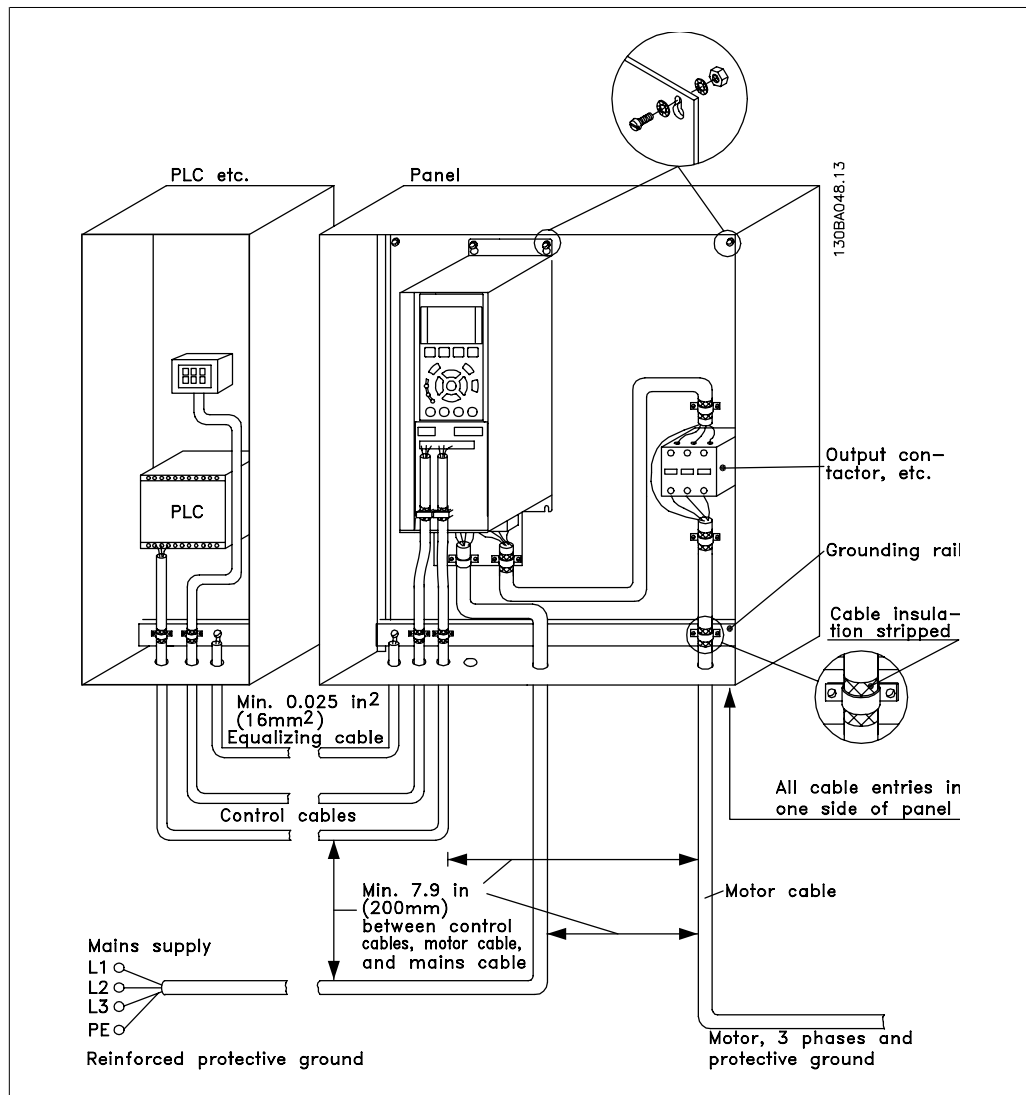
Good engineering practice to ensure EMC-correct electrical installation:

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

Leave the shield as close to the connectors as possible.

The illustration shows an example of an EMC-correct electrical installation of an IP 20 adjustable frequency drive. The adjustable frequency drive is fitted in an installation cabinet with an output contactor and connected to a PLC, which is installed in a separate cabinet. Other ways of performing the installation may result in an equally effective EMC performance, provided the above guidelines for engineering practice are followed.

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



5.20: EMC-compliant electrical installation of an IP 20 adjustable frequency drive.

5.8.2. Use of EMC-Compliant Cables

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

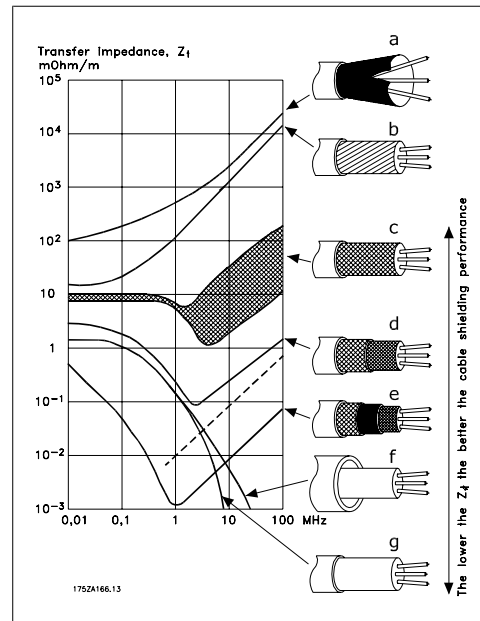
The ability of a cable to reduce the in and outgoing radiation of electric noise depends on the transfer impedance (Z_T). The shield of a cable is normally designed to reduce the transfer of electric noise; however, a shield with a lower transfer impedance (Z_T) value is more effective than a shield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

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

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

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

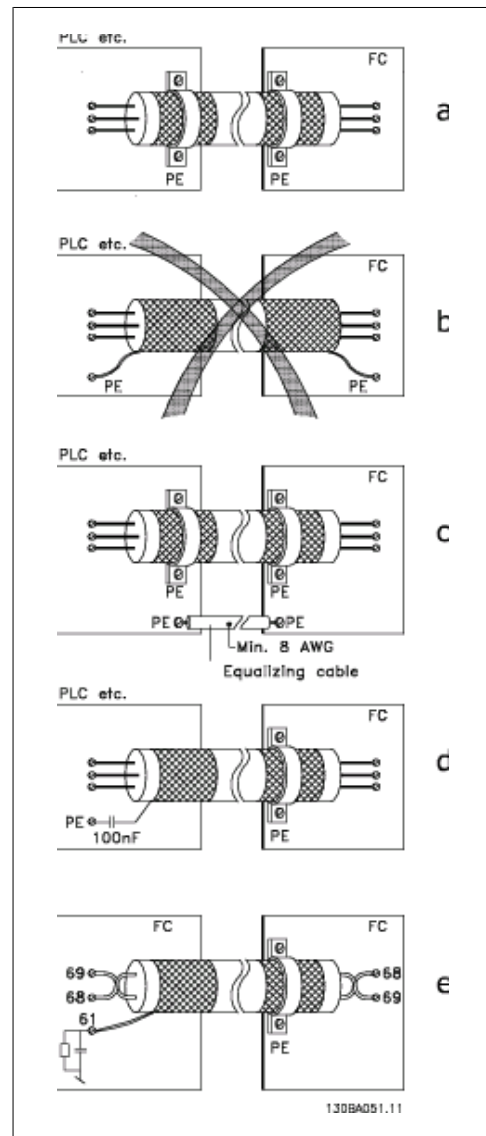
- a. Aluminum-clad with copper wire.¹
- b. Twisted copper wire or armored steel wire cable. 1
- c. Single-layer braided copper wire with varying percentage shield coverage. This is the typical Danfoss reference cable.¹
- d. Double-layer braided copper wire.¹
- e. Twin layer of braided copper wire with a magnetic, shielded/armored intermediate layer.¹
- f. Cable that runs in copper tube or steel tube.¹
- g. Lead cable with 0.43 in [1.1 mm] wall thickness.¹

**5.8.3. Grounding of Shielded/Armored Control Cables**

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

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

- a. **Correct grounding**
Control cables and cables for serial communication must be fitted with cable clamps at both ends to ensure the best possible electrical contact.¹
- b. **Wrong grounding**
Do not use twisted cable ends (pig-tails). They increase the shield impedance at high frequencies.¹
- c. **Protection with respect to ground potential between the PLC and VLT**
If the ground potential between the adjustable frequency drive and the PLC (etc.) is different, electric noise may occur that will disturb the entire system. Solve this problem by fitting an equalizing cable next to the control cable. Minimum cable cross-section: 0.025 in^2 [16 mm^2].¹
- d. **For 50/60 Hz ground loops**
If very long control cables are used, 50/60 Hz ground loops may occur. Solve this problem by connecting one end of the shield to ground via a 100nF capacitor (keeping leads short).¹
- e. **Cables for serial communication**
Eliminate low-frequency noise currents between two adjustable frequency drives by connecting one end of the shield to terminal 61. This terminal is grounded via an internal RC link. Use twisted-pair cables to reduce the differential mode interference between the conductors.¹

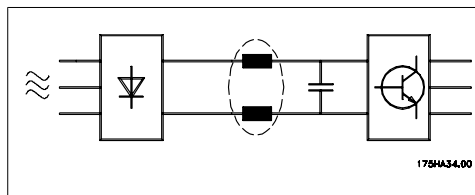


5.9.1. AC Line Supply Interference/Harmonics

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

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

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



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

5

Harmonic currents compared to the RMS input current:

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

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

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

$$THD\% = \sqrt{U\frac{2}{5} + U\frac{2}{7} + \dots + U\frac{2}{N}} \quad (U_N\% \text{ of } U)$$

5.10.1. Residual Current Device

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

If a ground fault appears, a DC content may develop in the faulty current.

If RCD relays are used, you must observe local regulations. Relays must be suitable for protection of 3-phase equipment with a bridge rectifier and for a brief discharge on power-up see section *Ground Leakage Current* for further information.

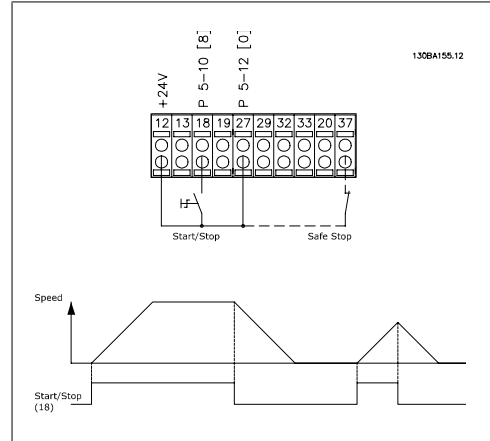
6. Application Examples

6.1.1. Start/Stop

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

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

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



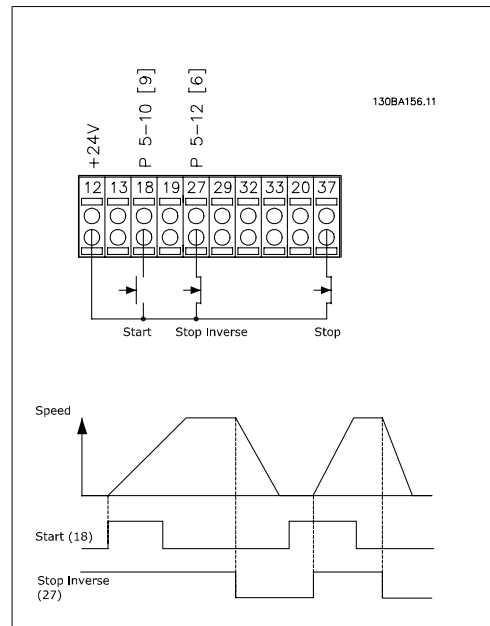
6.1: Terminal 37: Available only with Safe Stop Function!

6.1.2. Pulse Start/Stop

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

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

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



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

6.1.3. Potentiometer Reference

Voltage reference via a potentiometer.

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

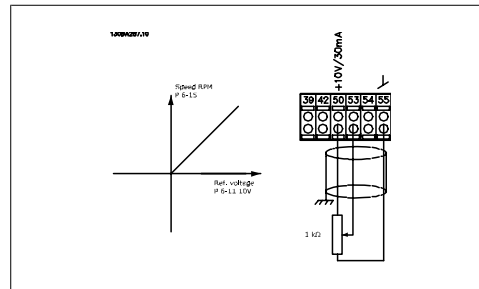
Par. 6-10 *Terminal 53, Low Voltage = 0 Volt*

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

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

Par. 6-15 *Terminal 53, High Ref./Feedb. Value = 1,500 RPM*

Switch S201 = OFF (U)



6

6.1.4. Automatic Motor Adaptation (AMA)

AMA is an algorithm used to measure the electrical motor parameters of a motor at standstill. This means that AMA itself does not supply any torque.

AMA is useful when commissioning systems and optimizing the adjustment of the adjustable frequency drive to the applied motor. In particular, this feature is used where the default setting does not apply to the connected motor.

Par. 1-29 allows a choice of complete AMA with determination of all electrical motor parameters, or reduced AMA with determination of only the stator resistance, R_s .

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 optimally determine the motor parameters, enter the correct motor nameplate data in par. 1-20 to 1-26.
- 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, R_s . Normally, this is not critical.
- An AMA can only be carried out if the rated motor current is a minimum of 35% of the rated output current of the adjustable frequency drive. An AMA can be carried out on up to one oversized 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.

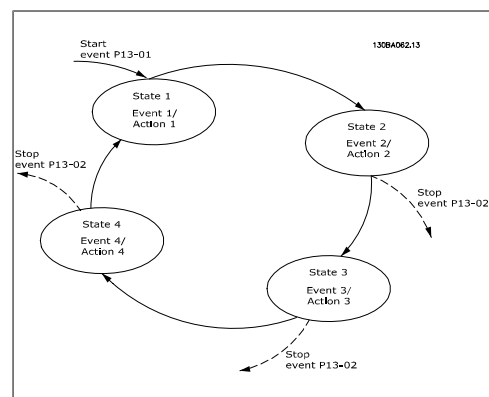
6.1.5. Smart Logic Control

The smart logic control (SLC) is essentially a sequence of user-defined actions (see par. 13-52) executed by the SLC when the associated user-defined *event* (see par. 13-51) is evaluated as TRUE by the SLC.

Events and *actions* are each numbered and are linked in pairs called states. This means that when *event [1]* is fulfilled (attains the value TRUE), *action [1]* is executed. After this, the conditions of *event [2]* will be evaluated and, if evaluated TRUE, *action [2]* will be executed and so on. Events and actions are placed in array parameters.

Only one *event* will be evaluated at any time. If an *event* is evaluated as FALSE, nothing happens (in the SLC) during the present scan interval and no other *events* will be evaluated. This means that when the SLC starts, it evaluates *event [1]* (and only *event [1]*) each scan interval. Only when *event [1]* is evaluated TRUE 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]*. The illustration shows an example with three *events / actions*.



6.1.6. Smart Logic Control Programming

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

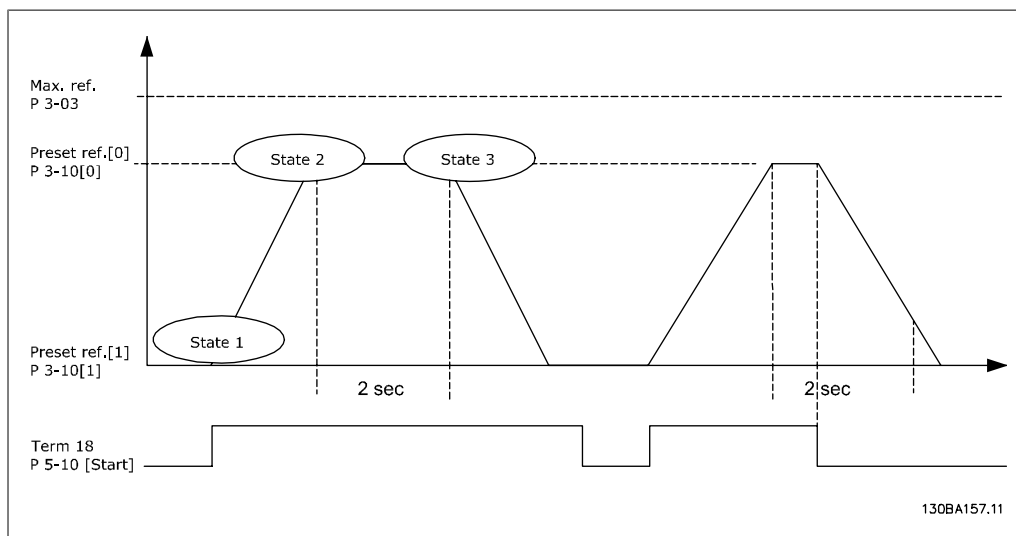
In applications where a PLC generates a simple sequence, the SLC may take over elementary tasks from the main control.

SLC is designed to act from event send to, or it is generated in the VLT AQUA Drive. The adjustable frequency drive will then perform the pre-programmed action.

6.1.7. SLC Application Example

One sequence 1:

Start – ramp-up – run at reference speed 2 sec – ramp-down and hold shaft until stop.



Set the ramping times in par. 3-41 and 3-42 to the desired times.

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

Set term 27 to *No Operation* (par. 5-12)

Set Preset reference 0 to first preset speed (par. 3-10 [0]) in percentage of Max Reference speed (par. 3-03). Ex.: 60%

Set preset reference 1 to second preset speed (par. 3-10 [1]) Ex.: 0% (zero).

Set the timer 0 for constant running speed in par. 13-20 [0]. Ex.: 2 sec.

Set Event 1 in par. 13-51 [1] to *True* [1]

Set Event 2 in par. 13-51 [2] to *On Reference* [4]

Set Event 3 in par. 13-51 [3] to *Time Out 0* [30]

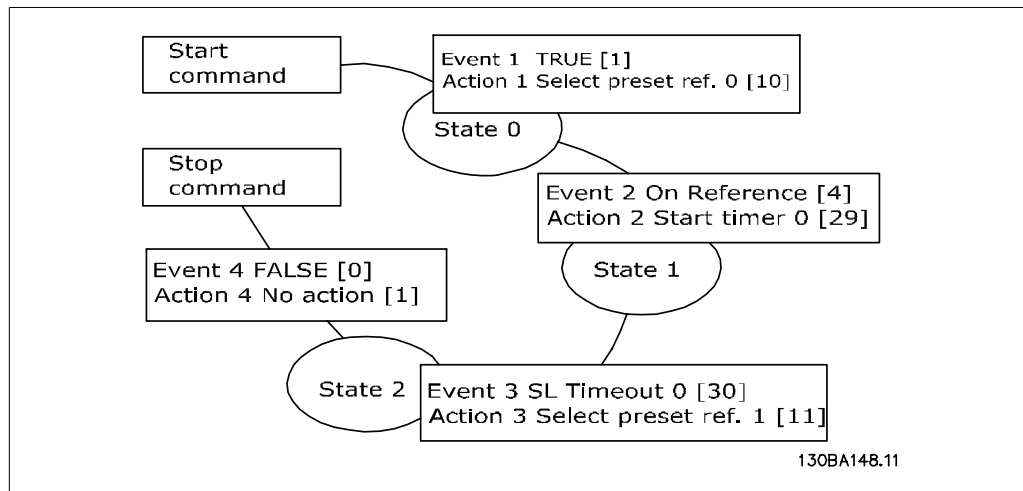
Set Event 4 in par. 13-51 [1] to *False* [0]

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

Set Action 2 in par. 13-52 [2] to *Start Timer 0* [29]

Set Action 3 in par. 13-52 [3] to *Select preset 1* [11]

Set Action 4 in par. 13-52 [4] to *No Action* [1]



Set the smart logic control in par. 13-00 to ON.

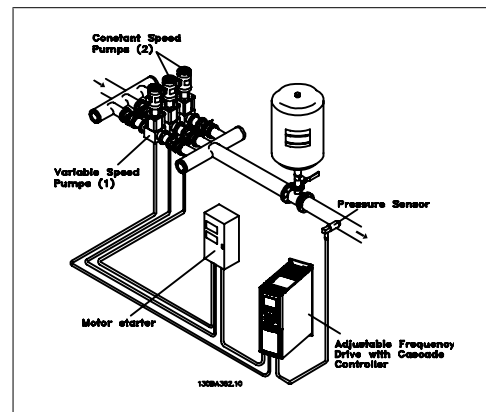
Start/stop command is applied on terminal 18. If stop signal is applied, the adjustable frequency drive will ramp down and go into free mode.

6.1.8. BASIC Cascade Controller

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

In the BASIC cascade controller, the adjustable frequency drive controls a variable speed (lead) motor as the variable speed pump and can stage up to two additional constant speed pumps on and off. By varying the speed of the initial pump, variable speed control of the entire system is provided. This maintains con-

stant pressure while eliminating pressure surges, resulting in reduced system stress and quieter operation in pumping systems.



Fixed Lead Pump

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

Lead Pump Alternation

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

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

A separate parameter limit's alternation is only to take place if the total capacity required is > 50%. Total pump capacity is determined as the sum of the capacities of the lead pump and the fixed speed pumps.

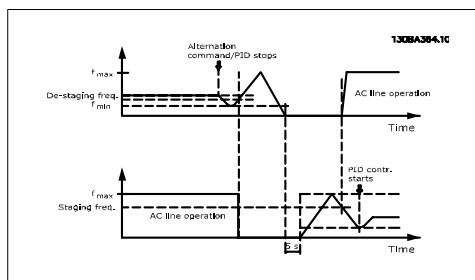
Bandwidth Management

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

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

6.1.9. Pump Staging with Lead Pump Alternation

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



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

If the lead pump has been running at minimum frequency (f_{min}) for a programmed amount of time with a fixed speed pump running, the lead pump contributes little to the system. When the

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

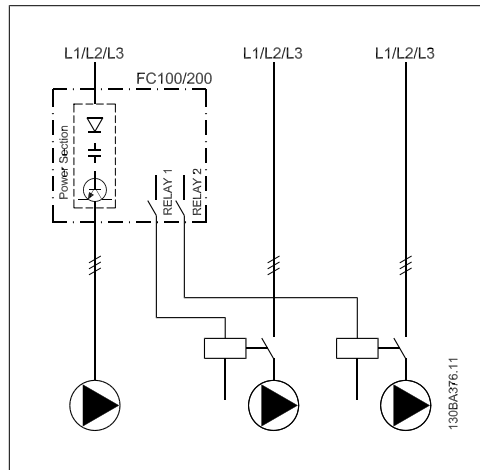
6.1.10. System Status and Operation

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

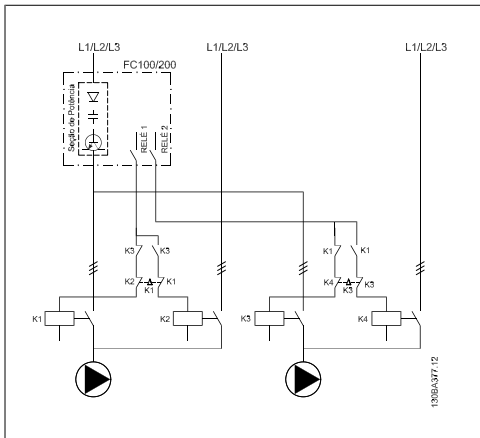
When the cascade controller is enabled, the operation status for each pump and the cascade controller is displayed on the local control panel. Information displayed includes:

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

6.1.11. Fixed Variable Speed Pump Wiring Diagram



6.1.12. Lead Pump Alternation Wiring Diagram

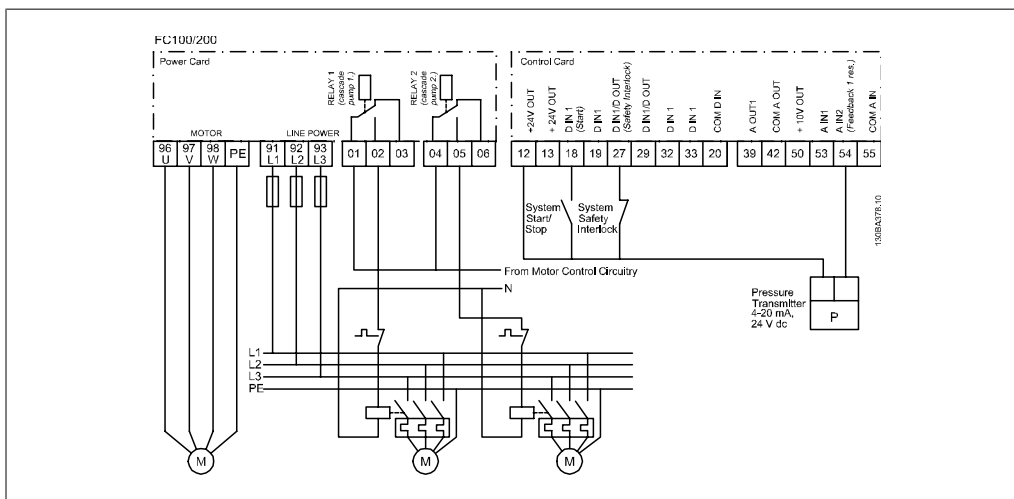


- RELAY 1 and RELAY 2 are the built-in relays in the adjustable frequency drive.
- When all relays are de-energized, the first built-in relay to be energized will cut in the contactor corresponding to the pump controlled by the relay. For example, RELAY 1 cuts in contactor K1, which then becomes the lead pump.
- K1 blocks K2 via the mechanical interlock, preventing line power to be connected to the output of the adjustable frequency drive (via K1).
- Auxiliary break contact on K1 prevents K3 from cutting in.
- RELAY 2 controls contactor K4 for on/off control of the fixed speed pump.
- At alternation, both relays de-energize, and RELAY 2 will be energized as the first relay.

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.

6.1.13. 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.



6.1.14. Start/Stop conditions

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

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

Function of buttons on the Local Control Panel

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

7. RS-485 Installation and Set-up

7.1. RS-485 Installation and Set-up

7.1.1. Overview

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

Network segments are divided up by repeaters. Please note that each repeater functions as a node within the segment in which it is installed. Each node connected within a given network must have a unique node address across all segments.

Terminate each segment at both ends using either the termination switch (S801) of the adjustable frequency drives or a biased termination resistor network. Always use shielded twisted pair (STP) cable for bus cabling, and always follow good common installation practice.

Low-impedance ground connection of the shield at every node is very important, also at high frequencies. This can be achieved by connecting a large surface of the shield to ground, by means of a cable clamp or a conductive cable gland, for example. It may be necessary to apply potential-equalizing cables to maintain the same ground potential throughout the network, particularly in installations where there are long lengths of cable.

To prevent impedance mismatch, always use the same type of cable throughout the entire network. When connecting a motor to the adjustable frequency drive, always use shielded motor cable.

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

7.1.2. Network Connection

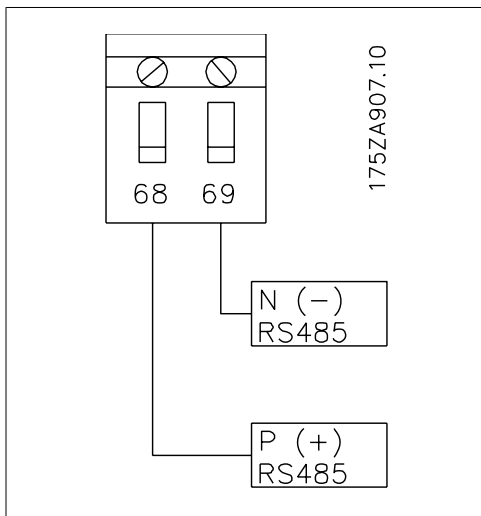
Connect the adjustable frequency drive to the RS-485 network as follows (see also diagram):

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



NOTE

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

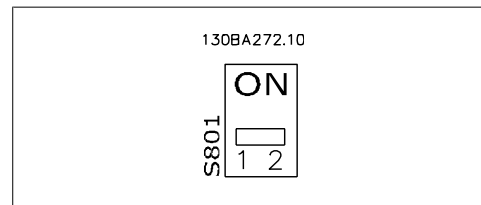


7.1: Network Terminal Connection


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7.1.3. VLT AQUA Hardware Set-up

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



Terminator Switch Factory Setting

 **NOTE**
The factory setting for the dip switch is OFF.

7.1.4. VLT AQUA Parameter Settings for Modbus Communication

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

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

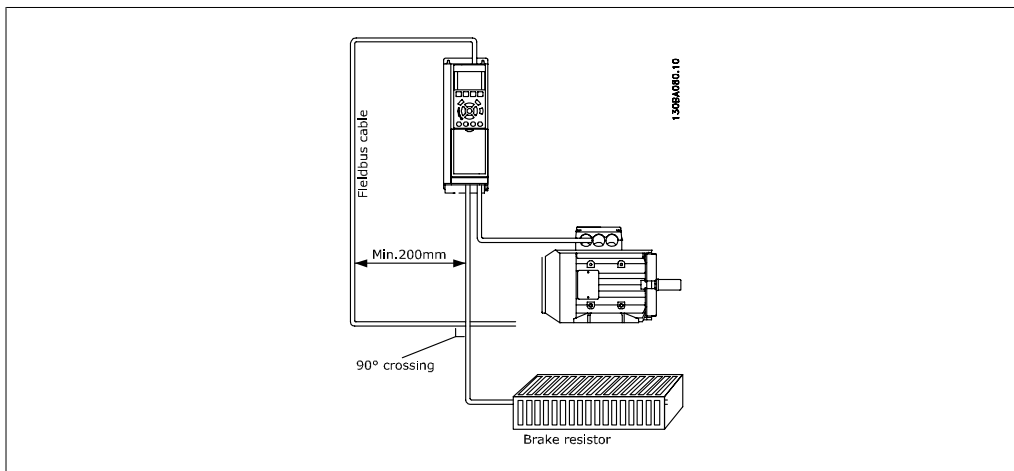
7.1.5. EMC Precautions

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



NOTE

Relevant national and local regulations, for example, regarding protective ground connection, must be observed. The RS-485 communication cable must be kept away from motor and brake resistor cables to avoid coupling of high frequency noise from one cable to another. Normally a distance of 200 mm (8 inches) is sufficient, but keeping the greatest possible distance between the cables is generally recommended, especially where cables run in parallel over long distances. When crossing is unavoidable, the RS-485 cable must cross motor and brake resistor cables at an angle of 90 degrees.



7.2. FC Protocol Overview

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

One master and a maximum of 126 slaves can be connected to the bus. The individual slaves are selected by the master via an address character in the telegram. A slave itself can never transmit without first being requested to do so, and direct message transfer between the individual slaves is not possible. Communications occur in the half-duplex mode.

The master function cannot be transferred to another node (single-master system).

The physical layer is RS-485, thus utilizing the RS-485 port built into the adjustable frequency drive. The FC protocol supports different telegram formats; a short format of 8 bytes for process data, and a long format of 16 bytes that also includes a parameter channel. A third telegram format is used for texts.

7.2.1. VLT AQUA with Modbus RTU

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

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

- Start
- Stop the adjustable frequency drive in various ways:
 - Coast stop
 - Quick stop
 - DC Brake stop
 - Normal (ramp) stop
- Reset after a fault trip.
- Run at a variety of preset speeds.
- Run in reverse.

- Change of the active set-up
- Control of the two relays built into the adjustable frequency drive

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

7.3. Network Configuration

7.3.1. VLT AQUA Adjustable Frequency Drive Set-up

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

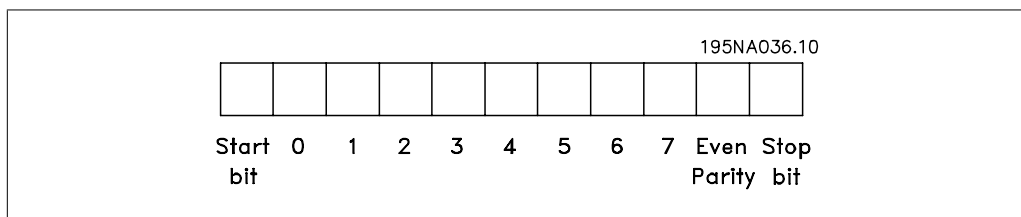
Parameter Number	Parameter name	Setting
8-30	Protocol	FC
8-31	Address	1 - 126
8-32	Baud Rate	2400 - 115200
8-33	Parity/Stop bits	Even parity, 1 stop bit (default)



7.4. FC Protocol Message Framing Structure

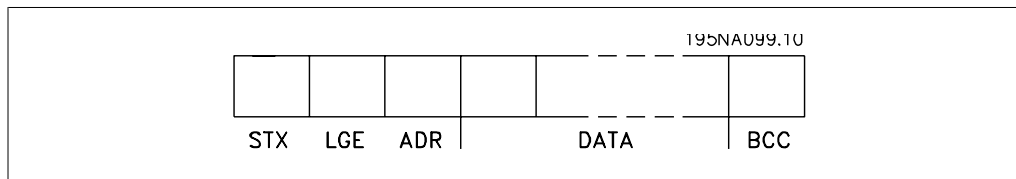
7.4.1. Content of a Character (byte)

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



7.4.2. Message Structure

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



7.4.3. Message Length (LGE)

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

The length of telegrams with 4 data bytes is $LGE = 4 + 1 + 1 = 6$ bytes

The length of telegrams with 12 data bytes is $LGE = 12 + 1 + 1 = 14$ bytes

The length of telegrams containing texts is 10^1+n bytes

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

7.4.4. Adjustable Frequency Drive Address (ADR)

Two different address formats are used.

The address range of the adjustable frequency drive is either 1-31 or 1-126.

1. Address format 1-31:

Bit 7 = 0 (address format 1-31 active)

Bit 6 is not used

Bit 5 = 1: Broadcast, address bits (0-4) are not used

Bit 5 = 0: No Broadcast

Bit 0-4 = Adjustable frequency drive address 1-31

2. Address format 1-126:

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

Bit 0-6 = Adjustable frequency drive address 1-126

Bit 0-6 = 0 Broadcast

The slave returns the address byte unchanged to the master in the response telegram.

7.4.5. Data Control Byte (BCC)

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

7.4.6. The Data Field

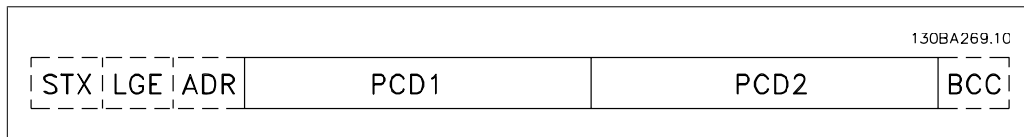
The structure of data blocks depends on the type of telegram. There are three telegram types, and the type applies for both control telegrams (master=>slave) and response telegrams (slave=>master).

The three types of telegram are:

Process block (PCD):

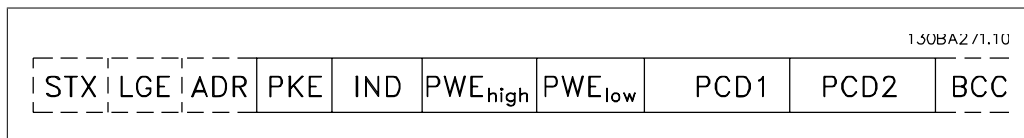
The PCD is made up of a data block of four bytes (2 words) and contains:

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



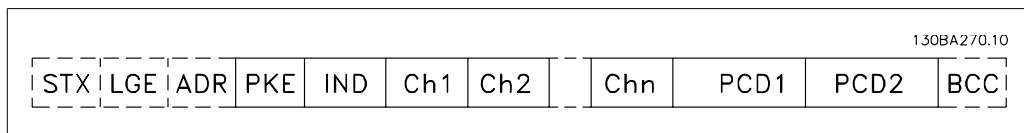
Parameter block:

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



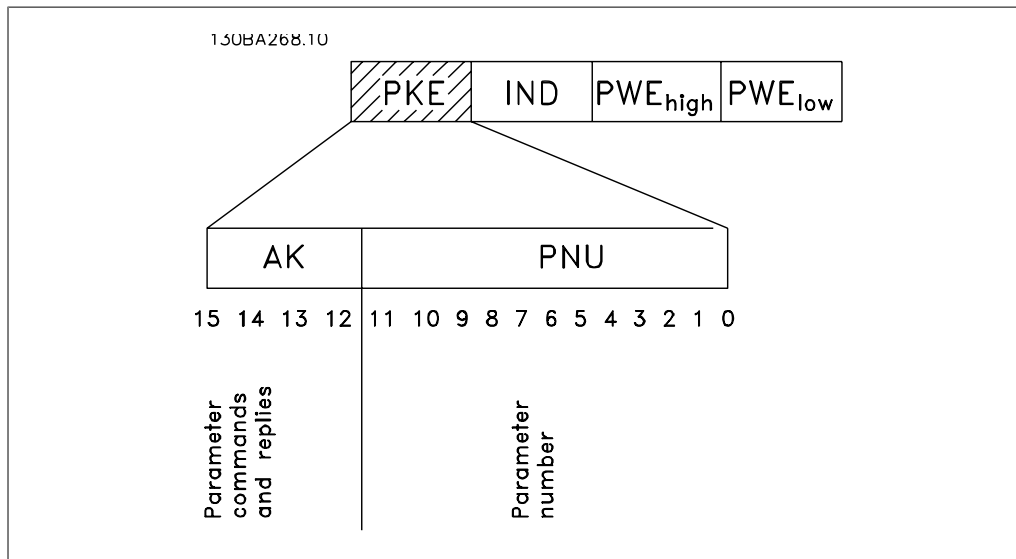
Text block:

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



7.4.7. The PKE Field

The PKE field contains two sub-fields: Parameter command and response AK, and parameter number PNU:



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

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

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

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

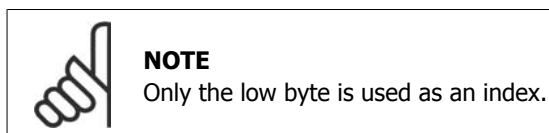
PWE low (Hex)	Fault Report
0	The parameter number used does not exist.
1	There is no write access to the defined parameter.
2	Data value exceeds the parameter's limits.
3	The sub index used does not exist.
4	The parameter is not the array type.
5	The data type does not match the defined parameter.
11	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

7.4.8. Parameter Number (PNU)

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

7.4.9. Index (IND)

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



7.4.10. Parameter Value (PWE)

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

When a slave responds to a parameter request (read command), the present parameter value in the PWE block is transferred and returned to the master. If a parameter contains not a numerical value but several data options, such as par. 0-01 Language where [0] corresponds to English, and [4] corresponds to Danish, select the data value by entering the value in the PWE block. See Example - Selecting a data value. Serial communication is only capable of reading parameters containing data type 9 (text string).

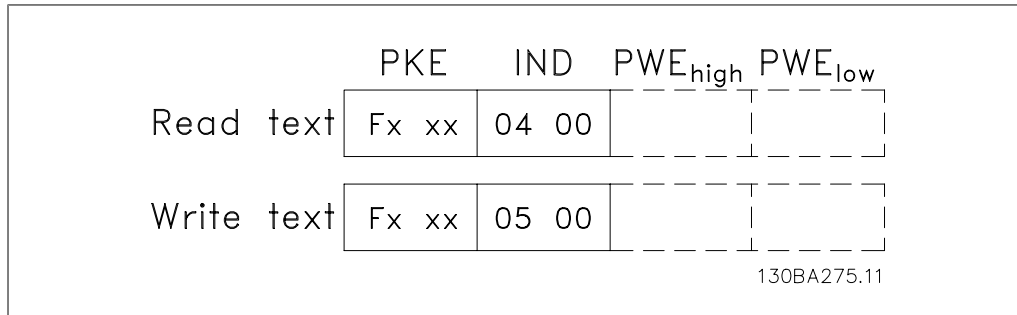
Parameters 15-40 to 15-53 contain data type 9.

For example, read the unit size and line voltage range in par. 15-40 *FC Type*. When a text string is transferred (read), the length of the telegram is variable, and the texts are of different lengths.

The message length is defined in the second byte of the telegram, LGE. When using text transfer, the index character indicates whether it is a read or a write command.

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

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



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7.4.11. Data Types Supported by VLT AQUA

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

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

7.4.12. Conversion

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

Par. 4-12 *Motor Speed, Low Limit* has a conversion factor of 0.1.

To preset the minimum frequency to 10 Hz, transfer the value 100. A conversion factor of 0.1 means that the value transferred is multiplied by 0.1. The value 100 is thus perceived as 10.0.

Conversion table	
Conversion index	Conversion factor
74	0.1
2	100
1	10
0	1
-1	0.1
-2	0.01
-3	0.001
-4	0.0001
-5	0.00001

7.4.13. Process Words (PCD)

The block of process words is divided into two blocks of 16 bits, which always occur in the defined sequence.

PCD 1	PCD 2
Control telegram (master→slave control word)	Reference value
Control telegram (slave →master) status word	Present output frequency



7.5. Examples

7.5.1. Writing a parameter value

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

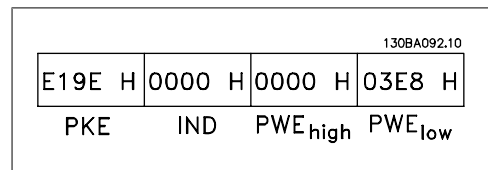
PKE = E19E Hex - Write single word in par. 4-14 *Motor Speed High Limit [Hz]*

IND = 0000 Hex

PWEHIGH = 0000 Hex

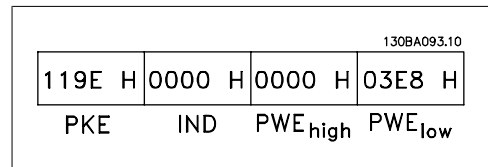
PWELOW = 03E8 Hex - Data value 1000, corresponding to 100 Hz, see Conversion.

The telegram will look like this:



Note: Parameter 4-14 is a single word, and the parameter command for write in EEPROM is "E". Parameter number 414 is 19E in hexadecimal.

The response from the slave to the master will be:



7.5.2. Reading a parameter value

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

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

IND = 0000 Hex

PWEHIGH = 0000 Hex

PWELOW = 0000 Hex

130BA094.10			
1155 H	0000 H	0000 H	0000 H
PKE	IND	PWE _{high}	PWE _{low}

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

130BA267.10			
1155 H	0000 H	0000 H	03E8 H
PKE	IND	PWE _{high}	PWE _{low}

NOTE
3E8 Hex corresponds to 1000 decimal. The conversion index for par. 3-41 is -2, i.e., 0.01.

7.6. Modbus RTU Overview

7.6.1. Assumptions

This instruction manual assumes that the installed controller supports the interfaces in this document and that all the requirements stipulated in the controller, as well as the adjustable frequency drive, are strictly observed, along with all limitations therein.

7.6.2. What the User Should Already Know

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

7.6.3. Modbus RTU Overview

Regardless of the type of physical communication networks, the Modbus RTU Overview describes the process a controller uses to request access to another device. This includes, among other things, how it will respond to requests from another device, and how errors will be detected and reported. It also establishes a common format for the layout and contents of message fields.

While communicating over a Modbus RTU network, the protocol determines how each controller will learn its device address, recognize a message addressed to it, determine the kind of action to be taken and extract any data or other information contained in the message. If a reply is required, the controller will construct the reply message and send it.

Controllers communicate using a master-slave technique in which only one device (the master) can initiate transactions (called queries). The other devices (slaves) respond by supplying the requested data to the master or taking the action requested in the query.

The master can address individual slaves or initiate a broadcast message to all slaves. Slaves return a message (called a response) to queries that are addressed to them individually. No responses are returned to broadcast queries from the master. The Modbus RTU protocol establishes the format for the master's query by placing into it the device (or broadcast) address, a function code defining the requested action, any data to be sent and an error-checking field. The slave's response message is also constructed using Modbus protocol. It contains fields confirming the action taken, any data to be returned and an error-checking field. If an error occurs in receipt of the message, or if the slave is unable to perform the requested action, the slave will construct an error message and send it in response, or a timeout will occur.

7.7. Network Configuration

7.7.1. VLT AQUA with Modbus RTU

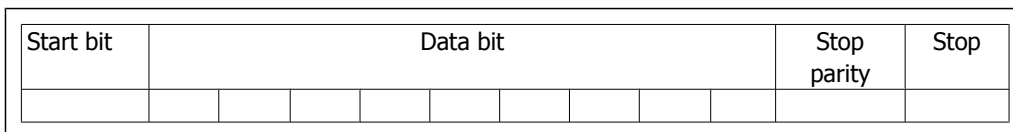
To enable modbus RTU on the VLT AQUA, set the following parameters:

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

7.8. Modbus RTU Message Framing Structure

7.8.1. VLT AQUA with Modbus RTU

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



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

7.8.2. Modbus RTU Message Structure

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

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

Typical Modbus RTU Message Structure

7.8.3. Start / Stop Field

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

7.8.4. Address Field

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

7.8.5. Function Field

The function field of a message frame contains 8 bits. Valid codes are in the range of 1-FF. Function fields are used to send messages between master and slave. When a message is sent from a master to a slave device, the function code field tells the slave what kind of action to perform. When the slave responds to the master, it uses the function code field to indicate either a normal (error-free) response, or that some kind of error occurred (called an exception response). For a normal response, the slave simply echoes the original function code. For an exception response, the slave returns a code that is equivalent to the original function code with its most significant bit set to logic 1. In addition, the slave places a unique code into the data field of the response message. This tells the master what kind of error occurred, or the reason for the exception. Please also refer to the sections *Function Codes Supported by Modbus RTU* and *Exception Codes*.

7.8.6. Data Field

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

7.8.7. CRC Check Field

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

7.8.8. Coil Register Addressing

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

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

Coil Number	Description	Signal Direction
1-16	Adjustable frequency drive control word (see table below)	Master to slave
17-32	Adjustable frequency drive speed or setpoint reference Range 0x0 – 0xFFFF (-200% ... ~200%)	Master to slave
33-48	Adjustable frequency drive status word (see table below)	Slave to master
49-64	Open-loop mode: Adjustable frequency drive output frequency closed-loop mode: Adjustable frequency drive feedback signal	Slave to master
65	Parameter write control (master to slave) 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.	Master to slave
66-65536	Reserved	

Coil	0	1
01	Preset reference LSB	
02	Preset reference MSB	
03	DC brake	No DC brake
04	Coast stop	No coast stop
05	Quick stop	No quick stop
06	Freeze freq.	No freeze freq.
07	Ramp stop	Start
08	No reset	Reset
09	No jog	Jog
10	Ramp 1	Ramp 2
11	Data not valid	Data valid
12	Relay 1 off	Relay 1 on
13	Relay 2 off	Relay 2 on
14	Set-up LSB	
15	Set-up MSB	
16	No reversing	Reversing
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
Adjustable frequency drive status word (FC profile)		

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

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

7.8.9. How to Control the VLT AQUA

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

7.8.10. Function Codes Supported by Modbus RTU

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

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

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

7.8.11. Exception Codes

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

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

7.9. How to Access Parameters

7.9.1. Parameter Handling

The PNU (Parameter Number) is translated from the register address contained in the Modbus read or write message. The parameter number is translated to Modbus as (10 x parameter number) DECIMAL.

7.9.2. Storage of Data

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

7.9.3. IND

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

7.9.4. Text Blocks

Parameters stored as text strings are accessed in the same way as the other parameters. The maximum text block size is 20 characters. If a read request for a parameter is for more characters than the parameter stores, the response is truncated. If the read request for a parameter is fewer characters than the parameter stores, the response is space-filled.

7.9.5. Conversion Factor

The different attributes for each parameter can be seen in the section on factory settings. Since a parameter value can only be transferred as a whole number, a conversion factor must be used to transfer decimals. Please refer to the *Parameters section*.

7.9.6. Parameter Values

Standard Data Types

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

Non standard Data Types

Non standard data types are text strings stored as 4x registers (40001 – 4FFFF). The parameters are read using function 03HEX "Read Holding Registers" and written using function 10HEX "Preset Multiple Registers." Readable sizes range from 1 register (2 characters) up to 10 registers (20 characters).

7.10. Examples

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

7.10.1. Read Coil Status (01 HEX)

Description

This function reads the ON/OFF status of discrete outputs (coils) in the adjustable frequency drive. Broadcast is never supported for reads.

Query

The query message specifies the starting coil and quantity of coils to be read. Coil addresses start at zero, i.e., coil 33 is addressed as 32.

Example of a request to read coils 33-48 (Status Word) from slave device 01:

Field Name	Example (HEX)
Slave Address	01 (adjustable frequency drive address)
Function	01 (read coils)
Starting Address HI	00
Starting Address LO	20 (32 decimals)
No. of Points HI	00
No. of Points LO	10 (16 decimals)
Error Check (CRC)	-

Response

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

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

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

7.10.2. Force/Write Single Coil (05 HEX)

Description

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

Query

The query message specifies the coil 65 (parameter write control) to be forced. Coil addresses start at zero, i.e., coil 65 is addressed as 64. Force Data = 00 00HEX (OFF) or FF 00HEX (ON).

Field Name	Example (HEX)
Slave Address	01 (adjustable frequency drive address)
Function	05 (write single coil)
Coil Address HI	00
Coil Address LO	40 (coil no. 65)
Force Data HI	FF
Force Data LO	00 (FF 00 = ON)
Error Check (CRC)	-

Response

The normal response is an echo of the query, which is returned after the coil state has been forced.

Field Name	Example (HEX)
Slave Address	01
Function	05
Force Data HI	FF
Force Data LO	00
Quantity of Coils HI	00
Quantity of Coils LO	01
Error Check (CRC)	-

7.10.3. Force/Write Multiple Coils (0F HEX)

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

The query message specifies the coils 17 to 32 (speed setpoint) to be forced. Coil addresses start at zero, i.e., coil 17 is addressed as 16.

Field Name	Example (HEX)
Slave Address	01 (adjustable frequency drive address)
Function	0F (write multiple coils)
Coil Address HI	00
Coil Address LO	10 (coil address 17)
Quantity of Coils HI	00
Quantity of Coils LO	10 (16 coils)
Byte Count	02
Force Data HI (Coils 8-1)	20
Force Data LO (Coils 10-9)	00 (ref. = 2000hex)
Error Check (CRC)	-

Response

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

Field Name	Example (HEX)
Slave Address	01 (adjustable frequency drive address)
Function	0F (write multiple coils)
Coil Address HI	00
Coil Address LO	10 (coil address 17)
Quantity of Coils HI	00
Quantity of Coils LO	10 (16 coils)
Error Check (CRC)	-

7.10.4. Read Holding Registers (03 HEX)

Description

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

Query

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

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

Response

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

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

7.10.5. Preset Single Register (06 HEX)

Description

This function presets a value into a single holding register.

Query

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

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

Response

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

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

7.10.6. Preset Multiple Registers (10 HEX)

Description

This function presets values into a sequence of holding registers.

Query

The query message specifies the register references to be preset. Register addresses start at zero, i.e., register 1 is addressed as 0. Example of a request to preset two registers (set parameter 1-05 = 738 (7.38 A)):

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

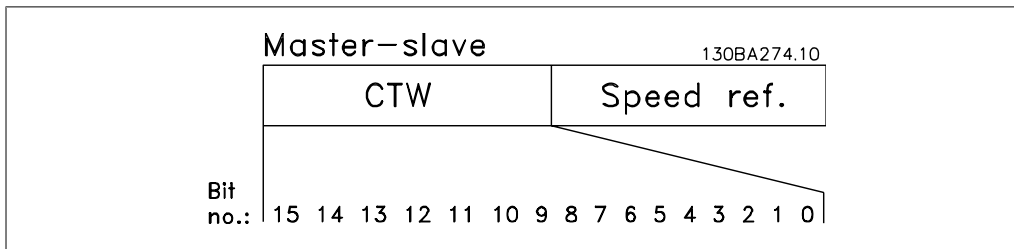
Response

The normal response returns the slave address, function code, starting address and quantity of preset registers.

Field Name	Example (HEX)
Slave Address	01
Function	10
Starting Address HI	04
Starting Address LO	19
No. of Registers HI	00
No. of registers LO	02
Error Check (CRC)	-

7.11. Danfoss FC Control Profile

7.11.1. Control Word According to FC Profile (Par. 8-10 = FC profile)



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

Explanation of the Control Bits

Bits 00/01

Bits 00 and 01 are used to choose between the four reference values, which are pre-programmed in par. 3-10 *Preset reference* according to the following table:

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

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

Bit 02, DC brake:

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

Bit 03, Coasting:

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

**NOTE**

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

Bit 04, Quick stop:

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

Bit 05, Hold output frequency

Bit 05 = '0': The present output frequency (in Hz) freezes. Change the frozen output frequency only by means of the digital inputs (par. 5-10 to 5-15) programmed to *Speed up* and *Slow down*.

**NOTE**

If freeze output is active, the adjustable frequency drive can only be stopped by the following:

- Bit 03 Coasting stop
- Bit 02 DC braking
- Digital input (par. 5-10 to 5-15) 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 par. Bit 06 = '1': Permits the adjustable frequency drive to start the motor if the other starting conditions are met.

**NOTE**

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

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

Bit 08, Jog:

Bit 08 = '1': The output frequency is determined by par. 3-19 *Jog Speed*.

Bit 09, Selection of ramp 1/2:

Bit 09 = "0": Ramp 1 is active (par. 3-40 to 3-47). Bit 09 = "1": Ramp 2 (par. 3-50 to 3-57) 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 telegram always contains the control word, regardless of the telegram type. Thus, you can turn off the control word if you do not want to use it when updating or reading parameters.

Bit 11, Relay 01:

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

Bit 12, Relay 04:

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

Bit 13/14, Selection of set-up:

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

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

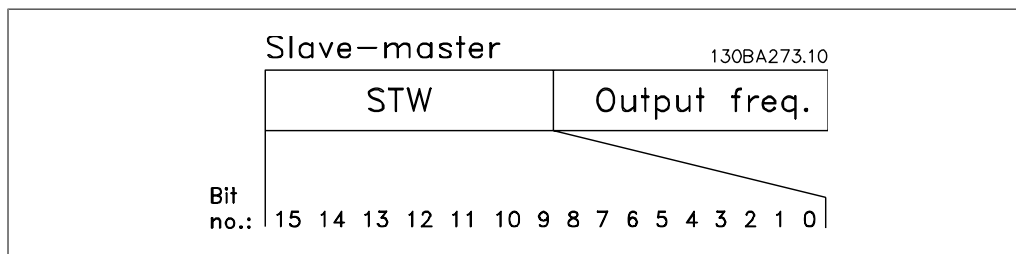
The function is only possible when *Multi Set-ups* is selected in par. 0-10 *Active Set-up*.

NOTE
Make a selection in par. 8-55 *Set-up select* to define how Bit 13/14 gates with the corresponding function on the digital inputs.

Bit 15 Reverse:

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

7.11.2. Status Word According to FC Profile (STW) (Par. 8-10 = FC profile)



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

Explanation of the Status Bits

Bit 00, Control not ready/ready:

Bit 00 = '0': The adj. 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 adj. frequency drive trips. To re-establish operation, enter [Reset].

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

Bit 04 = '0': The adjustable frequency drive is not in fault mode. Bit 04 = "1": The adjustable frequency drive shows an error but does not trip.

Bit 05, Not used:

Bit 05 is not used in the status word.

Bit 06, No error / triplock:

Bit 06 = '0': The adjustable frequency drive is not in fault mode. Bit 06 = "1": The adjustable frequency drive is tripped and locked.

Bit 07, No warning/warning:

Bit 07 = '0': There are no warnings. Bit 07 = '1': A warning has occurred.

Bit 08, Speed ≠ reference/speed = reference:

Bit 08 = '0': The motor is running, but the present speed is different from the preset speed reference. For example, this might be the case when the speed ramps up/down during start/stop.

Bit 08 = '1': The motor speed matches the preset speed reference.

Bit 09, Local operation/bus control:

Bit 09 = '0': [STOP/RESET] is activate on the control unit or *Local control* in par. 3-13 *Reference Site* is selected. You cannot control the adjustable frequency drive via serial communication. Bit 09 = '1' It is possible to control the adjustable frequency drive via serial communication or the serial communication bus.

Bit 10, Out of frequency limit:

Bit 10 = '0': The output frequency has reached the value in par. 4-11 *Motor Speed Low Limit* or par. 4-13 *Motor Speed High Limit*. 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 in the inverter. Bit 12 = '1': The inverter stops because of overtemperature, but the unit does not trip and will resume 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 intermediate circuit of the adjustable frequency drive is too low or too high.

Bit 14, Torque OK/limit exceeded:

Bit 14 = '0': The motor current is lower than the torque limit selected in par. 4-18 *Current Limit*.

Bit 14 = '1': The torque limit in par. 4-18 *Current Limit* is exceeded.

Bit 15, Timer OK/limit exceeded:

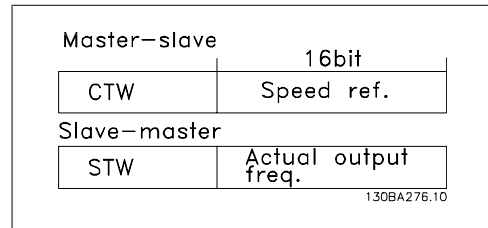
Bit 15 = '0': The timers for motor thermal protection and VLT thermal protection have not exceeded 100%. Bit 15 = '1': One of the timers exceeds 100%.

**NOTE**

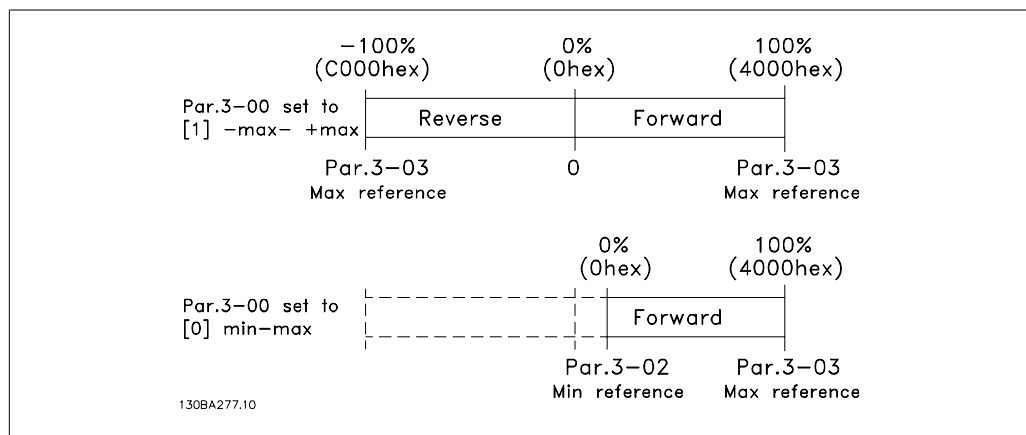
All bits in the STW are set to '0' if the connection between the Interbus option and the adjustable frequency drive is lost, or if an internal communication problem has occurred.

7.11.3. Bus Speed Reference Value

Speed reference value is transmitted to the adjustable frequency drive in a relative value in %. The value is transmitted in the form of a 16-bit word; in integers (0-32767) the value 16384 (4000 Hex) corresponds to 100%. Negative figures are formatted by means of 2's complement. The Actual Output frequency (MAV) is scaled in the same way as the bus reference.



The reference and MAV are scaled as follows:



8. Troubleshooting

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

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

In the event of an alarm, the adjustable frequency drive will have tripped. Alarms must be reset to restart operation once their cause has been rectified. This may be done in four ways:

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



NOTE

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

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

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

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

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

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

No.	Description	Warning	Alarm/Trip	Alarm/Trip Lock	Parameter Reference
1	10 Volts low	X			
2	Live zero error	(X)	(X)		6-01
3	No motor	(X)			1-80
4	Line phase loss	(X)	(X)	(X)	14-12
5	DC link voltage high	X			
6	DC link voltage low	X			
7	DC overvoltage	X	X		
8	DC undervoltage	X	X		
9	Inverter overloaded	X	X		
10	Motor ETR overtemperature	(X)	(X)		1-90
11	Motor thermistor overtemperature	(X)	(X)		1-90
12	Torque limit	X	X		
13	Overcurrent	X	X	X	
14	Ground fault	X	X	X	
15	Hardware mismatch		X	X	
16	Short Circuit		X	X	
17	Control word timeout	(X)	(X)		8-04
25	Brake resistor short-circuited	X			
26	Brake resistor power limit	(X)	(X)		2-13
27	Brake chopper short-circuited	X	X		
28	Brake check	(X)	(X)		2-15
29	Power board overtemp.	X	X	X	
30	Motor phase U missing	(X)	(X)	(X)	4-58
31	Motor phase V missing	(X)	(X)	(X)	4-58
32	Motor phase W missing	(X)	(X)	(X)	4-58
33	Soft-charge fault		X	X	
34	Serial communication bus fault	X	X		
38	Internal fault		X	X	
47	24 V supply low	X	X	X	
48	1.8 V supply low		X	X	
50	AMA calibration failed		X		
51	AMA check U_{nom} and I_{nom}		X		
52	AMA low I_{nom}		X		
53	AMA motor too big		X		
54	AMA motor too small		X		
55	AMA parameter out of range		X		
56	AMA interrupted by user		X		
57	AMA timeout		X		
58	AMA internal fault	X	X		
59	Current limit	X			
61	Tracking Error	(X)	(X)		4-30
62	Output Frequency at Maximum Limit	X			
64	Voltage Limit	X			
65	Control Board Overtemperature	X	X	X	
66	Heatsink Temperature Low	X			
67	Option Configuration Has Changed		X		
68	Safe Stop Activated		X		
80	Drive Initialized to Default Value		X		

8.1: Alarm/Warning code list

(X) Dependent on parameter

LED indication	
Warning	yellow
Alarm	flashing red
Trip-locked	yellow and red

Alarm Word and Extended Status Word						
Bit	Hex	Dec	Alarm Word	Warning Word	Extended Word	Status
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 Under-volt	DC Under-volt	Output Freq Low	
11	00000800	2048	DC Over-volt	DC Over-volt	Brake Check OK	
12	00001000	4096	Short Circuit	DC Voltage Low	Braking Max	
13	00002000	8192	Soft-charge fault	DC Voltage High	Braking	
14	00004000	16384	Line ph. Loss	Line ph. Loss	Out of Speed Range	
15	00008000	32768	AMA Not OK	No Motor	OVC Active	
16	00010000	65536	Live Zero Error	Live Zero Error		
17	00020000	131072	Internal Fault	10 V Low		
18	00040000	262144	Brake Overload	Brake Overload		
19	00080000	524288	U-phase Loss	Brake Resistor		
20	00100000	1048576	V-phase Loss	Brake IGBT		
21	00200000	2097152	W-phase Loss	Speed Limit		
22	00400000	4194304	Ser. com. bus fault	Ser. com. bus fault		
23	00800000	8388608	24 V Supply Low	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		

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

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

WARNING 1
10 Volts low:

The 10 V voltage from terminal 50 on the control card is below 10 V.
Remove some of the load from terminal 50, as the 10 V supply is overloaded. Max. 15 mA or minimum 590 Ω.

WARNING/ALARM 2
Live zero error:

The signal on terminal 53 or 54 is less than 50% of the value set in par. 6-10, 6-12, 6-20 or 6-22, respectively.

WARNING/ALARM 3
No motor:

No motor has been connected to the output of the adjustable frequency drive.

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 in case of a fault in the input rectifier on the adjustable frequency drive.

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 overvoltage limit of the control system. The adjustable frequency drive is still active.

WARNING 6

DC link voltage low

The intermediate circuit voltage (DC) is below the undervoltage limit of the control system. The adjustable frequency drive is still active.

WARNING/ALARM 7

DC overvoltage:

If the intermediate circuit voltage exceeds the limit, the adjustable frequency drive trips after a given period of time.

Possible corrections:

- Select Over Voltage Control function in par. 2-17
- Connect a brake resistor
- Extend the ramp time
- Activate functions in par. 2-10
- Increase par. 14-26

Selecting OVC function will extend the ramp times.

Alarm/warning limits:			
VLT AQUA	3 x 200-240 V AC	3 x 380-500 V AC	
	[VDC]	[VDC]	
Undervoltage	185	373	
Voltage warning low	205	410	
Voltage warning high (w/o brake - w/brake)	390/405	810/840	
Overvoltage	410	855	

The voltages stated are the intermediate circuit voltage of the VLT AQUA with a tolerance of $\pm 5\%$. The corresponding line voltage is the intermediate circuit voltage (DC link) divided by 1.35.

WARNING/ALARM 8

DC undervoltage:

If the intermediate circuit voltage (DC) drops below the "voltage warning low" limit (see table above), the adjustable frequency drive checks if 24 V backup supply is connected.

If no 24 V backup supply is connected, the adjustable frequency drive trips after a given period of time, depending on the unit.

To check whether the supply voltage matches the adjustable frequency drive, see 3.2 *General Specifications*.

WARNING/ALARM 9

Inverter overloaded:

The adjustable frequency drive is about to cut out because of an overload (too high current for too long). The counter for electronic, thermal inverter protection gives a warning at 98% and trips at 100%, while giving an alarm. You cannot reset the adjustable frequency drive until the counter is below 90%.

The fault is that the adjustable frequency drive has been overloaded by more than nominal current for too long.

WARNING/ALARM 10

Motor ETR overtemperature:

According to the electronic thermal protection (ETR), the motor is too hot. You can choose if you want the adjustable frequency drive to give a warning or an alarm when the counter reaches 100% in par. 1-90. The fault is that the motor has been overloaded by more than nominal current for too long. Check that the motor par. 1-24 is set correctly.

WARNING/ALARM 11**Motor thermistor overtemp.:**

The thermistor or the thermistor connection is disconnected. You can choose if you want the adjustable frequency drive to give a warning or an alarm in par. 1-90. Make sure the thermistor is connected correctly between terminal 53 or 54 (analog voltage input) and terminal 50 (+10 V supply), or between terminal 18 or 19 (digital input PNP only) and terminal 50. If a KTY sensor is used, check for correct connection between terminal 54 and 55.

WARNING/ALARM 12**Torque limit:**

The torque is higher than the value in par. 4-16 (in motor operation), or the torque is higher than the value in par. 4-17 (in regenerative operation).

WARNING/ALARM 13**Overcurrent:**

The inverter peak current limit (approximately 200% of the rated current) is exceeded. The warning will last approximately 8-12 sec., then the adjustable frequency drive trips and issues an alarm. Turn off the adjustable frequency drive and check if the motor shaft can be turned and if the motor size matches the adjustable frequency drive.

ALARM 14**Ground fault:**

There is a discharge from the output phases to ground, either in the cable between the adjustable frequency drive and the motor or in the motor itself.

Turn off the adjustable frequency drive and remove the ground fault.

ALARM 15**Incomplete hardware:**

A fitted option is not handled by the present control board (hardware or software).

ALARM 16**Short-circuit:**

There is a short-circuit in the motor or on the motor terminals.

Turn off the adjustable frequency drive and remove the short-circuit.

WARNING/ALARM 17**Control word timeout:**

There is no communication to the adjustable frequency drive.

The warning will only be active when par. 8-04 is NOT set to *OFF*.

If par. 8-04 is set to *Stop* and *Trip*, a warning appears and the adjustable frequency drive ramps down to zero speed, while giving an alarm.

Par. 8-03 *Control Word Timeout Time* could possibly be increased.

WARNING 25**Brake resistor short-circuited:**

The brake resistor is monitored during operation. If it short-circuits, the brake function is disconnected and the warning appears. The adjustable frequency drive still works, but without the brake function. Turn off the adjustable frequency drive and replace the brake resistor (see par. 2-15 *Brake Check*).

ALARM/WARNING 26**Brake resistor power limit:**

The power transmitted to the brake resistor is calculated as a percentage, as a mean value over the last 120 s, on the basis of the resistance value of the brake resistor (par. 2-11) and the intermediate circuit voltage. The warning is active when the dissipated braking energy is higher than 90%. If *Trip* [2] has been selected in par. 2-13, the adjustable frequency drive cuts out and issues this alarm when the dissipated braking energy is higher than 100%.

WARNING/ALARM 27**Brake chopper fault:**

The brake transistor is monitored during operation, and if it short-circuits, the brake function disconnects and the warning is issued. The adjustable frequency drive is still able to run, but since the brake transistor has short-circuited, substantial power is transmitted to the brake resistor, even if it is inactive.

Turn off the adjustable frequency drive and remove the brake resistor.



Warning: There is a risk of substantial power being transmitted to the brake resistor if the brake transistor is short-circuited.

ALARM/WARNING 28**Brake check failed:**

Brake resistor fault: the brake resistor is not connected/working.

WARNING/ALARM 29**Drive overtemperature:**

If the enclosure is IP 20 or IP 21/TYPER 1, the cut-out temperature of the heat-sink is 203 °F ± 10 °F [95 °C ± 5 °C]. The temperature fault cannot be reset until the temperature of the heatsink is below 158 °F [70 °C].

The fault could be a result of:

- Ambient temperature too high
- Motor cable too long

ALARM 30**Motor phase U missing:**

Motor phase U between the adjustable frequency drive and the motor is missing. Turn off 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. Turn off 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. Turn off the adjustable frequency drive and check motor phase W.

ALARM 33**Soft-charge fault:**

Too many powerups have occurred within a short period of time. See the chapter *General Specifications* for the allowed number of power-ups within one minute.

WARNING/ALARM 34**Ser. com. bus fault:**

The serial communication bus on the communication option card is not working.

ALARM 38**Internal fault:**

Contact your local Danfoss supplier.

WARNING 47**24 V supply low:**

The external 24 V DC backup power supply may be overloaded, otherwise contact your Danfoss supplier.

ALARM 48**1.8 V supply low:**

Contact your Danfoss supplier.

WARNING 49**Speed limit:**

The speed has been limited by range in par. 4-11 and par. 4-13.

ALARM 50**AMA calibration failed:**

Contact your Danfoss supplier.

ALARM 51**AMA check Unom and Inom:**

The setting of motor voltage, motor current and motor power is presumably wrong. Check the settings.

ALARM 52**AMA low Inom:**

The motor current is too low. Check the settings.

ALARM 53**AMA motor too big:**

The motor is too big for the AMA to be carried out.

ALARM 54**AMA motor too small:**

The motor is too small for the AMA to be carried out.

ALARM 55**AMA par. out of range:**

The par. values found from the motor are outside the acceptable range.

ALARM 56**AMA interrupted by user:**

The AMA has been interrupted by the user.

ALARM 57**AMA timeout:**

Try to start the AMA again a number of times, until the AMA is carried out. Please note that repeated runs may heat the motor to a level where the resistances R_s and R_r are increased. In most cases, however, this is not critical.

WARNING/ALARM 58**AMA internal fault:**

Contact your Danfoss supplier.

WARNING 59**Current limit:**

The current is higher than the value in par. 4-18.

WARNING 62**Output Frequency at Maximum Limit:**

The output frequency is limited by the value set in par. 4-19

ALARM 63**Mechanical Brake Low:**

The actual motor current has not exceeded the "release brake" current within the "Start delay" time window.

WARNING 64**Voltage Limit:**

The load and speed combinations demand a motor voltage higher than the actual DC link voltage.

WARNING/ALARM/TRIP 65**Control Card Overtemperature:**

Control card overtemperature: The cut-out temperature of the control card is 176°F [80°C].

WARNING 66**Heatsink Temperature Low:**

The heatsink temperature is measured at 32°F [0°C]. This could indicate that the temperature sensor is defective, and that the fan speed has increased to maximum, if the power part or control card is very hot.

ALARM 67**Option Configuration has Changed:**

One or more options has either been added or removed since the last power-down.

ALARM 70**Illegal Frequency Configuration:**

Current combination of control board and power board is illegal.

ALARM 80**Drive Initialized to Default Value:**

Parameter settings are initialized to default setting after a manual (three-finger) reset or via par. 14-22.

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