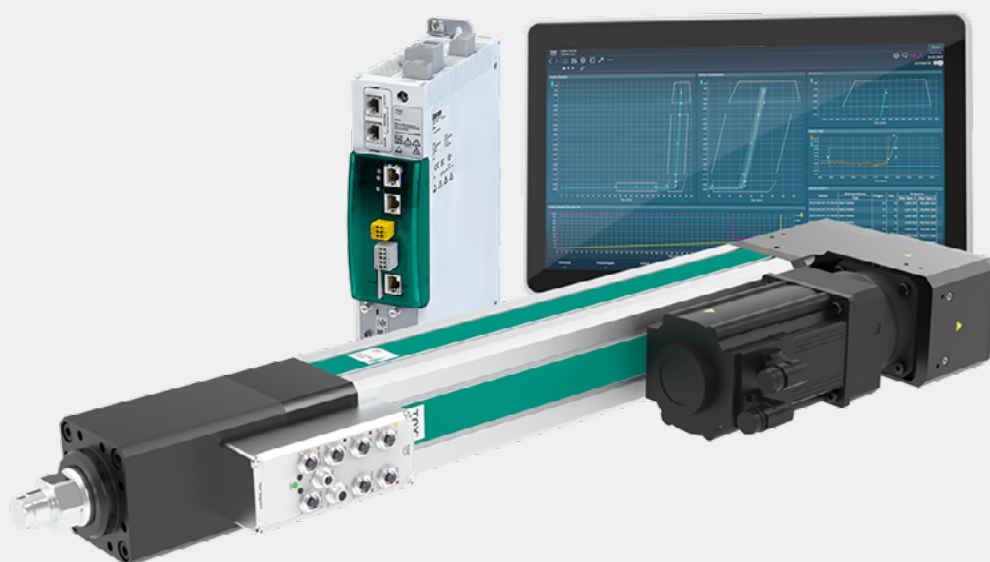


Whitepaper

Scalable Safety for Servo Presses and Joining Modules

Technical Whitepaper for System Integrators, Machine Builders and
Safety Professionals

From STO and SS1-t to Safety Brake, Safe Encoder
and Extended Safety



Scalable Safety for Servo Presses and Joining Modules

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Scalable Safety for Servo Presses and Joining Modules

Executive Summary

The TOX® ElectricDrive Core is a modular overall system for electromechanical servo presses, joining modules and automated pressing and joining applications. The system combines the TOX® ElectricPowerDrive with integrated EdgeUnit, TOX® PowerModule Core, TOX® WireSet and TOX® Software. This enables the drive, process control, quality monitoring and safety technology to be integrated into the customer's system in a coordinated manner.

The safety concept is based on a modular approach. Depending on the application, STO and SS1-t, a motor holding brake, safety brake, a safe encoder on the spindle side of the ElectricPowerDrive, SLS, and safe communication via PROFIsafe or FSoE can be combined. This allows different safety requirements to be addressed – from fully enclosed automated cells without regular personnel access to manual workstations, as well as setup and maintenance operations with safely monitored speed.

The TOX® ElectricPowerDrive is supplied as partly completed machinery with a Declaration of Incorporation. The system integrator incorporates it into the complete machine and is responsible for the risk assessment, validation of the safety functions, stopping-time measurement and CE conformity. TOX® provides safety-related characteristic values, component documentation, preconfigured system architectures and technical support for this purpose.

Application Note:

This whitepaper explains typical safety architectures and supports the selection of suitable system components. It does not replace the risk assessment of the complete machine, operating instructions, circuit diagrams or project-specific verification. The applicable standards and regulatory requirements depend on the specific machine function and the selected overall safety architecture.

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1. Safety as a System-Level Task

Safety in servo presses and joining modules is not achieved by a single component. It results from the coordinated interaction of the mechanical design, drive control, safety PLC, sensors, brakes, protective devices and operating modes.

The risk assessment of the complete machine determines which safety functions are required and which Performance Level or Safety Integrity Level the associated control functions must achieve.

The TOX® ElectricDrive Core provides a modular system for this purpose. Fully enclosed automated cells without regular personnel access require different safety measures than manual workstations with a light curtain or systems in which maintenance personnel need to move an axis while the safety door is open.

The required system components are therefore not defined universally, but are selected based on the hazard, operating mode and desired safety objective.

Basic Principle:

No single brake, encoder or individual drive function can replace the machine's overall safety concept. The added value of the system lies in the coordinated combination of suitable system components and the associated technical verification.

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2. Structure of the TOX® ElectricDrive Core

The TOX® ElectricDrive Core is the complete system comprising the mechanical servo drive, controller, cable set, integrated sensor interface and software. The system intelligence includes TOX® application logic, process control, diagnostics and the integration of safety functions.

System Component	Function within the Overall System
TOX® ElectricPowerDrive	Mechanical drive unit for joining, pressing, holding, testing, punching and controlled motion tasks, with integrated TOX® EdgeUnit.
TOX® EdgeUnit	Direct sensor connection on the drive, including for force, position and additional measurement signals, with data transfer to the internal bus system.
TOX® PowerModule Core	Control of the servo drive as well as an interface for STO, SS1-t and – in the Extended Safety version – safe communication and additional safe motion functions.
TOX® WireSet	Coordinated motor, resolver, power supply and system bus cables for connecting the system components.
TOX® Software	Parameterization, process programming, force and position control, diagnostics, brake testing, process monitoring and quality data provision.

The connection to the customer's control system is established via EtherCAT, PROFINET or EtherNet/IP. In Extended Safety architectures, PROFIsafe or FSoE are available for safe communication with the customer's safety PLC.

The TOX® ElectricPowerDrive series covers a pressing force range from 0.02 kN to 1,000 kN. Depending on the series and version, different combinations of safety brake, motor holding brake and safe encoder are available.

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3. The Scalable Safety Building Block System

“Scalable safety” does not mean that every application requires the same components. The controller version, brake concept, motion monitoring and safe communication are combined to match the safety objective of the complete machine. The following overview shows typical configuration levels. These are examples and can be combined to suit the specific application.

Safety Objective	Typical System Components	Suitable Applications	Key Assessment / Validation Criteria
Safe Shutdown	PowerModule Core Basic Safety; STO; SS1-t via the customer's safety PLC	Enclosed automated cell without regular personnel access; controlled stopping and prevention of unexpected start-up	Safety chain, stopping time, restart prevention
Mechanical Holding / Protection Against Lowering	Motor holding brake for the holding function; safety brake where a safety-related safety objective is required	Vertical installation, increased tool weight, holding in a de-energized state	Tool weight, holding torque, installation position, potential hazard due to lowering
Safeguarding Personnel Access	PowerModule Core Basic Safety or Extended Safety, SS1-t, safety brake, controlled via safety PLC or PLe Kit	Manual workstation, light curtain, accessible hazardous area; short and reproducible stopping time	Stopping time measurement, safety distance, brake function
Safely Monitoring Motion During Personnel Access	Extended Safety, safety brake, safe encoder, SLS, PROFIsafe/FSOE	Maintenance, setup, laboratory operation or controlled motion with access to the hazardous area	Speed limit, operating mode selection, safe communication, validation of the overall function

Important for Selection:

A PowerModule Core Basic Safety can also be combined with a safety brake as well as a safe encoder. The safety configuration is therefore not determined solely by the controller designation, but by the overall architecture of the machine.

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4. Key Safety Functions Explained

Function	Operating Principle	What the System Integrator Must Consider
STO – Safe Torque Off	The torque-generating energy supply to the motor is safely switched off. STO itself does not generate an active braking ramp.	Residual motion, gravity and stored energy must be controlled by additional measures
SS1-t – Safe Stop 1, Time-controlled	The controller decelerates the drive in a controlled manner. After a safely monitored time, STO is activated	The delay time must be derived from the actual stopping time and validated. A safety brake can be integrated as an additional measure
SBC – Safe Brake Control	The safety brake is activated via a safety-related control system	The complete safety function comprises the brake, control, feedback, test logic and the customer-side safety architecture
SLS – Safe Limited Speed	A defined speed limit is safely monitored	The measurement point, encoder architecture, reaction function and operating mode switching must be evaluated together
SOS – Safe Operating Stop	The standstill is safely monitored while the drive can maintain a holding torque	For applications with active force control and personnel access, the project-specific availability and design must be evaluated. In addition, the fault response as well as the reaction and stopping times must be defined and validated. Any resulting residual motion must be taken into account when designing the safety concept and, where relevant, the safety distance

Protective Stop, Emergency Stop and Reaction Chain:

Interruption of a light curtain or opening of a safety door triggers a defined protective response in accordance with the safety concept. The emergency stop is a supplementary protective measure and does not replace guards or electro-sensitive protective equipment.

When designing the system, the entire reaction chain must be taken into account: detection of a fault or limit violation → Safe reaction → Reaction and stopping time → Potential residual motion → Required safety concept or safety distance.

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5. Mechanical Safety: Motor Holding Brake and Safety Brake

Electromechanical servo drives have only limited self-locking capability. In vertical installations, a working piston subjected to a weight load may lower when the system is de-energized. The permissible tool weight must therefore be taken into account for the respective ElectricPowerDrive. Depending on the safety objective, a motor holding brake, safety brake, or a combination of both brakes is used.

Characteristic	Motor Holding Brake	Safety Brake
Position	Integrated into the servo motor	On the TOX® ElectricPowerDrive, on the spindle side
Primary Function	Holding the working piston at standstill and in the event of a power failure	Active braking and holding as part of a safety-related architecture
Suitable for Active Braking	No	Yes
Safety Component	No	Yes, with appropriate integration and validation
Protection in the Event of Gearbox/Belt Failure	No	Spindle-side arrangement reduces dependencies on upstream transmission elements
Functional Test	Can be tested before start-up	Brake status and braking force can be automatically monitored and tested

The safety brake is available for the EQe-K, EXe-K and EXe-L series. For safe speed monitoring, these series can be equipped with a safety brake and an additional safe encoder. Specific availability depends on the type and version.

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Performance-Level-Kit

For the TOX® ElectricPowerDrive with safety brake, a preconfigured Performance Level Kit is available. The pre-assembled and pre-wired unit includes a safety PLC, brake control module, PowerModule Core and the required connection components.

It provides safe control of the safety brake in accordance with Performance Level e and reduces the integration effort on the customer side. The Performance Level Kit is certified in accordance with Annex IX of the Machinery Directive 2006/42/EC (EC type-examination).

Performance Level e:

- Safe brake control
- Pre-assembled safety components
- Reduced integration effort
- Type-examined solution



SAFE CONTROL
in accordance with
Performance Level e



**PRE-ASSEMBLED AND
PRE-WIRED**
Components



**REDUCED INTEGRATION
EFFORT**
on the customer side



CERTIFIED
in accordance with Annex
IX of the Machinery
Directive 2006/42/EC
(EC type-examination)

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6. Safe Speed Monitoring (SLS)

For safe speed functions, it is crucial which motion is actually detected. In the TOX® ElectricPowerDrive, the safe encoder is mounted directly on the spindle side of the ElectricPowerDrive or on the spindle-side safety brake. This enables the motion of the working piston downstream of the gearbox and belt drive to be detected. As a result, faults or slippage in upstream transmission elements are not assessed solely on the basis of the motor speed.

The safe encoder and the servo motor resolver can be cross-checked for plausibility as a dual-encoder system. The specific safety-related assessment is performed by the selected evaluation unit and the overall architecture.

Three Possible Evaluation Architectures:

Architecture	Signal Processing	Reaction	Classification
Customer-Side Safety PLC	The safe encoder is evaluated directly by the safety PLC	The safety PLC triggers STO, SS1-t or another safe reaction, for example	Logic and parameterization are entirely the responsibility of the system integrator
PowerModule Core Extended Safety	The encoder is integrated into the Extended Safety controller; activation is via PROFIsafe or FSoE	The controller monitors limit values and responds internally, e.g. with SS1-t or STO	Compact architecture with safe communication and preconfigurable safety functions
Sensorless Speed Monitoring as a Retrofit Solution	The module monitors the motor frequency; evaluation and logic are handled on the customer side	The safety PLC triggers a safe reaction if a limit value is violated	Easy to retrofit, but without direct measurement of the motion on the spindle side. The mechanical transmission must be taken into account in the risk assessment

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7. Dynamics, Stopping Time and Safety Distance

Depending on the type, the TOX® ElectricPowerDrive series achieves acceleration and deceleration values of up to 8,000 mm/s². High deceleration values can significantly reduce the braking time and stopping distance.

This has a direct impact on the positioning of light curtains, safety doors and other protective devices.

A comparison between 3,000 mm/s² and 2,000 mm/s² shows a significantly shorter braking time and braking distance at the same initial speed.

However, for the safety-related design, the entire reaction chain is decisive: hazard detection, signal processing, communication, controller response, brake actuation and mechanical stopping.

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Influence of PLC Reaction Time and Braking Ramp on Stopping Time?

The stopping time is not determined solely by the drive mechanics. The reaction time of the higher-level control system and the configured braking ramp also influence how quickly a servo press or joining module comes to a standstill.

Practical Example:

Configuration	Relative Stopping Time	Graphical Comparison
Reference: PLC task time 10 ms, braking ramp 2,000 mm/s ²	100 %	
Higher braking ramp: 3,000 mm/s ²	approx. -10%	
Faster PLC processing: task time reduced from 10 ms to 1 ms	approx. -40%	
PLC processing and braking ramp optimized	approx. -55%	

Safety Distance:

The required safety distance must be determined based on the overall stopping time measured on the complete machine. All relevant control, communication, drive and braking components must be taken into account.

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8. Brake Testing, Diagnostics and Condition Monitoring

The functionality of a brake must remain verifiable throughout the entire life cycle of the machine. In the ElectricDrive Core, the brake test can be parameterized in the TOX® Software.

With the brake applied, the drive generates a defined test torque and the resulting motion is evaluated. If the permissible limit value is exceeded, the process is disabled and an error message is issued.

Depending on the application, the complete braking force test can be performed before each start or triggered based on time or events, for example after closing a protected area, following an emergency stop, or at defined intervals. This allows the test frequency to be adapted to the operating mode, access risk and cycle time requirements.

Regular inspection of the functionality of protective and safety devices is a legal requirement for operators in Germany. The type, scope and inspection intervals must be defined on the basis of the risk assessment. The automated brake test of the ElectricDrive Core can support compliance with these requirements.

The motor holding brake can also be function-tested. The test provides greater transparency regarding its condition but does not change its classification as a non-safety-related holding brake.

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9. Typical Applications and Suitable System Architectures

Application	Typical Hazard / Operating Mode	Possible TOX® System	Key Verification Requirements
Highly Automated System with Safety Fence	No access during automatic operation; during maintenance or in the event of a fault, the axis must be moved while the access point is open.	Extended Safety, SLS, safety brake, safe encoder; depending on the safety concept, enabling device or jog mode	Operating mode selection, speed limit, access control, safe stopping response
Manual Workstation with Light Curtain	Cyclic manual access for loading and unloading; crushing hazard due to residual movement of the working piston	SS1-t, safety brake, PLe Kit or customer-side safety PLC	Stopping time measurement, safety distance, brake testing, restart prevention
Manual Workstation with Interlocked Safety Door	Access only after a safe standstill; the load may lower when the system is de-energized	STO/SS1-t; depending on the tool weight, motor holding brake or safety brake	Guard locking logic, standstill time, tool weight, residual energy
Assembly or Fastening Under Load	Personnel working in the vicinity of a held axis or an axis under force	Safety brake; motor holding brake if required; safe encoder; project-specific SOS/SLS	Holding function, motion monitoring, safe operating mode, failure response, return stroke safety
Force-Controlled Process with Personnel Access	The motor must actively control the force; mechanical engagement of a brake can alter the process force.	Active force control, safe standstill or speed monitoring, safety brake as a defined failure response	Safety function during active control, limit values, fault behavior, process validation

The architectures described are examples. The final selection is based on the risk assessment, the specific machine function and the Type-C standards applicable to the application.

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10. Integration, Responsibility and Legal Framework

The TOX® ElectricPowerDrive is supplied as partly completed machinery with a Declaration of Incorporation. Commissioning is only permitted once the complete machine complies with the applicable European machinery legislation.

Until January 19, 2027, the Machinery Directive 2006/42/EC applies; from January 20, 2027, the Machinery Regulation (EU) 2023/1230 will apply.

The system integrator is responsible for the safety-related integration and conformity assessment of the complete machine.

This includes in particular:

- Risk assessment and risk reduction for all operating modes and life cycle phases of the machine.
- Definition of the required safety functions and safety-related characteristic values.
- Calculation and validation of the safety-related parts of the control system.
- Stopping time measurement and use of suitable protective devices.
- Integration of safety doors, light curtains, emergency stop, operating mode selection and restart prevention.
- Validation of the complete safety function, including sensor, logic, actuator and mechanics.
- Preparation of the technical documentation and the CE Declaration of Conformity for the complete machine.

TOX® provides the Declaration of Incorporation, operating instructions, component documentation, safety-related characteristic values and technical support for the selection and integration of the system components.

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11. Normative Guidance

The standards applicable to a specific project depend on the machine function, target market and risk assessment. For typical servo press and joining module applications, the following standards and regulations are particularly relevant:

Standard / Regulation	Typical Relevance
DIN EN ISO 12100	Risk Assessment and Risk Reduction
EN IEC 61800-5-2	Functional safety of electrical drive systems, including STO, SS1, SLS, SOS and SBC
DIN EN ISO 13849-1/-2	Design and validation of safety-related parts of control systems in accordance with Performance Level
EN IEC 62061	Functional safety of safety-related control systems in accordance with SIL
EN ISO 16092-1/-2	Safety requirements for presses; Part 2 covers mechanical servo presses
DIN EN ISO 13855	Positioning of protective devices based on approach speed and overall stopping time
EN IEC 61496-1/-2	Electro-sensitive protective equipment, e.g. light curtains
DIN EN ISO 14119	Interlocking and guard locking devices associated with guards
DIN EN ISO 14118	Prevention of unexpected start-up
DIN EN ISO 13850 / EN 60204-1	Emergency stop function and electrical equipment of machines

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12. Frequently Asked Questions from Practice

Can a Safety Brake Be Used Without an Encoder?

Yes. This is possible, for example, in applications with light curtains. Suitability is determined by the validated stopping function, stopping time measurement and the risk assessment of the complete machine.

Does SS1-t Always Require a Safety Brake?

No. SS1-t describes controlled deceleration followed by STO after a safely monitored time. A safety brake can additionally be used as a mechanical braking and holding path.

If the motor-controlled braking ramp fails in the event of a fault, the safely controlled safety brake, designed for dynamic braking, can bring the working piston to a mechanical standstill. The design and effectiveness must be validated on the complete machine.

What Is the Difference Between a Motor Holding Brake and a Safety Brake?

The motor holding brake is used to hold the drive at standstill and is not designed for active emergency or operational braking. The safety brake is designed for active braking and integration into a safety-related architecture.

Why Is the Safe Encoder Mounted on the Spindle Side?

This allows the actual movement of the working piston downstream of the gearbox and belt drive to be detected. The safety-related assessment is therefore less dependent on upstream transmission elements.

Can SLS Be Retrofitted?

Yes. In addition to encoder-based solutions, an external safe speed monitoring system can be used. Since this monitors the motor frequency rather than directly detecting the spindle motion, the mechanical transmission must be taken into account in the risk assessment.

Who Is Responsible for CE Conformity?

The system integrator or manufacturer of the complete machine. TOX® supplies the partly completed machinery, safety-related characteristic values and technical documentation as the basis for integration and assessment.

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13. Summary

The TOX® ElectricDrive Core provides a modular safety system for servo presses, joining modules and automated pressing and joining systems.

The safety technology can be adapted to the specific safety requirements: from STO and SS1-t to load securing and safety brakes, through to spindle-side speed monitoring with Extended Safety and safe communication.

This provides the system integrator not only with individual components, but also with defined integration paths, documented safety-related characteristic values and technical support for the selection, design and validation of the overall solution.

Responsibility for the risk assessment and CE conformity of the complete machine clearly remains with the system integrator.

Selection Principle:

As much safety as required, using the system components that match the specific hazard, operating mode and machine function.

Sources and further reading

- TOX® ElectricDrive Core – Data Sheet 40.15: System and Components
- TOX® ElectricDrive Core – Characteristic Safety Values
- Operating Instructions for TOX® ElectricPowerDrive EQe-K, EXe-K, EXe-F and EXe-L
- TOX® Product Page: Safety Technology for Servo Presses
- The standards and European machinery regulations listed in Chapter 11