copley controls

Xenus Plus Compact
STO Manual

P/N 16-01553 Rev 00

September 12, 2016

Table of Contents

1.0 About This Manual

1.1 Title, Number, Revision

Table 1

Title	***Xenus Plus Compact STO Manual***
Document Number	16-01553
Current Revision	00

1.2 Revision History

Table 2

Revision	Date	ECO #	Comments
00	9/12/2016	ECO-063895	Originated

1.3 EC Declaration of Conformity

The products covered by this manual comply with the EC Directives 2014/30/EU (EMC Directive), 2014/35/EU (Low Voltage Directive), 2006/42/EC (Machinery Directive) and 2011/65/EU (RoHS Directive). The complete EC Declaration of Conformity is available on the internet at www.copleycontrols.com.

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1.4 Original Instructions

This manual is considered to be “original instructions” as defined in EC Directive 2006/42/EC and the contents have been verified by Copley Controls.

1.5 Purpose and Scope of This Document

This document is intended to inform the reader about the Functional Safety features of the *Xenus Plus Compact* servo drive models and to provide information on the steps required to install it into systems so that a target level of Functional Safety performance can be achieved. The scope of this document is limited to those aspects of Functional Safety that relate to the installation, operation, and maintenance of the *Xenus Plus Compact*.

1.6 Product Naming

The STO function is the same in *XEC, XPC, 801-1891, 801-1892, and 801-1893* models.
References to *Xenus Plus Compact* in this document should be understood as references to all of these models.

1.7 Disclaimer

This manual contains information on the Safe Torque Off (STO) feature of the *Xenus Plus Compact* servo drive and how it may be incorporated into an industrial motion control system. While every effort has been made to ensure the completeness and accuracy of this manual it must be emphasized that the responsibility for functional safety in the overall system into which the drive is installed rests ultimately with the manufacturer of the system into which the *Xenus Plus Compact* is installed.

The equipment manufacturer which must take into account all the aspects of the system of which the *Xenus Plus Compact* is a component.

Copley Controls does not accept any liability for direct or indirect injury or damage caused by the use of information in this document. The equipment manufacturer is always responsible for the safety of its product and its suitability under applicable laws. Copley Controls hereby disclaims all liabilities that may result from this document.

1.8 Related Documentation

These documents have additional information on the *Xenus Plus Compact* and are required for proper installation and commissioning of the drives.

Available upon request from Copley Controls:

User Guide

Xenus Plus Compact User Guide (Document No. 16-01552)

Datasheet

Xenus Plus XEC Datasheet (Document No. 16-01435)

Xenus Plus XPC Datasheet (Document No. 16-01436)

Available on the Copley Controls web site:

http://www.copleycontrols.com/Motion/Downloads/index.html

Downloads > Documents > Xenus Plus > Manual:

Absolute & Serial Encoder Guide

CME 2 User Guide

Indexer 2 User Guide

ASCII Programmer's Guide

CMO Programmer's Guide

1.9 Reference Standards

ISO 13849-1: 2015
Safety of machinery Safety-related parts of control systems

Part 1: General Principles for Design

ISO 13849-2: 2012
Safety of machinery

Safety-related parts of control systems — Part 2: Validation

IEC 61508-1: Ed. 2.0 2010
Functional safety of electrical/electronic/programmable electronic safety-related systems

Part 1: General requirements

IEC 61508-2: 2010, 2nd Ed.
Functional safety of electrical/electronic/programmable electronic safety-related systems

Part 2: Requirements for electrical/electronic/programmable electronic safety related systems

IEC 61800-5-1: 2007, 2nd Ed.
Adjustable speed electrical power drive systems

Part 5-1: Safety requirements – Electrical, thermal and energy

IEC 61800-5-2:2007
Adjustable speed electrical power drive systems

Part 5-2: Safety requirements – Functional

1.10 Abbreviations and Acronyms

Acronym	Description
Safety-Related	
a,b,c,d,e	Denotation of performance level (PL)
Cat.	Category
CCF	Common Cause Failure
DC_{avg}	Diagnostic Coverage, Average
FS	Functional Safety
HFT	Hardware Fault Tolerance
MTTF	Mean Time to Failure
MTTFd	Mean Time to Dangerous Failure
OVC	Over-Voltage Category
PDS(SR)	Power Drive Systems (Safety Related)
PELV	Protected Extra Low Voltage (power supply)
PFD	Probability of Dangerous Failure upon Demand
PFH	Probability of Failure per Hour
PL	Performance Level
PLr	Performance Level requirement
S, S1, S2	Severity of Injury
SELV	Safety Extra Low Voltage (power supply)
SFF	Safety Failure Fraction
SIL	Safety Integrity Level
SIL CL	Safety Integrity Level Limit or Capability Level
SPD	Surge Protection Device
STO	Safe Torque Off
Copley Controls Related	
XEC	*Xenus Plus XEC* EtherCAT
XPC	*Xenus Plus XPC* CANopen

Table 3

2.0 Risk Assessment & Responsibility of the Installer

The STO feature of the *Xenus Plus Compact* is capable of the safety integrity level and category/performance level stated in this manual and operates in accordance with the characteristics and limitations described herein. But it must be noted that the drive STO function is intended to be used only as one element of an overall safety chain and is not a complete safety function unto itself. Therefore the suitability for use of the *Xenus Plus Compact* in a given application must be determined in part by one or more risk assessments of the overall safety of the end machine conducted in accordance with the applicable standards. Such risk assessments normally consist of a thorough review of overall machine operation to identify potential hazards. For each identified hazard, typical risk assessments take into account the severity of any potential injury resulting from the hazard, the frequency of exposure of persons to the hazard and the probability that persons are able to avoid the hazard if it were to occur. The machine designer is solely responsible for conducting any necessary risk assessments and for the ultimate determination as to the suitability of the *Xenus Plus Compact* and its STO function for use in realizing a given overall safety function. The installer should be experienced in motion control and functional safety.

3.0 Warnings

FAILURE TO CONSIDER THESE WARNINGS CAN RESULT IN EQUIPMENT DAMAGE, INJURY, OR DEATH

The user must take into consideration the necessary risk reductions, installation requirements, and other information contained in this manual in order to achieve the stated functional safety capabilities. Failure to do so could result in equipment damage, injury, or death.

3.1 Operate drives within the specifications provided in the relevant hardware manual or data sheet.

The information in this manual is specific to the functional safety features of the *Xenus Plus Compact* servo drives. The user must use this manual along with the *Xenus Plus Compact User Guide* and the datasheets for the *Xenus Plus Compact* models for proper and safe installation and overall commissioning of the drives.

3.2 Risk of electric shock

The *Xenus Plus Compact* servo drives are made for operation from 100~240 Vac mains power.
Therefore hazardous voltages are connected to and exist within these drives under normal operating conditions. Persons responsible for installing and commissioning these drives must be experienced in all aspects of electrical equipment installations.

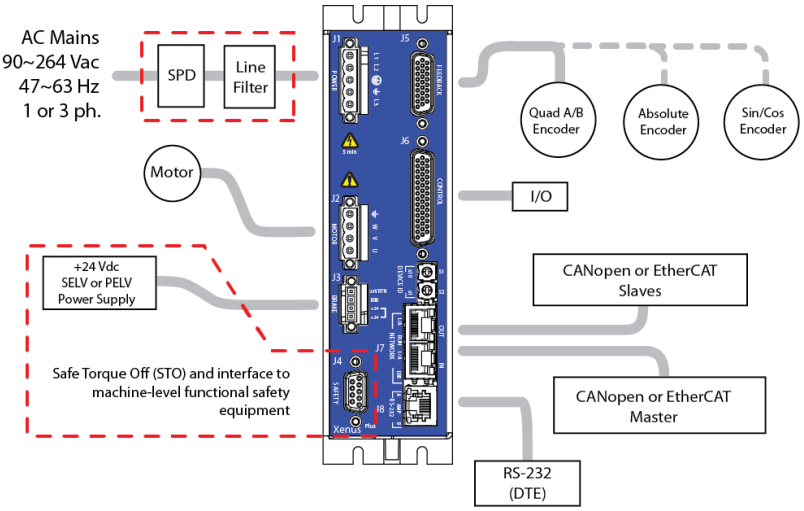
3.3 Disclaimer

There are no user serviceable parts in the *Xenus Plus Compact* servo drives.
Removal of the cover or tampering with internal components will void the warranty.

3.4 Installation Overview

This graphic shows all of the elements in a complete *Xenus Plus Compact* installation. The STO feature and interface to the machine-level functional safety equipment are highlighted in red to emphasize the aspects of the installation that are addressed in this manual.

Fig. 1



A UL RC (Recognized Component) SPD (Surge Protective Device) type 1CA, 2CA, 3CA or a UL Listed (VZCA) SPD type 1, 2, or 3 rated 2500 V, with a minimum SCCR of 5 kA, 240 Vac, and surge voltage monitoring needs to be provided. The purpose of the SPD is to establish an OVC II environment. Example parts are Cooper Bussman BSPM3240DLG (3 phase) or BSPM2240S3G (two-pole). Alternatively, an isolation transformer may be used between AC mains and the drive to establish an OVC II environment.

3.5 Definitions

There are certain terms used throughout this document that serve an important role in describing the operation and behavior of the *Xenus Plus Compact* STO feature. These terms are discussed and defined as follows:

Activate – This term is used to refer to action taken that results in the safe state being entered. In the case of the STO feature, the STO function is ***activated*** (made ***active***) by making the voltage at one or both STO inputs less than or equal to the maximum rated ***de-energize*** threshold voltage.

De-Activate – This term is used to refer to action taken that results in the safe state being exited. In the case of the STO feature, the STO function is ***de-activated*** (made ***inactive***) by making the voltage at both STO inputs greater than or equal to the minimum rated ***energize*** threshold voltage.

Energize – This term refers to the application of voltage greater than or equal to the minimum rated ***energize*** threshold voltage to an individual STO input. Note that simultaneously ***energizing*** both STO inputs results in the STO function being ***de-activated***.

De-Energize – This term refers to the application of voltage less than or equal to the maximum rated de-energize threshold voltage to an individual STO input. Note that de-energizing an STO input results in the STO function being activated.

4.0 Introduction to the *Xenus Plus Compact*

4.1 Product Description

The *Xenus Plus Compact* models are intended to be operated from single or three phase power in the 100 Vac to 240 Vac range and can drive motor currents up to 15 Adc. These drives have a Safe Torque Off (STO) function. When the STO function is activated, the ability to drive motor current is cut-off. In the case of rotary motors, the torque produced by the motor is zero when the current is cut-off. In the case of linear motors, the force produced by the motor is zero when the current is cut-off. The Safe Torque Off (STO) function has been developed in accordance with IEC 61508, ISO 13849-1 and IEC 61800-5-2. The *Xenus Plus Compact* is certified by UL as meeting the stated SIL Capability, Category and Performance Levels and other requirements of the given standards. The Safe Torque Off (STO) function is realized in "hardware only" such that no software, firmware, or programmable device is involved in the execution or reliability of the STO function.

4.2 Model Overview & Numbering

The *Xenus Plus Compact* models have the same electrical specifications and differ primarily in the communications or the type of motor position feedback they support. *XEC and 801-1891~1893* models work with EtherCAT, and *XPC* models work with CANopen. Models with the '-R" suffix and the *801-1891~1893* models support resolver feedback whereas those without the "-R" suffix support encoder feedback.
All models have the same Safe Torque Off (STO) feature.
Note that as a convenience to customers Copley offers a certain level of customization to tailor *Xenus Plus Compact* drives for a given application. This level of customization is most often limited to factory configuration of user programmable parameters, but can include signal level hardware differences to accommodate less common motor feedback devices. Drives with this customization carry the "*Xenus Plus XEC" and "Xenus Plus XPC*" marking, but are assigned customer specific model numbers that begin with "800-" followed by four or five alphanumeric characters. These "800" number models have the same STO feature as the standard *Xenus Plus Compact* models and are included within the scope of this manual.

The *Xenus Plus Compact* models are:

Table 4

EtherCAT	CANopen	Feedback
XEC-230-09	*XPC-230-09*	Encoder
XEC-230-12	*XPC-230-12*	
XEC-230-15	*XPC-230-15*	
XEC-230-09-R 801-1891	*XPC-230-09-R*	Resolver
XEC-230-12-R 801-1892	*XPC-230-12-R*	
XEC-230-15-R 801-1893	*XPC-230-15-R*	

5.0 Specifications Overview

5.1 Control Modes

Cyclic Synchronous Position-Velocity-Torque (CSP, CSV, CST in EtherCAT drives only)

Cyclic Synchronous Torque Mode with Commutation Angle (CSTCA in EtherCAT drives only)

Profile Position-Velocity-Torque, Interpolated Position, Homing (CANopen & EtherCAT drives)

Camming, Gearing

Indexer (Internal program execution)

5.2 Command Sources

XEC, *801-1891~1893*: CANopen application protocol over EtherCAT (CoE)

XPC: CANopen

ASCII and discrete I/O

Stepper commands

±10V position/velocity/torque

PWM velocity/torque command

Master encoder (Gearing/Camming)

5.3 Power Sources

Mains voltage:	100~240 Vac, ±10%, 1 Ø or 3 Ø, 47~63 Hz
Over-Voltage Category:	OVC III (An SPD or isolation transformer is required to limit overvoltages to OVC II levels)
Maximum Mains Current:	Model dependent – see the *Xenus Plus Compact User Guide*
Control Power	+24 Vdc typical, +20 to +32 Vdc

The 24V is required for operation and powers the control core and communications in the drive. Mains power may be removed and the drive can continue to communicate and report status via the communication link as long as the 24 Vdc power is maintained.

6.0 STO Architecture and Function

The *Xenus Plus Compact* STO function is suitable for use in safety loops up to SIL 3 and/or Cat. 3 PL d performance. The circuit concept uses a quasi three-channel architecture so that the safety function will continue to operate even in the event of two failures. This architecture is shown in the system block diagram below.

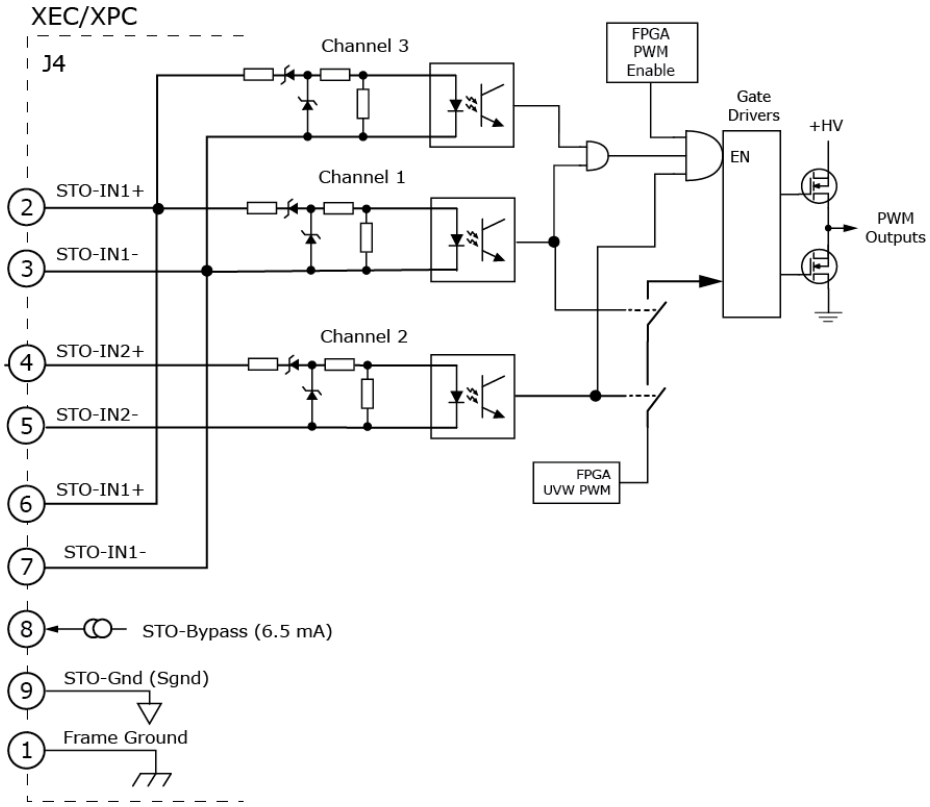


Fig. 2

In the Safe State, the drive will not produce torque or force in the motor. The STO function achieves and maintains a safe state by disabling the ability of the attached motor to produce torque/force. This both halts any drive induced acceleration already in process and prevents initiation of motion. The expectation is that an inability of the motor to produce torque/force translates into a reduction of risk of hazardous motion for the larger system.

The STO circuit concept involves disabling the ability of the motor drive output stages to produce current. The PWM outputs consists of three UVW totem-pole outputs, each composed of upper and lower IGBT devices. The UVW PWM signals go to gate-drivers that control the upper and lower devices, producing current in the motor windings which in turn can produce motion. STO channels 1 & 2 can cut-off the UVW PWM signals to the gate drivers as a group.

STO Channel 3 is ANDed with Channel 2 to disable the drive by disabling both the high and low side MOSFET gate drives. Any of the three channels by itself is therefore sufficient to prevent the initiation of motion or halt drive induced acceleration when the STO function is activated.

Each STO channel receives an input in the form of a voltage (typically +24 Vdc to energize and 0V or open to deenergize) applied to STO_IN1 (+,-) and STO_IN2 (+,-). Note in figure 2 that STO_IN1 (+,-) drives two parallel connected opto-coupler stages (Channel 1 and Channel 3). STO_IN2 (+.-) drives the opto-coupler stage for Channel 2 only. Both STO inputs must be simultaneously energized in order for torque/force to be produced. To achieve the rated SIL and PL capability, both STO inputs must be held simultaneously de-energized by the larger system when the STO function is activated. In a typical machine application, each STO input is driven by a +24 Vdc supply voltage switched through a safety relay. Note that the STO inputs are designed to withstand input voltages to +60 Vdc to provide a measure of overvoltage protection. By definition, the output of an SELV rated power supply is a maximum of +60 Vdc in a fault condition. Therefore a constraint on the larger system is that the power supply used to energize the STO inputs must be an SELV type.

6.1 STO Channel Operation

STO Function Active = No force/torque production is possible in motor

STO Function Inactive = Force/torque production in motor is under control of the drive

Table 5

STO	STO	STO Function State
0	0	STO function is active , both inputs de-energized
1	0	STO function is active, one input de-energized
0	1	
1	1	STO function is inactive, both inputs energized

The table above shows the operation of the STO channels.

0 = Voltage applied to the STO input is less than or equal to the rated maximum de-energize level.

1 = Voltage applied to the STO input is greater than or equal to the rated minimum energize level.

A motion control system design for Cat. 3 PL d, and/or SIL 3 rating must use 2 channels for the STO function.

6.2 STO Function Specifications

Table 6

Specification	Requirement
Operation	When STO is active, motor current that can cause rotation (or motion in the case of a linear motor) is not applied. The PWM outputs are disabled and cannot source or sink current. This STO function is defined in IEC-61800-5-2, clause 4.2.2.2
Standards Conformance	IEC-61508-1, IEC-61508-2, IEC-61800-5-2, ISO 13489-1
Safety Integrity Level	SIL 3
Category & Performance Level	Category 3, Performance Level PL d
Implementation	Hardware only – Type A components
Systematic Capability	SC 3
Certifications	UL Functional Safety Mark (Pending)
Signals (Functional Safety Related)	STO-IN1(+), STO-IN1(-), STO-IN2(+), STO-IN2(-), Frame ground (shield)
Signals (for muting)	STO-Bypass, STO-Gnd
STO Input Energize Voltage Level	Vin-HI ≥ +15.0 Vdc between STO-IN(+) and STO-IN(-)
STO Input De-energize Voltage Level	Vin-LO ≤ +6.0 Vdc or open between STO-IN(+) and STO-IN(-)
Input current (typical)	STO-IN1: 11.2 mA, STO-IN2: 11.2 mA Current flow is into STO-IN1(+) and STO-IN2(+) and out of STO-IN1(-) and STO-IN2(-). STO inputs must not be connected in series.
Response Time	From Vin ≤ 6.0 Vdc or open to STO Activated : 2 ms
Type	Opto-isolators, 24V compatible
Maximum cable length	30 m (98.4 ft)

6.3 Environmental Specifications

Table 7

Specification	Requirement
Operating Temperature	0 °C to 45 °C per IEC 60068-2-1:2007 and IEC 60068-2:2007
Operating Humidity	0 to 95 %RH, non-condensing per IEC 60068-2-78:2001
Storage Temperature	-40 °C to 85 °C per IEC 60068-2-1:2007 and IEC 60068-2-2:2007
Altitude	≤ 2000 m per IEC 60068-2-13:1983 or ≤ 4000 m if an isolation transformer is used to establish an OVC II environment.
Contaminants	Pollution Degree 2 per IEC 60664-1:2007
Mechanical Shock	10*g*, 10 ms, 1/2 Sine Pulse per IEC 60068-2-27:2008
Vibration	2g, peak, 10~500 Hz (Sine) per IEC 60068-2-6:2007

6.4 Safety Related Parameters

Table 8

IEC 61508: 2010			
SIL	3	HFT	2
PFH	6.5×10^{-9}	SFF	< 60%
PFD	5.7×10^{-4}	PTI	20 yrs

ISO 13849-1: 2015			
PL	d	Category	3
CCF	80	$MTTF_D$	100 yrs
DC_{avg}	61%		

6.5 Regulatory Specifications

Table 9

Specification	Requirement
Approvals	UL recognized component to UL 61800-5-1 UL Functional Safety to IEC 61508 and ISO 13849-1
Functional Safety	IEC 61508-1:2010, IEC 61508-2:2010, ISO 13849-1:2015, ISO 13849-2:2003, IEC 61800-5-2:2007
Electrical Safety	Directive 2014/35/EU – Low Voltage, IEC/UL/CSA 61800-5-1:2007
EMC	Directive 2014/30/EU - EMC Emissions: IEC 61800-3:2004 + A1: 2011, Category C3 Immunity: IEC 61800-3:2004 + A1:2011, Category C3 Functional Safety Immunity: IEC 61800-3:2004 + A1:2011 IFA “EMC and Functional Safety of PDS”, (Feb 2012)
Markings	• UL recognized component (Canada and US) <pending> • CE • UL Functional Safety <pending>
Hazardous Substances	Lead free and RoHS compliant

6.6 Limitations and Necessary Risk Reductions

6.6.1 Electrical Isolation

The STO function does not provide electrical isolation between the drive and the motor.
Hazardous voltages may be present on the motor output terminal J2, even with the STO function activated.

6.6.2 DC Brush Motors

Failure of an IGBT in the outputs of the drive that renders the IGBT a virtual short-circuit might result in continuous torque/force production in a DC motor. Unlike brushless motors that limit rotation to one half of an electrical cycle, a DC brush motor can rotate uncontrollably under a failed IGBT scenario. As result, the STO function cannot be used with DC brush motors.

6.6.3 180 Degree Electrical Movement

In the event of IGBT failures in the *Xenus Plus Compact* output stage, unexpected motor movement of up to 180 electrical degrees can occur. It is the responsibility of the designer of the larger system to assess and address any hazards that this unexpected movement could create.

6.6.4 Loads and Other Torque/Force Producing Sources

The STO function produces an uncontrolled stop of category 0 as described in IEC 60204-1.
Any motor that is moving when the STO function is activated will coast to a stop unless there are other forces operating on the same load. The STO function only removes torque/force produced by current flow from the drive to the associated motor. Torque/force created by gravity-influenced loads or other torque/force producing components mechanically connected to the motor shaft cannot and will not be affected by the drive STO function. It is the responsibility of the designer of the larger system to assess and address any hazards arising from torque/force producing sources.

6.6.5 STO Input Signal Level

The STO inputs (STO-IN1, STO-IN2) can withstand input voltages to 60V in case of an overvoltage fault condition. Therefore a constraint on the larger system is that the power supply used to drive the STO inputs must be a SELV or PELV type.

6.6.6 Control Modes and STO

The *Xenus Plus Compact* drive can control the position, velocity, and torque of motors while operating from a number of control sources. But it can only do this when the STO function is inactive. And, while the digital control core and firmware of the drive can observe the state of the STO function, it cannot interact with, or exercise any control over the STO function.

The STO function operates completely independently of the control core of the drive and is implemented entirely in hardware. It does not depend on the control core for its operation and the control core of the drive has no control over the STO function.

6.6.7 24V DC Power Supply

A constraint on the larger system is that the power supply used to provide the 24V control power to the drive must be a SELV or PELV type.

6.6.8 AC Mains Over-Voltage Category

The AC mains supplying the drive must be limited to over-voltages of Category II. The relevant standards assume AC mains with over-voltages per OVC III. An SPD or isolation transformer is required to limit over-voltages to OVC II levels.

6.6.9 Wiring to the STO Inputs

Electrical connections to the STO inputs must meet the requirements for fault exclusions for short circuits between conductors and short circuits between conductors and other conductive parts or earth or the protective bonding conductor. Fault exclusion requirements are given in ISO 13849-2 and IEC 61800-5-2.

Toward this end, the STO cable connector is a crimp and poke type in order to meet the relevant fault exclusions. The contacts and connector provide spacing that is greater than the minimum creepage and clearance of 1.24 mm that is required for fault exclusion when considering the FMEDA (Failure Modes, Effects, and Diagnostic Analysis) of the system.

6.6.10 Periodic Test Requirements

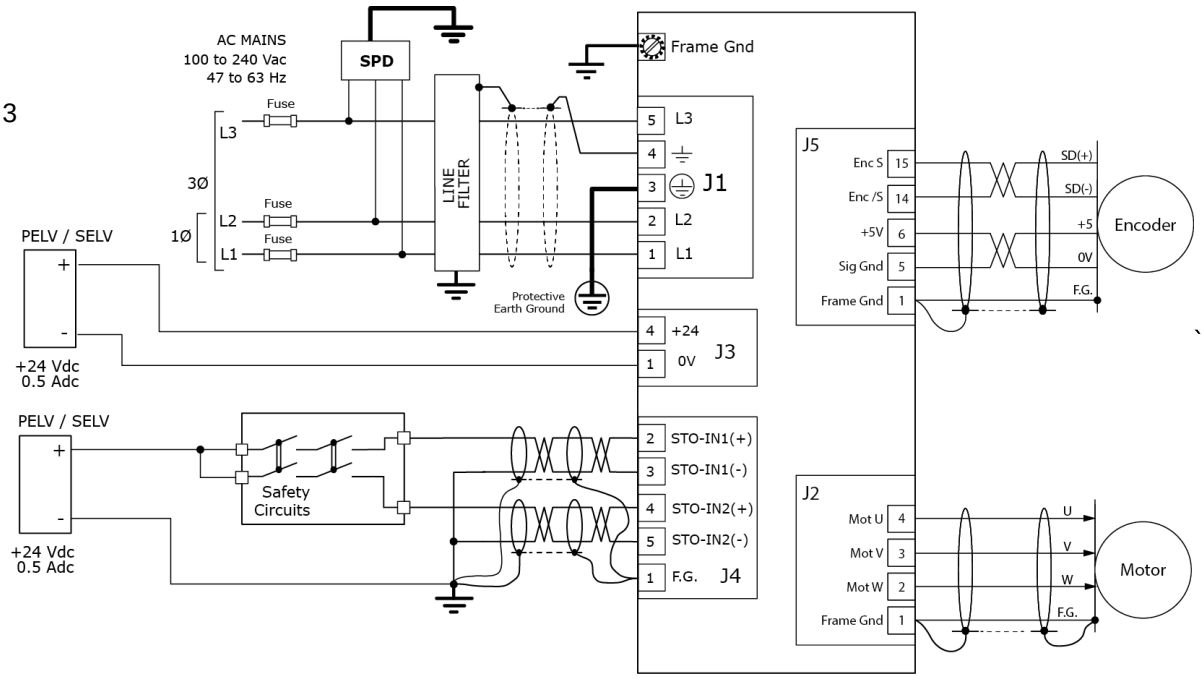
In order to meet the diagnostic coverage requirements for Cat. 3 PL d, the STO function must be checked at least once per year. See section 9 for specific details.

7.0 Installation Using STO for *Xenus Plus Compact*

7.1 STO Wiring Overview

This diagram gives detail on the physical cabling, shielding, and grounding of the wiring between the drive STO inputs and the machine level safety circuits.

Fig. 3



7.1.1 STO Power Requirements

The 24V power supply for the STO inputs must be SELV or PELV rated.

The 24V power supply for the drive control power must be SELV or PELV rated.

7.1.2 STO Wiring Requirements

Electrical connections to the STO inputs must meet the requirements for fault exclusions for short circuits between conductors and short circuits between conductors and other conductive parts or earth or the protective bonding conductor.

These requirements are given in ISO 13849-2 and IEC 61800-5-2.

Toward this end, the DB-9 mating connector for making connections to the STO inputs must be a crimp and poke type in order to meet the relevant fault exclusions.

A solder-cup style must not be used.

7.1.3 STO (Safety) Cable Connector

The *Xenus Plus Compact* STO connector J4 is a Kycon K22X-E9S-N. It is a Dsub-9F receptacle with gold-flash plating on the pins and #4-40 standoffs which can receive male jack-screws on the cable connector.
The mating cable connector must have crimp and poke contacts with gold flash or plating and jack-screws. Solder-cup contacts do not have the minimum 1.24 mm spacing to meet the functional safety requirements and must not be used.

This is an example of a cable connector that is suitable for the *Xenus Plus Compact* STO:

Housing: AMP Tyco PN 205204-4, D-Sub-9M, tin plated, crimp contacts
Contacts: AMP Tyco PN 66506-9, stamped, male, 10 micron gold, AWG 20-24
Backshell: 3M PN 3357-9209, metalized plastic with thumbscrews

Other types may be suitable as long as they have crimp and poke contacts with gold flash or plating, jack-screws for retention, and spacings adequate for fault exclusion.

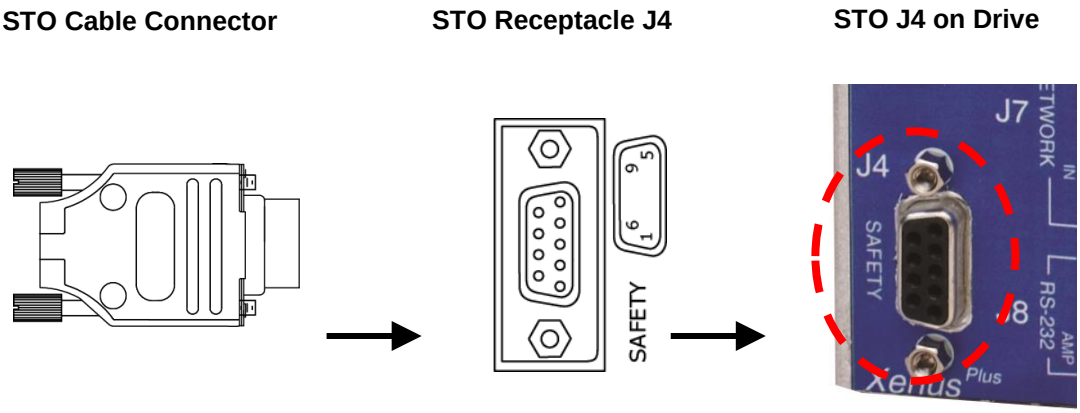


Fig. 4

7.1.4 Wiring Example:SIL 3/Cat. 3 PL d Emergency Stop - Stopping Category 1

Figure 5 below shows a wiring example for implementing a SIL3, Cat. 3 PL d, category 1 emergency stop function using a *Xenus Plus Compact*. This type of implementation brings the motor speed to near zero before the STO function is activated. It is important to note that the safe state is not entered immediately upon actuation of the E-stop button. The safe state is entered only after the STO inputs have become de-energized and the specified STO response time has elapsed.

The example shows a safety relay with two sets of output contacts – one set (K1, K2) responds immediately to changes on the safety relay inputs and the other (K3, K4) after a user switch-programmable delay. A double pole, single throw E-stop switch is used to drive two independent inputs to the safety relay. A momentary switch is wired to the safety relay reset input and is used to reset the relay at start-up and after an E-stop event. The enable input on the drive is wired to one of the immediate (INST) response contacts. The drive is programmed such that when this input is de-energized, the drive decelerates the motor speed in a controlled fashion. After the programmed delay time, contacts K3 and K4 open and de-energize the STO inputs to the drive. The drive STO function responds accordingly and the safe state is entered within the specified drive STO response time.

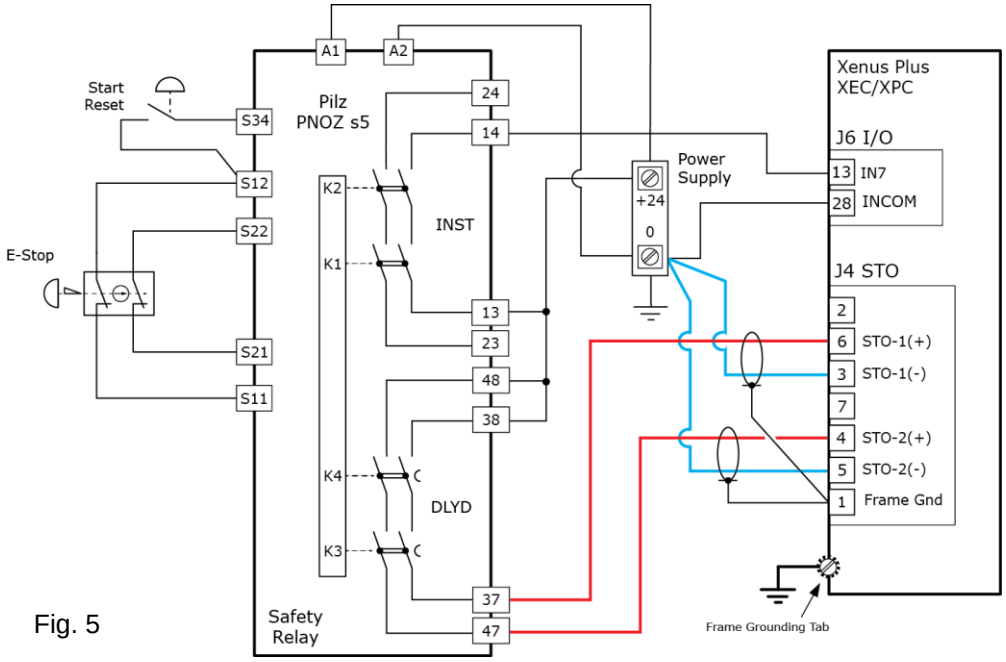


Fig. 5

7.1.5 *Xenus Plus Compact* Configuration

IN7 is an opto-isolated input that is programmed to Enable the drive. The INCOM signal for IN7 connects to ground. When 24V is applied to IN7 it will enable the *Xenus Plus Compact* if no other inputs are configured as Enables and no Enable inputs are inactive. If more than one input is configured as Enable, then all must be active in order to enable the drive. The PNOZ s5 relay uses both contacts of the delayed relay (DLYD) for two-channel control of the STO function, which is necessary for SIL 3, Cat. 3 PL d.

7.1.6 Example STO Timing

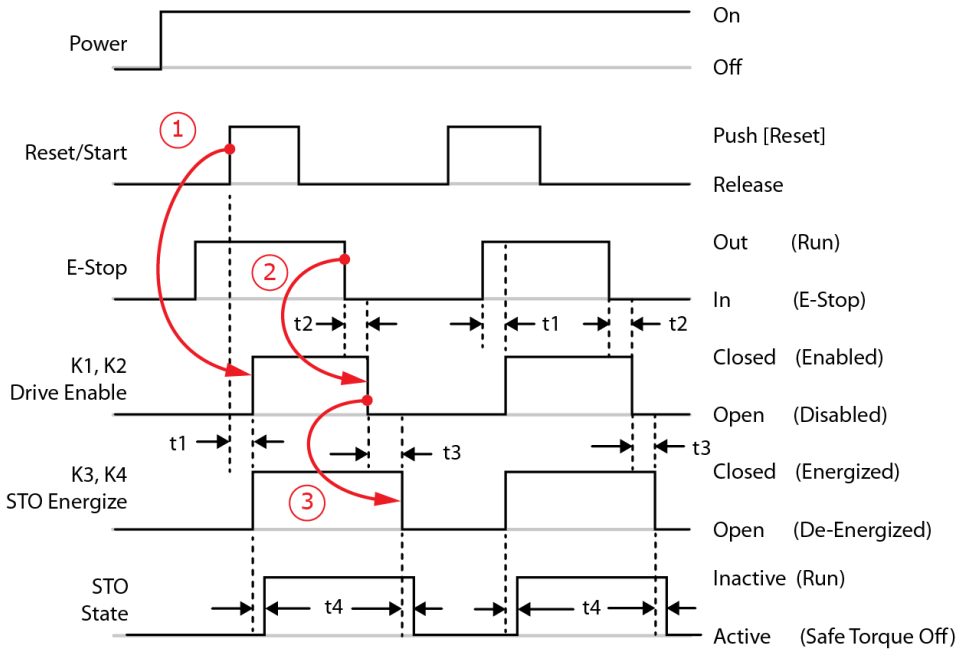


Fig. 6

Power	+24 VDC supplied to the safety relay
Reset/Start	Momentary push-button that causes the K1~K2 relay contacts to close, supplying power to the STO inputs of the drive, and de-activating the STO function. This allows the drive to produce torque/force in the motor when it is enabled.
E-Stop	The latching push-button switch inputs to the safety relay. The HI level of this indicates that the button has been released, opening the NC (Normally Closed) contacts.
K1, K2	The instantaneous contacts in the relay. A HI level indicates that the contacts are closed, supplying power to an Enable input of the drive to place it in an enabled state.
K3, K4	Relay contacts that will open after a pre-set time delay. This allows time for the drive to remain in an enabled state while it performs a controlled deceleration that brings the motor to a standstill before the STO function is activated, preventing any torque/force production in the motor.
t1	Switch-on delay. If the E-Stop button is out, this is the delay after the Reset/Start button is pressed in and the K1~K4 relay contacts close, deactivating the STO function and enabling the drive (1).
t2	Delay-on de-energization. When the E-Stop button is pressed in (E-Stop), this is the delay to the opening of the K1~K2 contacts which disables the drive, initiating a controlled deceleration of the motor (2).
t3	Waiting period. This is the time-delay that allows for the controlled deceleration of the motor. When the E-Stop button is pressed in, this is the time delay to the K3~K4 contact opening which will activate the STO (3).
t4	STO response time. This is the time between the de-energizing of the drive STO inputs (K3~K4 contacts open) and the entry into the safe-state.

7.2 Start-Up Checklist

Proper operation of a safety function must be validated at various points in the product lifetime of the end-use machine.

Validation tests, in accordance with the checklist given as table 10 must be conducted by an authorized person experienced in the functional safety of machines. Validation tests must be conducted:

- At initial installation and start-up of the safety function.
- After any changes related to the safety function (wiring, components, settings, etc.)
- After any maintenance work related to the safety function.
- At the required periodic test intervals.

7.2.1 Preliminary checks

Before powering the drive, and commencing with the functional safety tests, check:

- That the installation requirements given in the *Xenus Plus Compact User Guide* and this manual have been adhered to. Specifically ensure that proper grounding, shielding, overcurrent, and overvoltage protection measures are in place in regards to electrical safety and electromagnetic compatibility.
- That the wiring between the machine level safety circuits and the drive STO inputs meets the requirements set forth in this manual and those in IEC 61800-5-2 and ISO 13849-1 for wiring-associated fault exclusions.
- That the motor and associated loads are free to move.
- That any other safety measures or warnings needed to ensure safe execution of validation tests are in place.

7.2.2 Start-Up Checklist

Chk	Requirement	Comments	Initials
☐	Ensure that the drive can be run and stopped freely during the commissioning.		
☐	Stop the drive (if running), and safely remove AC power from the drive.		
☐	Check the STO-IN1 and STO-IN2 circuits and connections against a wiring diagram.		
☐	Apply AC mains power to the drive. Energize both the STO-IN1 and STO-IN2 circuits.		
☐	Test the operation of the STO-IN1 function when the motor is stopped. Give a stop command for the drive (if running) and wait for the motor to come to a standstill. While keeping STO-IN2 energized, de-energize the STO-IN1 circuit and give a start command for the drive. Ensure that the motor remains at a standstill. Energize the STO-IN1 circuit.		
☐	Test the operation of the STO-IN2 function when the motor is stopped. Give a stop command for the drive (if running) and wait for the motor to come to a standstill. While keeping STO-IN1 energized, de-energize the STO-IN2 circuit and give a start command for the drive. Ensure that the motor remains at a standstill. Energize the STO-IN2 circuit.		
☐	Restart the drive and check that the motor runs normally		
☐	Test the operation of the STO-IN1 function when the motor is running: Start the drive and ensure that the motor is running. While keeping STO-IN2 energized, de-energize the STO-IN1 circuit. Ensure that the motor stops. Reset any latching fault that may have occurred (these depend on the drive's control mode settings). Try to start the drive. Ensure that the motor stays at a standstill. Energize the STO-IN1 circuit		
☐	Test the operation of the STO-IN2 function when the motor is running: Start the drive and ensure that the motor is running. While keeping STO-IN1 energized, de-energize the STO-IN2 circuit. Ensure that the motor stops. Reset any latching fault that may have occurred (these depend on the drive's control mode settings). Try to start the drive. Ensure that the motor stays at a standstill. Energize the STO-IN2 circuit		
☐	Restart the drive and ensure that the drive and motor operate normally.		

Table 10

7.3 STO Status Indications

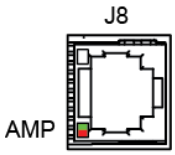
Although they are not and must not be considered part of the safety function, indications of the STO status are available from the Xenus Plus Compact drive for convenience purposes. Specifically the J8 LED, two user-accessible data objects bits, and the CME2 Control Panel provide some information on STO status. The LEDs, data objects, and CME2 are not part of the drive safety function.

7.3.1 J8 AMP LED

A bi-color LED gives the state of the drive. Colors do not alternate, and can be solid ON or blinking. When multiple conditions occur, only the top-most condition will be displayed.

When that condition is cleared the next one below will shown.

Fig. 7



Red/Blinking	=	Latching fault. Operation will not resume until drive is Reset
Red/Solid	=	Transient fault condition. Drive will resume operation when the condition causing the fault is removed.
Green/Double-Blinking	**=**	***STO circuit active, drive outputs are Safe-Torque-Off***
Green/Slow-Blinking	=	Drive OK but NOT-enabled. Will run when enabled.
Green/Fast-Blinking	=	Positive or Negative limit switch active. Drive will only move in direction not inhibited by limit switch.
Green/Solid	=	Drive OK and enabled. Will run in response to reference inputs or communication commands.

7.3.2 STO Circuit Status Data Objects

The *Xenus Plus Compact* has a variety of data objects that can be read by the end user via CANopen, EtherCAT, or serial communications. The status of the STO circuit is available in ASCII parameter 0x139 and DS-402 parameter 0x219D. Bits 0 & 1 show the status of the STO-IN1 and STO-IN2 inputs.

Bit 8 has no function in the *Xenus Plus Compact*.

Table 11

Bit	Safety Circuit Status
0	True (1) when STO-IN1 is de-energized and STO is active
1	True (1) when STO-IN2 is de-energized and STO is active

7.3.3 CME2 Control Panel

CME2 is the PC based software tool used for configuring, commissioning, and troubleshooting Copley Control digital servo drives. A graphic LED labeled “Safety” on the CME2 Control Panel screen gives the status of the STO function.

Green = STO inactive. Torque production in the motor is under user control.

Red = STO active. Drive outputs are Safe-Torque-Off

In the screen capture below the Safety (STO) LED is red, indicating that the STO function is active. The message in the box to the right “Active: STO-1, STO-2 off” refers to the STO channels, both of which are un-powered, activating the STO function.

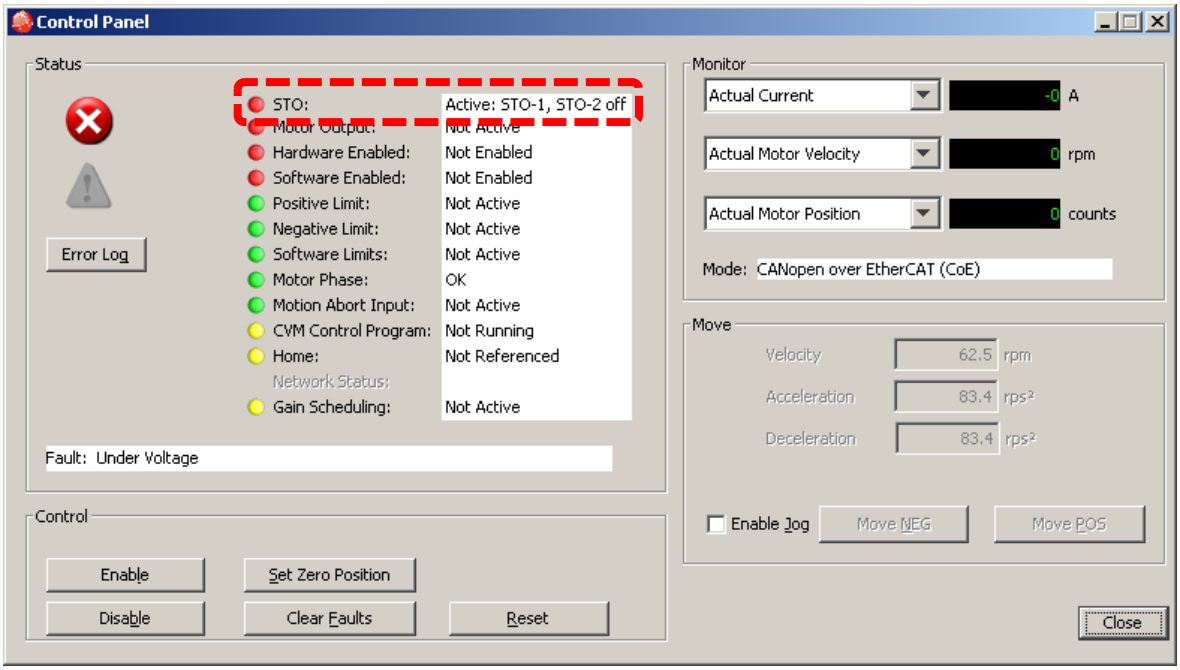


Fig. 8

7.4 Troubleshooting

The status of the STO function in the *Xenus Plus Compact* drive can be viewed via LED indicators on the drive, data objects accessible over CANopen, EtherCAT, and the configuration software CME2.

Other Copley software products such as CMO (Copley Motion Objects), CML (Copley Motion Libraries), CPL (Copley Programming Language) and ASCII communications can read the status of the STO function.

The LED indicators and data parameters are not part of the drive safety function. They are informational only, and cannot be relied upon for any safety related functions of the user.

7.4.1 How to tell if the STO function is active

- The voltage to one or both of the STO channels in the drive is < 6 Vdc, or open.
- The Amp LED on J8 double-flashes green, then pauses.
  This pattern repeats when the STO function is active.
- Bit 0 OR bit 1 of ASCII parameter 0x139 (DS-402 0x219D) is set (1).
- The Safety LED on the CME2 Control Panel is red when the STO function is active.
- For both EtherCAT and CANopen models, Bit 2 of the CANopen Status Word 0x6041 is zero, indicating a hardware-disabled state. This bit is controlled by any input that is programmed for the Enable function, and by the STO function. When bit is zero, then it is necessary to check 0x219D (ASCII 0x139) to see if bit 0 or bit 1 is set (1). If this condition is true, then the STO function is active.

7.4.2 How to tell if the STO function is inactive

- The voltage applied to both STO inputs of the drive is ≥ 15 Vdc.
- The Amp LED on J8 is solid green or slow-blinking green.
- Bit 0 AND bit 1 of ASCII parameter 0x139 (DS-402 0x219D) are zero.
- The Safety LED on the CME2 Control Panel is green when the STO function is inactive.
- For the EtherCAT and CANopen models, Bit 2 of the CANopen Status Word is set(1), indicating a hardware-enabled state. The drive cannot be hardware-enabled until all inputs programmed as Enable inputs are true AND the bits 0 AND bit t in the STO function status parameter (0x219D) are zero.

7.4.3 Why can’t the STO function be deactivated?

- The voltage between STO-IN1(+) and STO-IN1(-) is < 15 Vdc OR the voltage between STO-IN2(+) and STO-IN2(-) is < 15 Vdc. Both of these voltages must be ≥ 15 Vdc to deactivate the STO function

7.4.4 Why can’t the STO function be activated?

- The voltage between STO-IN1(+) and STO-IN1(-) is > 6 Vdc AND the voltage between STO-IN2(+) and STO-IN2(-) is > 6 Vdc. One or both of these voltages must be < 6.0 Vdc or the to activate the STO function

7.4.5 The drive is hardware-enabled but the motors don’t move.

- The STO function may be active. Check the Amp LED to see if it is double-flashing green.
  If so, then the STO function is active. If not, check the Amp LED blink patterns for indications of other faults or conditions that may inhibit motion.

8.0 Maintenance

8.1 Accessibility and Replacement of Internal Parts

There are no user-replaceable parts in the *Xenus Plus Compact*. The warranty will be void if the user removes the cover or attempts any repairs. For safety and to assure compliance with documented system data, only Copley Controls shall perform repairs to the *Xenus Plus Compact*.

8.2 Periodic STO Testing Interval

In order to meet the diagnostic coverage requirements corresponding to Cat. 3 PL d, the STO function must be tested at least once per year. The required test methodology is provided in checklist form in Table 12.

8.3 Periodic Testing Checklist

Table 12

Chk	Requirement	Comments	Initials
☐	Ensure that the drive can be run and stopped freely during the commissioning.		
☐	Stop the drive (if running), and safely remove AC power from the drive.		
☐	Check the STO-IN1 and STO-IN2 circuits and connections against a wiring diagram.		
☐	Apply AC mains power to the drive. Energize both the STO-IN1 and STO-IN2 circuits.		
☐	Test the operation of the STO-IN1 function when the motor is stopped. Give a stop command for the drive (if running) and wait for the motor to come to a standstill. While keeping STO-IN2 energized, de-energize the STO-IN1 circuit and give a start command for the drive. Ensure that the motor remains at a standstill. Energize the STO-IN1 circuit.		
☐	Test the operation of the STO-IN2 function when the motor is stopped. Give a stop command for the drive (if running) and wait for the motor to come to a standstill. While keeping STO-IN1 energized, de-energize the STO-IN2 circuit and give a start command for the drive. Ensure that the motor remains at a standstill. Energize the STO-IN2 circuit.		
☐	Restart the drive and check that the motor runs normally		
☐	Test the operation of the STO-IN1 function when the motor is running: Start the drive and ensure that the motor is running. While keeping STO-IN2 energized, de-energize the STO-IN1 circuit. Ensure that the motor stops. Reset any latching fault that may have occurred (these depend on the drive's control mode settings). Try to start the drive. Ensure that the motor stays at a standstill. Energize the STO-IN1 circuit		
☐	Test the operation of the STO-IN2 function when the motor is running: Start the drive and ensure that the motor is running. While keeping STO-IN1 energized, de-energize the STO-IN2 circuit. Ensure that the motor stops. Reset any latching fault that may have occurred (these depend on the drive's control mode settings). Try to start the drive. Ensure that the motor stays at a standstill. Energize the STO-IN2 circuit		
☐	Restart the drive and ensure that the drive and motor operate normally.		

9.0 Muting & Suspension of Safety Functions

9.1 STO Muting

Muting means de-activating the STO function. A convenient method for muting the STO function is provided for those applications not using the STO function.

An internal power source in the drive is brought out to the Safety connector J4. Connecting the STO inputs between this bypass power source and its ground supplies power to the STO opto-couplers allowing the PWM outputs to be controlled by the drive. Figure 10 below shows the muting connector circuit, table 13 lists the jumper connections, and fig. 9 shows the jumper locations.

From J4-pin to J4-pin

From	To
2	4
3	5
6	8
7	9

Table 13

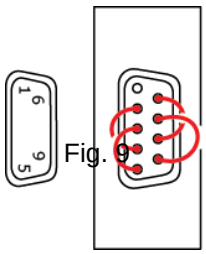


Fig. 9

Muting Connector Wiring (J4)

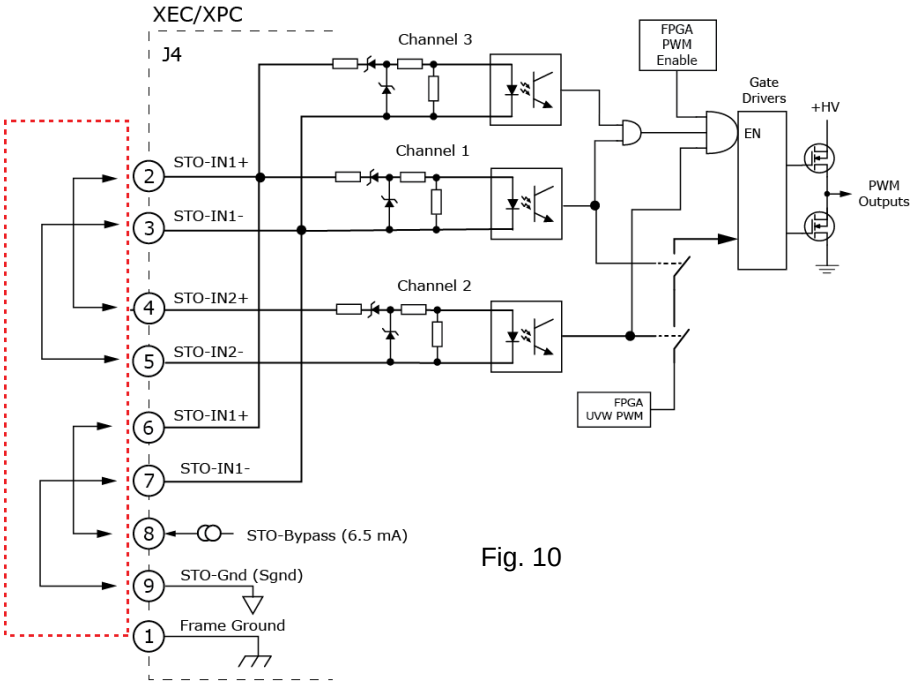


Fig. 10

10.0 Decommissioning

Before decommissioning any safety system from active service:

- Evaluate the impact of decommissioning on adjacent operating units and facilities or other field services.
- Conduct a proper review and obtain required authorization.
- Ensure that the safety functions remain appropriate during decommissioning activities.
- Implement appropriate change management procedures for all decommissioning activities.

Xenus Plus Compact STO Manual
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