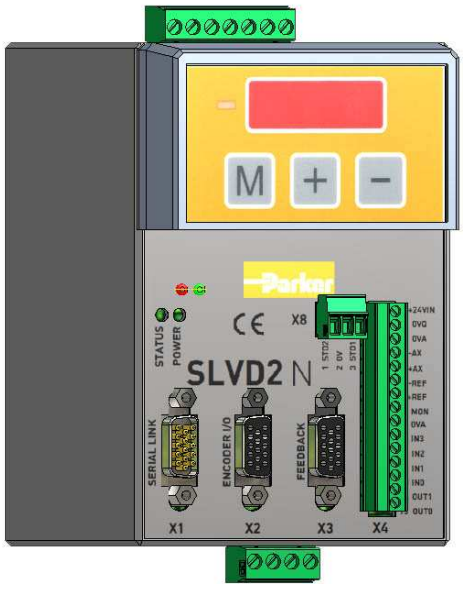
SLVD-N

SLVD1N SLVD2N
SLVD5N SLVD7N
SLVD10N SLVD15N
SLVD17N



Safe Torque Off

rev. preliminary
February 2010

1 Safe torque off

1.1. Introduction

The drive ordered with “R” option are manufactured and validated to implement category 3 PL = e, safe torque off (STO) as described in UNI EN ISO 13849-1.
By mean of this function it is possible to guarantee that unwanted restart of the motor movements will not be allowed, even without using electromechanical switches between drive and motor.
Drives labelled with “R” options are equipped of safe torque off function.
If external influences are present, additional measures may be necessary to prevent any hazard; for example, if there are falling suspended loads, mechanical brakes may be necessary.
The architecture adopted for safe torque off circuit consists of two redundant channels with cross-monitor. The input of the safety circuit is replicated (STO INPUT 1 and STO INPUT 2) because the safety circuit is made by two equal safety channels. If one channel does not work correctly because a single internal fault, the other channel performs correctly the safety function. The cross monitor controls that the outputs of the two STO channel are equal to detect failure and prevent hazardous situation.
If the safety function is activated, the optocouplers that drive the power semiconductors of the output stage are disabled, allowing no torque on the shaft of the motor. The power supply of the power board is not switched off, the DC BUS is at its nominal voltage.

WARNING

The safety function prevents from torque generation in an squirrel cage induction motor connected to the drive even if a drive fault does occur.
If a permanent magnet synchronous motor (brushless) is connected, a short rotation may occurs: 180° maximum, that becomes 90° maximum in c ase of salient poles technology motors.
Machines risk assessment activity must take care of this fact.

WARNING

The safety function does not provide an electrical shock prevention, so in case of service activity on electrical connections, electrical power must be disconnected from drive and operator must wait for the complete discharge of all internal capacitors (almost 6 minutes).

WARNING

The safety function inhibits the power stage of the drive including dynamic brake power stage: for this reason when the safe disable signal is activated a fast emergency stop will not be allowed.

WARNING

The user must carry out a periodical functional test of the safety function for the whole safety systems of the machine/application.

WARNING

The safety function guarantees machine safety only if it is correctly applied in the whole machine safety plant.
The machine have to be verified through a risk assessment activity to be sure that the residual risk of a dangerous event is compatible with risk class of the machine itself.
Safety related systems and plants have to be designed by people skilled and trained as required.
The main international standards and guidelines relating to security systems of electric motor driver were been adopted for the generation of safety requirements:

- CEI EN 61508-2:2000.
- CEI EN 61800-5-2:2009
- UNI EN ISO 13849-1
- CEI EN 61800-5-1:2009.
- CEI EN 61800-3:2004

According to EN ISO 13849-1, the method of performance level (PL) evaluation considers 20 years as period of use. The maximum performance level achievable is “e”. UNI EN ISO 13849-1 reports the relationship between performance level and safety integrity level capability.

PL = e	SIL = 3	10-8 ≤ PFHd < 10-7

with PFHd (average probability of dangerous failure per hour).

Ambient conditions:

temperature	operation	3K3 Class, 0 … +45 ℃ (+32 …+113 ℉)
	storage	1K4 Class, -25 … +55 ℃ (-4 …+131 ℉)
	transportation	2K3 Class, -25 … +70 ℃ (-13…+158 ℉)
humidity (3K3 class)	operation	3K3 Class, 5-85 % without ice and condensation
	storage	1K3 Class, 5-95 % without ice and condensation
	transportation	2K3 Class, 95% a 40℃
altitude (*)		≤ 1000 m slm (≤ 3281 feet asl)
Protection degree		IP20 (only in close electric cabinet) UL open type equipment
Pollution degree		2 or lower (no conductive dust allowed)

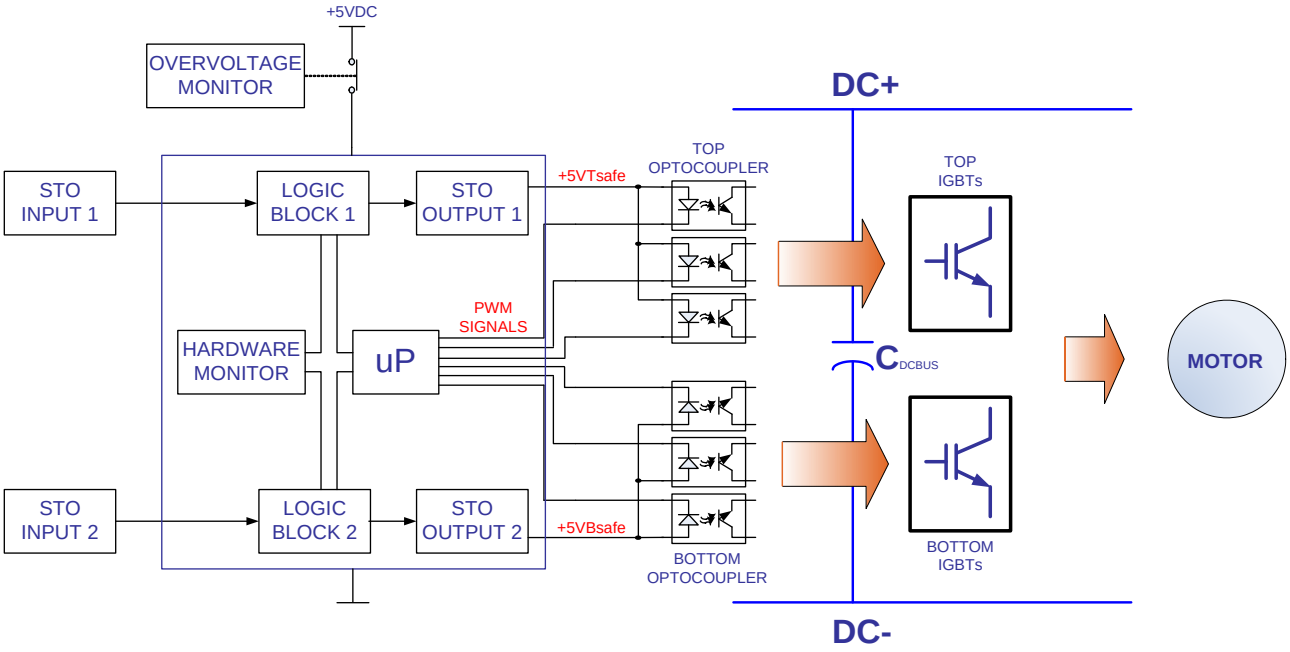
(*) For higher installation altitude, derate the output current by 1.5% each 100m up to 2000m maximum

Vibrations and shocks:

	frequency [Hz]	Width [mm]	acceleration [m/s^2]
working (3M1 class)	2 ≤ f < 9	0,3	-
	9 ≤ f < 200	-	1
transportation (2M1 class)	2 ≤ f < 9	3,5	-
	9 ≤ f < 200	-	10
	200 ≤ f < 500	-	15
	Free fall 0,25 meters max		

1.2. Safe torque off description:

In figure below, it is depicted a simplified schematic of the safety function with the top and bottom optocouplers and the power semiconductors that drive the motor. If the motor is in run condition and the safe torque off is activated, the optocouplers that drive the control voltage of the power semiconductors of the output stage are disabled, allowing no torque on the shaft of the motor. The power supply of the power board is not switched off, the DC BUS is at its nominal voltage.
The STO OUTPUT 1 is the electrical signals +5VTsafe, it controls the top optocouplers depicted in the picture below. If +5VTsafe signal is low (0V), the top optocouplers that drive top IGBTs shut down and no torque can be present at the motor shaft.
The STO OUTPUT 2 is the electrical signals +5VBsafe, it controls the bottom optocouplers depicted in the picture below. If +5VBsafe signal is low (0V), the optocouplers that drive bottom IGBTs shut down and no torque can be present at the motor shaft.



STO function is active low. If the inputs, STO IN 1 and STO IN 2, are high, the output signals, +5VTsafe and +5VBsafe are high (+5V), and the optocouplers that drive top and bottom IGBTs are enabled. If STO IN 1 and STO IN 2 input are low, +5VTsafe and +5VBsafe signals are low and top and bottom optocouplers shutdown.
If one channel does not work correctly, because a single internal fault, the other channel performs correctly the safety function.

The outputs signals are cross-monitored by a hardware monitor that checks if these signals are equals. If the outputs became different (+5VTsafe ≠ +5VBsafe) and remain different for less than 7s ($\Delta T < 7s^*$), the hardware monitor does not attend in this operation and STO outputs depend only by STO inputs.

If the outputs became different and remain different for a time greater than 7s, ($\Delta T > 7s^*$), the hardware monitor set up a latch which disables permanently both the output signals: +5VTsafe = +5VBsafe = 0V. To restore the latch it is necessary to turn off and on the 24V DC power supply of the drive.
In practice, a time tolerance of about 3 seconds must be considered. Time is evaluated as a voltage across a capacitor; the capacitors are affected by tolerance. Moreover, the voltage across the capacitor may increase in different ways, for examples if one STO output is fixed and the other is switched on and off.
So, if the outputs became different (+5VTsafe ≠ +5VBsafe) and remain different for a $\Delta T <$ 4s hardware monitor does not attend, if the outputs became different (+5VTsafe ≠ +5VBsafe) and remain different for $\Delta T >$ 10s hardware monitor wake up and sets both +5VTsafe = +5VBsafe = 0.
The outputs signals are also monitored by microprocessor. The digital signals that arrived to the microprocessor are labeled STO1mon and STO2mon. If almost one of these signals is low the micro-processor disables all 6 PWM signals that control the optocouplers, allowing no power at the motor. STO1mon and STO2mon are represented respectively by the read only binary parameters Pr230.12 and Pr230.13 available to the user.
The safety function is designed to prevent hazardous situation in the case of power supply switch off. If the 24V DC supply is switched off, +5VTsafe and +5VBsafe go to low value and top and bottom optocouplers switch off.

Signal description

In the table below are represented the voltage value of inputs signals of the STO circuit:

	LOW		HIGH	
	NOMINAL	INPUT RANGE	NOMINAL	INPUT RANGE
STO IN 1	0	(0 ÷ 1)	+24V	(22 ÷ 26)
STO IN 2	0	(0 ÷ 1)	+24V	(22 ÷ 26)

In the next tables are represented the value of output signals of the STO circuit and digital parameters (read only):

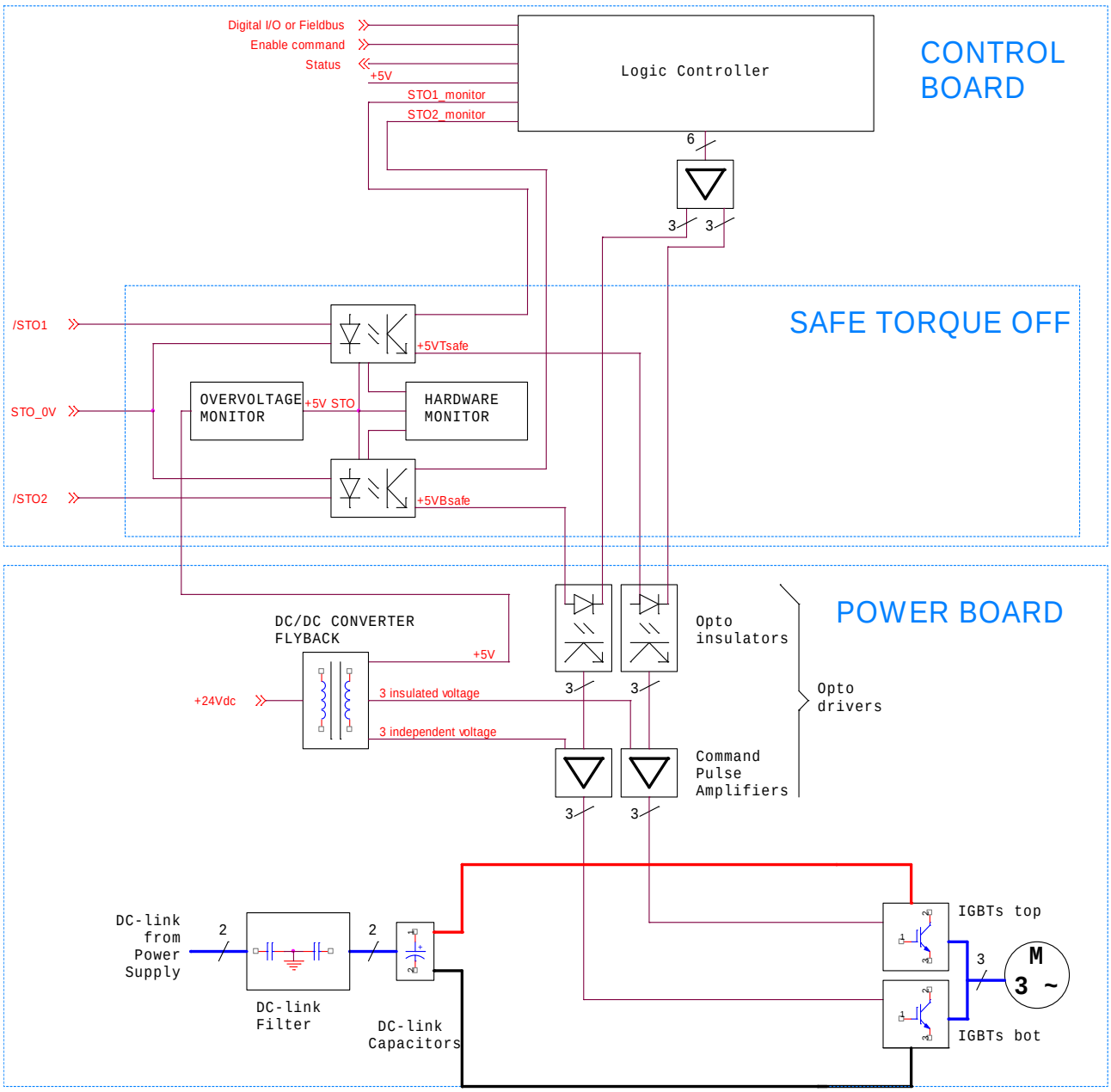
STO OUT 1	+5VTsafe	STO1mon	Pr230.12
LOW	0V	0	0
HIGH	+5V (4 ÷ 6V)	1	1

STO OUT 2	+5VBsafe	STO2mon	Pr230.13
LOW	0V	0	0
HIGH	+5V (4 ÷ 6V)	1	1

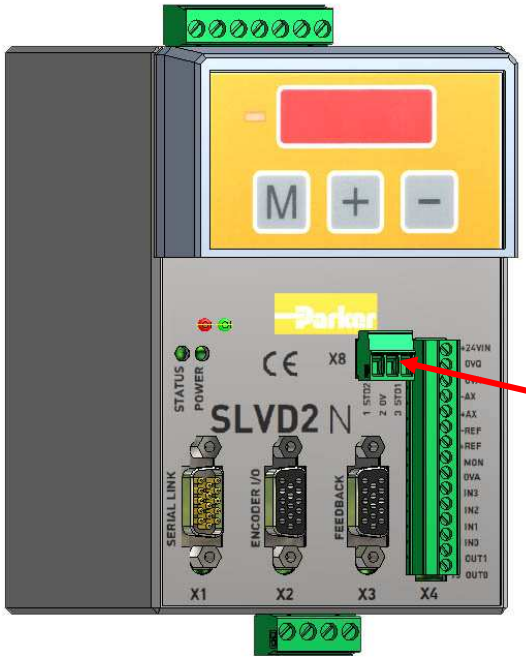
Characteristics:

STO	U. M.	Description
Nominal voltage	Vdc	24
Inputs	-	2
Current at 24Vdc	mA	16
Life time	years	20

1.3. Drive function blocks

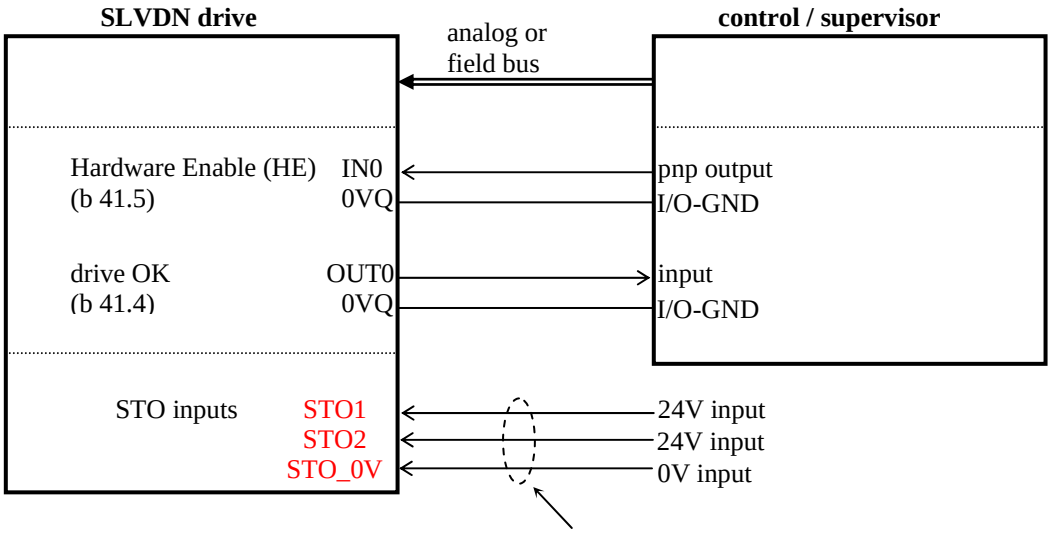


1.4. Electrical connections



3 poles connector X8 – STO inputs	
1	STO2
2	STO_0V
3	STO1

The following diagram shows how to use the safe torque off. They should be considered as a generic reference example. Any specific machine/application design must be analysed.



The user must exclude the risk of any short circuit. Cable installation in the cabinet according to the EN directives. The user must insert external fuse for 24VDC supply between the safe disable wiring and the 24V supply. Segregate the wiring in a dedicated raceway or use a shielded wire with grounded shield. The safety function guarantees machine safety only if it is correctly applied in the whole machine safety plant.

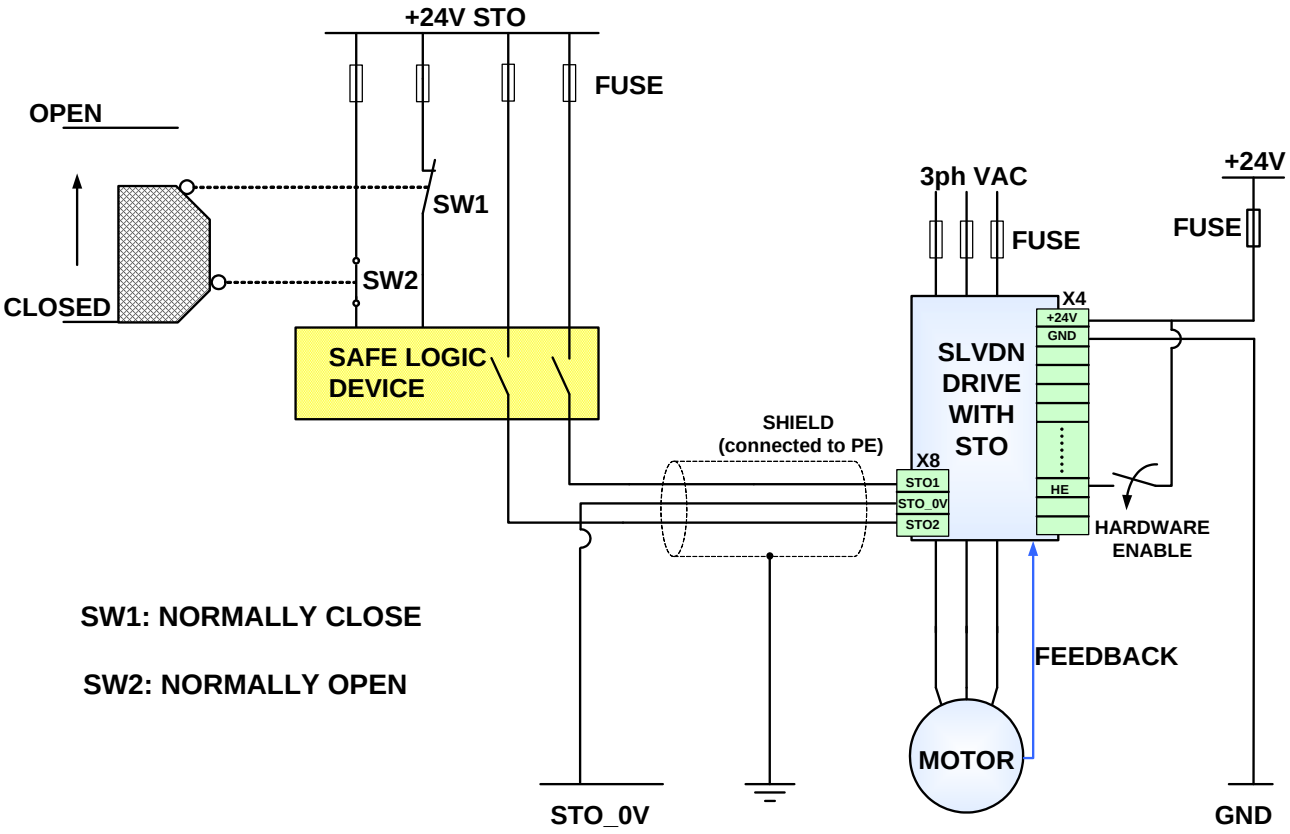
EXAMPLES OF POWER DRIVE SYSTEMS WITH SAFETY FUNCTION

Next, there are some examples of power drive systems with safety function. Consider that these schematics are not exhaustive. For each single installation the user must evaluates the risk reduction according to related standards.
STO inputs are optoisolated from the rest of the safety circuit, so, it is mandatory to use a +24VDC supply dedicated only for the safety inputs. In the next pictures, safety circuit supply is referred as +24VSTO, STO_0V.

Safety related stop function with door switch

Opening of the safety guard initiates the safety function STO.

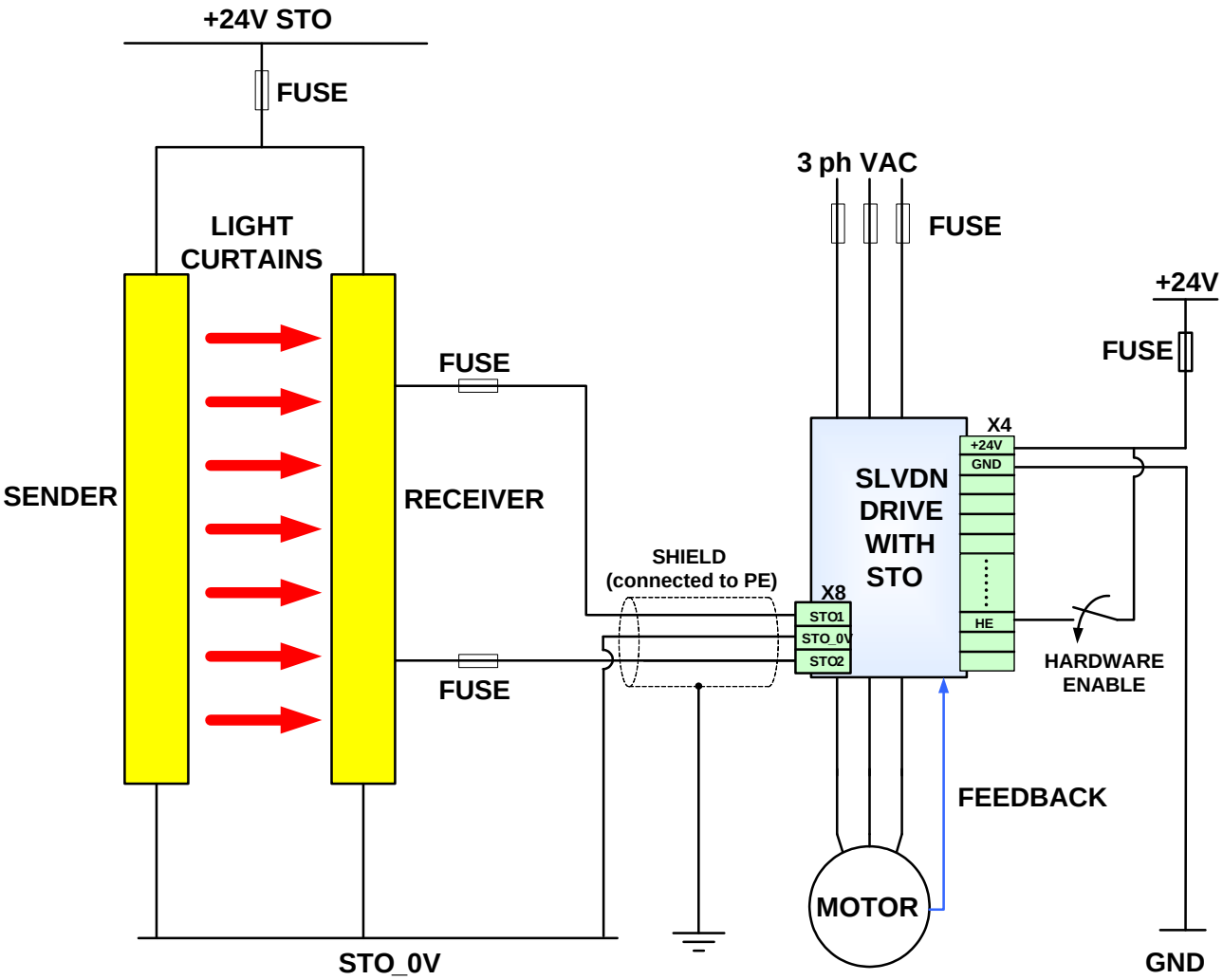
Category 3, maximum risk reduction achievable PL e.



Safety related stop function with light curtains

If the light is interrupted the safety function STO is initiated.
The outputs of the light curtains receiver are high (+24V), if the light is received.
The outputs of the light curtains receiver are low (0V), if the light is not received.

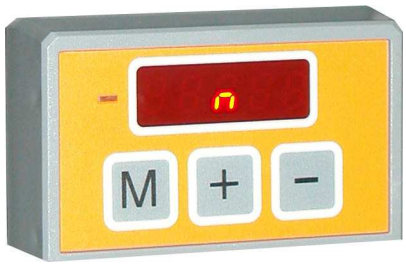
Category 3, maximum risk reduction achievable PL e.



1.5. Operation, sequence and timing

The drive can be in one of these status:

1. **NOT READY**
   - In this mode no alarms are present, power supply of power stage is off. Hardware and/or software enable are disabled. The driver is not ready because it is in the under voltage condition.
   - STO is active. In this condition no power can be present on the motor. The user sees “n” on the display: Pr230.12 = 0 and Pr230.13 = 0.

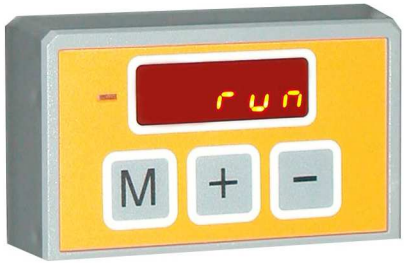


2. **READY – IDLE**

When the power supply of the power stage is switched on, the DC BUS voltage becomes nominal value according to voltage input. Hardware and/or software enable are disabled.
In IDLE condition, STO is not activated, no power on shaft motor.

3. **RUN**

In this condition the 24V DC is on, DC BUS is at nominal voltage. The hardware and software enable are enabled. STO is not active: Pr230.12 = 1 and Pr230.13 = 1. There is torque on the motor shaft.

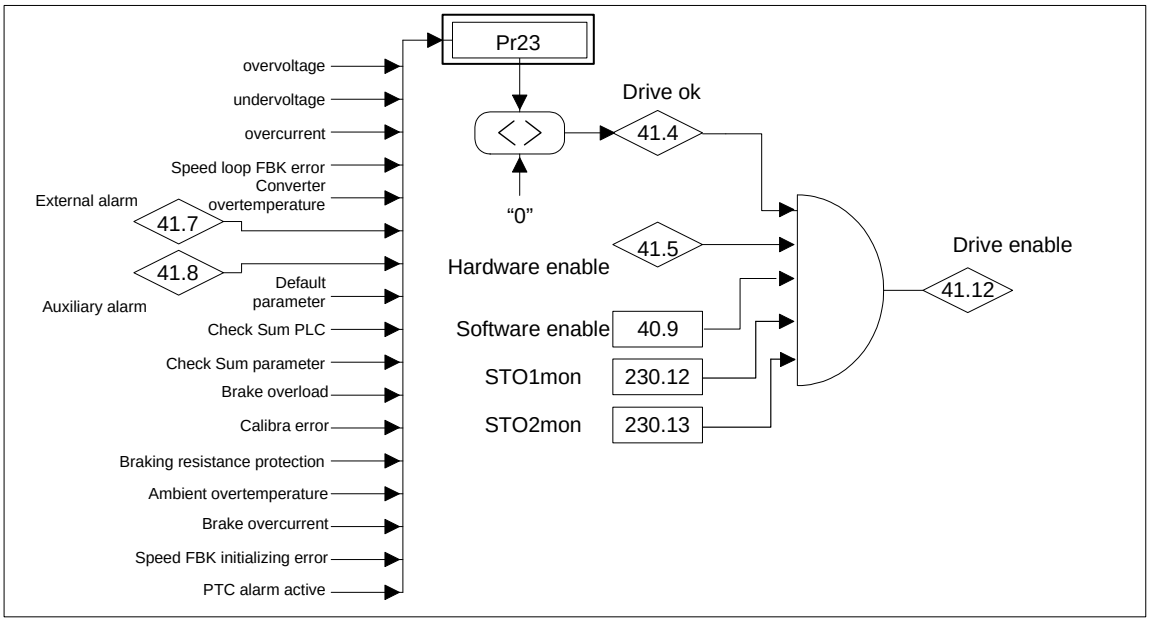


4. ERROR - ALARM

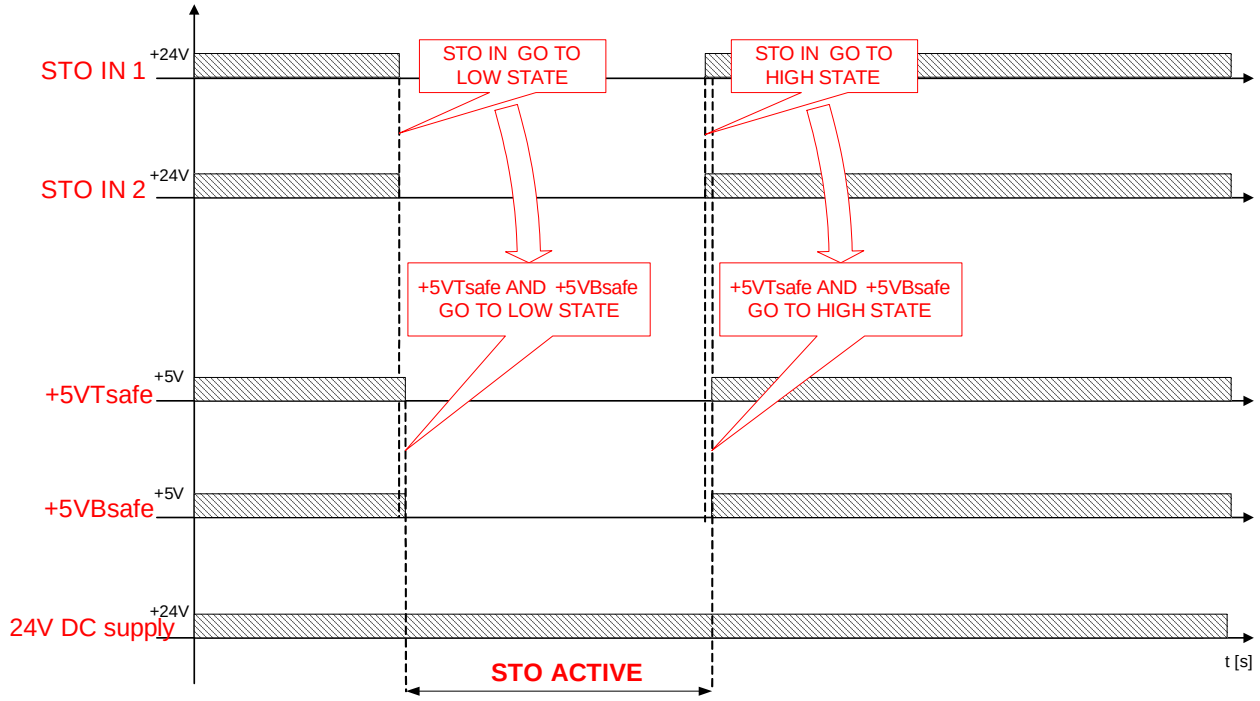
The drive is in alarm and it is disabled because an error is present. STO is not active. No power can be present on the motor, because the axis is disabled. In alarm condition a “Er” is displayed even when STO is activated.
As depicted in the picture below ALARM does not interact with safe torque off.
If STO is activated, the drive is in ALARM + STO condition; no power can be present on the motor.

The drive enable (b41.12) depends to the drive status (b41.4, b41.5 and b40.9), and to the STO monitor:

b230.12 : STO1 monitor (0= STO actives; 1= STO not actives);
b230.13 : STO2 monitor (0= STO actives; 1= STO not actives).



In figure below, it is represented the STO signals timing diagram. It is supposed that no fault are present in the safety circuit, so if STO INPUT 1 = STO INPUT 2 than +5VTsafe = +5VBsafe (the hardware monitor does not attends):



Warning :

in case of alarm during operation, the drive is automatically disabled. Therefore the capability of stopping the motor in a controlled way is lost. The motor will stop with its natural dynamic depending on the total inertia, friction and load torque. The same happens if the safety function STO is activated before the motor has been stopped in a controlled way.

1.6. Proof test

Necessary requisites:

SLVD-N Keypad; or in alternative a PC with tool MotionWiz installed.

The check must be made by qualified and trained personnel, and following all necessary safety precautions.

Test step	Action, activity	Expected reaction and effect	Status	Pr230.12	Pr230.13
1	Apply 24V DC tension on terminals STO1 and STO2.				
2	Switch on 24V DC drive voltage supply.				
3	– Configuring device, if it is not programmed (Er.25) and restart the device. – Switch on the power supply.	No error must be present (reset the alarm by the command b99.10)	IdLE	1	1
4	Test STO on STO1 terminal: Remove 24V DC at STO1 terminal longer than 10 sec.	STO is active. hardware monitor is activated after about 7sec	⊓	0	1 → 0 (after about 7sec)
5	Restore 24V DC at STO1 terminal	STO is active. hardware monitor remains active	⊓	0	0
6	switch off and on 24V DC drive voltage supply	STO is not active. No error must be present	IdLE	1 after switch on	1 after switch on
7	Test STO on STO2 terminal: Remove 24V DC at STO2 terminal longer than 10 sec.	STO is active. hardware monitor activated after about 7sec	⊓	1 → 0 (after about 7sec)	0
8	Restore 24V DC at STO2 terminal	STO is active. hardware monitor remains active	⊓	0	0
9	switch off and on 24V DC drive voltage supply	STO is not active. No error must be present	IdLE	1 after switch on	1 after switch on
10	Test STO on STO1 terminal: Remove 24V DC at STO1 terminal no longer than 4 sec.	STO is active. hardware monitor is not activated	⊓	0	1

Test step	Action, activity	Expected reaction and effect	Status	Pr230.12	Pr230.13
11	Restore 24V DC at STO1 terminal	STO is not active. No error must be present	IdLE	1	1
12	Test STO on STO2 terminal: Remove 24V DC at STO2 terminal no longer than 4 sec.	STO is active. hardware monitor is not activated	⊓	1	0
13	Restore 24V DC at STO2 terminal	STO is not active. No error must be present	IdLE	1	1
14	Test STO on STO1 and STO2 terminals: Remove 24V DC at STO1 and STO2 terminals	STO is active. hardware monitor is not activated	⊓	0	0
15	Restore 24V DC at STO1 and STO2 terminals	STO is not active. No error must be present	⊓	1	1

WARNING

The functionality must specifically be verified at commissioning, after any kind of maintenance operation on the machine (wiring, replacement of parts etc...) and before any potentially dangerous circumstance for personnel (need to access machine dangerous zones).

WARNING

The user must carry out a periodical functional test for the safety systems of the machine.
The frequency of testing should be determined by the machinery builder; consider that the safety function STO has to be tested once a week at least.
The machinery builder must set a suitable test method, for example, providing an automatic test initiated by PLC or providing a periodic test by worker or providing a test by opening a guard door during the normal work process (depending on application).

STO test log

Data:

Drive name: SLVD-N

Serial number: _____

PCB name: _____

PCB Serial number:_____

Name of the examiner:_____

STO function test:

STO function test step 1-9: ☐ successfully examined

STO function test step 10-13: ☐ successfully examined

STO function test step 14-15: ☐ successfully examined

All steps from 1-15 successfully examined: ☐ yes ☐ no

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