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### Appendix E: Safe Torque Off Function

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### INTRODUCTION

#### SAFE FUNCTION FAILURE RATE

Refer to the table below for relevant safe torque off performance and standards.

Item	Definition	Standard	Performance
<b>SFF</b>	Safe Torque Off	IEC61508	STO1-SCM: 88.35% STO2-SCM: 88.2%
<b>HFT (Type A Subsystem)</b>	Hardware Fault Tolerance	IEC61508	1
<b>SIL</b>	Safe Integrity Level	IEC61508	SIL 2
		IEC62061	SILCL 2
<b>PFH</b>	Average Frequency of Dangerous Failure [h <sup>-1</sup> ]	IEC61508	1.36×10 <sup>-9</sup>
<b>PFD<sub>av</sub></b>	Probability of Dangerous Failure on Demand	IEC61508	5.99×10 <sup>-6</sup>
<b>PTI</b>	Proof Test Interval	IEC61508	1 year
<b>Category</b>	Category	ISO13849-1	Category 3
<b>PL</b>	Performance Level	ISO13849-1	d
<b>MTTF<sub>d</sub></b>	Mean Time to Dangerous Failure	ISO13849-1	High
<b>DC</b>	Diagnostic Coverage	ISO13849-1	Low

*For more information on the above performance levels, please refer to the appropriate standard.*

#### SAFE TORQUE OFF TERMINAL FUNCTION DESCRIPTION

The Safe Torque Off (STO) function turns off the power supplied to the motor through the hardware, so that the motor cannot produce torque. This method of removing power from the motor is considered an emergency power off, also known as “coast to stop.”

The Safe Torque Off function utilizes two independent hardware circuits to control the motor current drive signal, and thus turns off the inverter power module output in order to achieve the status of safe stop. In normal E-stop situations, both circuits will be opened (using a dual-channel safety relay, etc.). To restart the drive, the Reset input must be turned ON and the Run command must be cycled from low to high. **If only one of the circuits is opened during an E-stop, the drive considers this an STLx fault and power must be cycled to the drive to clear the error.**

If unknown STO faults occur, the on-board +24V might be getting shorted to ground (+24V to SCM).

STO Terminal Function Descriptions		
Terminals	Function	Description
+24V	When the STO function is not used, you can disable the STO function by shorting STO1 and STO2 with + 24V.	Output voltage range: +24V ± 10% Output voltage capacity: 100 mA
STO1	Signal input for STO function channel 1	<b>STO1-SCM / STO2-SCM</b> Rated input voltage: +24 VDC ± 10%; maximum input voltage: +30 VDC ± 10% Rated input current: 6.67 mA ± 10% <b>STO activation mode</b> Input voltage level: 0 VDC < STO1-SCM and STO2-SCM < 5 VDC STO response time: ≤ 20 ms (time required for STO1 / STO2 to operate until the drive stops outputting) <b>STO cut-off mode</b> Input voltage level: 11 VDC < STO1-SCM and STO2-SCM < 30 VDC
STO2	Signal input for STO function channel 2	
SCM	Reference ground for STO1 and STO2 signal	

Operation Conditions Description						
Signal	Channel	STO Input Status				
<b>STO Signal</b>	STO1~SCM	ON	ON	OFF	OFF	x
	STO2~SCM	ON	OFF	ON	OFF	x
<b>Driver Output Status</b>	Ready	STL2 Mode (Torque Output Off)	STL1 Mode (Torque Output Off)	STO Mode (Torque Output Off)	STL3 Mode (Torque Output Off)	
<b>Error Displayed on Keypad</b>	No error displayed	STL2	STL1	STO	STL3	
<b>Response Time</b>	n/a	≤20ms				
<b>Method of Reset</b>	n/a	Cycle power to drive	Cycle power to drive	Press RESET directly	Cannot reset; Internal Drive failure	
<p><u>Definitions</u></p> <ul style="list-style-type: none"> <li>• STO = Channel 1 and 2 operate simultaneously and enter Safe Torque Off</li> <li>• STL1 = Channel 1 operates</li> <li>• STL2 = Channel 2 operates</li> <li>• STL3 = There is an error detected in the internal loop of channel 1 or channel 2</li> <li>• STO1-SCM/STO2-SCM ON = STO1-SCM/STO2-SCM inputs a power supply &gt; 11VDC</li> <li>• STO1-SCM/STO2-SCM OFF = STO1-SCM/STO2-SCM inputs a power supply &lt; 5VDC</li> </ul> <p><i>STO alarm is the expected method of Emergency Stop. Both channels open at the same time.</i></p>						

**INTERNAL STO CIRCUIT WIRING DIAGRAMS**

The GS30 series provides a Safe Torque Off (STO) function. The GS30 uses dual-channel STO1 and STO2 signal inputs to turn off IGBT switching, further preventing the generation of motor torque in order to achieve a safe stop.

The GS30 Safe Torque Off function meets the following international standards:

- ISO 13849-1: 2015 Category 3 PL d
- IEC 61508 SIL2
- EN 62061 SIL CL 2
- EN 60204-1 Category 0

### **CONTROL LOOP WIRING**

The illustration below shows the internal circuit diagram of the safe control loop. The terminals of the safe control loop + 24V-STO1-STO2 are short-circuited together with the jumper wire at the factory.

Refer to the safe control loop wiring diagram below:

- 1) Remove the jumper wire from +24V-STO1-STO2.
- 2) The wiring is shown below. Normally, you must close the ESTOP contact switch, so the drive can output without displaying an error.
- 3) In STO mode, the switch ESTOP is turned on. The drive stops outputting and the keypad displays STO.

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*NOTE: \*1 is factory jumper wire shorting +24V-STO1-STO2. To use the Safety function, remove this jumper wire. To disable the Safety function, short-circuit +24V-STO1-STO2 with a jumper wire.*

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**STO PARAMETERS**

Use P06.44 to specify the reset method when an STO alarm occurs.

	Type	Hex Addr	Dec Addr
<b>P06.44 STO Latch Selection</b>	◆R/W	062C	41581
<i>Range/Units (Format: 16-bit binary)</i>	<i>Default</i>		
0: STO Latch	0		
1: STO No Latch			

Use P06.44 to select STO latch.

- P06.44 = 0: STO Alarm Latch. After you clear the cause of the STO Alarm, use a Reset command to clear the STO Alarm.
- P06.44 = 1: STO Alarm no Latch. After you clear the cause of the STO Alarm, the STO Alarm clears automatically.

All of the STL1–STL3 errors are “Alarm Latch” mode (in STL1–STL3 mode, the P06.44 function is not available).

	Type	Hex Addr	Dec Addr
<b>P02.35 External Operation Control Selection after Reset and Reboot</b>	◆R/W	0223	40548
<i>Range/Units (Format: 16-bit binary)</i>	<i>Default</i>		
0: Disable	0		
1: Drive runs if the RUN command remains after reset or reboot.			

P02.35 allows the drive to resume running after a reset or reboot if an external control is still commanding it to RUN.

Setting value 1:

- Situation 1: After the drive is powered up and the external terminal for RUN stays ON, the drive runs.
- Situation 2: After clearing a detected fault and while the external terminal for RUN stays ON, you can run the drive by pressing the RESET key.

**NOTE:** When Safe Torque Off (STO) alarms STL1 or STL2 are activated, a power cycle is required to reset the drive. When P02.35 is set to 1, the drive will start on power-up while performing this reset condition.

	Type	Hex Addr	Dec Addr
<b>P02.13 Multi-function Output 1 (R1)</b>	◆R/W	020D	40526
<i>Range/Units (Format: 16-bit binary)</i>	<i>Default</i>		
66: SO output logic A	11		
68: SO output logic B			

Use P02.13 to set the STO functions of multi-function terminal R1.

Drive Status	Safety Output
–	NO (P02.13=66)
Normal Run	open
STO	close
STL1~STL3	close

### **TIMING DIAGRAM DESCRIPTION**

The following timing diagrams show the status of relevant signals under different conditions.

#### **NORMAL OPERATION STATUS**

When STO1–SCM and STO2–SCM are ON (STO function is not required), the drive executes Operating or Output Stop according to RUN command.

#### **STO, P06.44=0, P02.35=0**

*(External operation control selection after reset / reboot, 0=disable)*

When both STO1–SCM and STO2–SCM are OFF during operation (STO function is required), the drive stops outputting when it enters safe mode regardless of whether the RUN command is in ON or OFF status.

### **STO, P06.44=0, P02.35=1**

*(External operation control selection after reset / reboot, 1= drive runs if the RUN command remains after reset or reboot)*

The action is the same as in the previous example; however, because P02.35=1, if the RUN command remains after reset, the drive immediately executes the RUN command again.

### **STO, P06.44=1**

When both of STO1–SCM and STO2–SCM are OFF during operation (STO function is required), the drive stops outputting. When the STO1 / STO2 status is restored (ON), the STO alarm clears automatically. The drive outputs when the RUN command is executed again.

### ***STL1, P06.44=0 OR 1***

When STO1–SCM is OFF during operation (STO function is required) and STO2–SCM is ON (STO function is not required), the drive stops outputting and the keypad shows the STL1 error. However, you cannot reset the STL1 error even if the STO1 status is restored (ON) regardless of the parameter setting. You must cycle the power to reset and to restore the drive to the normal standby state.

### ***STL2, P06.44=0 OR 1***

When STO1–SCM is ON during operation (STO function is not required) and STO2–SCM is OFF (STO function is required), the drive stops outputting and the keypad shows the STL2 error. However, you cannot reset the STL2 error even if the STO2 status is restored (ON) regardless of the parameter setting. You must cycle the power to reset and to restore the drive to the normal standby state.



**ERROR CODE AND TROUBLESHOOTING INSTRUCTIONS**

**ERROR CODE DESCRIPTION**

Refer to P06.17–P06.22 for the fault record; the relevant STO error codes are 72/76/77/78. The definition is described below.

		<i>Type</i>	<i>Hex Addr</i>	<i>Dec Addr</i>
<b>P06.17</b>	<b>Fault Record 1</b>	Read	0611	41554
<b>P06.18</b>	<b>Fault Record 2</b>	Read	0612	41555
<b>P06.19</b>	<b>Fault Record 3</b>	Read	0613	41556
<b>P06.20</b>	<b>Fault Record 4</b>	Read	0614	41557
<b>P06.21</b>	<b>Fault Record 5</b>	Read	0615	41558
<b>P06.22</b>	<b>Fault Record 6</b>	Read	0616	41559

*Range/Units (Format: 16-bit binary)*

- 72: STO Loss (SrL1)
- 76: STO (SrO)
- 77: STO Loss 2 (SrL2)
- 78: STO Loss 3 (SrL3)

*Default*

0

<b>Error Code</b>	<b>Name</b>	<b>Description</b>
72 (SrL1)	STO Loss 1	STO1–SCM1 internal loop detection error
76 (SrO)	Safe Torque Off	Safe Torque Off function active
77 (SrL2)	STO Loss 2	STO2–SCM2 internal loop detection error
78 (SrL3)	STO Loss 3	STO1–SCM1 and STO2–SCM2 internal loop detection error

**TROUBLESHOOTING INSTRUCTIONS**

Refer to the following instructions for troubleshooting when STO / STL1 / STL2 / STL3 appear on the keypad (refer to Fault Codes in Chapter 6 for details).

<b>STO Fault Codes</b>												
<b>ID Number</b>	<b>Keypad Display</b>	<b>Description</b>										
72	SrL1	STO1–SCM1 internal loop detection error.										
		<table border="1"> <thead> <tr> <th><b>Cause</b></th> <th><b>Corrective Action</b></th> </tr> </thead> <tbody> <tr> <td>STO1 and SCM1 short circuit lines are not connected.</td> <td>Re-connect the short circuit line.</td> </tr> <tr> <td>Hardware failure</td> <td>After you make sure all the wiring is correct, if STL1 fault still exists after cycling the power, contact AutomationDirect technical support..</td> </tr> <tr> <td>Poor connection of the IO card</td> <td>1) Check if the PIN of the IO card is broken. 2) Check if the IO card connects to the control board correctly, and if the screws are tightened well.</td> </tr> <tr> <td>The IO card does not match the version of the control board</td> <td>Contact AutomationDirect technical support.</td> </tr> </tbody> </table>	<b>Cause</b>	<b>Corrective Action</b>	STO1 and SCM1 short circuit lines are not connected.	Re-connect the short circuit line.	Hardware failure	After you make sure all the wiring is correct, if STL1 fault still exists after cycling the power, contact AutomationDirect technical support..	Poor connection of the IO card	1) Check if the PIN of the IO card is broken. 2) Check if the IO card connects to the control board correctly, and if the screws are tightened well.	The IO card does not match the version of the control board	Contact AutomationDirect technical support.
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The IO card does not match the version of the control board	Contact AutomationDirect technical support.											

STO Fault Codes (continued)												
ID Number	Keypad Display	Description										
76	Sro	Safe Torque Off function active.										
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77	SrL2	STO2–SCM2 internal loop detection error.										
		<table border="1"> <thead> <tr> <th>Cause</th> <th>Corrective Action</th> </tr> </thead> <tbody> <tr> <td>STO2 and SCM2 short circuit lines are not connected</td> <td>Re-connect the short circuit line.</td> </tr> <tr> <td>Hardware failure</td> <td>After you make sure all the wiring is correct, if STL2 fault still exists after cycling the power, contact AutomationDirect technical support.</td> </tr> <tr> <td>Poor connection of the IO card</td> <td>1) Check if the PIN of the IO card is broken. 2) Check if the IO card connects to the control board correctly, and if the screws are tightened well.</td> </tr> <tr> <td>The IO card does not match the version of the control board</td> <td>Contact AutomationDirect technical support.</td> </tr> </tbody> </table>	Cause	Corrective Action	STO2 and SCM2 short circuit lines are not connected	Re-connect the short circuit line.	Hardware failure	After you make sure all the wiring is correct, if STL2 fault still exists after cycling the power, contact AutomationDirect technical support.	Poor connection of the IO card	1) Check if the PIN of the IO card is broken. 2) Check if the IO card connects to the control board correctly, and if the screws are tightened well.	The IO card does not match the version of the control board	Contact AutomationDirect technical support.
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		STO2 and SCM2 short circuit lines are not connected	Re-connect the short circuit line.									
Hardware failure	After you make sure all the wiring is correct, if STL2 fault still exists after cycling the power, contact AutomationDirect technical support.											
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78	SrL3	STO1–SCM1 and STO2–SCM2 internal loop detection error.										
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The IO card does not match the version of the control board	Contact AutomationDirect technical support.											

**TEST AND FAULT CONFIRMATION**

After wiring the STO circuit in accordance with the wiring diagram, follow the steps below to verify that the STO and related detection functions work normally.

- 1) When the drive is powered on, make sure that the STO1–SCM and STO2–SCM voltage falls between 11–30 VDC. At this time, the drive should enter Standby mode and wait for RUN command. There is no error displayed on the keypad.
- 2) Press RUN on the keypad and use the emergency button or other method to make the STO1–SCM and STO2–SCM voltage fall between 0–5 VDC. At the same time, after the output frequency is reached, the drive should enter Torque Stop mode STO and stop outputting voltage. The keypad displays the STO error, and the response time of the STO1 and STO2 signals to cause the drive to stop outputting voltage should be  $\leq 20$  ms. Then restore the STO1–SCM and STO2–SCM voltage to 11–30 VDC, and press RESET button on the keypad to clear the STO error. The drive should enter Standby mode and wait for RUN command.
- 3) Press RUN on the keypad and use the emergency button or other method to make the STO1–SCM voltage fall between 0–5 VDC, and the STO2–SCM voltage remain between 11–30 VDC after the output frequency is reached. At this time, the drive should enter Torque Stop mode STL1 and stop outputting voltage. The keypad displays the STL1 error, and the response time of STO1 signals to cause the drive to stop outputting voltage should be  $\leq 20$  ms. Then restore the STO1–SCM voltage to 11–30 VDC. However, pressing RESET button on the keypad cannot clear the STL1 error. You must cycle the power to the drive. Make sure that the STO1–SCM and STO2–SCM voltage falls between 11–30 VDC and then cycle the power to the drive, then the STL1 error is cleared. The drive should enter Standby mode and wait for RUN command.
- 4) Press RUN on the keypad and use the emergency button or other method to make the STO2–SCM voltage fall between 0–5 VDC, and the STO1–SCM voltage remain between 11–30 VDC after the output frequency is reached. At this time, the drive should enter Torque Stop mode STL2 and stop outputting voltage. The keypad displays the STL2 error, and the response time of the STO2 signals to cause the drive to stop outputting voltage should be  $\leq 20$  ms. Then restore the STO2–SCM voltage to 11–30 VDC. However, pressing RESET button on the keypad cannot clear the STL2 error. You must cycle the power to the drive. Make sure that the STO1–SCM and STO2–SCM voltage falls between 11–30 VDC and then cycle the power to the drive, then the STL2 error is cleared. The drive should enter Standby mode and wait for RUN command.
- 5) If you can conduct these four steps normally in sequence with no other error, then the Safe Torque Off function loop is normal. However, if you get a different result or if STL3 occurs, then the Safe Torque Off function loop does not work normally. Refer to the Error Code and Troubleshooting section for details.

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