• 15W0102B300 •

SINUS PENTA
PENTA MARINE
IRIS BLUE

SAFE TORQUE OFF FUNCTION
- Application Manual -

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R.01

English

• This manual is integrant and essential to the product. Carefully read the instructions contained herein as they provide important hints for use and maintenance safety.
• This device is to be used only for the purposes it has been designed to. Other uses should be considered improper and dangerous. The manufacturer is not responsible for possible damages caused by improper, erroneous and irrational uses.
• Enertronica Santerno S.p.A. is responsible for the device in its original setting.
• Any changes to the structure or operating cycle of the device must be performed or authorized by Enertronica Santerno S.p.A..
• Enertronica Santerno S.p.A. assumes no responsibility for the consequences resulting by the use of non-original spare-parts.
• Enertronica Santerno S.p.A. reserves the right to make any technical changes to this manual and to the device without prior notice. If printing errors or similar are detected, the corrections will be included in the new releases of the manual.
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1. BASICS

1.1. General

The Santerno Sinus Penta, Penta Marine and Iris Blue inverter product lines, now equipped with the new ES927 control board, support the Safety Torque Off (STO) function. This document instructs the user on how to properly apply the Safety Torque Off (STO) function implemented on the inverters.

The above mentioned inverters allow adjusting speed and torque values of three-phase asynchronous motors and brushless permanent-magnet AC motors with several control modes. Control modes may be user-defined and allow obtaining the best performances in terms of fine-tuning and energy saving for any industrial application.

The Safe Torque Off (STO) function, integrated in these product lines, is a particular stopping method defined in clause 4.2.2.2 of EN 61800-5-2 (2007-10), as listed below:

"4.2.2.2 Safe Torque Off (STO)
Power, that can cause rotation (or motion in the case of a linear motor), is not applied to the motor. The PDS(SR) (Power Drive System Safety-Related) will not provide energy to the motor which can generate torque (or force in the case of a linear motor).
NOTE 1 This safety function corresponds to an uncontrolled stop in accordance with stop category 0 of IEC 60204-1.
NOTE 2 This safety function may be used where power removal is required to prevent an unexpected start up.
NOTE 3 In circumstances where external influences (for example, falling of suspended loads) are present, additional measures (for example mechanical brakes) may be necessary to prevent any hazard.
NOTE 4 Electronic means and contactors are not adequate for protection against electric shock, and additional measures for isolation may be necessary."

The STO is a function that allows stopping the motor in a safe way if externally demanded. The STO function removes power from the motor by disabling the PWM commands from the CPU to the IGBT drivers.
The STO function can be used also to prevent unexpected start up of the motor.
The STO function in the Sinus Penta, Penta Marine and Iris Blue drives is obtained at a hardware level and its activation is absolutely independent of the software and the CPU of the inverter. The drive firmware implements only non-critical diagnostic functions related to the STO function.

Where external influences (for example, falling of suspended loads) are present, additional measures (for example mechanical brakes) may be necessary to prevent any hazard.

CAUTION

The Safe Torque Off function does not cut off the mains voltage and auxiliary circuits from the drive. Therefore, maintenance work on electrical parts of the drive or the motor can only be carried out after isolating the drive system from the mains supply.

NOTE

The Safe Torque Off function can be used for stopping the drive in emergency stop situations. In normal operating mode, it is recommended not to stop the drive by using the Safe Torque Off function. If a running drive is stopped by using the Safe Torque Off function, the motor will perform a coast to stop. If this is not acceptable, e.g. causes danger, the drive and machinery must be stopped using the appropriate stopping mode instead of adopting the STO function.

NOTE

Note concerning permanent magnet motor drives in case of multiple IGBT power semiconductor failure:
Due to the possible DC output voltage present for certain multiple IGBT failures, in spite of the activation of the Safe Torque Off function, the drive system can produce an alignment torque which maximally rotates the motor shaft by 180/p degrees (p is the pole pair number).

Figure 1 (compact inverter) and Figure 2, Figure 3, Figure 4 (modular inverter) show the different sizes and structures of inverters relative to the Sinus Penta drives.
The Penta Marine and Iris Blue product lines share the same sizes and physical appearance as the Sinus Penta; the only differences lie in the control functions and the selection of power conversion components, optimized for the target market.

This manual covers the three product lines as they share the same control board ES927 and the STO function is implemented exclusively in the control board hardware components.

Figure 1 – Some Sinus Penta compact models

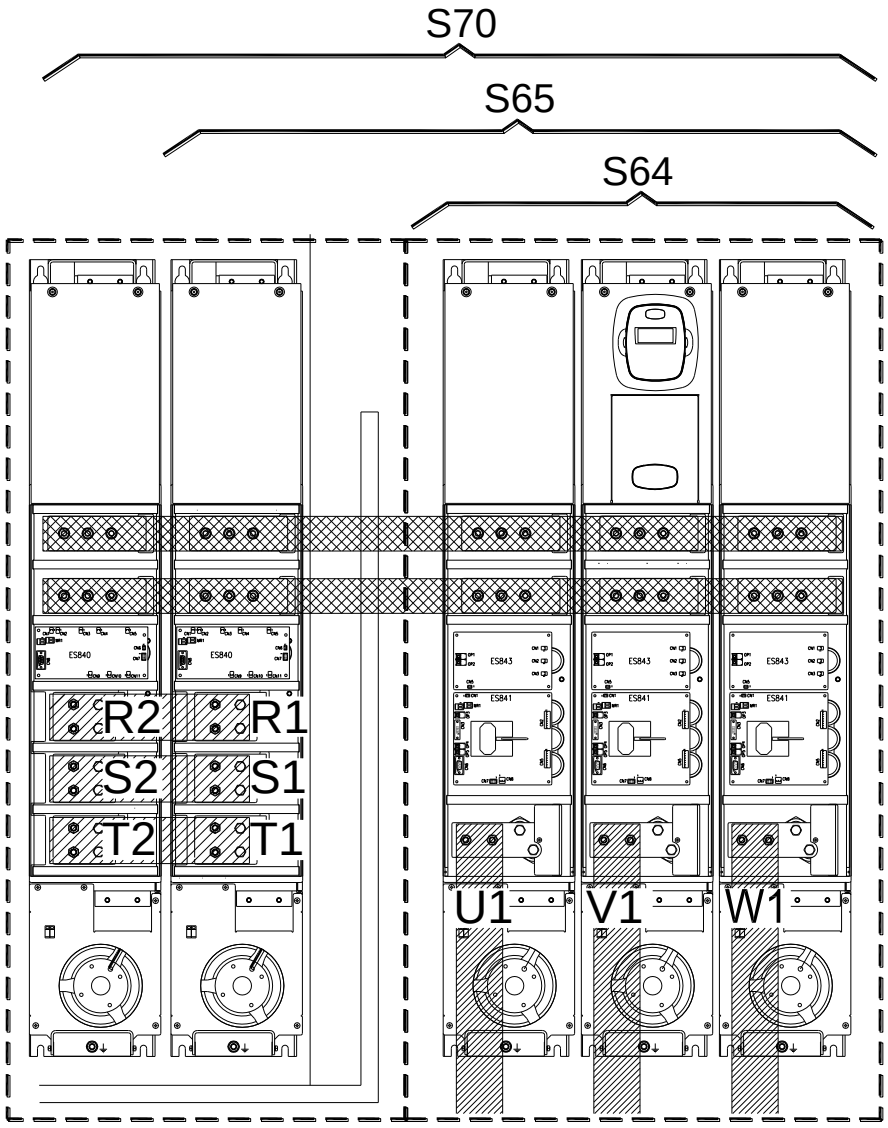

Figure 2 – Installation example of a Sinus Penta S64/S70

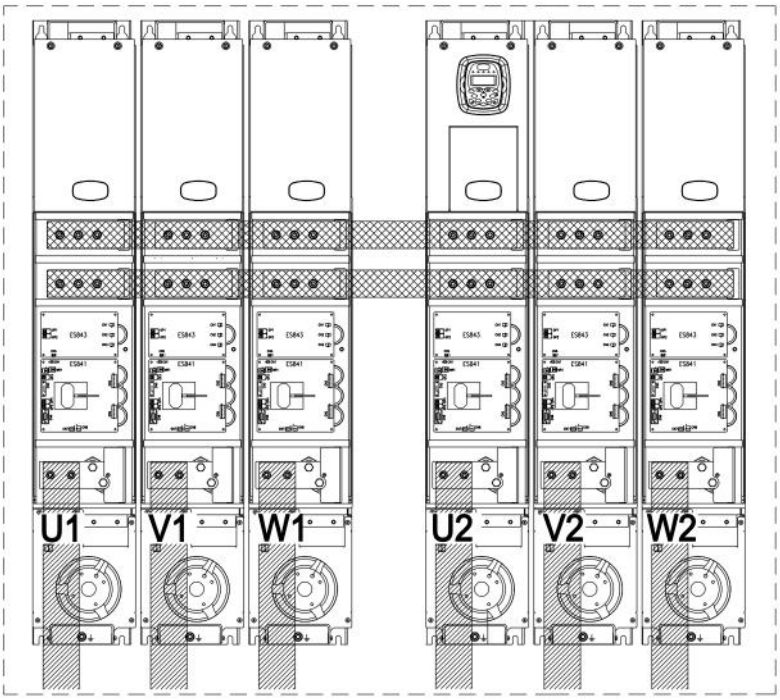

Figure 3 – Installation example of a Sinus Penta S74

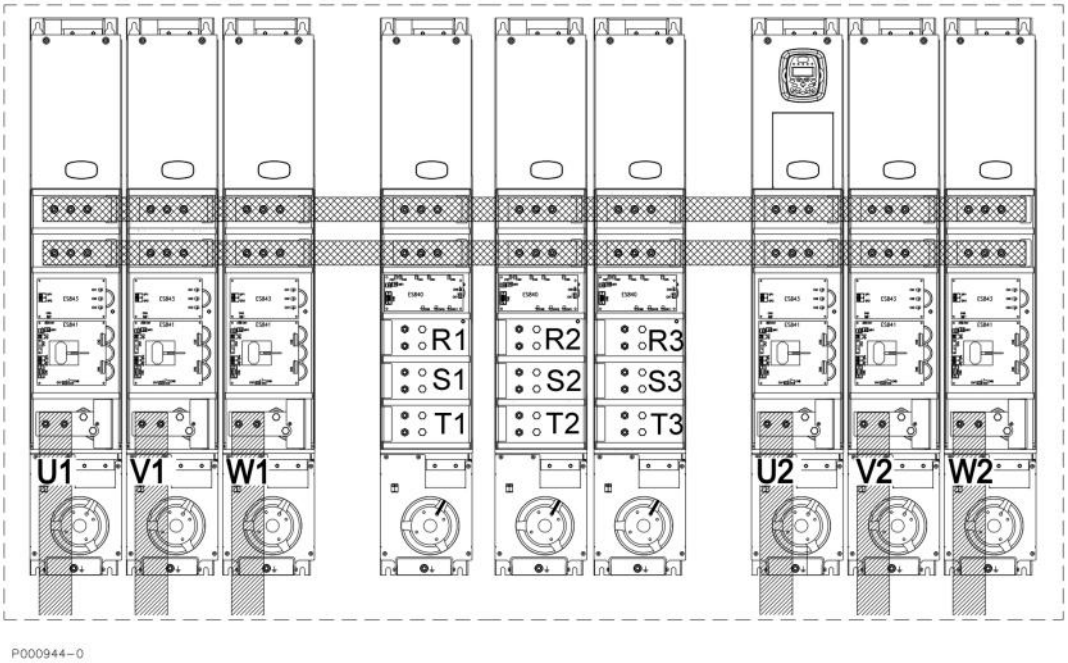

Figure 4 – Installation example of a Sinus Penta S75/S80

(S75 includes two power supply unit modules)

1.2. Scope and Application

The drives support the Safe Torque Off (STO) function according to standards EN 61800-5-2:2007, EN ISO 13849-1:2008, EN 61508:2010.
The STO may be used where power cut off is required to prevent unexpected start up. The STO function disables the control voltage of the power semiconductors of the drive output stage, thus preventing the inverter from generating the voltage required to rotate the motor (see diagram below). By using this function, short-time operations (like cleaning) and/or maintenance activities on non-electrical parts of the machinery can be performed without cutting off the power supply to the drive.

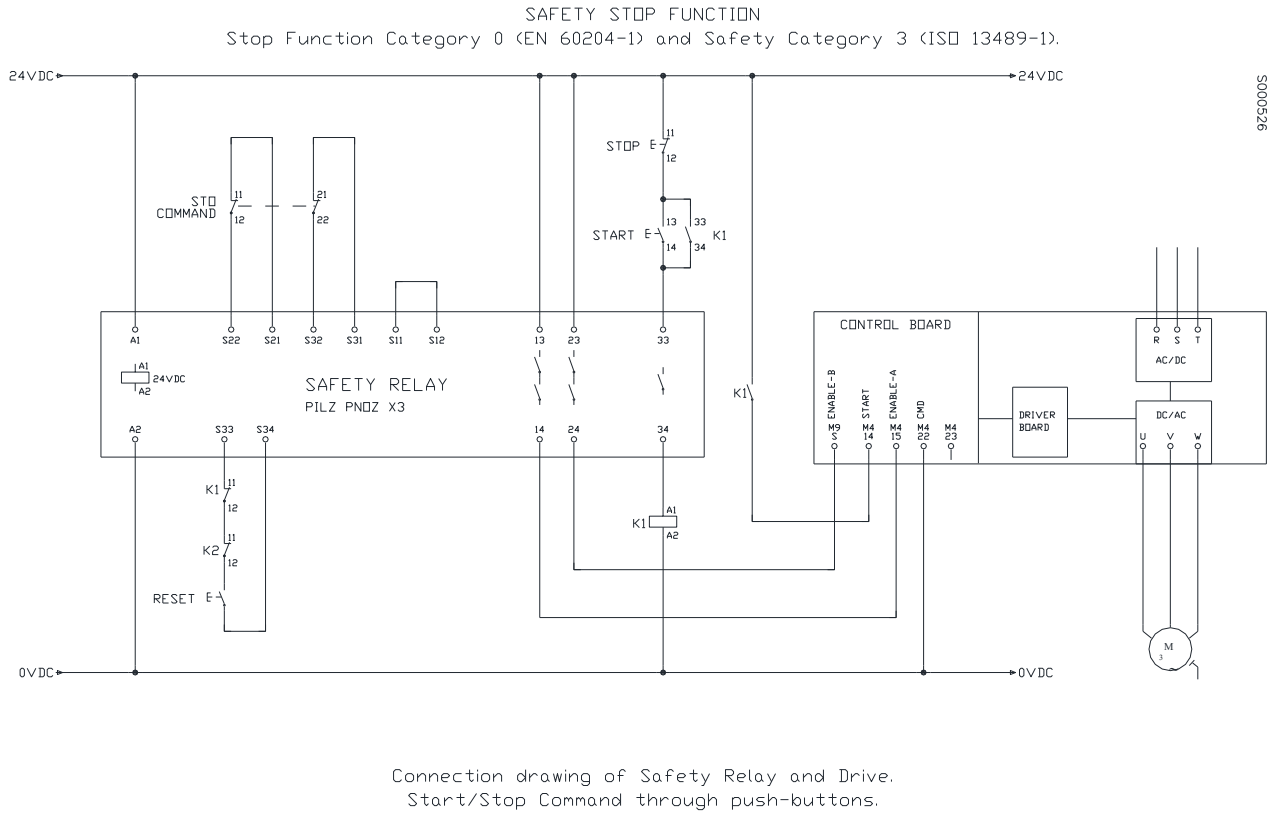

Figure 5 - Example schematic diagram of STO function with Safety Relay PILZ PNOZ X3 for safe power cut off

The circuit operation is described below.

Start/Stop command is obtained through special-purpose push-buttons.

When the STO command circuit is activated, for the Safety Relay PILZ PNOZ X3:
Input circuits S21-S22 and S31-S32 are open.
Instantaneous output contacts 13-14 and 23-24 will be opened.

At the same time, the 'Safe Torque Off' function is activated for the drive, because ENABLE-A (pin 15) end ENABLE-B (pin S) are de-energized, and consequently the output voltage to the motor is removed. The motor will be stopped in free-run and the time taken to come to a complete stop will depend on the load inertia.

The Safety Relay will be reset when, after deactivating the 'Emergency Stop', the 'RESET' push-button is pressed: in this case, 13-14 and 23-24 are closed and 24Vdc power supply is restored to the ENABLE-A and ENABLE-B inputs of the drive.
The 'Safe Torque Off' function is deactivated in the Drive and the output voltage to the motor is restored. The motor will start when receiving the start command through the 'START' push-button.

The output relay contacts of the drive can be programmed with one of the software functions available for remote signalling, including the input Enable Drive status. Being the output relay circuitry based on a single hardware channel, and being the activation function software programmable by the user, it cannot be considered as a safe status indication. Therefore, the confirmation that the STO function is active cannot be safely obtained from the output relay contact of the drive.

Figure 6 shows a simpler example where both ENABLE-A and ENABLE-B are directly controlled by a two-contact emergency switch.

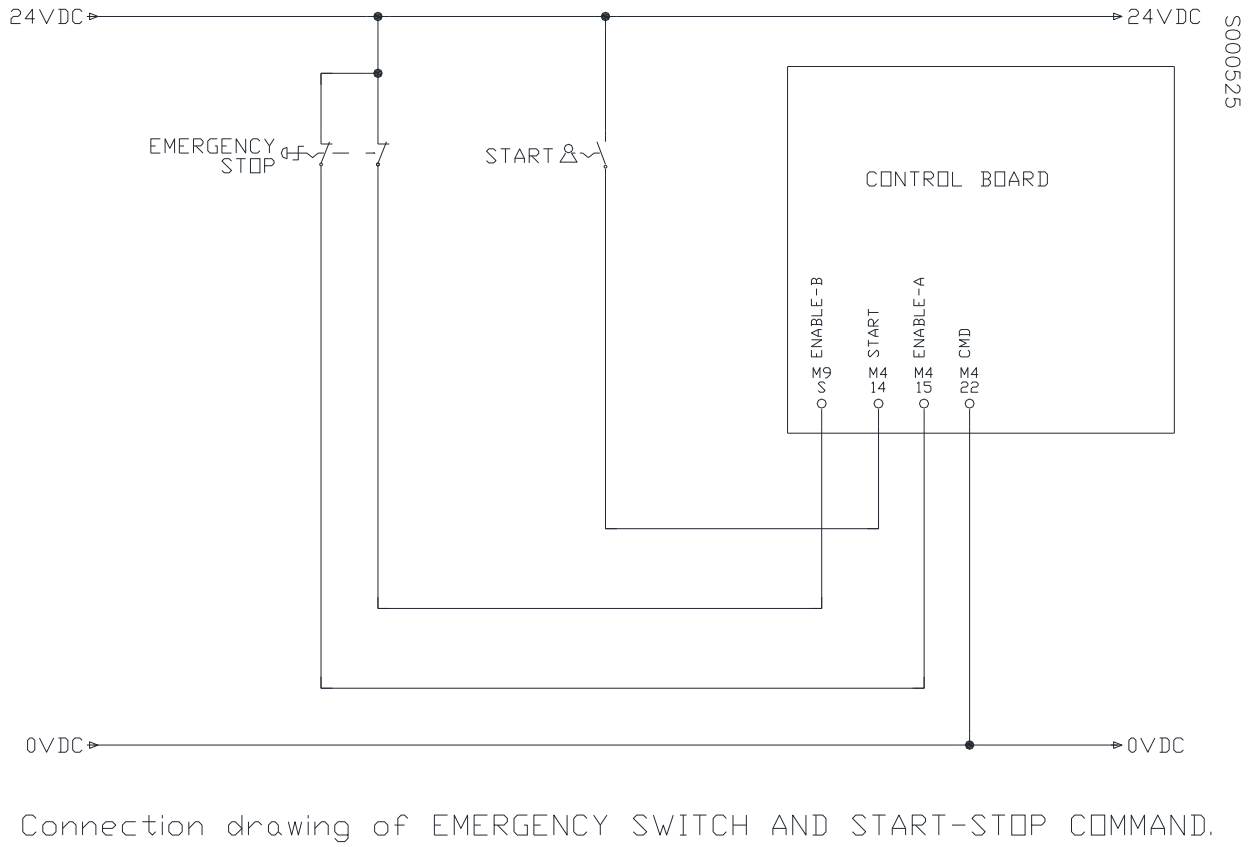

Figure 6 - Example schematic diagram of the STO function with simple emergency pushbutton

The circuit operation is straightforward, and similar to the previous example.
In both cases, the ENABLE-A and ENABLE-B command circuits shall be carried out with care on the cables layout, avoiding that possible damage to cable insulation could result in unwanted circuit excitation.
In particular, shielded cables are recommended if the signals shall be routed for long distances and cables might be damaged.
In this case, the shield shall be connected to the 0Vdc circuit. The '0' terminal beside the 'S' terminal and terminal "22" shall be used for the connection of the cable shield to the 0Vdc/CMD circuit.
If the shielded cable is severed, the short circuit between the shield and the internal conductor will de-energize the affected ENABLE circuit, guaranteeing the activation of the STO function.

CAUTION

The Safe Torque Off function does not cut off the mains voltage and auxiliary circuits from the drive. Therefore, maintenance work on electrical parts of the drive or the motor can only be carried out after isolating the drive system from the mains supply.

NOTE

The Safe Torque Off function can be used for stopping the drive in emergency stop situations. In normal operating mode, it is recommended not to stop the drive by using the Safe Torque Off function. If a running drive is stopped by using the Safe Torque Off function, the drive will trip and perform a coast to stop. If this is not acceptable, e.g. causes danger, the drive and machinery must be stopped using the appropriate stopping mode instead of adopting the STO function.

NOTE

Note concerning permanent magnet motor drives in case of multiple IGBT power semiconductor failure:
Due to the possible DC output voltage present for certain multiple IGBT failures, in spite of the activation of the Safe Torque Off function, the drive system can produce an alignment torque which maximally rotates the motor shaft by 180/p degrees (p is the pole pair number).

NOTE

It is recommended to route two separate conductors for the ENABLE-A and ENABLE-B input signals to the drive. This will avoid common failures that can result in an unwanted deactivation of the STO function.

2. ES927 CONTROL BOARD

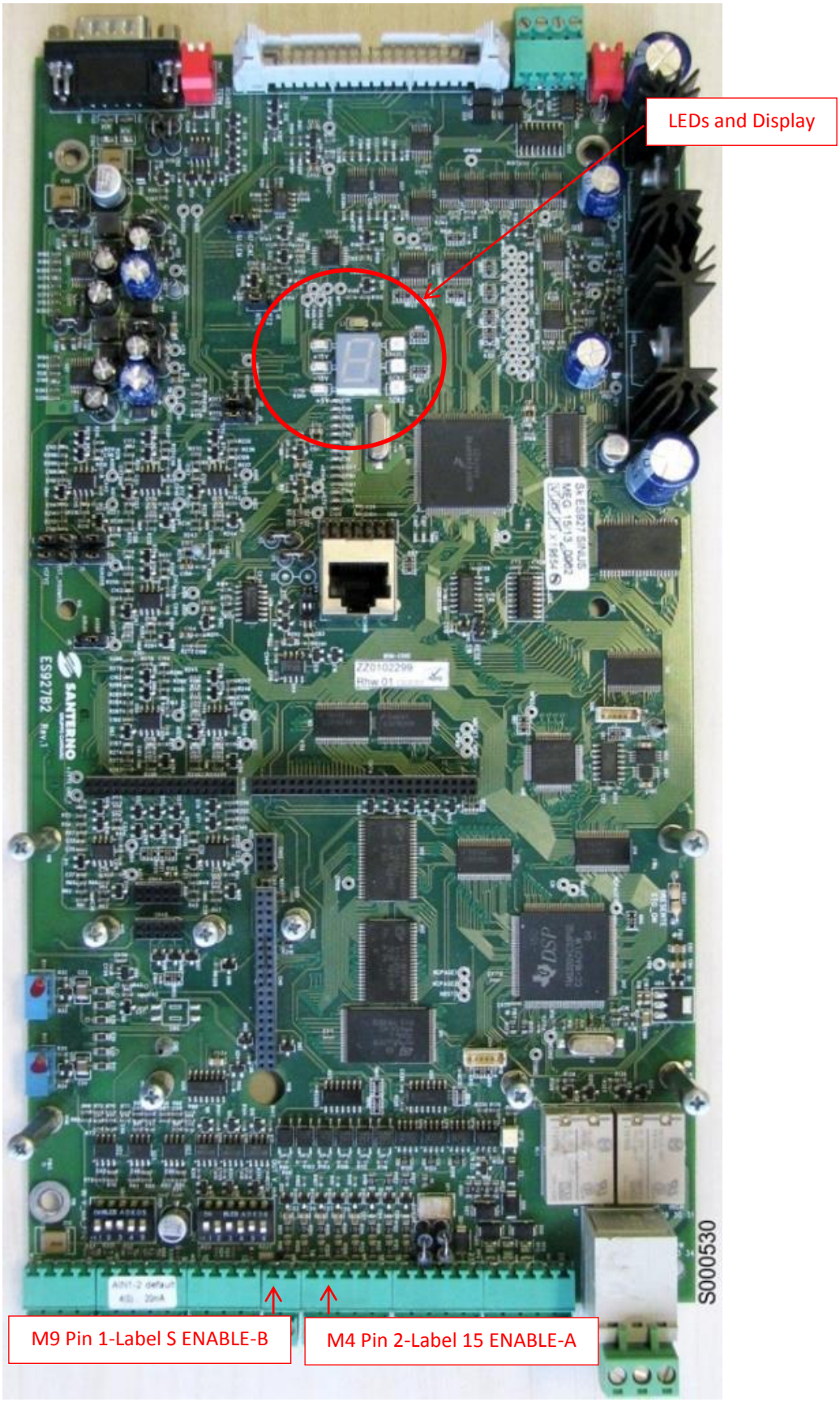

Figure 7 – Top view of ES927

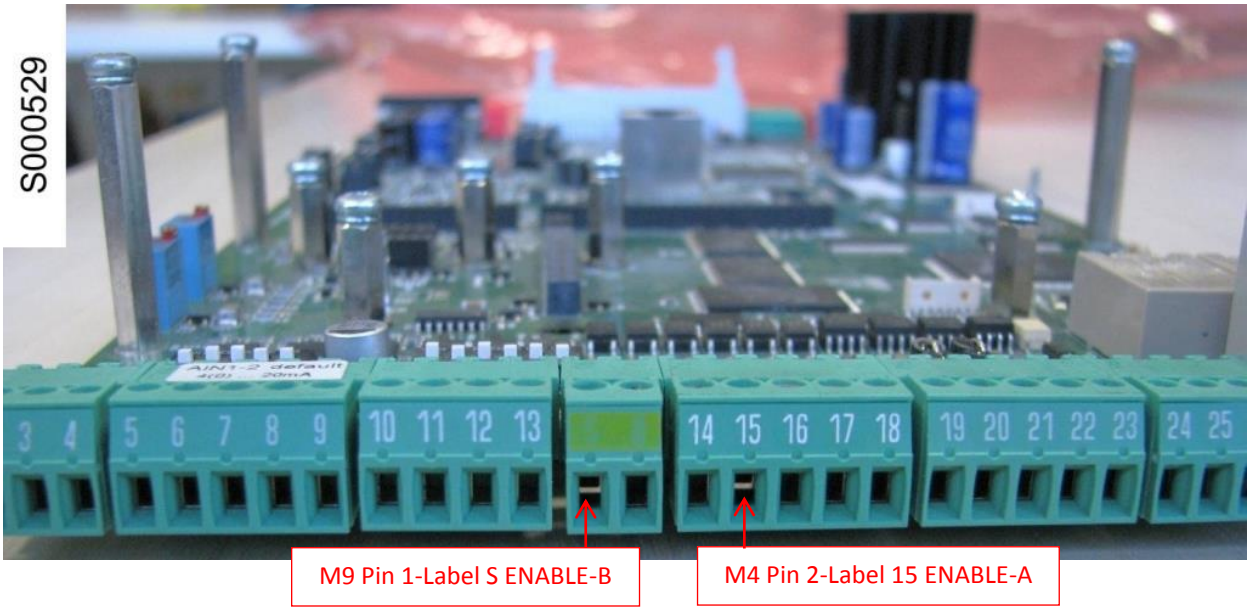

Figure 8 – Front view of terminal blocks for ES927

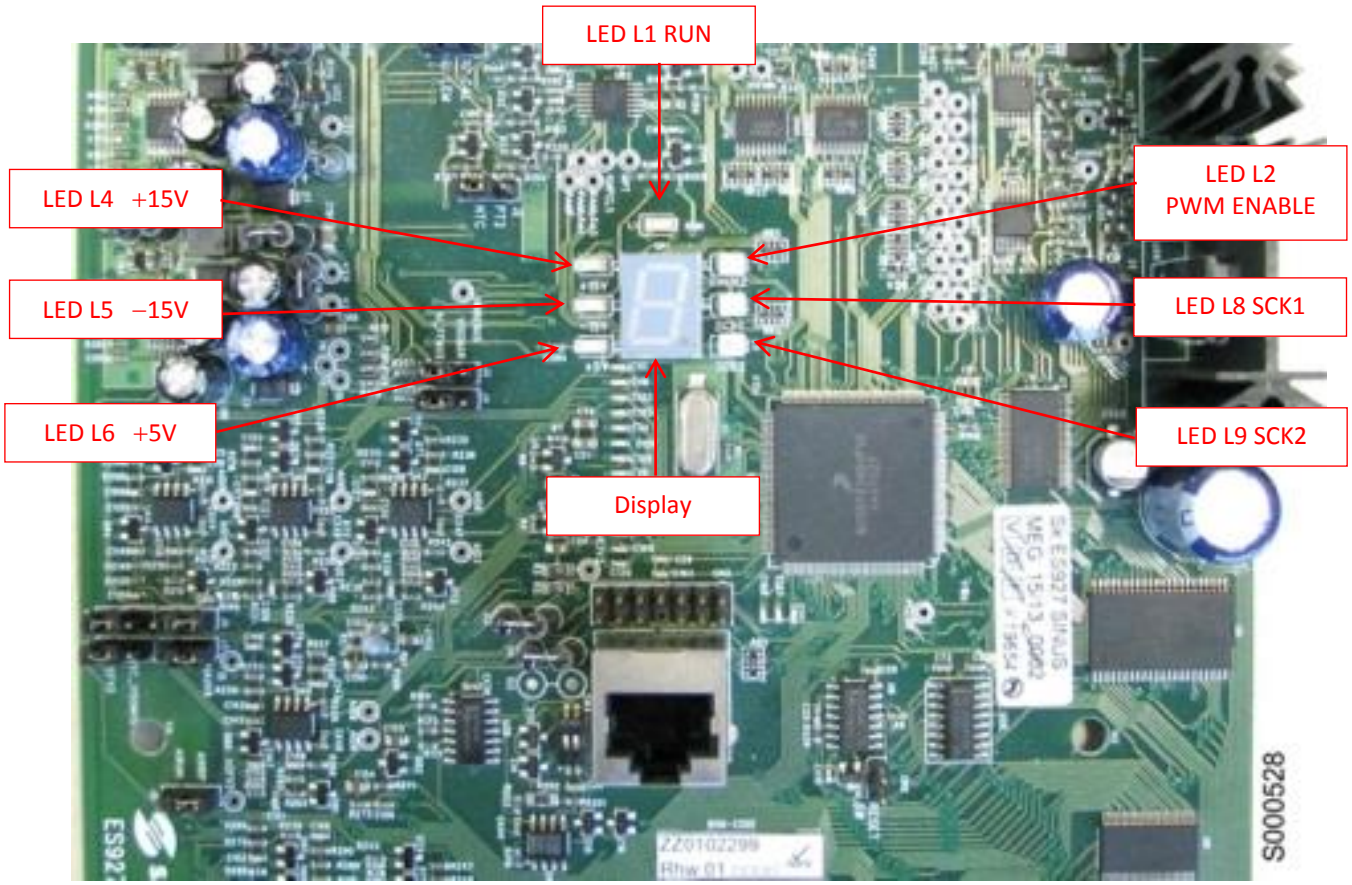

Figure 9 – LEDs and Display on ES927

All the Sinus Penta, Penta Marine and Iris Blue drives are equipped with the same ES927 control board.
Figure 7,
Figure 8 and
Figure 9 show the relevant components related to the STO function.
In particular, Figure 7 shows the diagnostic display and the ENABLE-A and ENABLE-B terminals locations, while
Figure 8 and
Figure 9 show the details of the terminals and the diagnostic LEDs indicators.
The diagnostic test procedure, covered in the following sections, refers to those LEDs indicators.

3. DEFINITION OF THE SYSTEM

3.1. System Structure

The STO function operates in the CPU & CONTROL LOGIC board called ES927.
When both STO inputs are energized, the STO function is on standby and the drive operates normally. The STO function is active (motor stopped) when one of the two inputs is de-energized: if at least one of the STO inputs is de-energized, the STO function is active and stops the drive; the drive can start only after the STO inputs have been energized and the drive faults (if any) have been reset.

CAUTION The STO function is based on a dual channel hardware implementation. To achieve the rated protection level guaranteed by ES927 board, both the ENABLE-A and ENABLE-B shall be de-energized to obtain the STO function.

3.2. Functional Description

The motor stop is obtained by cutting the PWM signals from the CPU to the IGBT Drivers. This cut is made with two series-connected, 3-state buffers: both buffers must be enabled to allow transferring the PWM signals to the IGBTs.
The enable signals (ENABLE-A and ENABLE-B) come from the two separate channels that process independently the external demand.
The motor can work only if both channels send the Enable signal, while if only one Enable signal is removed, the motor is stopped.
Figure 10 shows the block diagram of the integration of the STO function into the Sinus Penta, Penta Marine and Iris Blue drives.

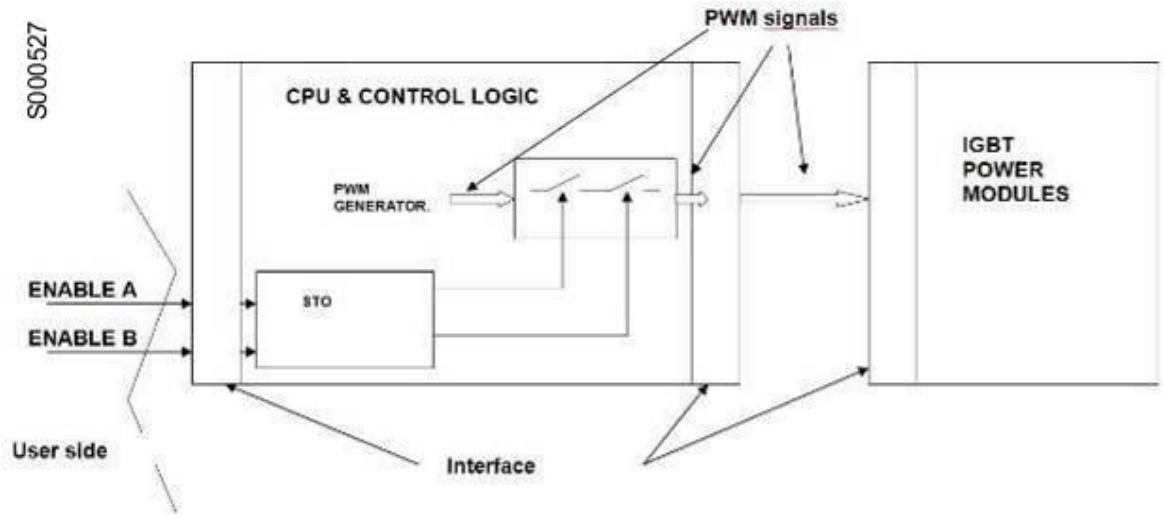

Figure 10 – Integration of the STO function into the drives

The STO function breaks out the PWM logic signals at ES927 control board level; therefore, it is completely independent of the power size of the drive.

4. DIAGNOSTICS

The STO function is based on a double channel with diagnostic (1oo2 in the IEC 61508-6 nomenclature) hardware architecture. This means that diagnostic tests are required to validate the STO function and to periodically verify the hardware integrity.
The two diagnostic tests, working at different levels and with different timing, are based on consistency check logics and three indicator LEDs.
The two diagnostic tests are the following:
DT01 Periodic proof-test (related to “System OK” L8 and L9 LEDs)
DT02 Periodic proof-test (related to “PWM Enable” L2 LED)

As specified in the following descriptions, the simple and easy diagnostic test DT01-DT02 has to be performed by the User at an interval time lower than or equal to one year.
To do that it is needed to remove, if present, the display/keypad from the front of the drive and to verify the status of the diagnostic LEDs from the transparent window.
The diagnostic test requires the individual energization and de-energization of the two ENABLE-A and ENABLE-B commands. Therefore, the drive application circuit shall allow for this operation. The easiest way to do this is to provide switches or pushbuttons, preferably operable only by service people, applied in series to the two ENABLE-A and ENABLE-B wires.
Another continuous coherency check is performed by the board CPU under firmware control. This is an additional verification of the STO related signals, and the result, if failing, is reported as alarm A140. When the alarm trips, the drive operation is locked. This test is independent of the drive status and does not require any operation by the user. Alarm A140 is detailed in section 6.5 Alarm Messages Generated by the Drive.

DT01 Periodic proof-test (Diagnostic LEDs “System OK” L8 and L9)

Based on hardware components only.
Performed with a specified sequence of 4 steps.
Checked by visual inspection of Diagnostic LEDs “System OK” L8 and L9.
Proof-test Interval: one year.

NOTE This proof-test circuit is integrated into ES927 board to prevent the presence of dormant failures.

A hardware proof-test circuit based on redundant logic gates has been implemented on ES927 and the periodic proof-test is activated by an external command. The check is performed with the activation of the STO function (by activation of external components for de-energization of at least one of the STO input signals).
The diagnostic circuit reads the command signals status present in the two channels of STO function circuit and, when the test is active, its combinational logic gives “true” only if all the command signals in both channels are correct. In this case, both the Diagnostic LEDs “System OK” L8 and L9 are ON.

In particular, when the STO function is activated, the proof-test hardware circuit checks the congruence of all the PWM signal across the logic output buffers, and it is able to detect failures associated with those components.

The DT01 proof-test needs to be performed in 4 steps:

Step nr1	Drive is working with motor torque applied to motor. This condition is obtained by energizing both STO input signals (ENABLE-A and ENABLE-B) and transmission of PWM commands from Microcontroller to the IGBT Drivers. CAUTION: Speed and torque applied during this step need to be compliant with acceptable working conditions of the application where the drive is installed.
Step nr1 partial result	No Test Result required: this condition is based on FW code and for this Diagnostic Test we need to use only HW components.
Step nr2	Activation of STO function, so no motor torque is applied to the motor. This condition is obtained by de-energization of one STO input signal (ENABLE-A).
Step nr2 partial result	Test Result PASS: Diagnostic LEDs “System OK” L8 and L9 are LIGHT ON. Both the Diagnostic LEDs “System OK” L8 and L9 are LIGHT ON only if all the internal and intermediate PWM signals are retained at the proper logic level corresponding to STO activation. Test Result FAIL: Diagnostic LEDs “System OK” L8 and/or L9 are LIGHT OFF. If at least one of the internal and intermediate PWM signals are not at the proper logic level or at least one of the related components are NOT correctly working, one or both the Diagnostic LEDs “System OK” L8 and L9 are LIGHT OFF.
Step nr3	Drive is working again with motor torque applied to motor. This condition is obtained by energizing again the STO input signal opened during Step nr2 (ENABLE-A) and transmission of PWM commands from Microcontroller to the IGBT Drivers. CAUTION: Speed and torque applied during this step need to be compliant with acceptable working conditions of the application in which the drive is installed.
Step nr3 partial result	No Test Result required: this condition is based on FW code and for this Diagnostic Test we need to use only HW components. Same as Step nr1.
Step nr4	Activation of STO function, so no motor torque is applied to motor. This condition is obtained by de-energizing the other STO input signal (ENABLE-B).
Step nr4 partial result	Test Result PASS: Diagnostic LEDs “System OK” L8 and L9 are LIGHT ON. Same as Step nr2. Test Result FAIL: Diagnostic LEDs “System OK” L8 and/or L9 are LIGHT OFF. Same as Step nr2.

For all steps we need to have Test Result PASS.
Measure to adopt in case of Test Result FAIL:
Board ES927 board is damaged → It is mandatory to replace the drive or the board with a new one.

DT02 <u>Periodic Proof-test (Diagnostic LED "PWM Enable" L2)</u>

Based on hardware components and firmware code.
Performed with a specified sequence of 4 steps.
Checked by visual inspection of Diagnostic LED "PWM Enable" L2.
Proof-test Interval: one year.

NOTE This proof-test circuit is integrated in ES927 board to prevent the presence of dormant failures.

A hardware proof-test circuit based on redundant logic gates reads the dedicated Enable commands for the PWM signal buffers inserted in the two channels of the STO function circuit.
The Enable command of the PWM signal buffers are conditioned also by the status of the drive firmware code. The firmware code has the limited action capability to disable the buffer Enable commands, but not to re-enable them if the STO function is active.
The coordination with firmware code is therefore needed for the completion of next Steps nr1 and nr3 requiring the transmission of PWM commands from Microcontroller to the IGBT Drivers.

The DT02 proof-test is to be performed in 4 steps:

Step nr1	Drive is working with motor torque applied to motor. This condition is obtained by energizing both STO input signals (ENABLE-A and ENABLE-B) and by the transmission of PWM commands from Microcontroller to the IGBT Drivers. CAUTION: Speed and torque applied during this step need to be compliant with acceptable working conditions of the application where the drive is installed.
Step nr1 partial result	Test Result PASS: Diagnostic LED “PWM Enable” L2 is LIGHT ON. If all buffer enable signals are at the right logic level and all related components are correctly working, then the Diagnostic LED “PWM Enable” L2 is LIGHT ON. Test Result FAIL: Diagnostic LED “PWM Enable” L2 is LIGHT OFF. If at least one buffer enable signals is not at the right logic level or at least one of the related components are NOT correctly working, then the Diagnostic LED “PWM Enable” L2 is LIGHT OFF.
Step nr2	Activation of the STO function, so no motor torque is applied to motor. This condition is obtained by de-energizing only one of the STO input signals (ENABLE-A).
Step nr2 partial result	Test Result PASS: Diagnostic LED “PWM Enable” L2 is LIGHT OFF. If the buffer Enable signal logic level configuration is correct and all related components are correctly working, then the Diagnostic LED “PWM Enable” L2 is LIGHT OFF. Test Result FAIL: Diagnostic LED “PWM Enable” L2 is LIGHT ON. If the buffer Enable signal logic level configuration is not correct or at least one of the related components are NOT correctly working, then the Diagnostic LED “PWM Enable” L2 remain LIGHT ON.
Step nr3	Drive is working again with motor torque applied to motor. This condition is obtained by energizing again the STO input signal opened during Step nr2 (ENABLE-A) and transmission of PWM commands from Microcontroller to the IGBT Drivers. CAUTION: Speed and torque applied during this step need to be compliant with acceptable working conditions of the application where the drive is installed.
Step nr3 partial result	Test Result PASS: Diagnostic LED “PWM Enable” L2 is LIGHT ON. Same as Step nr1. Test Result FAIL: Diagnostic LED “PWM Enable” L2 is LIGHT OFF. Same as Step nr1.
Step nr4	Activation of STO function, so no motor torque is applied to motor. This condition is obtained by de-energizing the other STO input signal (ENABLE-B).
Step nr4 partial result	Test Result PASS: Diagnostic LED “PWM Enable” L2 is LIGHT OFF. Same as Step nr2. Test Result FAIL: Diagnostic LED “PWM Enable” L2 is LIGHT ON. Same as Step nr2.

For all steps, the Test Result must be PASS.
Measure to adopt in case of Test Result FAIL:
Board ES927 is damaged → It is mandatory to replace the board with a new one.

5. VALIDATING THE OPERATION OF A SAFETY FUNCTION

Safety Standards EN IEC 62061 and EN ISO 13849 require that the final assembler of the machine validates the operation of the safety function with an acceptance test.

The acceptance tests must be performed:
At initial start-up (commissioning) of the safety function or installation of a new drive unit in place of an existing one,
At each periodic annual test of the safety function,
After any changes (wiring, components, settings, etc.) related to the safety function,
After any changes related to the CPU CONTROL BOARD ES927 of the drive,
After any maintenance activity related to the safety function,
After any Test Result FAIL during the STO acceptance test procedure and subsequent decommissioning of ES927 damaged board and replacement with a new one.

5.1. Acceptance Test Reports

Signed acceptance test reports must be stored into the Instruction's Manual of the machine. The report shall include documentation of start-up activities and test results, references to failure reports and resolution of failures. Any new acceptance tests performed due to periodic annual test (once a year), changes, maintenance and decommissioning shall be logged into the Instruction's Manual of the machine.
Section 5.3 Performing the Acceptance Test includes the template of the Check List for 'STO Acceptance Test', as a guide for a test report.

5.2. Authorized Person

The acceptance test of the safety function must be carried out by an authorized person having adequate expertise and knowledge of the safety function. The test must be documented and signed by the authorized person.

5.3. Performing the Acceptance Test

The drive is working with motor torque applied to motor during the acceptance test.
The following template shall be included in the Instruction's Manual of the machine incorporating the motor drive.

CAUTION

Speed and torque applied during the acceptance test need to be compliant with acceptable working conditions of the application where the drive is installed.

CAUTION

The Safe Torque Off function does not cut off the mains voltage and auxiliary circuits from the drive. Therefore, maintenance work on electrical parts of the drive or the motor can only be carried out after isolating the drive system from the mains supply.

NOTE

The Safe Torque Off function can be used for stopping the drive in emergency stop situations. In the normal operating mode, it is not recommended to stop the drive by using the Safe Torque Off function. If a running drive is stopped by using the Safe Torque Off function, the drive will trip and stop by coasting. If this is not acceptable, e.g. causes danger, the drive and machinery must be stopped using the appropriate stopping mode before using this function.

NOTE

Note concerning permanent magnet motor drives in case of multiple IGBT power semiconductor failure:
Due to the possible DC output voltage present for certain multiple IGBT failures, in spite of the activation of the Safe Torque Off function, the drive system can produce an alignment torque which maximally rotates the motor shaft by 180/p degrees (p is the pole pair number).

CHECK LIST for the Motor Drive 'STO ACCEPTANCE TESTS'	
Reason for performing the acceptance tests of the safety function STO:	
☐	Initial start-up (commissioning) of the safety function or installation of a new drive unit in place of an existing one.
☐	Each periodic annual test (once a year) of the safety function.
☐	Any changes (wiring, components, settings, etc.) related to the safety function.
☐	Any changes related to the CPU CONTROL BOARD ES927 of the drive.
☐	Any maintenance work related to the safety function.
☐	In case of any Test Result FAIL during the 'STO Acceptance Tests' procedure and related decommissioning of ES927 damaged board and replacement with a new one.
Acceptance test procedure steps and checklist	
☐	Ensure that the drive can be run and stopped freely during the acceptance tests.
☐	Stop the drive (if running), switch the input power off and isolate the drive from the power line by a disconnector.
☐	Check the STO circuit connections against the circuit diagram.
☐	Check that the core and the shield (if fitted) of the STO input cables are correctly connected (see the drive hardware manual).
☐	Close the disconnector and switch the input power on.
Test the operation of the STO function as specified by the DT01 test procedure: ***DT01 Periodic Proof-test (Diagnostic LEDs "System OK" L8 and L9)***	
☐	**DT01** Test Result PASS
☐	**DT01** Test Result FAIL: *Board ES927 is damaged → MANDATORY decommissioning of the damaged board and the replacement with a new one: restart of the safety function.*
Test the operation of the STO function as specified by the DT02 test procedure: ***DT02 Periodic Proof-test (Diagnostic LED "Enable" L2)***	
☐	**DT02** Test Result PASS
☐	**DT02** Test Result FAIL: *Board ES927 is damaged → MANDATORY decommissioning of the damaged board and the replacement with a new one: restart of the safety function.*
☐	In case of ES927 damaged board, the decommissioning of the board and the replacement with a new one is MANDATORY: restart the safety function. Any damaged ES927 board must be sent to the Customer Service of Enertronica Santerno S.p.A. for analysis and disposal. If any safety function failures are detected, including STO, please contact Enertronica Santerno S.p.A.
☐	Restart the drive and check that the motor runs smoothly.
☐	The STO function is safe and accepted to operate.
☐	Document and sign the Acceptance Tests Report which verifies that the safety function is safe and accepted to operation.
Date	Operator Name Signature

6. COMMISSIONING, MAINTENANCE AND DECOMMISSIONING, DISPOSAL, FAULT TRACING AND DIAGNOSTICS

6.1. Commissioning

The 'STO Acceptance Tests' described in section 5 VALIDATING THE OPERATION OF A SAFETY FUNCTION above are specific to initial start-up (commissioning) of the safety function.
Any acceptance tests performed due to commissioning shall be logged into the Instruction Manual of the equipment incorporating the inverter.

6.2. Maintenance

The 'STO Acceptance Tests' described in section 5 VALIDATING THE OPERATION OF A SAFETY FUNCTION are included into the routine maintenance program of the machinery that the drive runs.
Any acceptance tests performed due to maintenance shall be logged into the Instruction Manual of the machine incorporating the inverter.
The STO function or STO input terminals do not need any maintenance. Maintain the drive as per the instructions given in the drive hardware manual.

6.3. Decommissioning

If the ES927 board or wire sets are replaced inside the module, test the functionality of the new ES927 board as per the Check List for 'STO Acceptance Test'.
For any damaged ES927 board, it is MANDATORY to decommission the board and replace it with a new one: restarting the safety function as described in the 'STO Acceptance Tests'.
The Mean Time to Repair is assumed equivalent to 8 hours.
The damaged ES927 board needs to be sent to the Customer Service of Enertronica Santerno S.p.A. for analysis and disposal.
If you detect any failure in safety functions, including STO, contact Enertronica Santerno S.p.A.
Any acceptance tests performed due to decommissioning shall be logged into the Instruction's Manual of the machine incorporating the inverter.

6.4. Disposal

Damaged ES927 boards received by Enertronica Santerno S.p.A. are analyzed, registered and disposed of according to the Safety Case and regulations in force.

6.5. Alarm Messages Generated by the Drive

Fault	Cause	What to do
A140 “Torque Off not Safe”	Internal hardware logic or firmware failure	User could try to reset the alarm. In case of persistent alarm, board ES927 is damaged → board decommissioning and replacement with a new one is MANDATORY. After replacement, the validation of the STO function shall be repeated again.

7. COMPONENTS FOR STO APPLICATIONS

7.1. ES927 Board

Dimensions: 285 x 150 x 43 mm (H x W x D)

Weight: 0.360 kg

The environmental requirements for ES927 board are the same as for any other board mounted inside Sinus Penta, Iris Blue and Penta Marine inverter lines.
Please refer to the user manuals of the products above for detailed specifications.

7.1.1. Environmental Requirements for Equipment Installation, Storage and Transport

Any electronic board installed in the inverters manufactured by Enertronica Santerno S.p.A. is tropicalized. This enhances electrical insulation between the tracks having different voltage ratings and ensures longer life of the components. It is however recommended that the requirements below be met:

Maximum surrounding air temperature	–10°C to +55°C It might be necessary to apply 2% derating of the rated current for every degree beyond the stated temperatures depending on the inverter model and the application category.
Ambient temperatures for storage and transport	–25°C to + 70°C
Installation environment	Pollution degree 2 or better (according to IEC 61800-5-1). Do not install in direct sunlight and in places exposed to conductive dust, corrosive gases, vibrations, water sprinkling or dripping (except for IP54 models); do not install in salty environments.
Altitude	Max. altitude for installation 2000 m a.s.l. For installation above 2000 m and up to 4000 m, please contact Enertronica Santerno S.p.A.. Above 1000 m, derate the rated current by 1% every 100 m.
Operating ambient humidity	From 5% to 95%, from 1g/m^3 to 29g/m^3, non-condensing and non-freezing (class 3k3 according to EN 50178).
Storage ambient humidity	From 5% to 95%, from 1g/m^3 to 29g/m^3, non-condensing and non-freezing (class 1k3 according to EN 50178).
Ambient humidity during transport	Max. 95%, up to 60g/m^3; condensation may appear when the equipment is not running (class 2k3 according to EN 50178).
Storage and operating atmospheric pressure	From 86 to 106 kPa (classes 3k3 and 1k4 according to EN 50178).
Atmospheric pressure during transport	From 70 to 106 kPa (class 2k3 according to EN 50178).

CAUTION As environmental conditions strongly affect the inverter life, do not install the equipment in places that do not have the above-mentioned ambient conditions.

CAUTION Always transport the equipment within its original package.

7.2. Safety Relay Proposal for STO Application

General requirements	IEC 61508 and/or EN/ISO 13849-1
Type	Safety relay
Example	Manufacturer PILZ – Part Number PNOZ X3. 10P
Approvals	SILCL 3 according to EN 62061 and PL according to EN ISO 13849-1

7.3. Push-button Proposal to be used with Emergency Stop for STO Application

Type	A push-button operated switch with a palm or mushroom head type.
Example	Manufacturer New Elfin – Part Number 020PTFASRK+020GE02

7.4. Switch Proposal to be used with Prevention of Unexpected Start-up Function Implemented with STO for STO Application

Type	A lockable selector switch with a reliable and unambiguous indication of positions.
Example	Manufacturer Kraus & Naimer – Part Number DH11 A291-600, FT22-V+S0V845/A11/D11.

7.5. Cable Proposal for STO Application

Type	Low voltage, 2 x 2 x 0.75 mm^2 (AWG19) Shielded twisted pair cable
Maximum length	25 m between STO inputs (ENABLE-A and ENABLE-B) and the operating contact
Example	Manufacturer HELUKABEL – Part Number Li YCY TP 2×2×0.75 mm^2 Shielded twisted pair cable
	Manufacturer TE.CO. – Part Number 27265 O.R. PMXX (2x2x0.75) ST Shielded twisted pair cable

8. STO TECHNICAL DATA

8.1. STO Data Related to Safety Standards

Data related to safety standards IEC 61508, EN 61800-5-2, EN/ISO 13849-1 are listed below.
Data apply to all sizes of inverter of Sinus Penta, Iris Blue and Penta Marine line.

IEC 61508						EN/ISO 13849		
SIL	PFH_G	HFT	SFF	DC		Category	PL	CCF
3	2.383×10^{-9}	1	98.43 %	78.51 %		3	d	75

Maximum reaction time to ensure the safe state on demand:	**1.86 ms**
Maximum reaction time to ensure the safe state on fault detection:	**8.60 ms**

9. TERMS AND ABBREVIATIONS

According to EN 61508-6, Table B.1:

Abbreviation	Term (units)
T1	Proof-test interval (hour)
MTTR	Mean time to restoration (hour)
DC	Diagnostic coverage (expressed as a fraction in equation and as a percentage elsewhere)
β	Fraction of undetected failures that have a common cause (expressed as a fraction in equation and as a percentage elsewhere)
β_D	Fraction of detected failures that have a common cause (expressed as a fraction in equation and as a percentage elsewhere)
λ	Failure rate (per hour) of a channel in a subsystem
PFH_G	Probability of failure per hour for the group of voted channels
λ_D	Dangerous failure rate (per hour) of a channel in a subsystem, equal to 0.5 λ
λ_{DD}	Detected dangerous failure rate (per hour) of a channel in a subsystem (sum of all the detected dangerous failure rates within the channel of the subsystem)
λ_{DU}	Undetected dangerous failure rate (per hour) of a channel in a subsystem (sum of all the undetected dangerous failure rates within the channel of the subsystem)
λ_{SD}	Detected safe failure rate (per hour) of a channel in a subsystem (sum of all the detected safe failure rates within the channel of the subsystem)
λ_{SU}	Undetected safe failure rate (per hour) of a channel in a subsystem (sum of all the undetected safe failure rates within the channel of the subsystem)
t_{CE}	Channel equivalent mean down time (hour) for 1oo1, 1oo2, 2oo2 and 2oo3 architectures (combined down time for all the components in the channel of the subsystem)