

Bonfiglioli **Vectron**

ACTIVE CUBE

Application Manual
Safe Torque Off STO



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1 General information about the documentation

The present documentation complements the operating instructions and the Quick Start Guide of the following frequency inverters:

- ACU210 (device series ACTIVE CUBE 210)
- ACU410 (device series ACTIVE CUBE 410)
- ACU510 (device series ACTIVE CUBE 510)
- ACU610 (device series ACTIVE CUBE 610)

For reasons of convenience, we use the term ACU410 in the document below for all the above devices.

1.1 Instruction manuals

For better clarity, the documentation is structured according to the customer-specific requirements made on the frequency inverter.

Quick Start Guide

The “Quick Start Guide” describes the basic steps required for mechanical and electrical installation of the frequency inverter. The guided commissioning supports you in the selection of necessary parameters and the configuration of the frequency inverter by the software.

Operating Instructions

The Operating Instructions document the complete functionality of the frequency inverter. The parameters required for special purposes, for adjustment to the application and the numerous additional functions are described in detail.

Application manual

The application manual supplements the documentation for purposeful installation and commissioning of the frequency inverter. Information on various topics in connection with the use of the frequency inverter is described in context with the specific application.



If you need a copy of the documentation or additional information, contact your local representative of BONFIGLIOLI.

The present documentation was prepared with great care and it was subjected to extensive and repeated reviews. For reasons of clarity, it was not possible to include all details of all types of the product in the documentation. Neither was it possible to consider all conceivable installation, operation or maintenance situations. If you require further information or if you meet with specific problems which are not dealt with in sufficient detail in the documentation, contact your local BONFIGLIOLI agent.

The present document was created in German. Other language versions are translations.

1.2 This document

This documentation describes the frequency inverters of the *ACTIVE Cube* series. The modular hardware and software structure enables customer-specific adaptation of the frequency inverters. Applications with high functionality and dynamism requirements can be realized easily.

The applicable basic standards as well as application-specific and specific national standards shall also be complied with – the standards referred to in this manual shall also be complied with.

For this reason, make sure you read the user manual carefully.

IMPORTANT: Compliance with the documentation is required to ensure safe operation of the frequency inverter. BONFIGLIOLI VECTRON GmbH shall not be held liable for any damage caused by any non-compliance with the documentation.



In case any problems occur which are not covered by the documentation sufficiently, please contact the manufacturer.

1.3 Warranty and liability

BONFIGLIOLI VECTRON GmbH (hereinafter referred to as "manufacturer") notes that the contents of this Operating Instructions document do not form part of any previous or existing agreement, assurance or legal relationship between the manufacturer and the user of these Operating Instructions (hereinafter referred to as the "User"). Neither are they intended to supplement or replace such agreements, assurances or legal relationships. Any obligations of the manufacturer shall solely be based on the relevant purchase agreement which also includes the complete and solely valid warranty stipulations. These contractual warranty provisions are neither extended nor limited by the specifications contained in this documentation.

The manufacturer reserves the right to correct or amend the specifications, product information and omissions in these operating instructions without prior notice. The manufacturer assumes no responsibility to update these Operating Instructions. The manufacturer shall not be liable for any damage, injuries or costs which may be caused by the aforementioned reasons.

In addition, the manufacturer excludes any warranty and disclaims all liability, including without limitation direct, indirect, special, punitive, incidental, exemplary or consequential damages arising out of or in connection with one or more of the following causes:

- inappropriate use of the frequency inverter,
- non-compliance with the instructions, warnings and prohibitions contained in the documentation,
- unauthorized modifications of the solar inverter,
- insufficient monitoring of parts of the machine/plant which are subject to wear,
- repair work at the machine/plant not carried out properly or in time,
- catastrophes by external impact and Force Majeure.

1.4 Obligation

This user manual must be read before commissioning and complied with. Anybody entrusted with tasks in connection with the

- transport,
- assembly,
- installation of the frequency inverter and
- operation of the frequency inverter

must have read and understood the Operating Instructions and, in particular, the safety instructions in order to prevent personal and material losses.

1.5 Copyright

In accordance with applicable law against unfair competition, this user manual is a certificate. Any copyrights relating to it shall remain with

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Germany

These user manual is intended for the operator of the frequency inverter. Any disclosure or copying of this document, exploitation and communication of its contents (as hardcopy or electronically) shall be forbidden, unless permitted expressly.

Any non-compliance will constitute an offense against the copyright law dated 09 September 1965, the law against unfair competition and the Civil Code and may result in claims for damages. All rights relating to patent, utility model or design registration reserved.

1.6 Storage

The documentation form an integral part of the frequency inverter. It must be stored such that it is accessible to operating staff at all times. In case the frequency inverter is sold to other users, this user manual must also be handed over.

2 General safety instructions and information on use

This chapter contains general safety instructions for the Operator and the Operating Staff. At the beginning of certain main chapters, some safety instructions are included which apply to all work described in the relevant chapter. Special work-specific safety instructions are provided before each safety-relevant work step.

2.1 Terminology

According to the documentation, different activities must be performed by certain persons with certain qualifications.

The groups of persons with the required qualification are defined as follows:

Operator

This is the entrepreneur/company who/which operates the frequency inverter and uses it as per the specifications or has it operated by qualified and instructed staff.

Operating staff

The term Operating Staff covers persons instructed by the Operator of the frequency inverter and assigned the task of operating the frequency inverter.

Skilled Personnel

The term Skilled Personnel covers staff that are assigned special tasks by the Operator of the frequency inverter, e.g. installation, maintenance and service/repair and troubleshooting. Based on their qualification and/or know-how, Skilled Personnel must be capable of identifying defects and assessing functions.

Qualified electrician

The term Qualified Electrician covers qualified and trained staff who has special technical know-how and experience with electrical installations. In addition, Qualified Electricians must be familiar with the applicable standards and regulations, they must be able to assess the assigned tasks properly and identify and eliminate potential hazards.

Instructed person

The term Instructed Person covers staff who was instructed and trained about/in the assigned tasks and the potential hazards that might result from inappropriate behavior. In addition, instructed persons must have been instructed in the required protection provisions, protective measures, the applicable directives, accident prevention regulations as well as the operating conditions and verified their qualification.

Expert

The term Expert covers qualified and trained staff who has special technical know-how and experience relating to frequency inverter. Experts must be familiar with the applicable government work safety directives, accident prevention regulations, guidelines and generally accepted rules of technology in order to assess the operationally safe condition of the frequency inverter.

2.2 Designated use

The frequency inverter is designed according to the state of the art and recognized safety regulations.

The frequency inverters are electrical drive components intended for installation in industrial plants or machines. Commissioning and start of operation is not allowed until it has been verified that the machine meets the requirements of the EC Machinery Directive 2006/42/EC and DIN EN 60204-1.

The frequency inverters meet the requirements of the low voltage directive 2006/95/EEC and DIN EN 61800-5-1. CE-labeling is based on these standards. Responsibility for compliance with the EMC Directive 2004/108/EC lies with the operator. Frequency inverters are only available at specialized dealers and are exclusively intended for commercial use as per EN 61000-3-2.

No capacitive loads may be connected to the frequency inverter.

The technical data, connection specifications and information on ambient conditions are indicated on the rating plate and in the documentation and must be complied with in any case.

2.3 Misuse

Any use other than that described in "Designated use" shall not be permissible and shall be considered as misuse.

For, example, the machine/plant must not be operated

- by uninstructed staff,
- while it is not in perfect condition,
- without protection enclosure (e.g. covers),
- without safety equipment or with safety equipment deactivated,
- when general requirements, such as operating conditions and technical data, are not met.

The manufacturer shall not be held liable for any damage resulting from such misuse. The sole risk shall be borne by the operator.

2.3.1 Explosion protection

The frequency inverter is an IP 20 ingress protection rating device. For this reason, use of the device in explosive atmospheres is not permitted.

2.4 Residual risks

Residual risks are special hazards involved in handling of the frequency inverter which cannot be eliminated despite the safety-compliant design of the device. Residual risks are not obviously identifiable and can be a potential source of injury or a health hazard.

Typical residual hazards include:

- Electrical hazard
- Danger of contact with energized components due to a defect, opened covers or enclosures or improper working on electrical equipment.
- Danger of contact with energized components in frequency inverter if no external disconnection device was installed by the operator.

During operation, all covers must be installed correctly, and all electrical cabinet doors must be closed to minimize electrical hazards.

When LEDs and other indicating elements on the frequency inverter go out, this does not necessarily mean that the device is deenergized. Before carrying out any Work at the device where contact with energized parts might be possible, it must be checked in any case, i.e. irrespective of the status of any indicating elements that may be installed, if the device is deenergized.

Charged capacitors in DC link

Sizes 1 through 7 (up to 160 kW): The DC-link may have dangerous voltage levels even up to 3 minutes after shutdown.

Size 8 (as from 160 kW): The DC-link may have dangerous voltage levels even up to 10 minutes after shutdown.

Electrostatic charging

Touching electronic components entails the risk of electrostatic discharges.

Thermal hazards

Risk of accidents by hot machine/plant surfaces, e.g. heat sink, transformer, fuse or sine filter.

Danger of equipment falling down/over, e.g. during transport

Center of gravity is not the middle of the electrical cabinet modules.

2.5 Safety and warning signs on frequency inverter

- Comply with all safety instructions and danger information provided on the frequency inverter.
- Safety information and warnings on the frequency inverter must not be removed.

2.6 Warning information and symbols used in the Operating Instructions

2.6.1 Hazard classes

The following hazard identifications and symbols are used in the Operating Instructions to mark particularly important information:



DANGER

Identification of immediate threat holding a high risk of death or serious injury if not avoided.



WARNING

Identification of immediate threat holding a medium risk of death or serious injury if not avoided.



CAUTION

Identification of immediate threat holding a low risk of minor or moderate physical injury if not avoided.

NOTICE

Identification of a threat holding a risk of material damage if not avoided.

2.6.2 Hazard symbols

Symbol	Meaning	Symbol	Meaning
	General hazard		Suspended load
	Electrical voltage		Hot surfaces
	Danger of crushing		

2.6.3 Prohibition signs

Symbol	Meaning
	No switching; it is forbidden to switch the machine/plant, assembly on

2.6.4 Personal safety equipment

Symbol	Meaning
	Wear body protection
	Wear ear protectors


2.6.5 Recycling

Symbol	Meaning
	Recycling, to avoid waste, collect all materials for reuse


2.6.6 Grounding symbol

Symbol	Meaning
	Ground connection

2.6.7 ESD symbol

Symbol	Meaning
	ESD: Electrostatic Sensitive Devices, i.e. components and assemblies sensitive to electrostatic energy

2.6.8 Information signs

Symbol	Meaning
	Tips and information making using the frequency inverter easier.

2.6.9 Font style in documentation

Example	Font style	Use
1234	bold	Representation of parameter numbers
<i>Parameter</i>	inclined, font: Times New Roman	Representation of parameter names
P.1234	bold	Representation of parameter numbers without name, e.g. in formulas
Q.1234	bold	Representation of source numbers

2.7 Directives and guidelines to be adhered to by the operator

The operator must follow the following directives and regulations:

- Ensure that the applicable workplace-related accident prevention regulations as well as other applicable national regulation are accessible to the staff.
- An authorized person must ensure, before using the frequency inverter, that the device is used in compliance with its designated use and that all safety requirements are met.
- Additionally, comply with the applicable laws, regulations and directives of the country in which the frequency inverter is used.
- For liquid cooled frequency inverters, comply with the cooling water guideline VGB-R 455 P.
- Any additional guidelines and directives that may be required additionally shall be defined by the operator of the machine/plant considering the operating environment.

2.8 Operator's general plant documentation

- In addition to the Operating Instructions, the operator should issue separate internal user manuals for the frequency inverter. The Operating Instructions of the frequency inverter must be included in the Operating Instructions of the whole plant.

2.9 Operator's/operating staff's responsibilities

2.9.1 Selection and qualification of staff

- Any work on the frequency inverter may only be carried out by skilled personnel. The staff must not be under the influence of any drugs. Note the minimum age required by law. Define the staff's responsibility pertaining to all work on the frequency inverter clearly.
- Work on the electrical components may only be performed by a qualified electrician according to the applicable rules of electrical engineering.
- The operating staff must be trained for the relevant work to be performed.

2.9.2 General work safety

- In addition to the Operating Instructions of the machine/plant, any applicable legal or other regulations relating to accident prevention and environmental protection must be complied with. The staff must be instructed accordingly.
Such regulations and/or requirements may include, for example, handling of hazardous media and materials or provision/use of personal protective equipment.
- In addition to this Operating Instructions, issue any additional directives that may be required to meet specific operating requirements, including supervision and reporting requirements, e.g. directives relating to work organization, workflow and employed staff.
- Unless approved of expressly by the manufacturer, do not modify the frequency inverter in any way, including addition of attachments or retrofits.
- Only use the frequency inverter if the rated connection and setup values specified by the manufacturer are met.

- Provide appropriate tools as may be required for performing all work on the frequency inverter properly.

2.9.3 Ear protectors

- The frequency inverter produces noise. Due to noise development, frequency inverters should only be installed in normally unstaffed areas.
- Noise emission in operation is < 85 dB(A) in the case of sizes 1 through 7.
- Noise emission in operation is approx. 86 dB(A) in the case of size 8. Ear protectors must be used when staying near the frequency inverter.

2.10 Organizational measures

2.10.1 General

- Train your staff in the handling and use of the frequency inverter and the machine/plant as well as the risks involved.
- Use of any individual parts or components of the frequency inverter in other parts of the operator's machine/plant is prohibited.
- Optional components for the frequency inverter must be used in accordance with their designated use and in compliance with the relevant documentation.

2.10.2 Use in combination with third-party products

- Please note that Bonfiglioli Vectron GmbH will not accept any responsibility for compatibility with third-party products (e.g. motors, cables or filters).
- In order to enable optimum system compatibility Bonfiglioli Vectron GmbH offers components facilitating commissioning and providing optimum synchronization of the machine/plant parts in operation.
- If you use the frequency inverter in combination with third-party products, you do so at your own risk.

2.10.3 Handling and installation

- Do not commission any damaged or destroyed components.
- Prevent any mechanical overloading of the frequency inverter. Do not bend any components and never change the isolation distances.
- Do not touch any electronic construction elements and contacts. The frequency inverter is equipped with components which are sensitive to electrostatic energy and can be damaged if handled improperly. Any use of damaged or destroyed components will endanger the machine/plant safety and shall be considered as non-compliance with the applicable standards.
- Only install the frequency inverter in a suitable operating environment. The frequency inverter is exclusively designed for installation in industrial environments.
- If seals are removed from the case, this can result in the warranty becoming null and void.

2.10.4 Electrical connections

- The five safety rules must be complied with.
- Never touch live terminals. In sizes 1 through 7, the DC-link may have dangerous voltage levels up to 3 minutes after shutdown. In size 8, the DC-link may have dangerous voltage levels up to 10 minutes after shutdown.
- When performing any work on/with the frequency inverter, always comply with the applicable national and international regulations/laws on work on electrical equipment/plants of the country in which the frequency inverter is used.
- The cables connected to the frequency inverters may not be subjected to high-voltage insulation tests unless appropriate circuitry measures are taken before.
- Only connect the frequency inverter to suitable supply mains.

2.10.4.1 The five safety rules

When working on/in electrical plants, always follow the five safety rules:

- 1 Isolate
- 2 Secure to prevent restarting
- 3 Check isolation
- 4 Earth and short-circuit
- 5 Cover or shield neighboring live parts

2.10.5 Safe operation

- During operation of the frequency inverter, always comply with the applicable national and international regulations/laws on work on electrical equipment/plants.
- Before commissioning and the start of the operation, make sure to fix all covers and check the terminals. Check the additional monitoring and protective devices according to the applicable national and international safety directives.
- During operation, all covers must be installed correctly, and all electrical cabinet doors must be closed. During operation, never open the machine/plant.
- No connection work shall be carried out while power supply is on.
- The machine/plant holds high voltage levels during operation, is equipped with rotating parts (fan) and has hot surfaces. Any unauthorized removal of covers, improper use, wrong installation or operation may result in serious injuries or material damage.
- Some components, e.g. the heat sink or braking resistor, may be hot even some time after the machine/plant was shut down. Don't touch any surfaces directly after shutdown. Wear safety gloves where necessary.
- The frequency inverter may hold dangerous voltage levels until the capacitor in the DC link is discharged. After shutdown, wait for at least 3 minutes (sizes 1 through 7) and at least 10 minutes (size 8) before starting any electrical or mechanical work on the frequency inverter. Even after this waiting time, make sure that the equipment is deenergized in accordance with the safety rules before starting the work.
- In order to avoid accidents or damage, only skilled personnel and electricians may carry out the work such as installation, commissioning or setup.
- In the case of a defect of terminals and/or cables, immediately disconnect the frequency inverter from mains supply.
- Persons not familiar with the operation of the frequency inverter and children must not have access to the device.
- Do not bypass nor decommission any protective devices.
- The frequency inverter may be connected to power supply every 60 s. This must be considered when operating a mains contactor in jog operation mode. For commissioning or after an emergency stop, a non-recurrent, direct restart is permissible.
- After a failure and restoration of the power supply, the motor may start unexpectedly if the Auto Start function is activated.
If staff are endangered, a restart of the motor must be prevented by means of external circuitry.
- Before commissioning and the start of the operation, make sure to fix all covers and check the terminals. Check the additional monitoring and protective devices according to EN 60204 and applicable the safety directives (e.g. Working Machines Act or Accident Prevention Directives).

2.10.6 Maintenance and service/troubleshooting

- Visually inspect the frequency inverter when carrying out the required maintenance work and inspections at the machine/plant.
- Perform the maintenance work and inspections prescribed for the machine carefully, including the specifications on parts/equipment replacement.
- Work on the electrical components may only be performed by a qualified electrician according to the applicable rules of electrical engineering. Only use original spare parts.
- Unauthorized opening and improper interventions in the machine/plant can lead to personal injury or material damage. Any repair work may only be carried out by the manufacturer or persons approved/licensed by the manufacturer. Any repair work must be carried out by qualified electricians. Check protective equipment regularly.
- Before performing any maintenance work, the machine/plant must be disconnected from mains supply and secured against restarting. The five safety rules must be complied with.

2.10.7 Final decommissioning

Unless separate return or disposal agreements were made, recycle the disassembled frequency inverter components:

- Scrap metal materials
- Recycle plastic elements
- Sort and dispose of other component materials



Electric scrap, electronic components, lubricants and other utility materials must be treated as special waste and may only be disposed of by specialized companies.



In any case, comply with any applicable national disposal regulations as regards environmentally compatible disposal of the frequency inverter. For more details, contact the competent local authorities.

3 Storage and transport



For information on weight and dimensions of the frequency inverter and further information on storage please refer to the applicable operating instruction document or the corresponding quick start guide document.

4 Safety Instructions on Function "Safe Torque Off" (STO)

The function „Safe Torque Off“ (STO) is a functional safety feature, i.e. it protects staff from damage, provided that projecting, installation and operation are performed properly. This function does not disconnect the plant from power supply.

In order to disconnect the plant from power supply (e.g. for maintenance work), an "Emergency Stop" provision as per EN 60204 must be installed.



WARNING

Uncontrolled starting

Improper installation of the safety technique can cause an uncontrolled starting of the drive. This may cause death, serious injuries and significant material damage.

- Safety functions may only be installed and commissioned by qualified staff.

The STO function does not provide an Emergency Switch Off as required under EN 60204. An Emergency Switch Off can be realized by installing a switch disconnecter for example.

An EMERGENCY STOP according to EN 60204 must be functioning in all operation modes of the application. Resetting of an EMERGENCY STOP or an EMERGENCY SWITCH OFF must not result in uncontrolled starting of the drive.

The drive is started again when the function STO is no longer triggered. In order to comply with EN 60204, it must be ensured by taking external measures that the drive does not start without prior confirmation.

Without a mechanical brake, the drive might not stop immediately but coast to a standstill. If this may result in personal or material damage, additional safety measures must be taken.

- If persons may be endangered after disconnection of the motor control by STO, access to the hazard areas must be prevented until the drive has stopped.
- Check the safety function at regular intervals according to the results of your risk assessment. BONFIGLIOLI VECTRON recommends that the check is performed after one year, at the latest.

The STO function is one fault fail-safe. No single fault or component failure can cause a disabled drive to produce motor shaft torque. Only in extremely unlikely combinations of component faults the motor shaft could move jerky with sudden acceleration (maximum $180^\circ/\text{number of pole pairs}$, for example jerky movement of 90° for 4-pole motor, $180^\circ/2$) and produce torque.

- It must be checked if this behavior can cause a dangerous machine movement.
- If the STO function is used, the special safety, installation and instructions on use instructions shall be complied with.



WARNING!

Dangerous voltage!

The "Safe Torque Off" function is only suitable for mechanical work on driven machines and not for work on live parts.

After switching off an external DC 24 V voltage supply, the mains voltage continues to be applied to the dc link circuit of the frequency inverter.

High voltages may still be present on the motor terminals, even when the motor energy supply is switched off and the motor is coasting down or at a standstill.

Before conducting work (e.g. Maintenance) on live parts, a galvanic disconnection from the mains (main switch) is required. This must be documented on the system.

When the "Safe Torque Off" function is triggered, the motor is not galvanically separated from the frequency inverter intermediate circuit. High voltages may be present on the motor.

- Do not touch live connections.

4.1 Approved Devices

The safety functions described in this documentation are valid if the ACU410 device bears an FS logo on the name plate.

Sample device type plate with functional safety:	Sample device type plate with functional safety (production date September 2020):	Sample device type plate without functional safety:
<p>Bonfiglioli 47807 Krefeld Vectron Germany</p> <p>Frequency Inverter ACU 410- 05 1 FA</p> <p>Input 400 V / 480 V 50 - 60 Hz 3ph 1.8 A</p> <p>Output 0 - Uinput, 0 - 599 Hz, 3ph</p> <p>0.55kW</p> <p>cont.[A] 1.8 60s [A] 2.7 1s [A] 3.6</p> <p>Ratings for temp. range 0 - 40°C Refer to Instruction Manual IP20</p> <p>integrated Filter</p> <p>PART No.: ACU-410051FASBXS0 SIACU123456789 SERIAL No.: 18042345 SW.: 12345678</p> <p>Made in Germany</p> <p>FS-Logo</p>	<p>Bonfiglioli 47807 Krefeld Vectron Germany</p> <p>Frequency Inverter ACU 410- 05 1 FA</p> <p>Input 400 V / 480 V 50 - 60 Hz 3ph 1.8 A</p> <p>Output 0 - Uinput, 0 - 599 Hz, 3ph</p> <p>0.55kW</p> <p>cont.[A] 1.8 60s [A] 2.7 1s [A] 3.6</p> <p>Ratings for temp. range 0 - 40°C Refer to Instruction Manual IP20</p> <p>integrated Filter</p> <p>PART No.: ACU-410051FASBXS0 SIACU123456789 SERIAL No.: 20072345 SW.: 12345678</p> <p>Made in Germany</p> <p>FS-Logo</p>	<p>Bonfiglioli 47807 Krefeld Vectron Germany</p> <p>Frequency Inverter ACU 410- 05 FA</p> <p>Input 400 V / 480 V 50 - 60 Hz 3ph 1.8 A</p> <p>Output 0 - Uinput, 0 - 1kHz, 3ph</p> <p>0.55kW</p> <p>83KA cont.[A] 1.8 E204867 60s [A] 2.7 Power Conversion 1s [A] 3.6 Equipment</p> <p>Ratings for temp. range 0 - 40°C Refer to Instruction Manual IP20</p> <p>integrated Filter</p> <p>PART No.: 603 404 000 SIACU123456789 SERIAL No.: 04072345 SW.: 12345678</p> <p>Made in Germany</p>



The name plates show examples of functional safety identification by the "functional safety" logo. Other features (e.g. UL approval) may deviate.

Depending on the production date, different FS logos are used to state the safety functions certified. Whatever the design, the FS logo is used to indicate that this device fulfills the safety function as described in this manual.

5 General description of safety function

5.1 Integrated safety function

Electronic protection systems are integrated in the drive control system and perform safety functions in order to minimize or eliminate hazards caused by functional errors of machines.

The integrated safety functions replace time-consuming and expensive installation of external safety components.

The safety function can be requested or triggered by an error.

In hazard areas, setup work or work for elimination or errors may be required where the isolating protection devices such as mains contactors or motor contactors must not be triggered. Here, the additional safety function may be used. STO can be used as an alternative to mains or motor contactors, which can be omitted dependent on the application.

The integrated safety functions reduce the risk of personal damage in hazard areas and reduce installation requirements.

5.2 Functional safety

The safety function of the control system must be ensured for normal, trouble-free operating states as well as in the case of an error. As a result of this requirement:

- The safety function must be checked in case errors are present. Possible methods include: error tree analysis, FMEA, etc.).

5.3 Classification the safety requirement

The integrated safety function “Safe Torque Off” of the ACU frequency inverter meets the following requirements:

- up to safety integrity level SIL 3 according to DIN EN 61800-5-2 and
- performance level (PL) e according to EN 13849-1

In the case of an error, thanks to the safety function STO, the frequency inverter does not supply energy to the motor which would cause a revolution or torque (or a movement or force in the case of a linear motor).

Characteristic for the classification mentioned above:

- If an error occurs, the safety function is maintained.

By using appropriate safety control devices, stop category 0 and stop category 1 according to EN 60204 can be achieved in the machine. For safety control devices, please refer to chapter 10.

Stop category 0: Stop by immediate disconnection of energy supply to the machine drive elements, i.e. uncontrolled stop.

Stop category 1: Controlled stop, where energy is still being supplied to the drive elements of the machine to perform the stopping operation. Energy supply is stopped only after the drive has come to a standstill.

Note that the drive may not stop immediately but coast to a standstill. If no mechanical brake is installed, or a defective brake may involve a risk, further protective measures (for example guard locking) are to be taken.

6 Description of ACTIVE Cube safety function

The frequency inverters of the ACU410 series feature the integrated safety function „Safe torque off, STO“.

With a suitable external switching device, the “Safe Stop 1 (SS1 c)” function can be realized with the ACU410 as per EN 61800-5-2.

Definitions according to EN 61800-5-2:

STO: No power is supplied to the motor, which may cause a revolution (or a movement with a linear motor). The frequency inverter supplies no power to the motor, which can produce a torque.

SS1 c: The safety switching device + frequency inverter system implements the following function:

Triggering of the motor delay and after an application-specific time lag, triggering of the STO function.

This safety function corresponds to the controlled standstill as per EN 60204-1, stop category 1.

Definitions according to EN 60204-1:

Stop category 0: Stop through immediate shutdown of power to the machine drive elements, i.e. uncontrolled standstill.

Stop category 1: A controlled stop, whereby the power supply to the machine drive elements is retained in order to achieve standstill. The power is only interrupted once standstill has been achieved.

Stop functions must always be given priority over start functions, and be able to function in all operating modes.

The resetting of the stop function may not trigger a dangerous state.

The mechanical elements must be dimensioned accordingly for the application. If for example a mechanical brake is applied with rapidly rotating machines in stop category 0, this brake must be capable of safely bringing the system to a standstill. The wear on mechanical elements must be taken into account during project planning for the operating states, and be labelled in the maintenance specifications.



Stop category 0 always has priority over stop category 1.

6.1 Definitions of the ACU410 safety functions

- **SF1:** Safety function 1
- **SF2:** Safety function 2
- **DF1:** Diagnosis function 1
- **DF2:** Diagnosis function 2

Response time:

The time delay between the request of the safety function at the user interface and the achievement of the safe state.

Example of STO: At the user interface, the signal level changes from over 12V to below 3V. The response time begins at the latest when the level falls below 5V, and ends when no more momentum can be generated.

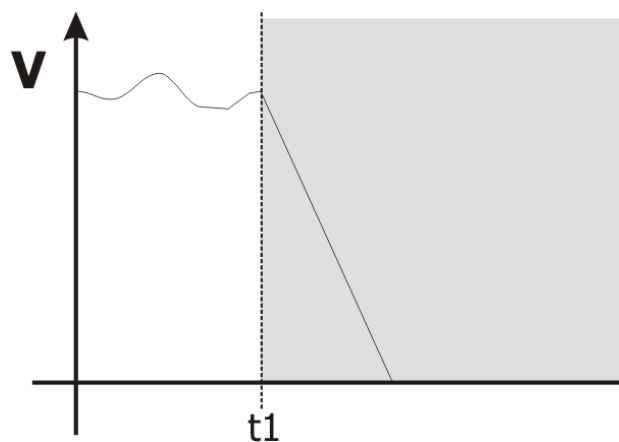
Fault response time:

The time delay between the occurrence of a recognizable error and the achievement of the safe state in the frequency inverter.

Example: The STO safety function can no longer be requested via channel A. The internal device diagnosis detects the error and initiates the necessary error response functions. Overall, the error response period runs until no more momentum can be generated.

6.2 Specification of safety function 1 (SF1): STO

Type of safety function SF1 in accordance with EN 61800-5-2	Safe Torque Off (STO)
Operating principle of the SF1	Interruption of the power supply to the motor
Request rate	High
SIL level (IEC 61800)	3
Redundancy	Dual-channel (2)
Performance level (EN ISO 13849-1)	e
Category (EN ISO 13849-1)	3
Number of process interfaces	Two (2)
Process interface configuration	X210A.3 and X210B.2 connections on two separate, disconnectable terminals (STOA and STOB inputs)
Process interface type	High signal: DC 12...30 V Low signal: DC 0...3.3 V
Operating modes with restricted functioning of the SF1	None
Response time SF1	None or equivalent of 10 ms
Fault response time DF1	None or equivalent of 100 ms

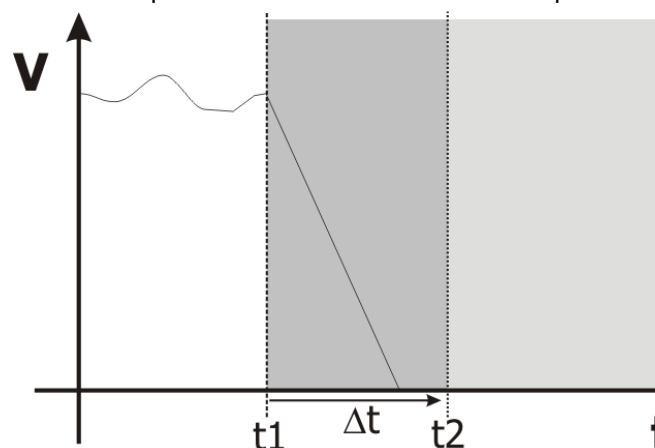


V Speed axis
t Time axis
t1 Point in time at which the STO is requested
 Area of shutdown

6.3 Specification of safety function 2 (SF2): SS1

Type of safety function SF2 in accordance with EN 61800-5-2	Safe Stop 1 (Safe Stop 1, SS1 c)
Operating principle of the SF2	Delay of the motor with appropriate brake ramp Interruption of the power supply to the motor following expiry of a safety-oriented time delay
Request rate	High
SIL level (IEC 61800)	3 with corresponding safety switching device
Redundancy	Dual-channel (2)
Performance level (EN ISO 13849-1)	e with corresponding safety switching device
Number of process interfaces	External safety switching device according to the risk analysis standards Two (2) on ACU410
Process interface configuration	External safety switching device according to the risk analysis standards X210A.3 and X210B.2 connections on two separate, disconnectable terminals (STOA and STOB inputs)
Process interface type STO	High signal: DC 12...30 V Low signal: DC 0...3.3 V
Operating modes with restricted functioning of the SF2	None
Response time SF2	External safety switching device: in accordance with the device data sheet ACU410: None or equivalent of 10 ms
Fault response time DF2	External safety switching device: in accordance with the device data sheet ACU410: None or equivalent of 100 ms

The safety function corresponds to a controlled standstill as per EN 60204-1, stop category 1.



V	Speed axis
t	Time axis
t1	Point in time at which the brake ramp is activated (non-secure path)
t2	Point in time at which the STO is requested
Δt	Time between activation of the brake ramp and STO request
	Maximum brake ramp range, set on the external safety switching device
	Area of shutdown

6.4 Description of the safety function

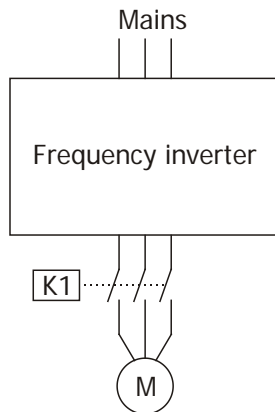
If an error occurs, or on request, power semiconductors of the frequency inverter will be switched off. After this, the frequency inverter does not supply energy to the drive which would cause a revolution or a torque (or a movement or force in the case of a linear drive). Mains voltage is still present. The function STO can be used, for example, for safe stopping in the case of a dangerous situation or for maintenance work on the machine. If an error occurs, the machine can still be (or remain) switched off safely.

Unlike shut-down via mains contactors or motor contactors, the integrated safety function enables easy combination of drives in a machine to form functional groups. The Safe Torque Off can be limited to certain plant areas in this way. Another advantage is the fact that it is not necessary to wait until the frequency inverter has been charged and discharged. Thus, readiness of the machine for operation can be restored more quickly. Standard electromechanical operating equipment is subject to wear; through the use of the STO function, this type of equipment is no longer required, and maintenance costs can be reduced.

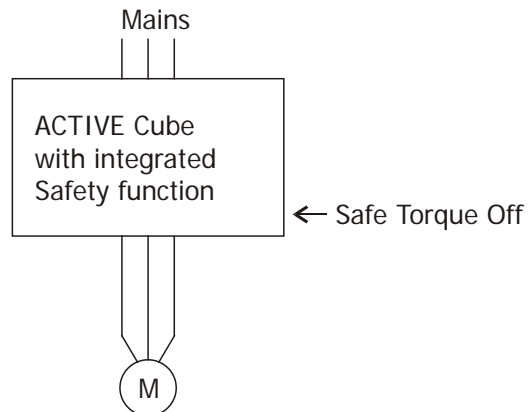
Safe Torque Off:

- Energy supply for the rotary field of the motor is interrupted; the motor coasts to a standstill
- Used if monitoring for standstill is not required
- Accidental start of the motor is prevented
- No galvanic isolation of motor from frequency inverter DC link

Sample standard system:



Integrated solution with ACU410 and use of the STO:



Further advantages:

- Contactors on motor side not required, reduced installation requirements, less components, more space in electrical cabinet
- Simple realization with external safety control device
- The drive can be connected to power supply continuously; communication and parameter configuration of the frequency inverter are maintained while the torque is disabled.
- Easier machine approval, because the safety function is certified via a type examination check.



Triggering of the “Safe Torque Off” function

The Safe Torque Off state can be achieved as follows:

- Intentional triggering during operation in order to shut down a drive and securely prevent re-starting, e.g. during maintenance work on a machine.
- Triggering through actuation of an emergency stop switch, or through monitoring of safety equipment, e.g. safety door.
- Detection of an error. The drive may only re-start when the error has been acknowledged and rectified.

Protection against re-starting

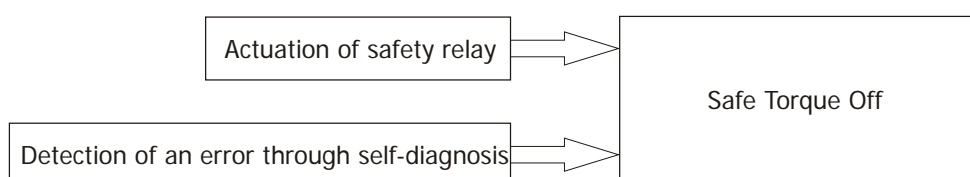
Note the following warning regarding re-starting.



WARNING

Unintended re-starting!

The drive restarts when the STO function is no longer requested. In order to meet the standards of the EN 60204 norm, it must be ensured through external measures that the drive only re-starts after an acknowledgement.



Application example:

The danger zone near a transport conveyor is monitored by a light grid. If anybody enters the danger zone, the light grid is interrupted. The DC 24 V supply for the digital inputs STO of the function „Safe Torque Off“ is switched off and the frequency inverter output stage is disabled. The drive coasts to a standstill. Disconnection from mains supply is not necessary. Communication via field bus or addressing via the terminals is still possible. An external brake which stops the motor can be addressed.

6.5 Two-Channel Monitoring

The STO function (Safe torque off) is realized via two channels in the frequency inverter (redundant design). Via two redundant monitored stop paths with fail-safe release (STOA and STOB), the frequency inverter is switched off safely even if an error occurs and the control voltage fails at the same time. Thus, the drive is stopped safely if an error occurs. An error is identified and can then be repaired (e.g. by replacing of a unit). Triggering can be effected, for example, via a two-channel contactor control with two release circuits and redundant disconnection of the main current or via a sensor or emergency stop switch with two contacts and separate cable routing to the evaluation unit.

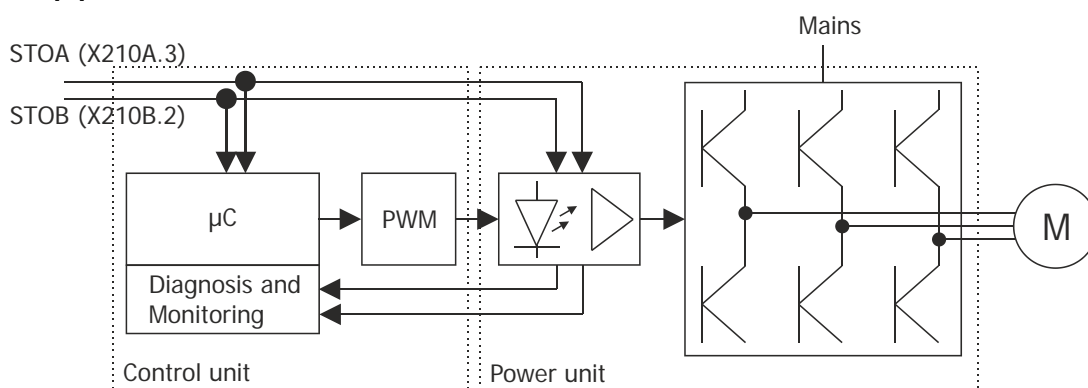
The stop paths are monitored cyclically every 32 ms. Both stop paths are designed identically.

Via the digital inputs STOA (X210A.3) and STOB (X210B.2), two DC 24 V control voltages of a protection device are applied. If the protection device is actuated, the control voltages are interrupted and the pulse block is activated; energy supply to the motor is switched off. Disconnection is effected at a delay of less than 10 ms.

If the STO function has been requested and triggered, the overriding controller has no influence on the pulse block¹ in the frequency inverter. For a re-start, the STO request must be reset and the operator or the superior PLC must issue a release. The release by the operator or the superior PLC can also continue to be active during the triggering of the STO. In this case, the release leads to an immediate re-start when the STO trigger is reset.

One single error will not result in a failure of the safety function.

Stop paths



The test required for monitoring the internal shutdown paths is performed by the frequency inverter automatically. If the test results negative, the releases are interrupted and the frequency inverter cannot be switched on anymore. Starting is possible again only after the inverter has been completely de-energized, the error repaired and the next test has been completed successfully.

Truth table

In the truth table, the states of the safety-relevant inputs STOA and STOB for activation and deactivation of the safety function STO are listed.

Truth table		
STOA	STOB	Description of state
0	0	Safety function "Safe Torque Off" (STO) has been triggered. The frequency inverter signals no error in STO function.
0	1	STO is triggered. Monitoring for error in frequency inverter or external circuitry (5-second monitoring). After 5 seconds, an error is signaled.
1	0	
1	1	STO is not triggered. Release for operation.

¹ If the pulse block is set, no motor revolving field is generated.

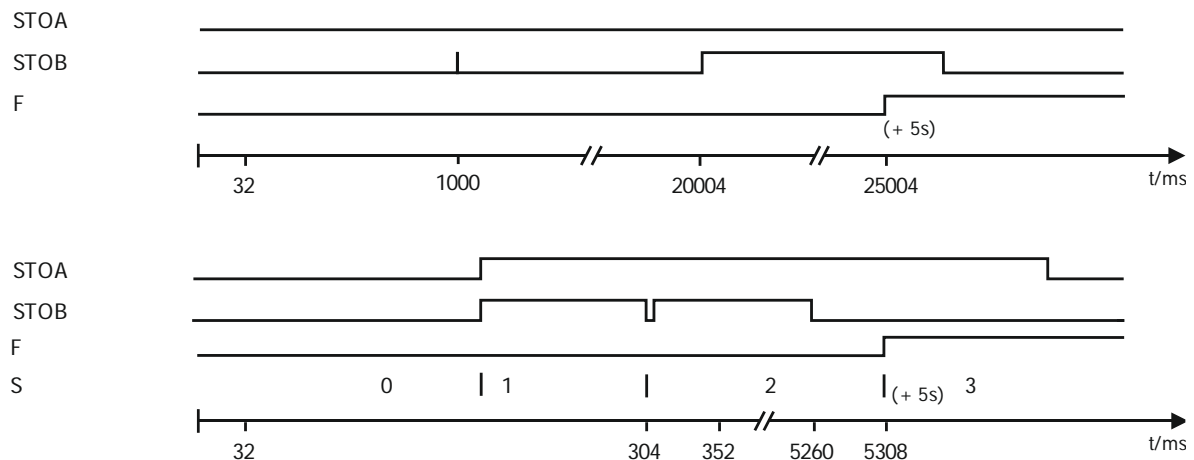
5-second monitoring

A check is made if the two inputs STOA or STOB are switched on within an interval of less than 5 sec for requesting the release of the frequency inverter output stages.

If function STO is triggered by removing one of the signals from inputs STOA or STOB, the status changes to "STO triggered". Now, the unit waits that both inputs are switched off. If this has not been done within 5 s after occurrence of this state, an error is triggered (5-second monitoring).

- Different signal states on inputs STOA or STOB start the 5-second monitoring. Exceptions are short impulses when the STO signals are in an idle state.
- Within 5 seconds, the same signal must be present of both inputs, otherwise an error will be signaled (F1205). Exceptions are short impulses when the STO signals are in an idle state.
- If the STO function is requested on one channel, the STO function must be requested on both channels within the next 5 s.

The F1205 error can be acknowledged via the error acknowledgement function of the frequency inverter.



F = error F1205 triggered

S = state

0 = drive blocked, no error

1 = drive without error, released

2 = STO function triggered

3 = 5 seconds after triggering of the STO function, an error is triggered, since the second channel has not experienced the same level changes within the 5-second period

Behavior of frequency inverter after start

- Initialization
- Monitoring for release request (5-second monitoring)
- Preparation of release (check of stop paths)
- Release of frequency inverter

Behavior of frequency inverter in the case of an error

- Switch off of IGBT in power output stage by disconnection of optocoupler supply voltage
- Suppression of control pulses of IGBT
- Setting of error bit with possibility of transfer to overriding controller
- Setting of digital output for error message
- Release of digital input for error acknowledgement.

6.6 Diagnosis function and enforced dynamizing

The test required to monitor the shutdown paths within the device is conducted independently by the frequency inverter. The shutdown paths are checked for errors using automated enforced dynamizing. If the test is negative, the frequency inverter can no longer be switched on and an error is reported to the "F12" group (e.g. F1201). The frequency inverter can only be switched back on after it has been disconnected from the voltage and the error has been corrected.

6.7 Diagnosis indicators

The LEDs of the frequency inverter indicate if the safety function is activated properly.

LED			
green	red	Description	Rotary field at motor
Off	Off	No supply voltage, unit is off	No
On	On	Initialization and self-test	No
Flashing	Off	Operation mode	No
On	Off	Operating message	Yes
On	Flashing	Warning message in operation	Yes
Flashing	Flashing	Ready for operation and warning message	No
Off	Flashing	Fault message	No
Off	On	Error message can be acknowledged	No

7 Requirements to be met by installation

7.1 Instructions on installation of safety equipment

- If work is to be carried out on live components, it must be possible to disconnect the machine from mains supply by means of a main switch.
- According to EN 61800-5-2 a fault exclusion can be considered with one of the following possibilities:
 - The conductor is installed permanently and in example protected against external damage with a cable duct or reinforcement.
 - Single multi-conductors are used.
 - The conductors are situated in an electrical cabinet.
 - The conductors are shielded independently and have grounding.
 - If applicable, the requirements of EN 60204-1 have to be considered to install the connectors correctly.
- Protection against dirt is ensured if the ACU410 frequency inverters and safety control equipment is installed in electrical cabinets with high IP protection, e.g. IP 54.
- If external forces act on the drive axis, e.g. in the case of vertical axes (suspended loads) or round axes with asymmetrical weight distribution, mechanical brakes must be installed additionally.
- Only use voltage sources with safe disconnection (SELV/PELV) according to VDE0100. Comply with the specifications in chapter 7.3.
- The ACU410 frequency inverters must not be supplied with pulsed signals. Cross fault detection via pulsed signals cannot be used for this reason. Errors can be excluded in the case of the ACU410 units because the terminal blocks for the STO function are physically separate from one another. The signal cables between the safety control equipment and ACU410 must either be physically separate from one another or suitable, cross fault proof cables.
- Comply with applicable EMC instructions mentioned in the operating instructions.
- After installation, check the safety function and error reaction and issue an acceptance report.
- Interrupting the STO signals prevents a start of the motor. According to EN 60204-1, STO must not be released during an impending endangerment.
- Also comply with the instructions on external safety control equipment.
- During commissioning, check the safety function.

Select the dimensions of the safety application such that for the STOA and STOB inputs, the input current is available in each case in accordance with the operating instructions (typically: 10 mA). If more than one ACU410 frequency inverters are connected to one safety control device, the safety control device must provide sufficient power for all of them.

7.2 External Safety Control Equipment

Safety control equipment, upon request (e.g. actuation of emergency stop or access to hazard area, must trigger appropriate responses in order to protect people, the machine and the environment. They evaluate sensor signals or safely switch off dangerous states.

External safety control devices must meet the following requirements:

- External safety control equipment and safety modules for control of the digital inputs (STO) must meet one of the following classifications, to meet the classification of the ACU device:
 - Safety integrity level SIL 3 as per DIN EN 61800-5-2, and
 - PL e / category 3 as per DIN EN ISO 13849-1
 - The entire installation must satisfy these standards.
- The switching capacity of the safety control equipment must be designed for the maximum permissible, limited output current of the DC 24 power supply. Comply with the instructions of the manufacturer of the safety control equipment on the permissible contact load and any safeguards to be provided for the safety contacts.
- The emergency stop device must comply with Standard EN ISO 13850.
- If a safety request (e.g. emergency stop actuated or sensor signals that safety door is open) is reset (emergency stop unlocked, safety door closed) this alone shall not result in a restart of the drive. Restart may only occur after the safety control device has been reset.

External safety control devices evaluate sensors:

Examples of contact sensors:

- Emergency stop control device for stop in dangerous situations
- Position switch, e.g. for monitoring slide doors, safety grids or moving machine parts

Examples of no-contact sensors:

- Light barriers, e.g. for monitoring areas with dangerous movements
- Light curtains

7.3 External DC 24 V power supply

During projection and installation of a DC 24 V supply connected to the frequency inverter, comply with the following instruction. This also includes supply of a safety control device the output of which is connected to a control input (including STOA and STOB) of the frequency inverter.



CAUTION

Use a suitable SELV/PELV voltage supply the nominal voltage of which must be DC 24 V $\pm 10\%$. The highest overvoltage may not exceed DC 32 V if an error occurs (one-fault protection). The one-fault protection can be secured through the overvoltage protection of the power supply unit (overvoltage protection OVP with restriction of the output voltage to maximum DC 32 V) or through external switching, such as a crowbar. It must be ensured that an adequate overvoltage category of the voltage supply is provided.

7.3.1 External DC 24 V voltage supply with group switching

If several frequency inverters are shut down by a DC 24 V voltage supply, the total power requirement of the STO inputs must be determined. The power requirement is given in the operating instructions.

Typical levels are 10 mA per STO input, per device.

Plan the cable profiles according to the calculated power, taking into account the maximum connectable cable profiles.

7.4 DC 24 V voltage supply through ACU410

A DC 24 V voltage supply of an external switching device by the ACU410 is not permissible.

8 Requirements to be met in operation

During operation, the projected and commissioned machine components must not be changed. If the machine is modified a new acceptance inspection is required.

Check the safety function at regular intervals. The test intervals are to be determined according to the risk analysis. However, the check should be performed once every year, at the latest.

9 Requirements to be met by acceptance inspection

The acceptance inspection of the safety function is ordered by the manufacturer of the machine. The inspection (acceptance) shall be performed by a properly qualified person.

The result of the inspection is to be documented and must be signed by the inspector. Each safety function must be documented in detail in this report.

The inspections also include the machine documentation, including its safety functions. The safety functions must be checked particularly during the inspection and documented in the inspection report. Parameter settings shall be attached to the report. Further documents shall be added, as required, depending on the machine.

Depending on the result of the risk analysis, inspection reports of the regular inspections shall be issued and signed by the inspector.

10 Application Examples

The following examples illustrate the method of functioning of the "Safe Torque Off" and "Safe Stop 1 (SS1)". According to EN 60204-1, stop functions are divided into different categories. Stop categories 0 and 1 can be realized in connection with the ACU410 frequency inverter using suitable safety switching devices.



Terminal X210A.1 can be used for DC 24 V supply of the safety control unit.

- Please note the current capacity of the frequency inverter (and the current requirements of the safety control device).

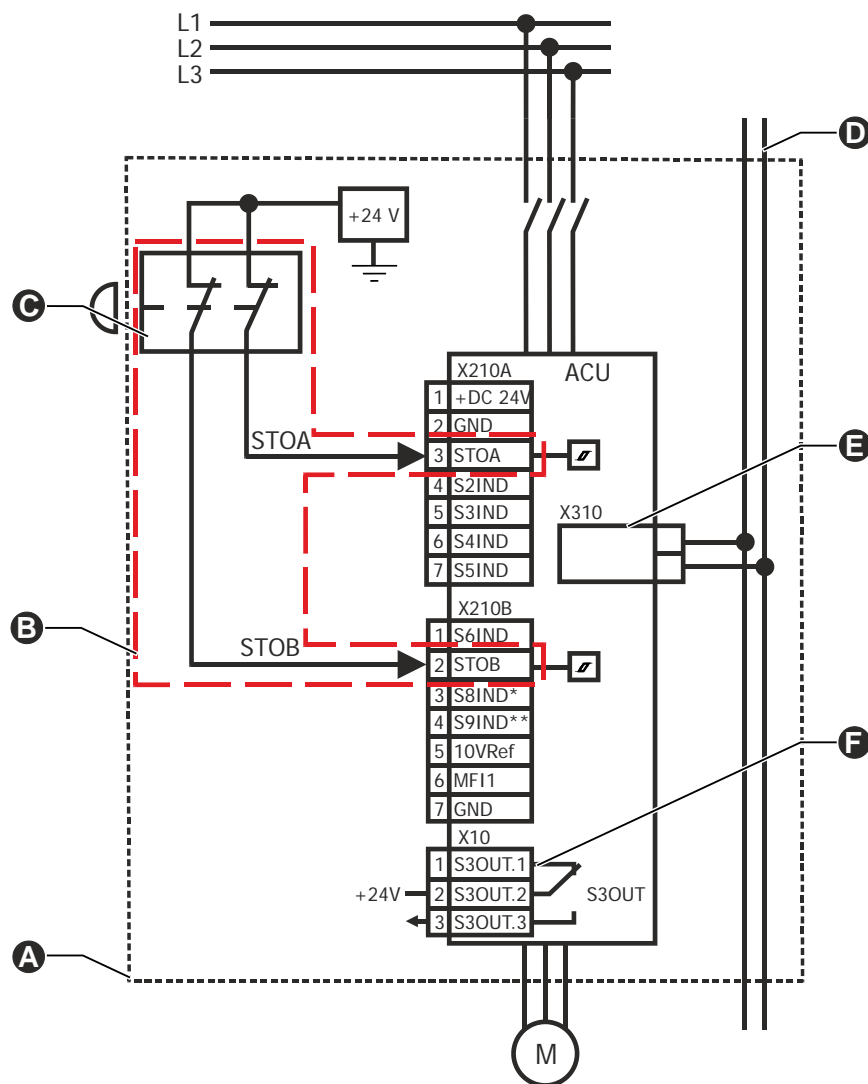
10.1 STO according to Stop Category 0

10.1.1 STO direct stop

The application example shows the **minimum circuitry** for ACTIVE cube frequency inverters for realization of the safety function STO "Safe Torque Off" with an emergency stop device in a common electrical cabinet according to EN ISO 13849-1 PL e, IEC 61508 SIL 3.

If the emergency stop device with **two stop channels** is actuated, both stop paths STOA and STOB of the frequency inverter are interrupted. The integrated safety function is activated.

A (non-safe) feedback to a process controller can be effected, for example, via a connected field bus. If STO is requested, the overriding controller has no more influence on the pulse block in the frequency inverter.



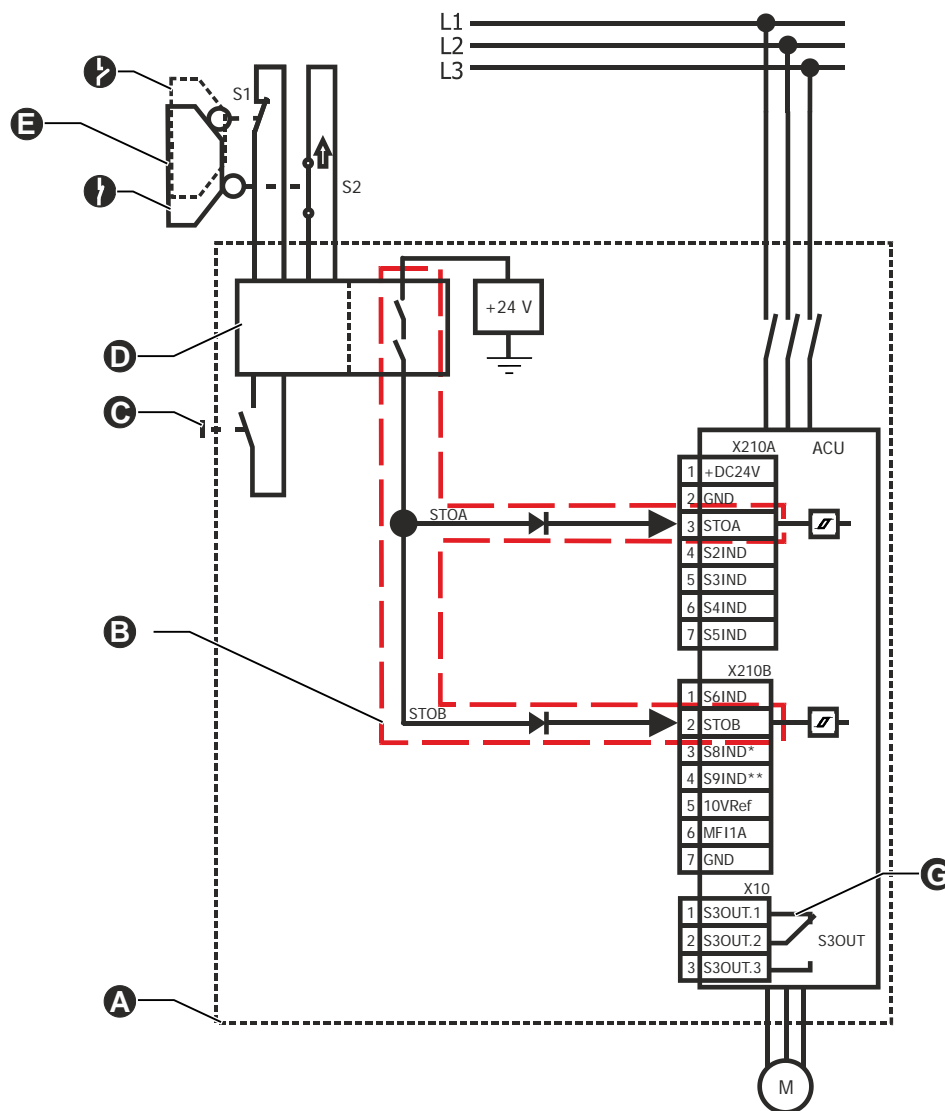
ACUx10-TD-STO_01-V00

A	Electrical cabinet	STOA / STOB	First and second shutdown path of the safety function
B	Safety circuit	X210A, X210B, X10	Control terminals of the frequency inverter
C	Safety control equipment	X310	Communication interface
D	Field bus	+ DC24 V	Input or output for control voltage
E	Field bus connection	GND	Earth
F	Relay	SxIND	Digital input
		S8IND*	Optionally, also S1OUTD digital output
		S9IND**	Optionally, also MFO1 multifunction output
		MFI	Multifunction input (analogue, digital, frequency signal, temperature evaluation)
		10VRef	Reference output DC 10 V

10.1.2 STO direct stop with “short-circuit” error exclusion in the electrical cabinet

The application circuit shows a drive control system according to EN ISO 13849-1 PL e, DIN EN 61800-5-2 SIL 3. Instead of a Safety equipment with two shutdown paths, a **safety control equipment with one shutdown path** and **one connection line** is selected. The following requirements must be met:

- The Safety equipment and the frequency inverter must be in the same electrical cabinet.
- The error exclusion in the case of a short-circuit must be guaranteed when laying the connection line between the Safety equipment and the ACU410 (e.g. insulated line).



ACUx10-TD-STO_02-V00

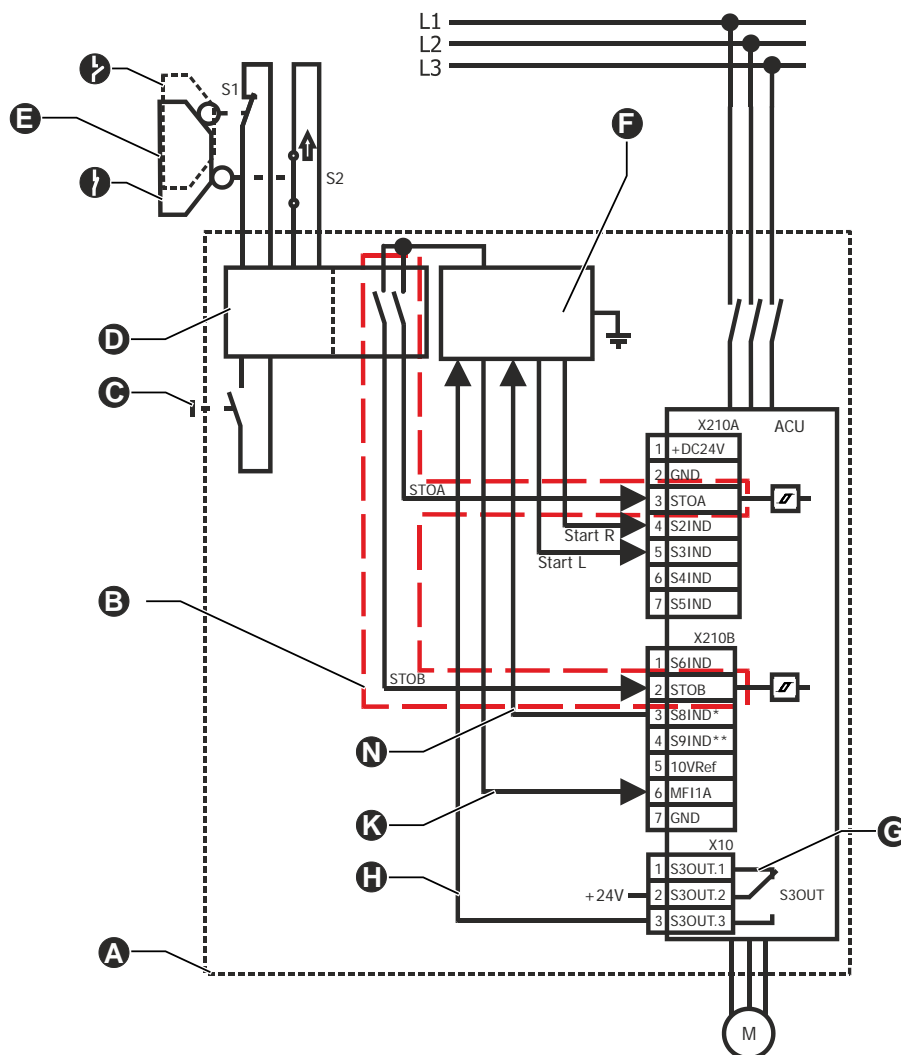
A	Electrical cabinet	STOA / STOB	First and second shutdown path of the safety function
B	Safety circuit	X210A, X210B, X10	Control terminals of the frequency inverter
C	Acknowledgement	X310	Communication interface
D	Safety equipment	+DC24 V	Input or output for control voltage
E	Emergency stop device	GND	Earth
⚡	Open	SxIND	Digital input
ⓘ	Closed	S8IND*	Optionally, also S1OUTD digital output
G	Relay	S9IND**	Optionally, also MFO1 multifunction output
		MF1	Multifunction input (analogue, digital, frequency signal, temperature evaluation)
		10VRef	Reference output DC 10 V
		↑	Position switch shown as actuated

10.1.3 STO direct stop with Feedback to PLC

The application circuit shows a drive control with PLC and a Safety equipment as per EN ISO 13849-1 PL e, DIN EN 61800-5-2 SIL 3. A PLC takes on the process control of the frequency inverter and can start the drive profiles using commands.

When the emergency stop device is actuated with **two shutdown channels**, e.g. via the safety door, the two release paths of the Safety equipment are interrupted. In this way, the loss of the control voltages on the STOA and STOB of the frequency inverter is interrupted. The integrated safety function according to SIL 3 is requested as per EN 61800-5-2 when the inverter release is interrupted.

The safety equipment monitors the function of the S1 and S2 switches.



ACUx10-TD-STO_03-V00

A	Electrical cabinet	STOA / STOB	First and second shutdown path of the safety function
B	Safety circuit	X210A, X210B, X10	Control terminals of the frequency inverter
C	Acknowledgement	X310	Communication interface
D	Safety equipment	+DC24 V	Input or output for control voltage
E	Emergency stop device	GND	Earth
F	Open	SxIND	Digital input
G	Closed	S8IND*	Optionally, also S1OUTD digital output
H	PLC	S9IND**	Optionally, also MFO1 multifunction output
I	Relay	MFI	Multifunction input (analogue, digital, frequency signal, temperature evaluation)
J	Report back	10VRef	Reference output DC 10 V
K	Set value	↑	Position switch shown as actuated
L	Rotation speed > 0		

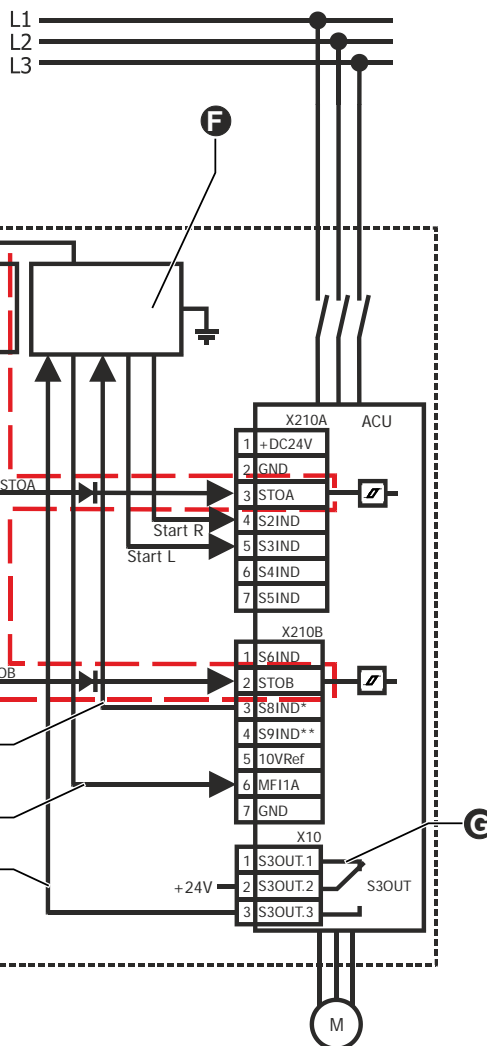
10.1.4 STO direct stop with feedback to PLC and with “short-circuit” error exclusion in the electrical cabinet

The application circuit shows a drive control with PLC and a Safety equipment as per EN ISO 13849-1 PL e, DIN EN 61800-5-2 SIL 3. Instead of a safety equipment with two shutdown paths, a **safety equipment with one shutdown path and one connection line** is selected. The following requirements must be met:

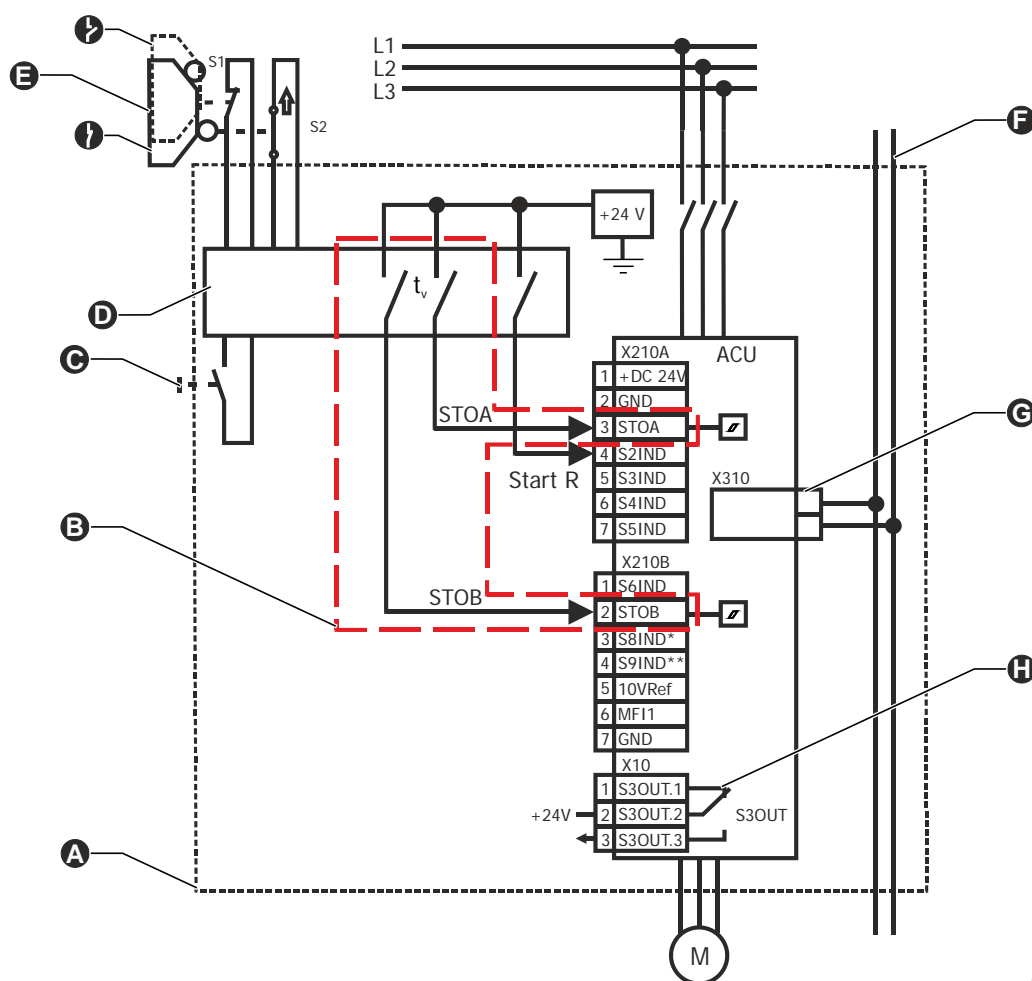
- The Safety equipment and the frequency inverter must be in the same electrical cabinet.

The error exclusion in the case of a short-circuit must be guaranteed when routing the connection line between the Safety equipment and the ACU410 (e.g. insulated line).

The safety equipment monitors the function of the S1 and S2 switches.



A (non-secure) report back to a process control can be made e.g. via a connected field bus. If the STO function has been requested, the superordinate control can have no further influence over the inverter release in the frequency inverter.



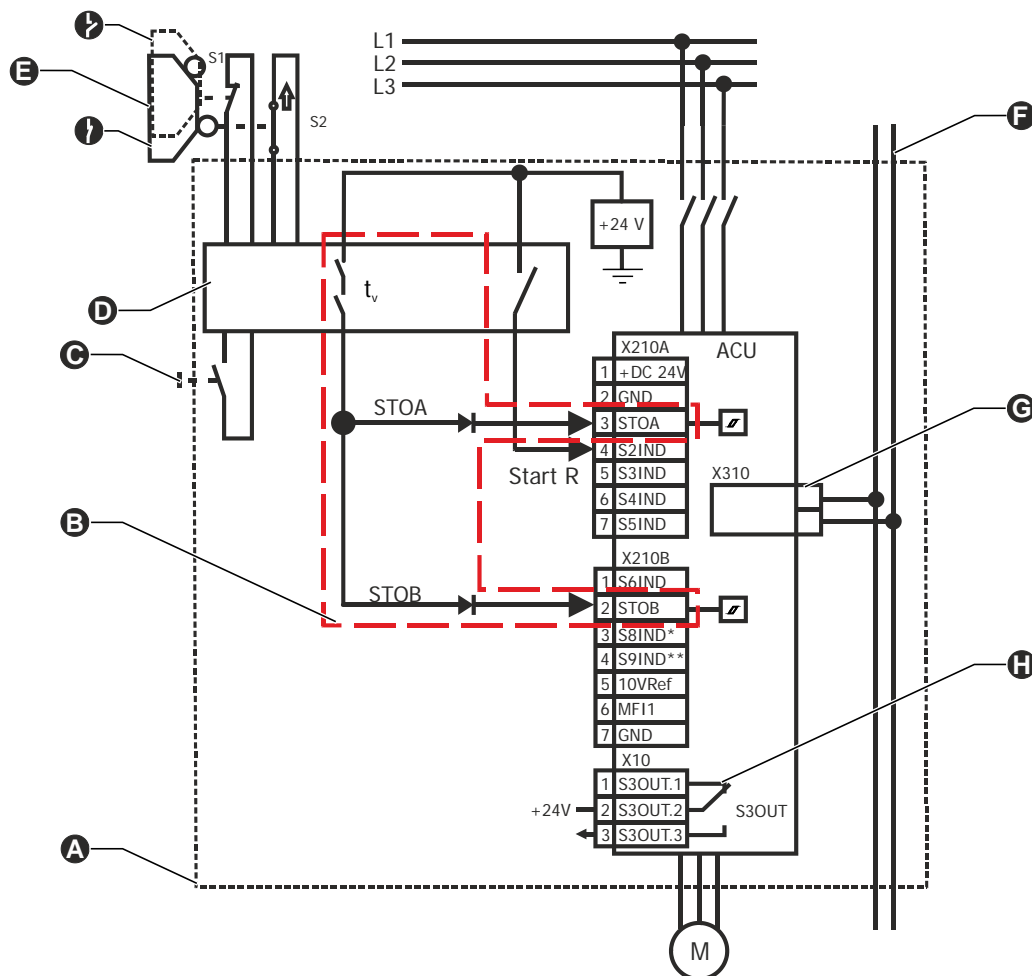
ACUx10-TD-SS1_01-V00

A	Electrical cabinet	STOA / STOB	First and second shutdown path of the safety function
B	Safety circuit	X210A, X210B, X10	Control terminals of the frequency inverter
C	Acknowledgement	X310	Communication interface
D	Safety equipment	+DC 24 V	Input or output for control voltage
E	Emergency stop device	GND	Earth
F	Open	SxIND	Digital input
G	Closed	S8IND*	As required, also S10OUTD digital output
H	Field bus	S9IND**	As required, also MFO1 multifunction output
I	Field bus connection	MF1	Multifunction input (analogue, digital, frequency signal, temperature evaluation)
J	Relay	10VRef	Reference output DC 10 V
		↑	Position switch shown as actuated
		tv	Time delay between report and trigger contact

10.2.2 SS1 direct shutdown with “short-circuit” error exclusion in the electrical cabinet

The application circuit shows a drive control with PLC and a Safety equipment as per EN ISO 13849-1 PL e, DIN EN 61800-5-2 SIL 3. Instead of a Safety equipment with two shutdown paths, a **Safety equipment with one shutdown path** and **one connection line** is selected. The following framework conditions must be maintained:

- The Safety equipment and the frequency inverter must be in the same electrical cabinet.
- The error exclusion in the case of a short-circuit must be guaranteed when laying the connection line between the Safety equipment and the ACU410 (e.g. insulated line).



ACUx10-TD-SS1_02-V00

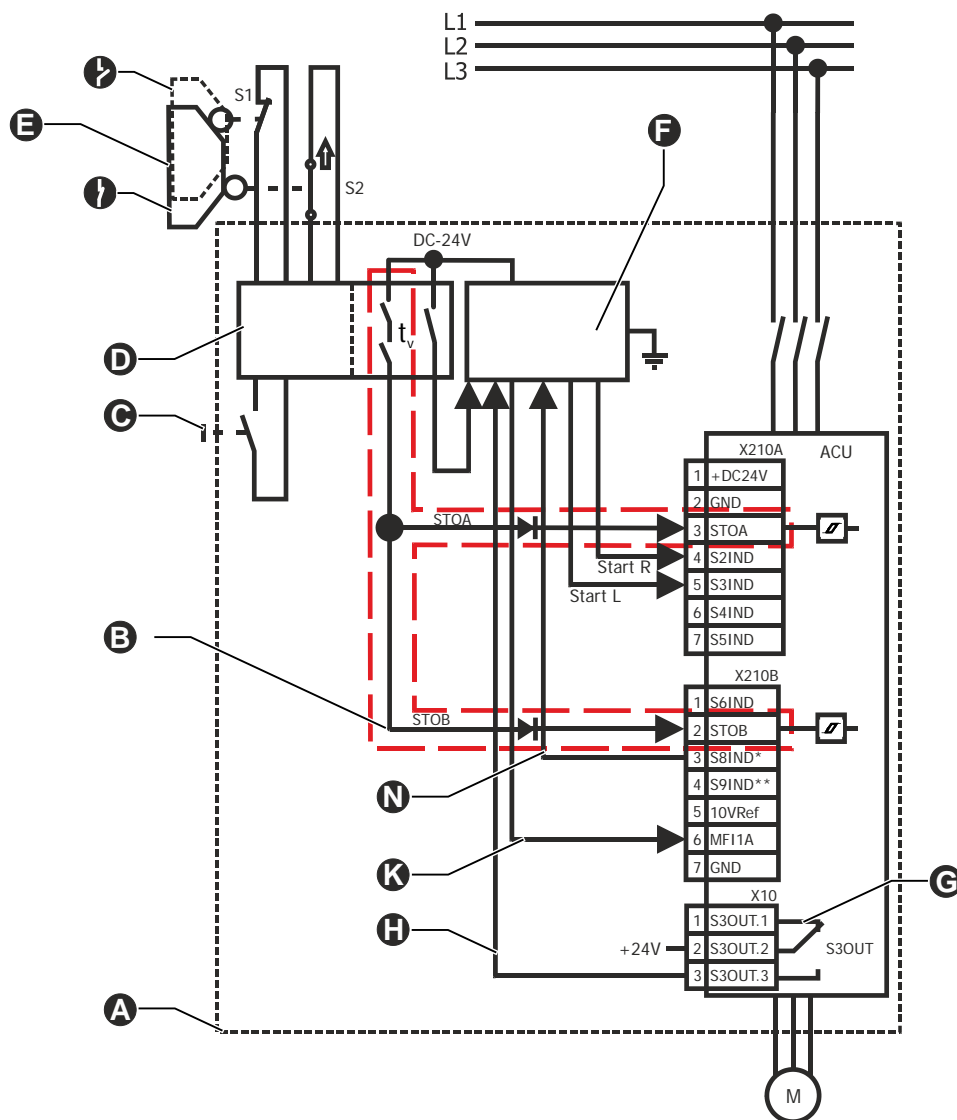
A	Electrical cabinet	STOA / STOB	First and second shutdown path of the safety function
B	Safety circuit	X210A, X210B, X10	Control terminals of the frequency inverter
C	Acknowledgement	X310	Communication interface
D	Safety equipment	+DC24 V	Input or output for control voltage
E	Emergency stop device	GND	Earth
F	Open	SxIND	Digital input
G	Closed	S8IND*	As required, also S10OUTD digital output
H	Field bus	S9IND**	As required, also MFO1 multifunction output
I	Field bus connection	MFI	Multifunction input (analogue, digital, frequency signal, temperature evaluation)
J	Relay	10VRef	Reference output DC 10 V
		\uparrow	Position switch shown as actuated
		t _v	Time delay between report and trigger contact

10.2.3 SS1 direct shutdown with report back to PLC

The application circuit shows a drive control with PLC and a Safety equipment as per EN ISO 13849-1 PL e, DIN EN 61800-5-2 SIL 3. A PLC takes on the process control of the frequency inverter and can start the drive profiles using commands.

When the protective equipment is activated, e.g. by a safety door, the release paths of the Safety equipment are interrupted. At first, a report is sent to the PLC regarding the triggering of the safety function. The PLC then brakes the motor in a controlled manner via a reset of the direction of rotation ("start right" or "start left"). Following expiry of the time delay period t_v , the controller release of the frequency inverter is interrupted through the loss of the control voltages on the STOA and STOB, and the integrated STO safety function is requested through the interruption of the inverter release.

The Safety equipment monitors the function of the S1 and S2 switches that lie outside of the electrical cabinet.



ACUx10-TD-SS1_04-V00

A	Electrical cabinet	STOA / STOB	First and second shutdown path of the safety function
B	Safety circuit	X210A, X210B, X10	Control terminals of the frequency inverter
C	Acknowledgement	X310	Communication interface
D	Safety equipment	+DC24 V	Input or output for control voltage
E	Emergency stop device	GND	Earth
F	Open	SxIND	Digital input
G	Closed	S8IND*	As required, also S1OUTD digital output
H	PLC	S9IND**	As required, also MFO1 multifunction output
I	Relay	MFI	Multifunction input (analogue, digital, frequency signal, temperature evaluation)
J	Report back	10VRef	Reference output DC 10 V
K	Set value	↑	Position switch shown as actuated
L	Rotation speed > 0	tv	Time delay between report and trigger contact

10.3 Shutdown of several devices, SS1

The application circuit shows a drive control with a PLC connected via a field bus and a Safety equipment as per EN ISO 13849-1 PL e, DIN EN 61800-5-2 SIL 3. A PLC takes on the process control of the frequency inverter and can start the drive profiles using commands, which are communicated via the field bus.

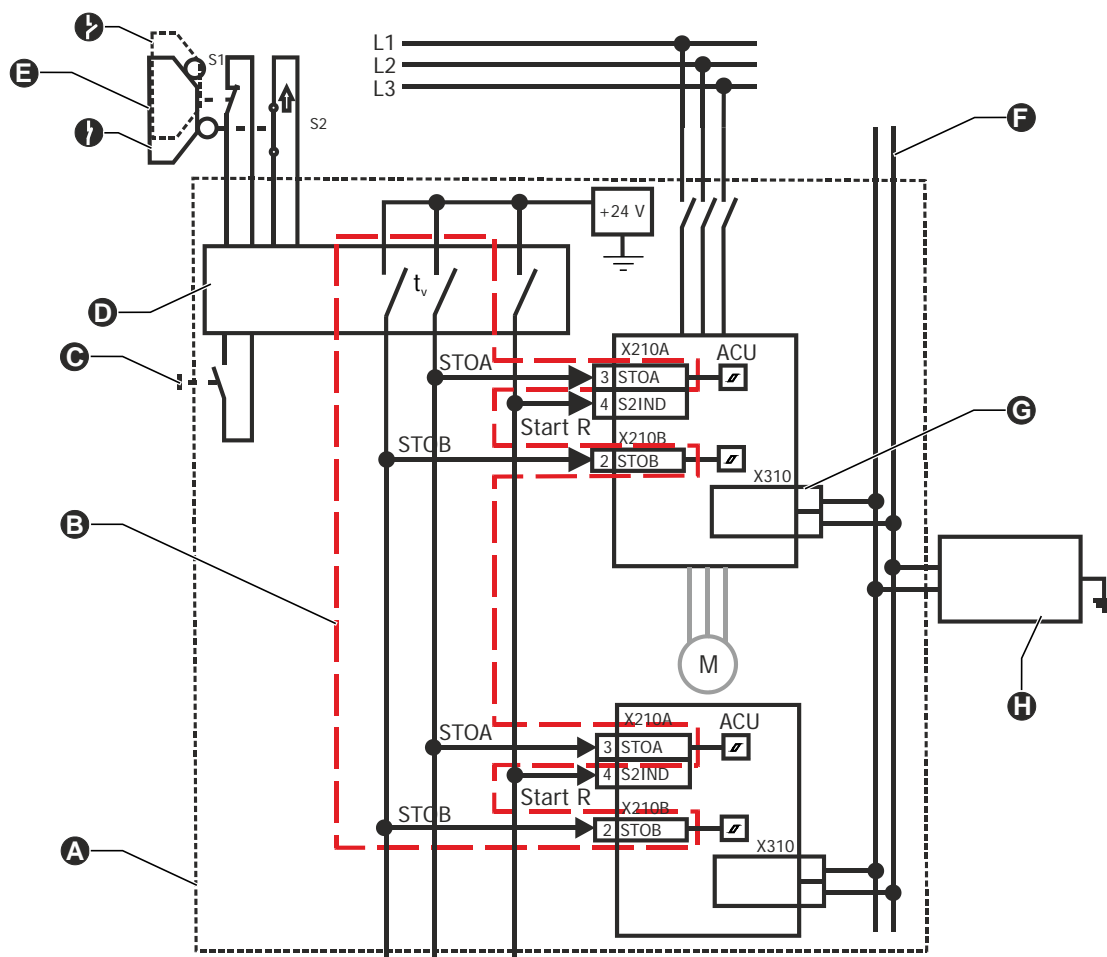
When the protective equipment is activated, e.g. by an emergency off switch, the release paths of the Safety equipment are interrupted. At first, the drive signal "right" is reset. The motors are then braked in a controlled manner. Following expiry of the time delay period t_v , the controller release of the frequency inverter is interrupted through the loss of the control voltages on the STOA and STOB, and the integrated STO safety function is requested.

The (non-secure) report back to the PLC, that the drives have been stopped, is issued via the field bus. No further terminals are then required for the connection aside from those shown in the diagram.

The external DC 24 V supply must be of a sufficient level, see Chapter 7.3.



If a high current is required, it may be necessary to install fuses upstream of the safety relays according to the information provided by the safety equipment manufacturer.



ACUx10-TD-SS1_05-V00

A	Electrical cabinet	STOA / STOB	First and second shutdown path of the safety function
B	Safety circuit	X210A, X210B, X10	Control terminals of the frequency inverter
C	Acknowledgement	X310	Communication interface
D	Safety equipment	SxIND	Digital input
E	Emergency stop device	↑	Position switch shown as actuated
F	Open	tv	Time delay between report and trigger contact
G	Closed		
H	Field bus		
I	Field bus connection		
J	PLC		

11 Checklist

This list provides an overview of the requirements to be met in installation, commissioning and operation of the safety function. Depending on the application, additional requirements must be met. Complete this list according to your application.

Risk analysis:

- was performed
- requires the use of the safety function “Safe Torque Off” requires category 3 according to the following classifications:
 - - PL e (or smaller) according to EN ISO 13849-1
 - - SIL 3 (or smaller) according to IEC 61508
- considers the stopping behavior of the ACU410 frequency inverter
- permits coasting of the drive to a standstill or requires the installation of a mechanical brake.
- considers the access time to the hazard area
- defines intervals for regular functional checks of the safety function

Installation:

- EMC instructions in the operating instructions considered?
- The shield of the 24 V power supply was connected on both sides.
- Emergency stop devices meet the following classifications:
 - - PL e (or smaller) according to EN ISO 13849-1
 - - SIL 3 according to IEC 61508
- Emergency Stop devices have a cross fault monitoring (2-channel connection) or protected wiring?
- It is ensured that resetting of the safety control device alone does not result in a restart of the drive.
- It is ensured that no voltage higher than DC 30 V can occur on the terminals of the control electronic unit (voltage resistance).
- The protection against unexpected restart is set up.

Commissioning:

- Functional check of safety function performed?
- Wiring of safety components checked?
- Acceptance report issued?

Operation:

- The safety function is checked regularly.

12 Safety Function Test Report

The concept relating to the safety function STO (Safe Torque Off) described in this manual was assessed and certified by Berufsgenossenschaftliches Institut für Arbeitsschutz (Trade Association Institute for Work Safety).

Test institute	Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung
Test sample	Frequency inverter of ACUx10 series
Basis of test	DIN EN ISO 13849-1:2008-12
	DIN EN ISO 13849-2:2013-02
	DIN EN 61800-5-1:2008-04
	DIN EN 61800-5-2:2008-04
Assessment	Due to the realized error tolerance and the measures for error management, error prevention and error identification, the presented concept meets the requirements up to safety integrity level SIL 3 according to DIN EN 61800-5-2, category 3 according to DIN EN 954-1 as well as performance level PL e according to DIN EN ISO 13849-1. With correct circuitry according to the application manual, in conjunction with a suitable external safety switching device, this also applies to the "Safe Stop 1" (SS1) safety function.

Characteristic Data

SIL (DIN EN 61800-5-2)	3
PFH	$1,18 \cdot 10^{-8} \text{ 1/h}$
PLE (DIN EN ISO 13849-1)	e
Category	3
MTTF	high (>100 yrs)
DC_{avg}	medium (90-99 %)
CCF	65

13 STO status (diagnosis)

The actual value *STO state 277* can be used for an extended diagnosis of the two inputs STOA and STOB. The states of the inputs are displayed bit coded.

Bit	Significance	Description
0	1	Input STOA missing
1	2	Input STOB missing
2	4	Input STOA switch off
3	8	Input STOB switch off
4	16	Timeout STOA
5	32	Timeout STOB
6	64	Diagnosis fault
7	127	Frequency Inverter fault (error)

14 Version history

V2	ACU410-STO-V2: Changes due to prolongation of certificate for the safety function STO for ACUx10 series drives, new testing label Figures made language-independent
V1	ACU410-STOV1-00SV1-00: First version

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