INOVANCE

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MD630 Series General-Purpose AC Drive

Safety Function Guide

Industrial Automation | Intelligent Elevator | New Energy Vehicle | Industrial Robot | Rail Transit

Data code PS00017950A00

Preface

Introduction

The MD630 series AC drive is a general-purpose high-performance current vector control AC drive. It is designed to control and regulate the speed and torque of three-phase AC asynchronous motors. It can be used to drive textile machines, paper making machines, wire drawing machines, machine tools, packaging machines, food machines, fans, water pumps, and other automated production equipment.

This guide describes the safety function precautions, prerequisites, operating recommendations, operating principles, related technical parameters, installation, commissioning, acceptance, standards, and certifications.

Revision History

Date	Version	Description
December 2024	A00	First release.

Access to the Guide

This guide is not delivered with the product. You can obtain the PDF version by the following methods:

- Do keyword search under Service and Support at *http://www.inovance.com*.
- Scan the QR code on the product with your smart phone.
- Scan the QR code below to install My Inovance app, where you can search for and download user guides.

Warranty Disclaimer

Inovance provides warranty service within the warranty period (as specified in your order) for any fault or damage that is not caused by improper operation of the user. Maintenance will be charged after the warranty expires.

Within the warranty period, maintenance fee will be charged for the following damage:

- Damage caused by operations not following the instructions in the user guide
- Damage caused by fire, flood, or unusual voltage
- Damage caused by unintended use of the product
- Damage caused by use beyond the specified scope of application of the product

- Damage or secondary damage caused by force majeure (natural disaster, earthquake, and lightning strike)

The maintenance is charged according to the latest Price List of Inovance. If otherwise agreed upon, the terms and conditions in the agreement shall prevail.

For details, see Product Warranty Card.

Table of Contents

Fundamental Safety Instructions

Safety Precautions

- This chapter provides essential safety instructions for proper use of the equipment. Before operating the equipment, read through the guide and comprehend all the safety instructions. Failure to observe the safety precautions may result in serious injuries or death of personnel or device damage.
- "Danger", "Warning", and "Caution" items in this guide do not indicate all safety precautions that need to be followed; instead, they just supplement the safety precautions.
- Use this product according to the designated environment requirements. Damage caused by improper use is not covered by warranty.
- Inovance shall take no responsibility for any personal injuries or property damage caused by improper usage.

Safety Levels and Definitions

Indicates that failure to comply with the notice will result in death or severe personal injuries.

Indicates that failure to comply with the notice may result in death or severe personal injury.

Indicates that failure to comply with the notice may result in minor or moderate personal injury or equipment damage.

Fundamental Safety Instructions

- Drawings in the guide are sometimes shown without covers or protective guards. Remember to install the covers or protective guards as specified first, and then perform operations in accordance with the instructions.
- The drawings in the guide are shown for illustration only and may be different from the product you purchased.
- Operators must take mechanical precautions to protect personal safety and wear protective equipment, such as anti-smashing shoes, safety clothing, safety glasses, protective gloves, and protective sleeves.

Unpacking
 • Do not install the equipment if you find damage, rust, or signs of use on the equipment or accessories upon unpacking. • Do not install the equipment if you find water seepage or missing or damaged components upon unpacking. • Do not install the equipment if you find the packing list does not conform to the equipment you received.
 • Check whether the packing is intact and whether there is damage, water seepage, dampness, and deformation before unpacking. • Unpack the package by following the unpacking sequence. Do not strike the package violently. • Check whether there is damage, rust, or injuries on the surface of the equipment and equipment accessories before unpacking. • Check whether the package contents are consistent with the packing list before unpacking.

Storage and Transportation

- Large-scale or heavy equipment must be transported by qualified professionals using specialized hoisting equipment. Failure to comply may result in personal injuries or equipment damage.
- Before hoisting the equipment, ensure the components such as the front cover and terminal blocks are secured firmly with screws. Loosely-connected components may fall off and result in personal injury or equipment damage.
- Never stand or stay below the equipment when the equipment is being hoisted by the hoisting equipment.
- When hoisting the equipment with a steel rope, ensure the equipment is hoisted at a constant speed without suffering from vibration or shock. Do not turn the equipment over or let the equipment stay hanging in the air. Failure to comply may result in personal injuries or equipment damage.

- Handle the equipment with care during transportation and mind your steps to prevent personal injuries or equipment damage.
- When carrying the equipment with bare hands, hold the equipment casing firmly with care to prevent parts from falling. Failure to comply may result in personal injuries.
- Store and transport the equipment based on the storage and transportation requirements. Failure to comply will result in equipment damage.
- Avoid storing or transporting the equipment in environments with water splash, rain, direct sunlight, strong electric field, strong magnetic field, and strong vibration.
- Avoid storing the product for more than 3 months. When the product needs to be stored for an extended period, take more strict protection and necessary inspection.
- Pack the equipment strictly before transportation. Use a sealed box for long-distance transportation.
- Never transport the drive with other equipment or materials that may harm or have negative impacts on the drive.

Installation
 DANGER • The equipment must be operated only by professionals with electrical knowledge. Non-professionals are not allowed.
 WARNING • Read through the guide and safety instructions before installation. • Do not install this equipment in places with strong electric or magnetic fields. • Before installation, check that the mechanical strength of the installation site can bear the weight of the equipment. Failure to comply will result in mechanical hazards. • Do not wear loose clothes or accessories during installation. Failure to comply may result in an electric shock. • When installing the equipment in a closed environment (such as a cabinet or casing), use a cooling device (such as a fan or air conditioner) to cool the environment down to the required temperature. Failure to comply may result in equipment over-temperature or a fire. • Do not retrofit the equipment. • Do not fiddle with the bolts used to fix equipment components or the bolts marked in red. • When the equipment is installed in a cabinet or final assembly, a fireproof enclosure providing both electrical and mechanical protections must be provided. The IP rating must meet IEC standards and local laws and regulations. • Before installing devices with strong electromagnetic interference, such as a transformer, install a shielding device for the equipment to prevent malfunction. • Install the product on an incombustible object such as metal and do not contact or attach the product with combustible objects. Failure to comply will cause fires.
 CAUTION • Cover the top of the equipment with a piece of cloth or paper during installation. This is to prevent unwanted objects such as metal chippings, oil, and water from falling into the equipment and causing faults. After installation, remove the cloth or paper on top of the equipment to prevent over-temperature caused by poor ventilation due to blocked ventilation holes. • Resonance may occur when the equipment operating at a constant speed executes variable speed operations. In this case, install the vibration-proof rubber under the motor frame or use the vibration suppression function to reduce resonance.

Wiring

- Equipment installation, wiring, maintenance, inspection, or parts replacement must be performed only by professionals.
- Before wiring, cut off all the power supplies of the equipment, and wait for at least the time designated on the equipment warning label before further operations because residual voltage still exists after power-off. Measure the DC voltage of the main circuit and ensure that the voltage is within the safety range. Failure to comply can result in an electric shock.
- Do not perform wiring, remove the equipment cover, or touch the circuit board with power ON. Failure to comply will result in an electric shock.
- Check that the equipment is grounded properly. Failure to comply can result in an electric shock.

- Do not connect the input power supply to the output end of the equipment. Failure to comply can result in equipment damage or even a fire.
- When connecting a drive to the motor, check that the phase sequences of the drive and motor terminals are consistent to prevent reverse motor rotation.
- Cables used for wiring must meet cross sectional area and shielding requirements. The shield of the cable must be reliably grounded at one end.
- Fix the terminal screws with the tightening torque specified in the user guide. Improper tightening torque may overheat or damage the connecting part, resulting in a fire.
- After wiring is done, check that all cables are connected properly and no screws, washers or exposed cables are left inside the equipment. Failure to comply may result in electric shock or equipment damage.

- Follow the proper electrostatic discharge (ESD) procedure and wear an anti-static wrist strap to perform wiring. Failure to comply may result in damage to the equipment or to the internal circuit of the product.
- Use shielded twisted pairs for the control circuit. Connect the shield to the grounding terminal of the equipment for grounding purpose. Failure to comply can result in equipment malfunction.

Power-on

- Before power-on, check that the equipment is installed properly with reliable wiring and the motor can be restarted.
- Check that the power supply meets equipment requirements before power-on to prevent equipment damage or a fire.
- Do not open the cabinet door or protective cover of the product, contact any wiring terminal of the product, or remove any part of the product at power-on. Failure to comply will result in an electric shock.

- Perform a trial run after wiring and parameter setting to ensure the equipment operates safely. Failure to comply may result in personal injuries or equipment damage.
- Before power-on, check that the rated voltage of the equipment is consistent with that of the power supply. Failure to comply may result in a fire accident.
- Before power-on, check that no one is near the equipment, motor, or machine. Failure to comply may result in death or personal injury.

Operation

- The equipment must be operated only by professionals. Failure to comply can result in death or personal injury.
- Do not touch any connecting terminals or disassemble any unit or component of the equipment during operation. Failure to comply can result in an electric shock.

- Do not touch the equipment casing, fan, or resistor with bare hands to feel the temperature. Failure to comply may result in personal injuries.
- Prevent metal or other objects from falling into the equipment during operation. Failure to comply may result in a fire or equipment damage.

Maintenance

- Equipment installation, wiring, maintenance, inspection, or parts replacement must be performed only by professionals.
- Do not maintain the equipment with power ON. Failure to comply can result in an electric shock.
- Before maintenance, cut off all the power supplies of the equipment and wait for at least the time designated on the equipment warning label.
- In case of a permanent magnet motor, do not touch the motor terminals immediately after power-off because the motor terminals will generate induced voltage during rotation even after the equipment power supply is off. Failure to comply will result in an electric shock.

- Perform routine and periodic inspection and maintenance on the equipment according to maintenance requirements and keep a maintenance record.

Repair

- Equipment installation, wiring, maintenance, inspection, or parts replacement must be performed only by professionals.
- Do not repair the equipment with power ON. Failure to comply can result in an electric shock.
- Before inspection and repair, cut off all the power supplies of the equipment and wait for at least the time designated on the equipment warning label.

- Submit the repair request according to the warranty agreement.
- When the fuse is blown or the circuit breaker or earth leakage current breaker (ELCB) trips, wait for at least the time designated on the equipment warning label before power-on or further operations. Failure to comply may result in death, personal injury or equipment damage.
- When the equipment is faulty or damaged, the troubleshooting and repair work must be performed by professionals that follow the repair instructions, with repair records kept properly.
- Replace quick-wear parts of the equipment according to the replacement instructions.
- Do not operate on damaged equipment. Failure to comply may result in death, personal injury, or severe equipment damage.
- After the equipment is replaced, check the wiring and set parameters again.

Disposal
WARNING • Dispose of retired equipment in accordance with local regulations and standards. Failure to comply may result in property damage, personal injury, or even death. • Recycle retired equipment by observing industry waste disposal standards to avoid environmental pollution.

Safety Labels

For safe operation and maintenance, comply with the safety labels on the equipment. Do not damage or remove the safety labels. See the following table for descriptions of the safety labels.

To ensure safe operation, comply with equipment-related safety labels. See the following table for descriptions of the safety labels.

Safety Label	Description
	• Read through the safety instructions before operating the equipment. Failure to comply may result in death, personal injuries, or equipment damage. • Do not touch the terminals or remove the cover with power ON or within 10 min after power-off. Failure to comply will result in an electric shock.

1 Precautions for Use

1.1 Fundamental Safety Instructions

Before operating the equipment, read the information in this guide to ensure that all safety information is properly understood before using the safety function.

The icons, illustrations, and figures used in this guide are for your reference and may not be applicable to all products. The content of this guide and the safety function specifications may be changed without notice due to upgrade of the product or the guide.

Danger

If the safety function is used incorrectly or the safety function does not meet onsite safety requirements, equipment damages or personal injuries may arise.

- 本章包含安全功能说明中使用的警告符号，以及安装或维护驱动器或逆变器的安全选项模块时必须遵守的安全说明。如果忽视安全说明，可能会造成设备损坏或人身安全。
- 在电气安装及系统设计之初，用户应当高度重视风险评估以预防伤害。
- 系统的设计、安装、调试、操作及维护等操作，均应由受过功能安全专业培训且有经验的专业人员实施。操作前，应充分阅读功能安全相关手册，了解功能安全相关信息。
- 生产厂商或其授权人有义务在将一台设备投放市场前进行风险分析，确保采取相应措施，减少或消除相关风险。同时根据所采取的相应措施，选定符合要求的元件，确保设备的风险得以充分减少。

Table 1–1 Warning labels

Label	Name	Description	Consequence of Negligence
	DANGER	Critical risk	Indicates that failure to comply with the notice will result in death or severe personal injuries.
	WARNINGS	General risk	Indicates that failure to comply with the notice may result in death or severe personal injuries.
	CAUTION	Minor risk	Indicates that failure to comply with the notice may result in minor or moderate personal injuries or equipment damage.
	STOP!	Damage to equipment or environment	Indicates that failure to comply with the notice may result in damage to equipment or environment.

1.2 Safety Measures

Carefully read and observe the following important precautions when using safety functions:

- As one of safety control mechanisms to prevent hazards, the STO function cannot replace the emergency stop function (E-stop). In an emergency, when the emergency stop function triggers STO, the motor cannot be powered off. The high-voltage part of the motor and the drive may be live, which may result in electric shock or other risks caused by electric power. Necessary measures must be taken. Therefore maintenance work on electrical parts of the drive or motor can be carried out only after the drive system is disconnected from the main power supply.
- Depending on the standards and requirements for a particular application, the STO function can be used as a part of an E-stop system. In case of emergency stop, the STO function can be used to stop the drive.

- The design requirements for emergency stop are different from those for safety interlock. Generally, the emergency stop function is required to be independent from any complex or intelligent control. It uses independent electromechanical devices to either cut off the power supply or initiate rapid stop through other means such as dynamic or regenerative braking.
- To ensure that a complete control system is safe, design the whole system according to safety principles. An individual subsystem with the STO function is intentionally designed for safety-related applications. However, it cannot ensure the safety of the entire system.
- In processes without personnel protection, do not to use the STO function to stop the drive. If a running drive is stopped by using the STO function, the drive coasts to stop. If this is not acceptable, the system should be stopped using the correct mode instead of the STO function.
- The designer who designs the safety-related system must be professional. It is the responsibility of the end product or application designer to ensure that it is safe and in compliance with the relevant regulations.

2 Prerequisites for Using Safety Functions

2.1 Risk Assessment

Before using the safety function, perform risk assessment on the drive system in advance to ensure compliance with the standard safety integrity level. Even when the safety function is in use, residual risks may still exist. Therefore, safety must always be considered during risk assessment.

Companies and individuals that establish safety-related systems must take full responsibility for system installation and commissioning.

In addition, when complying with European machinery directives, the related sub-system must acquire safety standard certification. The whole equipment or system is subject to all risk assessments and safety integrity level certification.

2.2 Common Residual Risks

The following content describes residual risks concerning the safety function of this product.

- The STO function only cuts off the torque of the motor, and does not cut off the power supply of the drive. Before servicing the drive, cut off the power supply of the drive to make sure the drive is powered off.
- When faults occur on multiple IGBTs, the drive generates aligning torque regardless of whether the STO function is enabled. This torque may drive the motor shaft to rotate to the maximum angle of 180/p (180/2p for synchronous reluctance motors). The variable p indicates the number of motor pole pairs.
- If external force (such as gravitational force of a vertical axis) exists when the safety function is applied, the motor will rotate. Therefore, you must use a separate mechanical brake to secure the motor.

3 Recommendations for Stable Operation

3.1 Recommendations for Stable Operation

The following conditions must be met for the selection of the motor and AC drive:

1. The AC drive operates under the rated current.
2. The rated current coefficient of the motor and AC drive should be less than 6 (current coefficient = rated current of the AC drive/rated motor current). It is not recommended to use high-power AC drives to drive low-power motors.

4 Working Principle of Safety Function

4.1 Overview of Safety Function

Safe torque off (STO) is a safety function that complies with IEC 61800-5-2:2016. The STO function is optional for the MD630.

After the STO function is enabled, the PWM drive control signal of the power semiconductor (such as IGPT) is blocked. Therefore, the input motor current is cut off to prevent the drive from generating any torque at the motor shaft, and make the motor stop operating and enter the safety status.

4.2 Function Triggering Principle

The STO function is enabled through external redundant hardware terminals STO1 and STO2. When the input signals of STO1 and STO2 terminals are at high level (+24 V), the drive works normally. If the input signals of STO1 or/and STO2 are at low level (0 V), the PWM signal will be blocked.

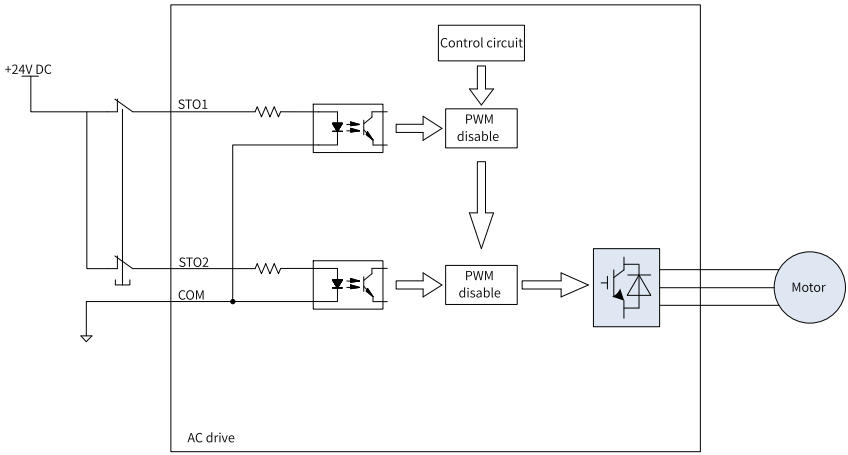

Figure 4-1 Function triggering principle

Table 4–1 STO function

STO1 Input	STO2 Input	PWM Signal	System Status	Solution
H	H	Normal	Normal	-
L	H	Inhibited	Err47.1 is reported when STO1 is disconnected and the STO1/STO2 input states are inconsistent.	Check the wiring to ensure that it is normal and reset it manually.
H	L	Inhibited	Err47.2 is reported when STO2 is disconnected and the STO1/STO2 input states are inconsistent.	Check the wiring to ensure that it is normal and reset it manually.
L	L	Inhibited	STO is triggered and the operating panel displays the STO status.	Check the circuit to ensure that the circuit is normal. The reset method (manual or automatic) of the STO status displayed on the operating panel is set by P0-29.

Note

- H (1): The corresponding input end is connected to 24 V voltage.
- L (0): The corresponding input end is disconnected from 24 V voltage.

- Trigger the STO function at least once every three months.
- This function cuts off only the torque of the motor, and does not cut off the power supply of the drive. Before servicing the drive, cut off the power supply of the drive to make sure the drive is powered off.

4.3 Time Sequence Diagram

1. When the drive is running normally, the STO1/STO2 input state is H and the STO function is disabled.

2. The STO function is triggered. The STO1/STO2 input state is L, the STO function is enabled, and the PWM signal is blocked. If the motor is still rotating when the STO function is enabled, the motor will coast to stop.
3. The STO function is restored and the STO1/STO2 input state is H. You can restart the operation after automatic or manual reset as set by P0-29.

When the STO1/STO2 input delay is within the set range, the STO triggering state is displayed, as shown in Figure 4–2.

When only one signal input of STO1/STO2 is L, and the input delay exceeds the set range, the STO1/STO2 input inconsistency fault is reported. If the other signal is also input L after the set delay elapses, the STO function is triggered after the time set P0-30 plus 6 ms. The STO1/STO2 input inconsistency fault is cleared, as shown in Figure 4–3.

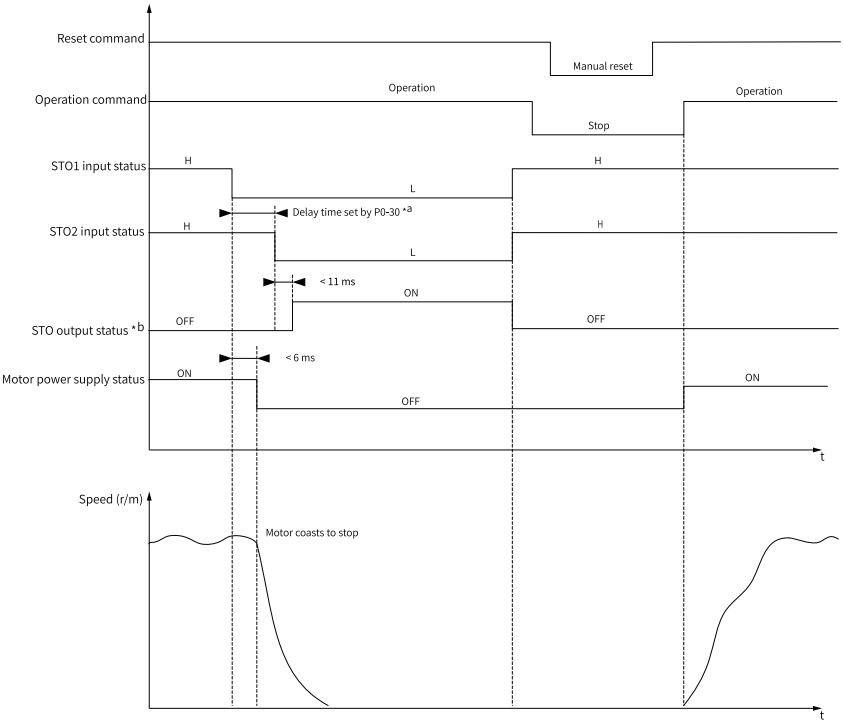

Figure 4-2 Safety Function sequence (consistent input)

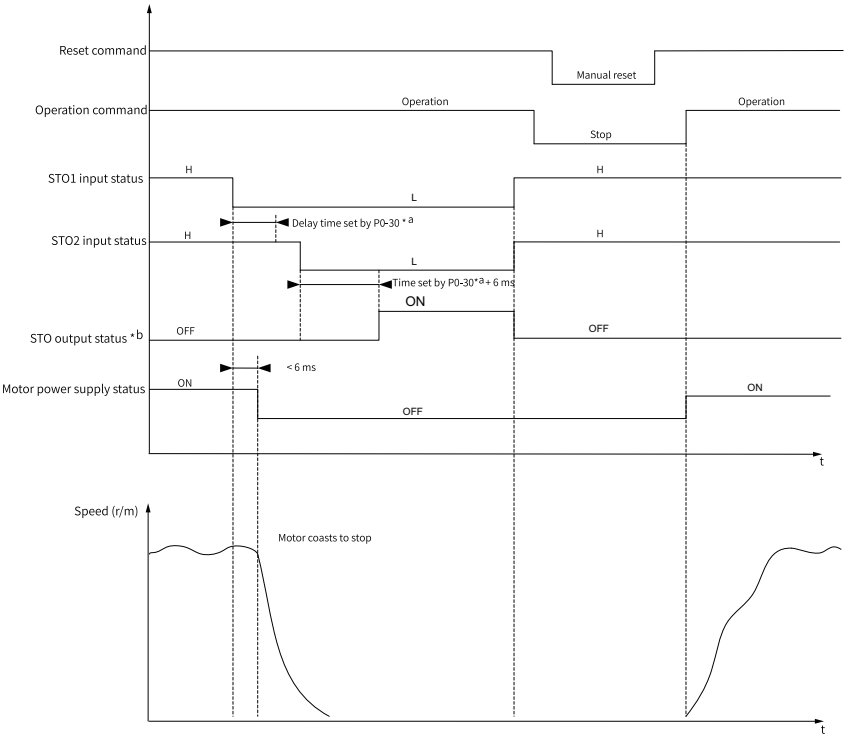

Figure 4-3 Safety Function sequence (inconsistent input)

Note *a: The input delay range of STO1 and STO2 is set by P0-30. It can range from 0.02s to 1s, and the default value is 0.05 s.

Note *b: The STO output state indicates the triggering state of the STO. The relationship between the STO1/STO2 input signal and the STO output signal is shown in the following table. The STO output can be configured by E1-00 and E1-02.

Signal Name	Symbol	Signal Status			
Safety input1	STO1	H	H	L	L
Safety input 2	STO2	H	L	H	L
STO output	STO output	OFF	OFF	OFF	ON

4.4 Response Time

The response time of the STO, that is, time from STO function triggering to torque off is shorter than or equal to 20 ms.

5 Safety and Technical Parameters

5.1 Safety and Technical Parameters

Item	Safety Parameter
SIL	SIL 3, IEC 61508:2010 Maximum SIL 3, EN IEC 62061:2021
PFH	PFH $\leqslant 3.41 \times 10^{-10}$ [1/h] (0.34% of SIL3), IEC 61508:2010
Cat.	3, EN ISO 13849-1
PL	e, EN ISO 13849-1
$MTTF_d$	1938 years (high)
DC_{avg}	$\geqslant$ 90% (medium)
T_1	20 years
HFT	1
SC	SC3
λ_S	7.96×10^{-8} [1/h]
λ_{DD}	5.78×10^{-8} [1/h]
λ_{DU}	1.04×10^{-9} [1/h]
MTTR	0 hour
MRT	0 hour
Application mode	High demand or continuous mode
Device type	Type B

λ_S indicates the safe failure rate (per hour) in a subsystem.

λ_{DD} indicates the detected dangerous failure rate (per hour) in a subsystem.

λ_{DU} indicates the undetected dangerous failure rate (per hour) in a subsystem.

Note

- See ISO 13849-2:2012 for failure modes of components.
- Failures of each component in different failure modes are evenly distributed.
- For failure rate of each component, see SN29500.

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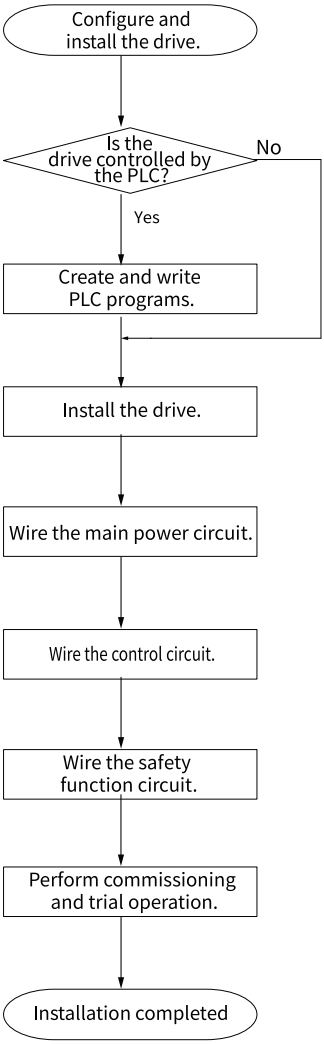
6 Installation and Wiring

6.1 Installation Sequence of AC Drive with Safety Function

To use the safety functions of the AC drive, install the AC drive in the following order.



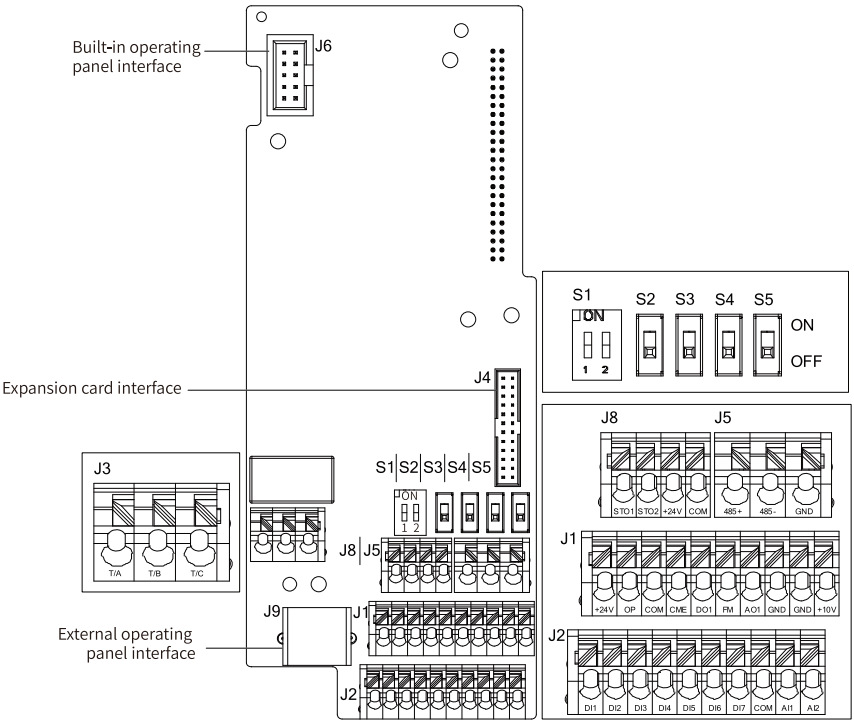
1. If the AC drive is controlled by a PLC, create a PLC program first.
2. Install the AC drive into the cabinet as required.
3. Connect power cables such as power supply input, motor output, and braking resistor (optional) cables according to the requirements of the main circuit connection.

4. Complete control circuit wiring such as DI/DO/AI/AO according to I/O wiring requirements.
5. Complete the wiring of the safety function circuit according to STO wiring requirements.
6. After the wiring is correct, power on the device, commission the PLC program and related AC drive parameters, perform trial operation of the AC drive, and check whether the safety function circuit is active.

For details, see the operation guide of this product.

6.2 Wiring

6.2.1 Terminal Layout and Assignment



External Terminal	Terminal Type	Transmission Information Type	Terminal Mark	Terminal Name	Function
J8	Crimping terminal block with four terminals, 3.5 mm	STO safety function	STO1	STO input 1	By default, STO1/ STO2/+24 V is shorted. If you need to use external function safety wiring, remove the jumper and connect the STO terminal correctly by referring to the STO wiring section. For details, see the operation guide of this product.
			STO2	STO input 2	
			+24V	STO power supply	
			COM	STO reference ground	

6.2.2 Terminal Wiring

The STO terminal supports only the source connection method. You can use the internal 24 V power supply of the AC drive or the external 24 V power supply. The wiring method is shown in the following figure.

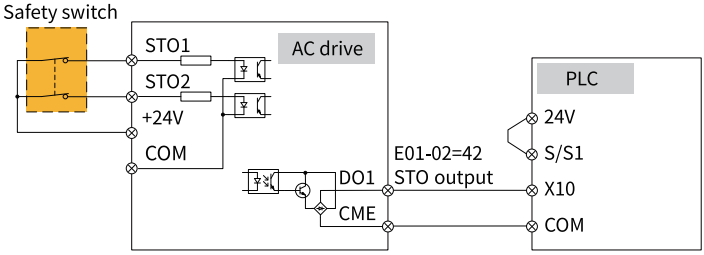


Figure 6-1 Wiring when the internal 24 V power supply of the AC drive is used

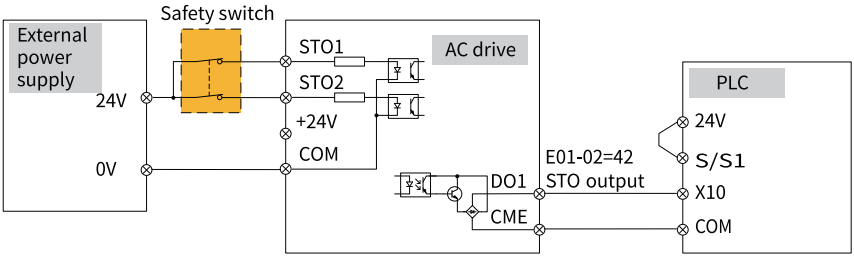


Figure 6-2 Wiring when the external 24 V power supply is used

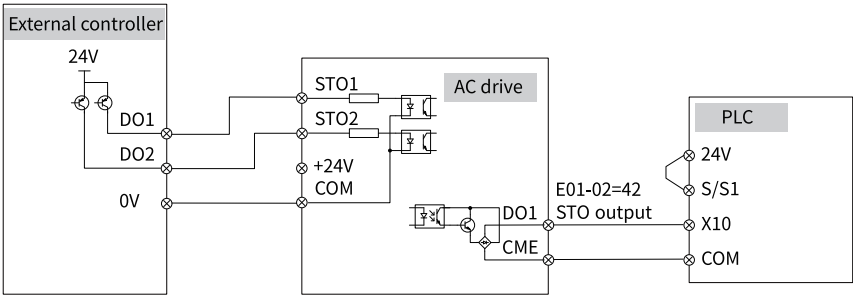


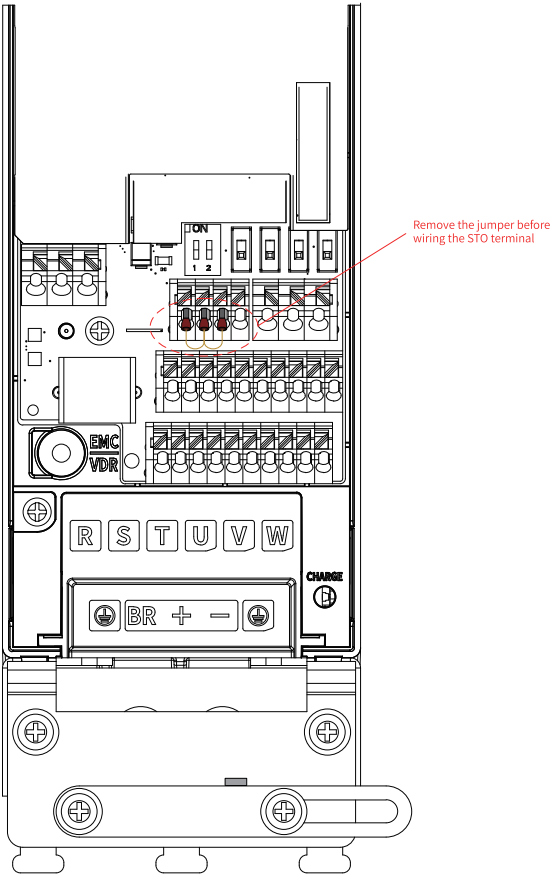
Figure 6-3 Using the external controller PNP output as the STO input wiring method

6.2.3 EMC Requirements

- Ensure that the cable between the drive and safety switch is no longer than 30 m.
- It is recommended to use double-shielded or single-shielded multi-pair cables and crimp the STO cable shield to the grounding bracket to enhance the resistance of the STO cable to electromagnetic interference.

6.2.4 Wiring of STO Terminals

1. Remove the default jumpers on STO1/STO2/+24V terminals.



2. If the internal 24 V power supply of the drive is used, crimp the common terminal of the two external safety switches to the tubular terminal and connect the terminal to the +24V terminal, as shown in the Figure Wiring when the internal 24 V power supply is used. If the external 24 V power supply is used, crimp the common terminal of the two external safety switches to the tubular terminal and connect the terminal to the positive output terminal of the external power supply. Connect the COM terminal of the external power supply to the COM terminal of the AC drive, as shown in the figure Wiring when the external 24 V power supply is used.

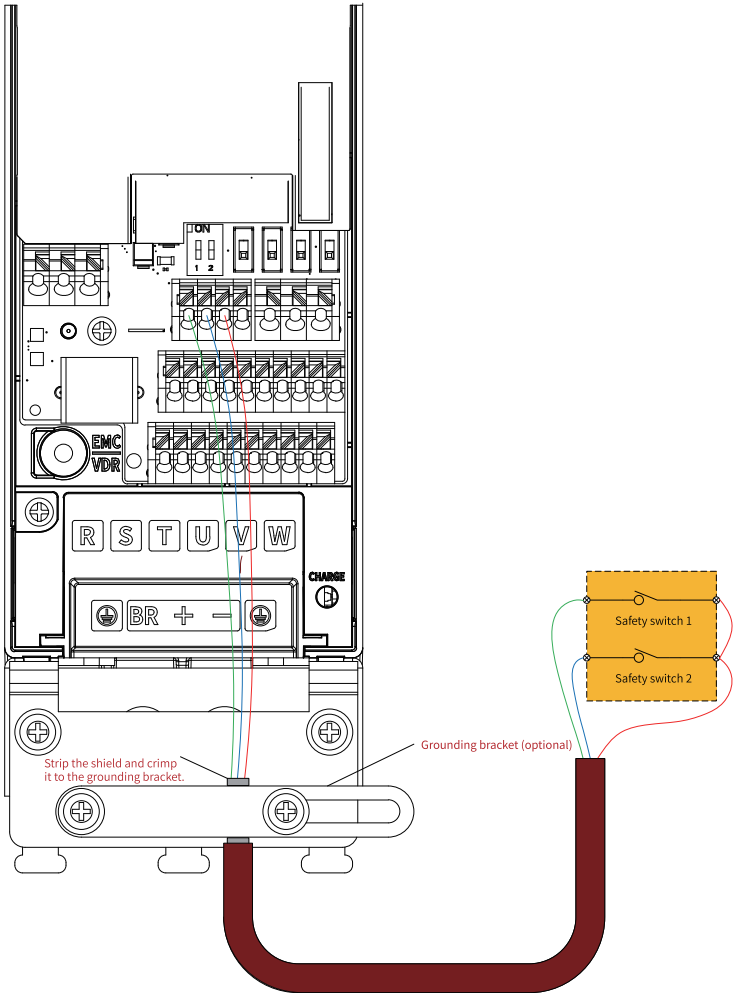


Figure 6-4 Wiring when the internal 24 V power supply is used

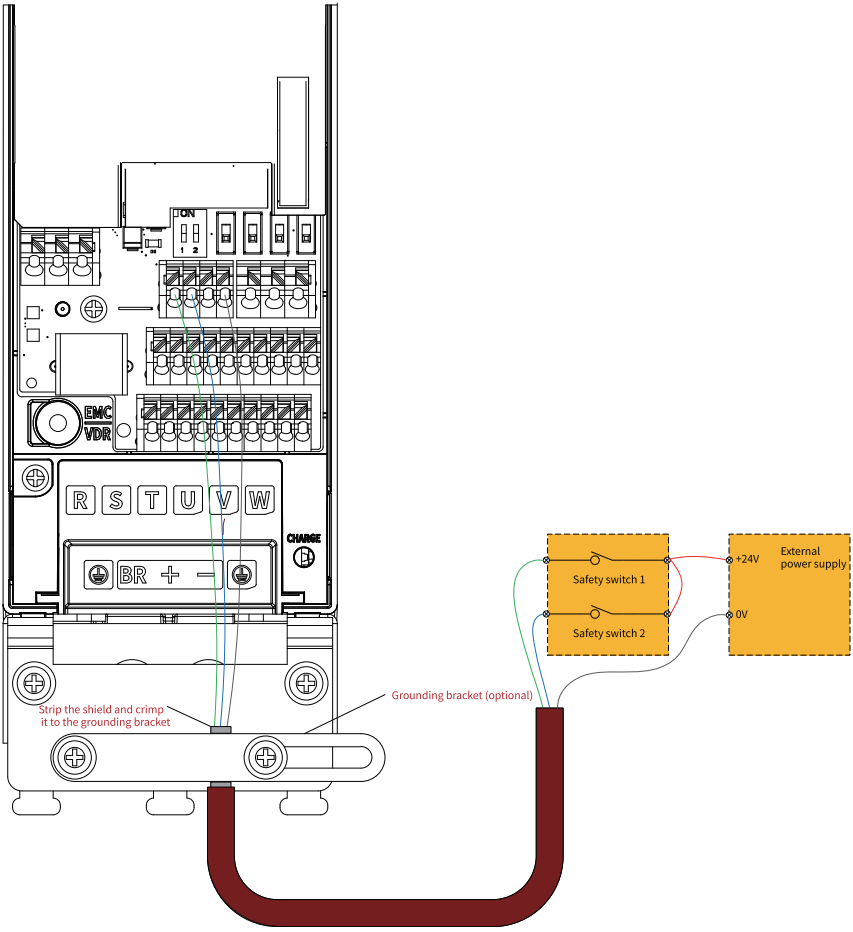


Figure 6-5 Wiring when the external 24 V power supply is used

3. Check the wiring of the main power circuit and control circuit, and put the safety switch in the closed state.

4. Power on the drive and perform trial run. Disconnect the safety switch, and check whether the STO circuit is active.

7 Safety Function Commissioning

7.1 Pre-commissioning Inspection

Check the following items before commissioning.

Table 7–1 Pre-commissioning checklist

No.	Item	Checked
Wiring		
1	The power supply input terminals (L1C, L2C, L1, L2, L3, R, S, T) of the drive are connected properly.	☐
2	The phases of the drive output terminals (U, V, W) and motor main circuit cables (U, V, W) must be consistent and the drive output terminals (U, V, W) are connected correctly to the motor main circuit cables (U, V, W).	☐
3	No short circuit exists in the power supply input terminals (L1, L2, L3, R, S, T) or main circuit output terminals (U, V, W) of the drive.	☐
4	The control signal cables, such as the brake signal cables and overtravel protection signal cables, are connected properly.	☐
5	The drive and motor are grounded properly.	☐
6	The stress suffered by the cable is within the specified range.	☐
7	All the wiring terminals are insulated properly.	☐
Environment and mechanical conditions		
1	There are no unwanted objects (such as cable terminals and metal chippings) that may cause short circuit of the signal cable and power supply cable inside or outside the drive.	☐
2	The drive and the external braking resistor are placed on incombustible objects.	☐
3	Motor installation and shaft and mechanical connection are reliable.	☐
4	The motor and the connected machine are in good condition and ready to run.	☐

7.2 Personnel Requirements

- Technical personnel must be trained to understand the requirements and principles of designing and commissioning safety-related systems.
- Operators must be trained to understand the requirements and principles of designing and operating safety-related systems.

7.3 SIL and PL Verification

- Ensure that all safety functions of the product are fully verified.

- When verifying the safety function system, ensure that the safety system complies with the mechanical directives and safety-related standards.
- The most convenient way to verify whether the system where the product is installed meets the required SIL/PL is to use a specific safety calculator software.

- Never assume that the system is safe before verifying all the safety functions.
- Validation tests must be performed for each safety function.

7.4 Safety Function Validation Test

According to IEC 61508, EN IEC 62061, and EN ISO 13849 standards, the equipment must pass the validation test before safety function acceptance.

The test program and report must be documented and signed by the test engineer, and the signed report must be kept in the log of the equipment. Any new validation tests that are performed due to changes or maintenance must also be recorded.

Follow the checklist below to perform the validation test.

Table 7–2 Validation test checklist

Procedure	Item	Checked
1	Ensure that the drive runs and stops freely during commissioning.	☐
2	Stop the drive in operation, switch the input power supply off and isolate the drive from the power supply line by a circuit breaker.	☐
3	Check the STO circuit connection against the circuit diagram.	☐
4	Check that the shield of the STO input cable is grounded to the drive frame.	☐
5	Close the circuit breaker and turn on the power supply.	☐
6.1	Test execution of STO1 when the motor is stopped. 1. Close STO1 and STO2 input switches. 2. Send a stop command to the drive (if running) and wait until the motor shaft stops. 3. Disconnect the STO1 input switch to activate the STO function. 4. Make the drive to send a start command. 5. Check whether the motor remains stationary and the drive displays "E47.1".	☐

Procedure	Item	Checked
6.2	1. Close the STO1 input switch and disable the ON/RUN command of the drive. 2. Restart the drive, enable the ON/RUN command of the drive, and check whether the motor runs properly.	☐
6.3	Test STO2 execution when the motor is stopped. 1. Close STO1 and STO2 input switches. 2. Send a stop command to the drive (if running) and wait until the motor shaft stops. 3. Disconnect the STO2 input switch to activate the STO function. 4. Make the drive to send a start command. 5. Check whether the motor remains stationary and the drive displays "E47.2".	☐
6.4	1. Close the STO2 input switch and disable the ON/RUN command of the drive. 2. Restart the drive and enable the ON/RUN command of the drive. Check whether the motor operates properly.	☐
7.1	Test execution of STO1 when the motor is running. 1. Close STO1 and STO2 input switches. 2. Start the drive and ensure the motor is running. 3. Disconnect the STO1 input switch to activate the STO function. Make sure that the motor stops and the drive device trips. 4. Make the drive to send a start command. 5. Ensure that the motor remains stationary and the drive displays "E47.1".	☐
7.2	1. Close the STO1 input switch and disable the ON/RUN command of the drive. 2. Restart the drive and enable the ON/RUN command of the drive. Check whether the motor operates properly.	☐
7.3	Test execution of STO2 when the motor is running. 1. Close STO1 and STO2 input switches. 2. Start the drive and ensure the motor is running. 3. Disconnect the STO2 input switch to activate the STO function. Make sure that the motor stops and the drive device trips. 4. Make the drive to send a start command. 5. Ensure that the motor remains stationary and the drive displays "E47.2".	☐

Procedure	Item	Checked
7.4	1. Close the STO2 input switch and disable the ON/RUN command of the drive. 2. Restart the drive and enable the ON/RUN command of the drive. Check whether the motor operates properly.	☐
8	Document and sign the validation test report to demonstrate that the safety function is normal and can be used.	☐

8 Safety Function Acceptance after Maintenance

8.1 Operation Safety Responsibility

- Operation and maintenance personnel must be trained on the requirements and principles of designing and operating safety-related systems.
- If safety-related circuits on the control board do not function properly, replace the control board or the entire equipment.

8.2 Acceptance after Component Replacement

If any of the following conditions are met, the safety function must be verified again to ensure that the safety function is normal.

- Any changes (such as cabling, component replacement, parameter settings) related to safety functions are made.
- After any maintenance work related to safety functions are done.

For information about the safety function confirmation test, see the verification test checklist in *"7.4 Safety Function Validation Test" on page 30*.

9 Parameters and Fault Codes Related to Safety Function

9.1 Parameters Related to Safety Function

The following table describes parameters related to the safety function.

Parameter Code	Parameter Name	Default	Value Range	Description
P0-29	Automatic reset of STO status	1	0: Manual reset 1: Automatic reset	This parameter sets whether the STO status indicated on the operating panel can be reset automatically.
P0-30	Detection time for inconsistent STO status	0.050s	0.020s to 1.000s	This parameter sets the detection time for inconsistency between STO1 status and STO2 status.

Parameter Code	Parameter Name	Default	Value Range	Description
E1-00	RO output function selection	2	0: No output 1: AC drive running 2: Fault 3: Frequency level detection FDT1 output 4: Frequency reach 5: Running at zero speed (no output at stop) 6: Motor overload warning 7: AC drive overload warning 11: Simple PLC cycle completed 12: Cumulative running time reach 13: Wobble frequency limited 14: Torque limited 15: Ready to run 17: Frequency upper limit reach 18: Frequency lower limit reach (no output at stop) 19: Undervoltage 20: Communication setting 23: Running at zero speed 2 (output at stop) 24: Cumulative power-on time reach 25: Frequency level detection FDT2 output 26: Frequency 1 reach 27: Frequency 2 reach 28: Current 1 reach 29: Current 2 reach	You can set E1-00 to 42 (STO). In this case, when the AC drive enters the STO state, the RO will output an active signal.

Parameter Code	Parameter Name	Default	Value Range	Description
E1-00	RO output function selection	2	30: Timing duration reach 31: AI1 input limit exceeded 32: Three phase loss 33: Reverse running 34: Zero current state 35: Module temperature reach 36: Output current out of limit 37: Frequency lower limit reach (output at stop) 38: Abnormality (fault/ minor fault/warning) 40: Current running time reach 41: Fault (excluding undervoltage) 42: STO 43: Minor fault or warning 44: AI2 input limit exceeded 46: Component service life warning Others: B connector	You can set E1-00 to 42 (STO). In this case, when the AC drive enters the STO state, the RO will output an active signal.

Parameter Code	Parameter Name	Default	Value Range	Description
E1-02	DO output function selection	0	0: No output 1: AC drive running 2: Fault 3: Frequency level detection FDT1 output 4: Frequency reach 5: Running at zero speed (no output at stop) 6: Motor overload warning 7: AC drive overload warning 11: Simple PLC cycle completed 12: Cumulative running time reach 13: Wobble frequency limited 14: Torque limited 15: Ready to run 17: Frequency upper limit reach 18: Frequency lower limit reach (no output at stop) 19: Undervoltage 20: Communication setting 23: Running at zero speed 2 (output at stop) 24: Cumulative power-on time reach 25: Frequency level detection FDT2 output 26: Frequency 1 reach 27: Frequency 2 reach 28: Current 1 reach 29: Current 2 reach	You can set E1-02 to 42 (STO). In this case, when the AC drive enters the STO state, the DO will output an active signal.

Parameter Code	Parameter Name	Default	Value Range	Description
E1-02	DO output function selection	0	30: Timing duration reach 31: AI1 input limit exceeded 32: Three phase loss 33: Reverse running 34: Zero current state 35: Module temperature reach 36: Output current out of limit 37: Frequency lower limit reach (output at stop) 38: Abnormality (fault/ minor fault/warning) 40: Current running time reach 41: Fault (excluding undervoltage) 42: STO 43: Minor fault or warning 44: AI2 input limit exceeded 46: Component service life warning Others: B connector	You can set E1-02 to 42 (STO). In this case, when the AC drive enters the STO state, the DO will output an active signal.

9.2 List of Faults

Fault Code	Fault Name	Cause	Check Method	Solution	Reset Method
E47.1	STO1 disconnection	The STO1 signal is disconnected.	Displayed on the operating panel	Check whether the STO1 wiring is normal.	Manual reset
E47.2	STO2 disconnection	The STO2 signal is disconnected.	Displayed on the operating panel	Check whether the STO2 wiring is normal.	Manual reset
E47.3	STO circuit power supply exception	Undervoltage or overvoltage occurs on the STO circuit.	Displayed on the operating panel	Contact Inovance for technical support.	Manual reset
E47.4	STO input subsystem fault	The STO circuit input subsystem is abnormal.	Displayed on the operating panel	Contact Inovance for technical support.	Manual reset

Fault Code	Fault Name	Cause	Check Method	Solution	Reset Method
E47.5	STO buffer chip fault	The STO buffer chip is abnormal.	Displayed on the operating panel	Contact Inovance for technical support.	Manual reset
E47.7	STO FLASH check failure	The STO FLASH check fails.	Displayed on the operating panel	Contact Inovance for technical support.	Manual reset
E47.8	STO RAM check failure	The STO RAM check fails.	Displayed on the operating panel	Contact Inovance for technical support.	Manual reset
E47.9	STO check configuration failure	Configuration of the STO function safety library fails.	Displayed on the operating panel	Contact Inovance for technical support.	Manual reset
N194.1	STO1 and STO2 disconnection	The STO1 and STO2 input signals are disconnected.	Displayed on the operating panel	Check the wiring and power supply of the STO input circuit.	Automatic reset

10 Safety Standard and Certification

10.1 Safety Standard and Certification

Safety standard

Category	Reference Standard
Functional safety	IEC 61508: 2010
	ISO 13849-1:2023
	ISO 13849-2:2012
	IEC 62061: 2021
	IEC 61800-5-2:2016
	EN 61508: 2010
	EN ISO 13849-1:2015
	EN ISO 13849-2:2012
	EN IEC 62061:2021
	EN 61800-5-2:2007
EMC	IEC 61000-6-7:2014
	IEC 61326-3-1:2017
	IEC 61800-5-2:2016
	IEC 61800-3:2017
	EN 61000-6-7:2015
	EN 61326-3-1:2017
	EN 61800-5-2:2017
	EN IEC 61800-3:2018
Safety regulation	IEC 61800-5-1:2007/AMD1:2016
	EN 61800-5-1:2007/A11:2021

Certificate query

The safety function of the drive is certified by a third-party inspection organization, which grants certificates and proves that the safety function complies with EN 61508 and EN ISO 13849. EN IEC 62061 and EN 61800-5-2.

To query the certificate, do as follows:

1. Enter the following URL in the browser:
   https://www.inovance.com/portal/serviceSupport/download
2. Search for the product family name to be queried.
3. Under **Download Certificate**, click **Function Safety Certification**.

11 Appendix

11.1 Terms and Abbreviations

Term/Abbreviation	Description
STO	Safe torque off (safety function of IEC 61800-5-2)
FIT	1 FIT = 10^{-9} [1/h]
Cat (category)	Category of safety-related parts in the control system, including B, 1, 2, 3, and 4 (according to ISO 13849-1:2023 standard)
CCF	Common cause failure
DC	Diagnostic coverage (%)
DTI	Diagnostic test interval
SFF	Safe failure fraction
HFT	Hardware fault tolerance
PFH	Average frequency of dangerous failure per hour
PL	Performance level
SC	Systematic capability
SIL	Safety integrity level
$MTTF_d$	Mean time to dangerous failure (in years)
T_1	Proof test interval (PTI)
T_2	Diagnostic test interval (DTI)
β	CCF factor
λ_S	Safe failure Rate
λ_D	Dangerous failure rate
λ_{DD}	Detected dangerous failure rate
λ_{DU}	Undetected dangerous failure rate

11.2 Standards and Directives

11.2.1 Machinery Directive

The Machinery Directive is a legal regulation applicable to EU. It is designed to ensure the safety and compliance of mechanical equipment in the market.

- Directive 2006/42/EC is the latest version of the Machinery Directive issued in 2006 and replaces the previous directive. This directive covers safety requirements during the design, manufacture, sale, and use of machinery.

- Applicable scope: The Machinery Directive applies to most mechanical equipment, including industrial machinery, domestic machinery, and farm machinery. However, some equipment such as medical equipment or vehicles may be subject to other directives.
- Conformance assessment: The manufacturer must ensure that its products comply with the essential health and safety requirements (EHSRs) in the directive through risk assessment, design adjustment, and compliance testing.
- Purpose: The directive aims at guaranteeing safety of consumers and workers and ensuring uniform standards of machinery and equipment within the EU, therefore facilitating the free circulation of products.

11.2.2European Harmonized Standards

The European harmonized standards (EN) are technical standards developed by European standards organizations such as CEN, CENELEC, and ETSI. The standards aim to ensure the consistency and safety of products in the EU market and supports EU legislation, including EU directives and regulations.

- Legal effect: The ENs are voluntary. However, when the product complies with the ENs, it is considered to comply with the basic requirements of relevant directives or regulations, such as the safety requirements in the Machinery Directive.
- Coverage: The ENs cover a wide range of product types, including mechanical, electrical, medical, and construction equipment.
- Technical specifications: The ENs provide detailed technical requirements for product design, manufacturing, testing, and use, ensuring that products have uniform safety and performance standards across the EU market.
-

Class A, class B, and class C standards in the ENs are distinguished according to their application scopes and purposes. Each type of standard has a different role in mechanical equipment design and safety.

- Class A (basic standards): Class A standards define basic concepts, design principles, and general features applicable to all machines.
- Class B (group safety standards: Class B standards standards involve safety features of machines or safety devices with a wide range of applications.
  - Class B1: Standards for specific safety features (such as safety distance, surface temperature, and noise)
  - Class B2: Standards for safety devices (such as devices operated with two hands, interlocking devices, voltage dependent devices, protective devices).
- Class C (machine-specific standards): Class C standards are for specific types of mechanical equipment and specify the detailed safety requirements of the equipment.

ENs related to the functional safety of the drive:

- EN 61800-5-2: Adjustable Speed Electrical Power Drive Systems, Part 5-2 Safety Requirements
- EN ISO 13849-1: Safety of Machinery - Safety-related Parts of Control Systems, Part 1 General Principles for Design
- EN 62061: Safety of Machinery - Functional Safety of Safety-related Electrical, Electronic and Programmable Electronic Control Systems

11.2.3Standards Related to Safety Design of Control System

The functional safety level of the machine is defined as follows:

- SIL or PL IEC 61508, IEC61800-5-2 and IEC 62061 are evaluation systems based on the SIL.
- ISO 13849 is an evaluation system based on the PL.

11.2.4EN 62061

EN 62061 is an European standard for functional safety of safety-related electrical, electronic, and programmable electronic control systems (SRECS) dedicated for mechanical equipment. This standard specifies how to design, integrate, and verify these systems to ensure safe operation of the systems in mechanical equipment.

11.2.5EN ISO 13849-1

EN ISO 13849-1 is an international standard for the design and evaluation of safety-related control systems in mechanical equipment. It is applicable to the safety design of all kinds of mechanical equipment, especially in industrial automation, manufacturing equipment, and robot systems. This standard provides manufacturers and designers with a systematic set of principles to ensure that the safety-related parts of mechanical equipment (SR/CS) can reliably carry out safety functions throughout the life cycle of the equipment.

11.2.6EN 61508

EN 61508 is an international standard published by the International Electrotechnical Commission (IEC). The original name is IEC 61508. EN 61508 is adopted in Europe. It is widely used in the industrial field and focuses on ensuring functional safety of electrical, electronic, and programmable electronic (E/E/PE) safety related systems. This standard provides a comprehensive framework for designing, developing, implementing, operating, or retiring the systems to ensure that their safety functions can apply in potentially hazardous situations.

11.2.7Risk Analysis and Assessment

Risk analysis and assessment are key steps to ensure the safety of mechanical equipment and industrial systems. Safety risks during equipment and system operation can be reduced by identifying and controlling potential hazards.

- EN ISO 12100 is the basic safety standard for mechanical equipment. It focuses on the overall design safety of mechanical equipment and covers all potential hazard identification and risk control measures. It provides a comprehensive risk assessment framework for the overall safety design of the equipment.
- EN ISO 13849-1: The standard focuses on the safety-related control system of mechanical equipment, and the design and evaluation of safety-related control system parts through performance level (PL) to ensure that hazards can be prevented effectively during operation.

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