ABB Drives

Safety Manual
Safe Torque Off (STO) function for MicroFlex e150 drives

The information in this manual applies to:

- ABB MicroFlex e150 drives.

LT0313A02
EN
EFFECTIVE: 2014-03-18

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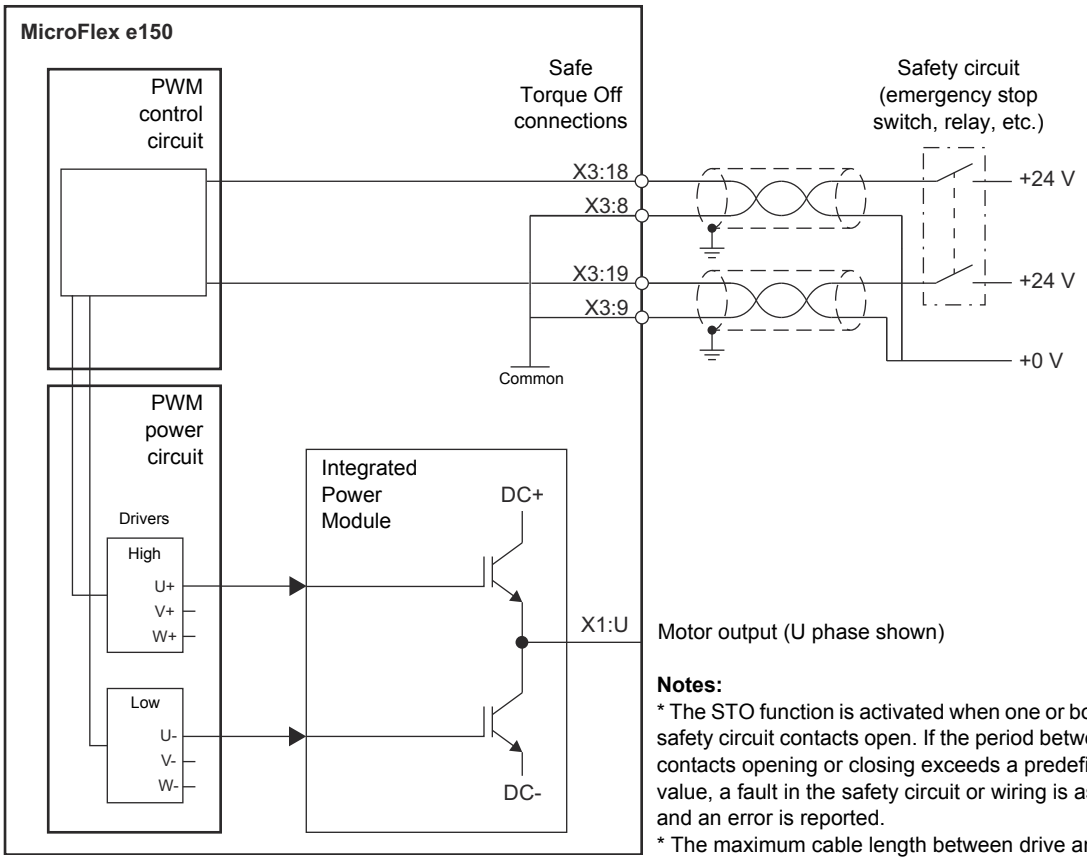
Basics

Introduction

The drive supports the Safe Torque Off (STO) function according to standards IEC 61800-5-2:2007, IEC 61508:2010, EN ISO 13849-1:2008 and IEC 62061:2005.

STO may be used where power removal is required to prevent an unexpected start. The function disables the signals that control 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 work on non-electrical parts of the machinery can be performed without switching off the power supply to the drive.



Motor output (U phase shown)

Notes:

* The STO function is activated when one or both of the safety circuit contacts open. If the period between both contacts opening or closing exceeds a predefined value, a fault in the safety circuit or wiring is assumed and an error is reported.
* The maximum cable length between drive and the safety switch is 30 m (98 ft).

WARNING! The STO function does not disconnect the voltage of the main 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 main supply. If the drive was connected to the input power, wait for 5 minutes after disconnecting the input power.

Special considerations for using the STO function

Drive location

The MicroFlex e150 and all associated STO wiring must be installed in an indoor location. The MicroFlex e150 must be installed in a cabinet. The suitability of the cabinet for the intended environment must be determined by the installer. See *Ambient conditions* on page 20 for further details.

Hazard analysis

A hazard analysis of the application should be performed before using the STO function in the application.

Additional stopping methods

It is not recommended to stop the drive by using the STO function. If a running drive is stopped by using the 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. For example, suspended or tensioned loads (e.g. cranes, hoists) will require additional brakes or mechanical interlocks.

IGBT failure

If a permanent magnet motor drive experiences multiple power semiconductor failure, the drive system can produce an alignment torque which maximally rotates the motor shaft by 180/*p* degrees (*p* = pole pair number), even if the STO function has been correctly activated.

Failure of one or more IGBTs can cause the drive output to fail due to:

- IGBT desaturation protection causing all IGBTs to be stopped.
- Rupture of the AC input fuse.

Terminology

‘Active’ or ‘activated’ means that the STO *function* has been triggered. This removes power from the motor and disables the drive. The drive cannot be restarted without further operator intervention.

‘Standby’ means that the STO *function* has not been triggered. The drive can power the motor, provided all other criteria are satisfied to allow motor operation.

Installation

Wiring principles

The Safe Torque Off connector is X3 on MicroFlex e150 drives.

Wiring principles are shown in the diagrams below. See chapter *Technical data* for the cable specification and possible safety relay types.

- The wiring to each STO input must be routed separately.
- Wiring the STO inputs in accordance with the following diagrams provides Safety Integrity Level 3 (SIL3). It is not permissible to control both STO inputs from one safety circuit, as this will not provide SIL3 protection.
- The Safe Torque Off (STO) function provides a stop function equivalent to 'stop category 0' according to EN 60204-1.
- The STO element is classified as type A, according to IEC 61508-2.

Connected components

Ensure that all components controlling the STO inputs, including cabling, will not cause the STO inputs to become constantly powered (a 'dangerous failure') or constantly unpowered (a 'safe failure').

Diagnostic pulses produced by Safe Digital Output devices are not recognised by the MicroFlex e150, and must be disabled. Short circuit conditions on the STO inputs must be tested within the proof test interval.

Power supply

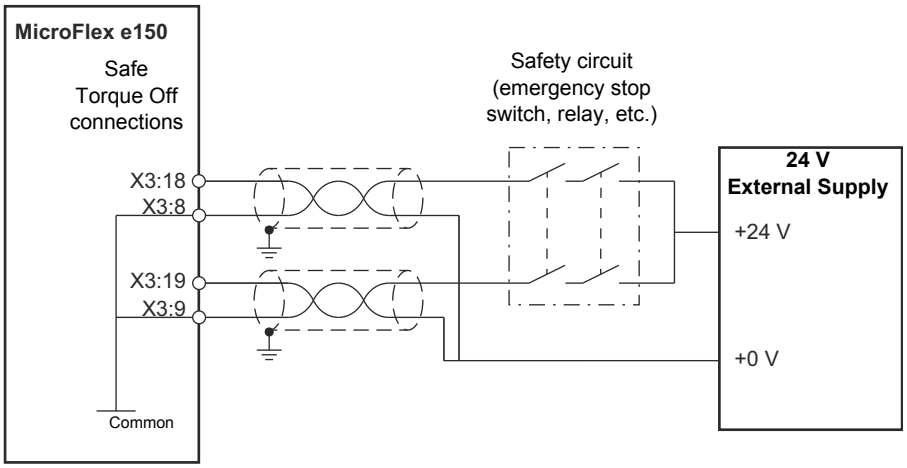
The 24 V DC power supply used for the drive logic supply or STO inputs must fulfil the following criteria:

- It must be a Safety Extra Low Voltage (SELV) supply.
- It must be suitable for the desired safe application and safety integrity level.
- It must be protected against over voltages.
- It must limit the output voltage under all fault conditions <60V.
- It must be TüV certified to EN 60950.

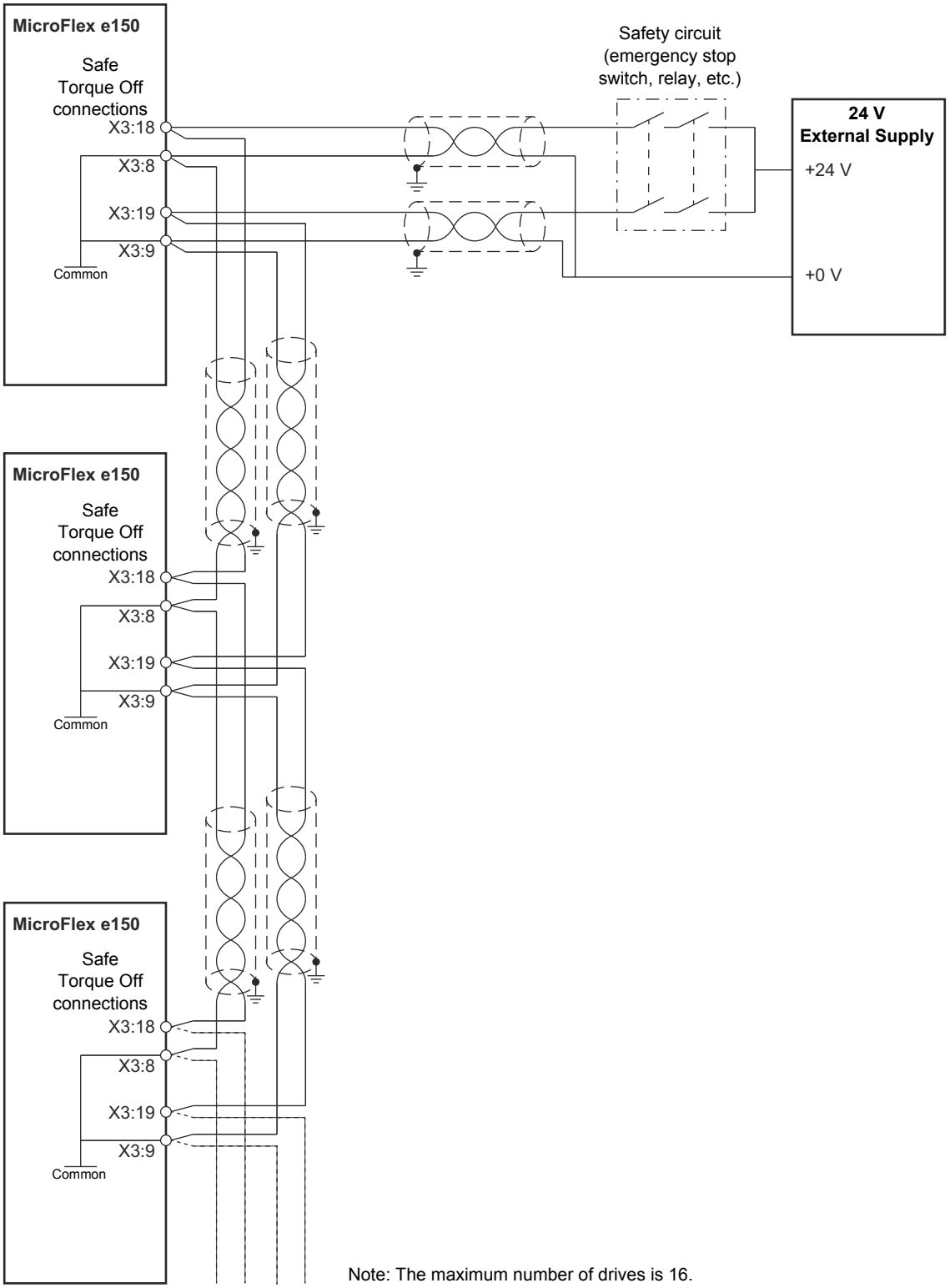
Drive enable input

If an additional hardware 'drive enable' input is used to control the drive, it must not be wired as part of the STO input circuit.

Single drive module



Multiple drive modules



Note: The maximum number of drives is 16.

Program features, settings and diagnostics

Operation of the STO function and its diagnostics function

Hardware activation of the STO function

The drive contains two STO inputs. If both STO inputs are powered, the STO function is in the standby state and the drive operates normally.

If power is removed from one or both of the STO inputs, the STO function is activated. The drive's motor output power stage is disabled. Enabling is possible only after both STO inputs have been powered, and the fault has been cleared.

Firmware monitoring of the STO function

STO function activation

The firmware detects when the STO function is activated and generates the 'STO active' error (10033). The drive can be enabled only after the fault has been cleared.

STO input states

The state of the STO inputs are monitored by the firmware. The state of the STO inputs are stored in a hardware register within the drive. The register is monitored by the drive over a period specified by the `STOINPUTMISMATCHTIME` Mint keyword. If the inputs are in different states after the specified period has elapsed, the 'STO input mismatch' error (10035) is generated.

Internal fault circuit state

The drive also contains two internal fault circuits that detect internal hardware faults in the STO circuits. The firmware detects internal faults and generates the 'STO hardware fault' error (10034). This fault could indicate a drive failure that requires repair.

Software monitoring of the STO function

The drive can be programmed using the Mint language. The software application *Mint WorkBench* is available for configuring, programming and monitoring the status of the drive. The `SAFETORQUEOFF` Mint keyword can be used to report the status of the STO hardware registers. `SAFETORQUEOFF` contains an array of values indicating the states of the STO1 and STO2 inputs, two internal hardware fault circuits, and one internal STO status output. This array is described in the following table:

Parameter	Meaning
SAFETORQUEOFF(0)	The combined state of the two STO inputs: STO1 = bit 0, STO2 = bit 1
SAFETORQUEOFF(1)	The state of STO1 input: 0 = not powered, 1 = powered
SAFETORQUEOFF(2)	The state of STO2 input: 0 = not powered, 1 = powered
SAFETORQUEOFF(3)	The combined state of the two hardware fault circuits: STO1 = bit 0, STO2 = bit 1
SAFETORQUEOFF(4)	The state of the STO1 internal hardware fault circuit: 0 = no fault, 1 = fault
SAFETORQUEOFF(5)	The state of the STO2 internal hardware fault circuit: 0 = no fault, 1 = fault
SAFETORQUEOFF(6)	The state of the internal STO status output: 0 = fault, 1 = no fault

See the table in *STO status indications* on page *12* for a complete listing of SAFETORQUEOFF values.

See *Maintenance, fault tracing and diagnostics* on page 16, which describes the error codes displayed by the drive.

STO status indications

The following table lists the state of the STO function with reference to:

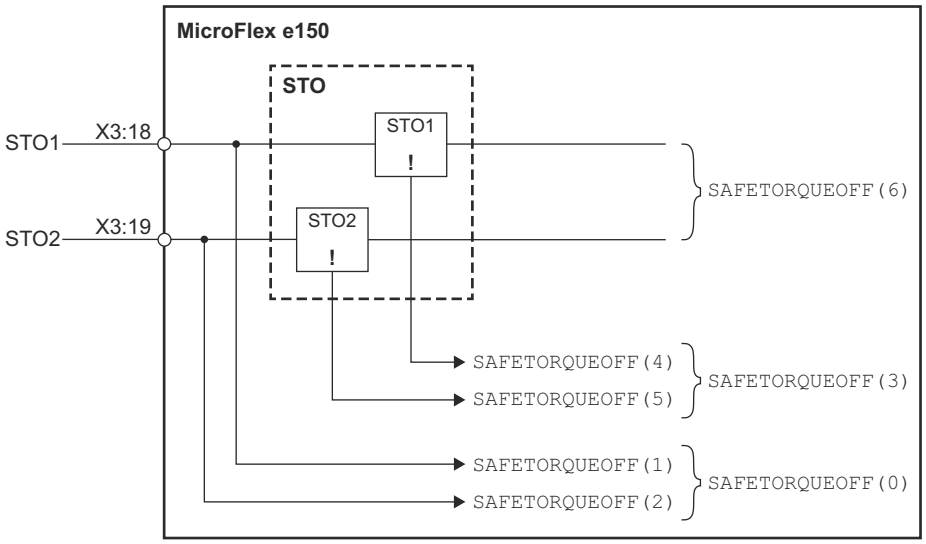
- values of the SAFETORQUEOFF Mint keyword (see page 11).
- status of the STO inputs STO1 and STO2.
- status of the internal fault circuit outputs $FAULT_{STO1}$ and $FAULT_{STO2}$

SAFETORQUEOFF(1) and SAFETORQUEOFF(2) return 1 when the respective STO input is powered (STO in standby, motor output enabled). SAFETORQUEOFF(6) returns 1 when both inputs are powered *and* there are no internal hardware faults.

SAFETORQUEOFF(4) and SAFETORQUEOFF(5) return 1 when the respective internal fault output is asserted (STO activated, motor output disabled).

	No FAULTs	**$FAULT_{STO1}$ present**	**$FAULT_{STO2}$ present**	**$FAULT_{STO1}$ $FAULT_{STO2}$ both present**
STO1 & STO2 powered	**STO in standby.** **Motor output enabled.** SAFETORQUEOFF(0)=3 SAFETORQUEOFF(1)=1 SAFETORQUEOFF(2)=1 SAFETORQUEOFF(3)=0 SAFETORQUEOFF(4)=0 SAFETORQUEOFF(5)=0 SAFETORQUEOFF(6)=1	**STO activated.** **Motor output disabled.** SAFETORQUEOFF(0)=3 SAFETORQUEOFF(1)=1 SAFETORQUEOFF(2)=1 SAFETORQUEOFF(3)=1 SAFETORQUEOFF(4)=1 SAFETORQUEOFF(5)=0 SAFETORQUEOFF(6)=0	**STO activated.** **Motor output disabled.** SAFETORQUEOFF(0)=3 SAFETORQUEOFF(1)=1 SAFETORQUEOFF(2)=1 SAFETORQUEOFF(3)=2 SAFETORQUEOFF(4)=0 SAFETORQUEOFF(5)=1 SAFETORQUEOFF(6)=0	**STO activated.** **Motor output disabled.** SAFETORQUEOFF(0)=3 SAFETORQUEOFF(1)=1 SAFETORQUEOFF(2)=1 SAFETORQUEOFF(3)=3 SAFETORQUEOFF(4)=1 SAFETORQUEOFF(5)=1 SAFETORQUEOFF(6)=0
STO1 not powered	**STO activated.** **Motor output disabled.** SAFETORQUEOFF(0)=2 SAFETORQUEOFF(1)=0 SAFETORQUEOFF(2)=1 SAFETORQUEOFF(3)=0 SAFETORQUEOFF(4)=0 SAFETORQUEOFF(5)=0 SAFETORQUEOFF(6)=0	**STO activated.** **Motor output disabled.** SAFETORQUEOFF(0)=2 SAFETORQUEOFF(1)=0 SAFETORQUEOFF(2)=1 SAFETORQUEOFF(3)=1 SAFETORQUEOFF(4)=1 SAFETORQUEOFF(5)=0 SAFETORQUEOFF(6)=0	**STO activated.** **Motor output disabled.** SAFETORQUEOFF(0)=2 SAFETORQUEOFF(1)=0 SAFETORQUEOFF(2)=1 SAFETORQUEOFF(3)=2 SAFETORQUEOFF(4)=0 SAFETORQUEOFF(5)=1 SAFETORQUEOFF(6)=0	**STO activated.** **Motor output disabled.** SAFETORQUEOFF(0)=2 SAFETORQUEOFF(1)=0 SAFETORQUEOFF(2)=1 SAFETORQUEOFF(3)=3 SAFETORQUEOFF(4)=1 SAFETORQUEOFF(5)=1 SAFETORQUEOFF(6)=0
STO2 not powered	**STO activated.** **Motor output disabled.** SAFETORQUEOFF(0)=1 SAFETORQUEOFF(1)=1 SAFETORQUEOFF(2)=0 SAFETORQUEOFF(3)=0 SAFETORQUEOFF(4)=0 SAFETORQUEOFF(5)=0 SAFETORQUEOFF(6)=0	**STO activated.** **Motor output disabled.** SAFETORQUEOFF(0)=1 SAFETORQUEOFF(1)=1 SAFETORQUEOFF(2)=0 SAFETORQUEOFF(3)=1 SAFETORQUEOFF(4)=1 SAFETORQUEOFF(5)=0 SAFETORQUEOFF(6)=0	**STO activated.** **Motor output disabled.** SAFETORQUEOFF(0)=1 SAFETORQUEOFF(1)=1 SAFETORQUEOFF(2)=0 SAFETORQUEOFF(3)=2 SAFETORQUEOFF(4)=0 SAFETORQUEOFF(5)=1 SAFETORQUEOFF(6)=0	**STO activated.** **Motor output disabled.** SAFETORQUEOFF(0)=1 SAFETORQUEOFF(1)=1 SAFETORQUEOFF(2)=0 SAFETORQUEOFF(3)=3 SAFETORQUEOFF(4)=1 SAFETORQUEOFF(5)=1 SAFETORQUEOFF(6)=0
STO1 STO2 both not powered	**STO activated.** **Motor output disabled.** SAFETORQUEOFF(0)=0 SAFETORQUEOFF(1)=0 SAFETORQUEOFF(2)=0 SAFETORQUEOFF(3)=0 SAFETORQUEOFF(4)=0 SAFETORQUEOFF(5)=0 SAFETORQUEOFF(6)=0	**STO activated.** **Motor output disabled.** SAFETORQUEOFF(0)=0 SAFETORQUEOFF(1)=0 SAFETORQUEOFF(2)=0 SAFETORQUEOFF(3)=1 SAFETORQUEOFF(4)=1 SAFETORQUEOFF(5)=0 SAFETORQUEOFF(6)=0	**STO activated.** **Motor output disabled.** SAFETORQUEOFF(0)=0 SAFETORQUEOFF(1)=0 SAFETORQUEOFF(2)=0 SAFETORQUEOFF(3)=2 SAFETORQUEOFF(4)=0 SAFETORQUEOFF(5)=1 SAFETORQUEOFF(6)=0	**STO activated.** **Motor output disabled.** SAFETORQUEOFF(0)=0 SAFETORQUEOFF(1)=0 SAFETORQUEOFF(2)=0 SAFETORQUEOFF(3)=3 SAFETORQUEOFF(4)=1 SAFETORQUEOFF(5)=1 SAFETORQUEOFF(6)=0

STO software functional diagram:



Monitoring the delay between the STO inputs

The STO function monitors the switching time difference between the STO inputs. See *Operation of the STO function and its diagnostics function* on page 10.

STO function activation and indication delays

Hardware activation delay (the delay between removing power from an STO input and switching off the drive output bridge): <1 ms.

Hardware indication delay (the delay between switching off the drive output bridge and being indicated to the Mint program): approximately 1 ms.

Software STO indication delay, Mint program (the delay between a mismatch occurring on the STO inputs and being indicated to the Mint program): 5 ms - 500 ms user defined period, set by `STOINPUTMISMATCHTIME`.

Internal STO hardware fault indication delay (the delay between an internal fault occurring and being indicated to the Mint program): approximately 5 ms.

Start-up and validation

Validating the operation of a safety function

IEC 61508, IEC 62061 and EN ISO 13849-1 require that the final assembler of the machine validates the operation of the safety function with an acceptance test at the installation site. The acceptance tests for the standard safety functions of the drive are described in the drive manual.

The acceptance test must be performed:

- by an authorized person
- at initial 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.

Authorized person

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

Acceptance test reports

Signed acceptance test reports must be stored in the logbook 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 changes or maintenance shall be recorded in the logbook.

Preliminary checks

Before powering the drive, check:

- Grounding has been properly connected.
- Energy sources have been properly connected and are operational.
- Transportation stops and packing materials have been removed.
- No physical damage is present.
- All instruments have been properly calibrated.
- All field devices are operational.
- Interfaces are operational.
- Interfaces to other systems and peripherals are operational.

Start-up checklist

	Action
☐	Ensure that the drive can be run and stopped freely during the commissioning.
☐	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 shield of the STO input cable is grounded to the drive frame (see the drive hardware manual).
☐	Close the disconnector and switch the power on.
☐	Test the operation of the STO function when the motor is stopped: • Disable the drive and ensure the motor shaft is not rotating. • Activate the STO function (remove power from the STO inputs) and attempt to enable the drive. • Ensure that the drive can not be enabled (see section *Operation of the STO function and its diagnostics function* on page *10*.) • Deactivate the STO function (apply power to the STO inputs).
☐	Test the operation of the STO function when the motor is running: • Enable the drive and start motion. Ensure the motor is rotating. • Activate the STO function (remove power from the STO inputs). • Ensure that the drive disables and the motor stops rotating. • Attempt to enable the drive. • Ensure that the drive can not be enabled (see section *Operation of the STO function and its diagnostics function* on page *10*.) • Deactivate the STO circuit (apply power to the STO inputs).
☐	Document and sign the acceptance test report which verifies that the safety function is safe and accepted to operation.

Restarting the drive

Restarting the drive is not part of the STO test or certification processes, but is included here for convenience.

Action
Deactivate the STO circuit (apply power to the STO inputs). If the drive holds a Mint program, or is connected to an Ethernet master device that can enable the drive, it is possible for the drive to restart and begin to control the motor without further intervention. If the drive does not hold a Mint program, some of the following actions will be necessary, depending on the installation: • Activate the additional drive enable input (if present). • In Mint WorkBench (if connected), click the Clear errors button on the System toolbar, followed by the Drive Enable button on the Motion toolbar. • Enable the drive from the Ethernet master device (if connected).

Maintenance, fault tracing and diagnostics

Maintenance / servicing

Include the STO operation tests described in *Start-up and validation* in the routine maintenance program of the machinery to which the drive is connected.

The STO function must be tested by authorized service personnel as frequently as required by the proof test interval. See also *Data related to safety standards* on page *21*.

The STO input terminals do not need any maintenance. Maintain the drive according to the instructions given in the drive hardware manual.

The exchange of safety related systems or subsystems must be performed only in a powerless condition.

The drive may only be opened by ABB authorized personnel.

Error messages generated by the drive

When an error occurs, the drive displays the error code on its front panel 7 segment display. The symbol E is displayed, followed by the digits of the error code in sequence.

For example, error code 10033 is displayed as E....1..0..0..3..3.

Additionally, the right decimal point is illuminated for any STO error.

STO error

The STO errors are listed in the following table:

Error	Cause	What to do
10033 ecSTO_ACTIVE	Either one or both of the STO inputs is not powered. This error is detected when the drive is enabled, or when attempting to enable the drive in software. - safe switch or relay has dropped an output that controls the STO input. - emergency stop switch has been operated. - faulty safety relay	 Use a test meter to check that the device controlling the STO input is providing the required output. Check the operation of the emergency stop switch. Check that the contacts close correctly when the switch is reset. Check the operation of the safety relay.
10034 ecSTO_HARDWARE_FAULT	Either one or both of the internal fault circuit outputs has been asserted, indicating an internal hardware fault in the STO circuits. This error can occur when the drive is enabled or disabled. - a hardware fault in the drive has occurred. This fault might be detected only when STO activation occurs. In this case, the other STO channel and non-safe circuitry in the drive will disable the power semiconductor devices and remove torque from the motor.	 Remove the drive from service and test the operation of the STO function before attempting to use the drive. It might be necessary to return the drive for repair.
10035 ecSTO_INPUT_MISMATCH	The drive has detected a mismatch in its internal STO registers. This error can occur while the drive is enabled or disabled. - emergency stop switch fault - wiring fault	Check the operation of the emergency stop switch. Check that the contacts close correctly when the switch is reset. Check that the period defined by `STOINPUTMISMATCHTIME` is long enough to allow both STO inputs to settle. Check the operation of the emergency stop switch. Check that the contacts close correctly when the switch is reset. Check all wiring for the STO inputs.

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.

Technical data

STO components

STO safety relay type

General requirements	IEC 61508 and/or IEC 61511 and/or EN ISO 13849-1
Output requirements	
No. of current paths	2 independent paths (one for each STO path)
Switching voltage capability	30 V DC per contact
Switching current capability	10 mA per contact per drive
Maximum switching delay between contacts	1 ms
Internal supply/multiple units	
Maximum length of safety circuit from operating contact to most distant drive	30 m (98.4 ft)
Maximum number of drives in circuit	16
External supply/multiple units	
External power supply	24 V DC $\pm$10% SELV
Current requirement	20 mA per connected drive
Example 1	Simple SIL3 approved safety relay
Type and manufacturer	PSR-SCP- 24UC/ESP4/2X1/1X2 by Phoenix Contacts
Approvals	EN 954-1, cat 4; IEC 61508, SIL3
Example 2	Programmable safety logic
Type and manufacturer	PNOZ Multi M1p by Pilz
Approvals	EN 954-1, cat 4; IEC 61508, SIL3; and EN ISO 13849-1, PL e

STO cable

Type	2×2×0.75 m^2 low voltage, single shielded, twisted pair cable
Maximum length	30 m between STO inputs and the operating contact
Example cable	Li YCY TP 2×2×0.75 mm^2 shielded twisted pair cable by HELUKABEL or CEAM

Ambient conditions

Description	Unit	All models			
Operating temperature range		**°C**		**°F**	
Minimum Maximum Derate	V DC	+0 +45* Subject to derating; see manual LT0291A*nn*.		+32 +113* Subject to derating; see manual LT0291A*nn*.	
Storage temperature range		-40 to +85		-40 to +185	
Humidity (maximum)	%	93			
		1 A	**3 A**	**6 A**	**9 A**
Forced air cooling flow (vertical, from bottom to top)	m/s	None required	None required	1	2.5
Maximum installation altitude (above m.s.l.) non-STO parts: STO function:	 m ft m ft	 1000. Above 1000 m derate 1.1% / 100 m 3280. Above 3280 ft derate 1.1% / 330 ft 2000 6561			
Shock		10 G			
Vibration		1 G, 10-150 Hz			

* Subject to derating. See User's Manual LT0291A*nn* for full environmental and derating specifications.

Data related to safety standards

IEC 61508						EN ISO 13849-1				
SIL	**PFH**	**HFT**	**SFF**	**PTI**	**PFD**	**PL**	**CCF**	**$MTTF_D$**	**DC***	**Category**
3	1.12×10^{-10} / h (0.112 FIT)	1	96.48%	10 years	1.12×10^{-5}	e	75 points	20420.9 years	90%	3

* According to the categorization defined in EN ISO 13849-1:2008.

Abbreviations

Abbreviation	Reference	Description
CCF	EN ISO 13849-1	Common Cause Failure (%)
DC	EN ISO 13849-1	Diagnostic Coverage
FIT	IEC 61508	Failure In Time: 1×10^{-9} hours
HFT	IEC 61508	Hardware Fault Tolerance
IGBT		Insulated-gate bipolar transistor: The electrical components that drive the motor power outputs
$MTTF_D$	EN ISO 13849-1	Mean Time To dangerous Failure: (The total number of life units) / (the number of dangerous, undetected failures) during a particular measurement interval under stated conditions
PFD	IEC 61508	Probability of Failure on Demand
PFH	IEC 61508	Probability of Dangerous Failures per Hour
PL	EN ISO 13849-1	Performance Level: Corresponds SIL, Levels a-e
PTI		Proof Test Interval
SFF	IEC 61508	Safe Failure Fraction (%)
SIL	IEC 61508	Safety Integrity Level
STO	IEC 61800-5-2	Safe Torque Off

TÜV certificate – MicroFlex e150

TÜV NORD

Certificate

No. SLA-0041/2010, V1.0

TÜV NORD Systems GmbH & Co. KG hereby certifies

Baldor UK Ltd

Mint Motion Centre
6 Bristol Distribution Park
Hawkley Drive
Bristol BS32 0BF
United Kingdom

that the safety function "Safe Torque Off" (STO) in the drive system

MicroFlex e150

is capable for safety related applications up to SIL 3, PL e respectively. The requirements listed in the following standards are fulfilled.

- IEC 61508 part 1:2010; part 2:2010; capable up to SIL 3
- ISO 13849-1:2008; capable up to PL e
- IEC 62061:2005; capable up to SIL_{CL} 3
- IEC 61800-5-2:2007; capable up to SIL 3

The certification is based on the report No. SLA-0041/2010TB-2 in the valid version.
This certificate entitles the holder to use the pictured Safety Approved mark.

Expiry date: 2017-01-31
Reference No.: G.SEB.BS.02.027.01.031

Gerhard M. Rieger
Augsburg, 2012-01-31

Voluntary Certification
TÜV NORD
TÜV NORD Systems GmbH & Co. KG
Safety Approved
MicroFlex e150
IEC 61508 SIL3
ISO 13849-1 PL e
IEC 62061 SIL_{CL}3
IEC 61800-5-2 SIL3
SLA-0041/2010

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Baldor UK Ltd is a member of the ABB group.

Further information

Product and service inquiries

Address any inquiries about the product to your local ABB representative, quoting the type designation and serial number of the unit in question. A listing of ABB sales, support and service contacts can be found by navigating to www.abb.com/drives and selecting *Sales, Support and Service network*.

Product training

For information on ABB product training, navigate to www.abb.com/drives and select *Training courses*.

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