Standstill monitoring with 3TK2810-0 and 3TK2845 according to SIL 3 per EN 62061 or PL e per EN ISO 13849-1:2006

SIRIUS Safety

Application description • September 2012

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SIRIUS Safety
Standstill monitoring with 3TK2810-0 and 3TK2845

according to SIL 3 per EN 62061 or
PL e per EN ISO 13849-1:2006

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1 Application description

1.1 Aim of the application

Introduction

In machines in which machine movement or moving parts can pose a hazard to people and machinery, the hazardous movement can be monitored with a standstill monitor.

Description of the automation task

If people (e.g. in manufacturing) work anywhere near machines, technical means must be used to provide appropriate protection.

This Safety Functional Example describes monitoring a speed and a protective device providing physical separation in the form of a protective door. One solution in the area of equipment and machines is to protect hazard areas by means of guard elements or access flaps which ensure mechanical separation. The aim here is to monitor unauthorized access to parts of a plant or equipment and to prevent hazardous machine functions when the guard door / flap is opened.

Standstill of a machine is to be monitored. Standstill is acquired using a 3TK2810-0 standstill monitor.

If the emergency stop device or the ON/OFF switch is operated, the safety relay opens downstream contactors Q1 and Q2 via the safe outputs with a positively driven operation in accordance with stop category 0 as indicated in EN 60204-1. When the motor is stopped, the protective door can be released by means of a door release and opened.
Before switching on again or acknowledging with the start button, a check is made that the protective door is closed and locked, the contacts of the emergency stop are closed, and both contactors are open.

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1.2 Advantages of this solution

- Certified devices
- No additional sensors required
- No software required
- Solution by wiring only

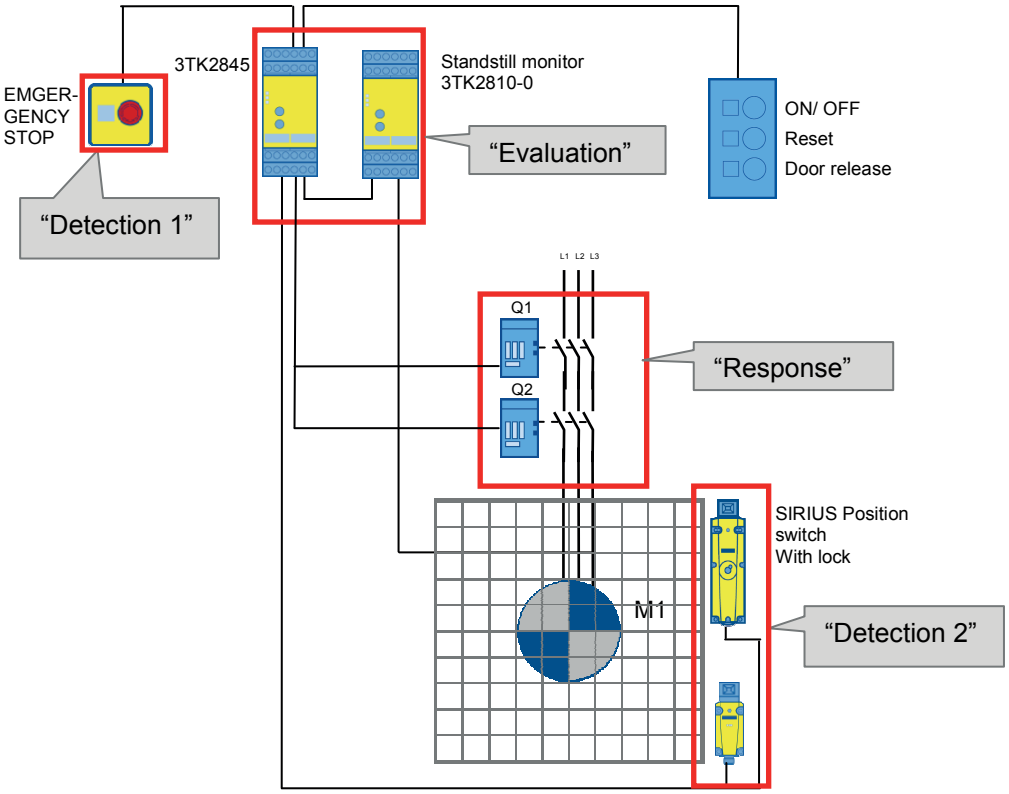
2 Configuration and wiring

2.1 Contents

Schematic

The following figure schematically shows the most important components of the solution:

Fig. 2-1



Note If the door release is operated when the motor is stopped, the protective door must be opened before starting is possible again because of discrepancy evaluation in the 3TK.

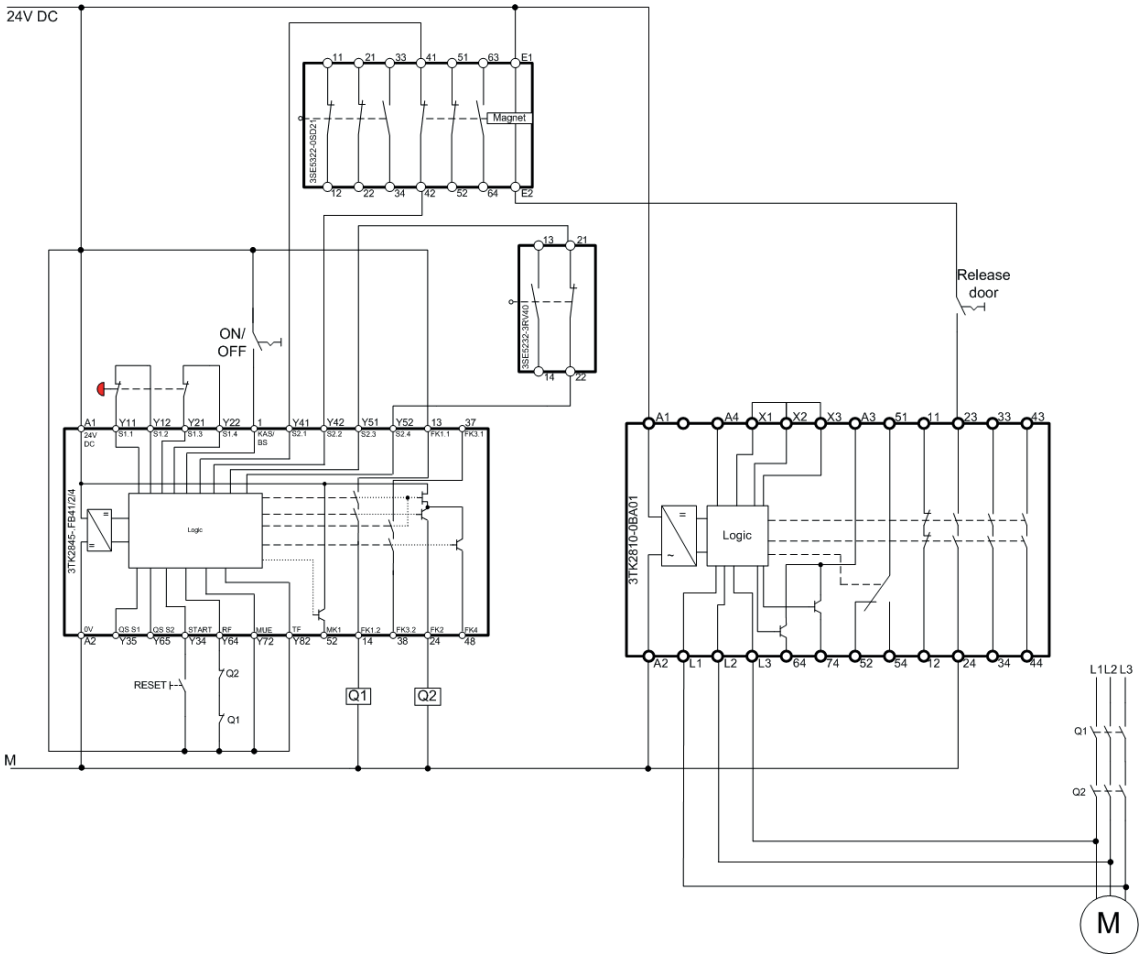
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2.2 Wiring

Installing the hardware

The following figure shows the hardware configuration of the application.

Fig. 2-2



Note Alternatively, a single-phase motor can also be monitored. You will find the connection to the main circuit in the operating instructions.
http://support.automation.siemens.com/WW/view/en/25437254

Note Alternatively, a position switch with a solenoid lock can also be used. In that case, the NC contacts 11/12 and the door release switch with the NC contact must be used simultaneously to release the door.

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2.3 Hardware and software components used

The application was created with the following components:

Hardware components

Table 2-1

Component	Qty.	MLFB / order number	Note
Multifunction device	1	3TK2845-1FB41	RC instant.: 2S, RC delayed: 1, MK: 1, spring-locked tumbler
Standstill monitor	1	3TK2810-0BA01	
Position switch	1	3SE5 232-0RV40	With separate actuator
Position switch with lock	1	3SE5322-0SD21	Spring-locked
Actuator for position switch	2	3SE5 000-0AV05	Radius actuator
Contactor Q1, Q2	2	3RT2015-1BB42	Contactor, AC-3, 3 KW / 400 V, 1NC, 24 V DC, 3-pole, size S00, screw terminal
Start button, service operation, and protective door release	1	3SB3 803-0AA3	Empty housing, three command points
	3	3SB3 420-OB	1 NO contact for floor attachment
	1	3SB3 000-0AA11	Black pushbutton with flat button, nominal diameter 22 mm
	1	3SB3000-4LD01	CES key switch
	1	3SB3000-2KA11	Knob
Emergency stop	1	3SB3 801-0EG3	Mushroom pushbutton, 2NC contactor, 40 mm, with yellow top section, without protective collar

Note The functionality was tested with the hardware components stated. Other similar products not listed above can also be used. Please note that in such a case the example code may have to be modified (e.g. use of another position switch).

Example files

The list below contains all the files and projects used in this example. You will find these on:

- http://support.automation.siemens.com/WW/view/en/51446399

Table 2-2

Component	Note
SIL3_PLe_Schutztür_Zuhaltung_ Stillstand_CD-FE-I-53.zip	<This packed file contains the project for the Safety Evaluation Tool.>

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3 Evaluation according to IEC 62061 and ISO 13849-1:2006

3.1 Safety functions

Preliminary remark

- Emergency stop is not a way of reducing the risk.
- Emergency stop is a "supplementary safety function."

Safety functions

The following safety functions are used as basis for further consideration:

Table 3-1

Supplementary Safety function	
SF 1	When "emergency stop" is operated, the motor must be shut down.

Table 3-2

Safety function	
SF 2	When "protective door" is opened, the motor must be shut down.
SF 3	While the motor is being operated, the protective door must be locked.

The safety functions stated above are evaluated according to the two standards EN 62061 and EN ISO 13849-1:2006 below.

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3.2 Evaluation safety function 1

3.2.1 Evaluation according to EN 62061

Table 3-3 Parameters for calculating PFH_D for "Detection 1" (emergency stop) and "Response" (contactor).

Parameters	Value	Reason	Rule
B10 Emergency stop Contactor	 $1 * 10^5$ $1 * 10^6$	 Specified by manufacturer	Siemens AG
Dangerous failure fraction Emergency stop Contactor	 0,2 0,75	Specified by manufacturer (20 %) (75 %)	
T1 Service life	175,200 h (20 years)	Specified by manufacturer	
C Number of emergency stop cycles Number of operating cycles of the contactors	 $6 * 10^{-3}$ / h 0.125 / h	Assumptions: Operated once per week (7 * 24 hours) (test emergency stop). One operating cycle occurs per shift, that is, once every 8 hours. Operations are performed on all days in the year (365 days).	User
T2 Diagnostic test interval Emergency stop Diagnostic test interval contactor	 168 h 8 h	 A defective contact is detected in the 3TK when the emergency stop is operated. It is operated every week (7 * 24 hours) (see "C"). A defective contactor is detected in the 3TK on operation. It is operated once per shift, that is, every 8 hours (see "C").	
β (CCF factor) Susceptibility to common-cause failures	0,1	In the case of installation according to EN 62061, a CCF factor of 0.1 (10 %) can be assumed. This value puts the calculation on the safe side ("conservative value").	
DC Diagnostics coverage	0,99 (99 %)	Discrepancy evaluation on emergency stop; evaluation of the read-back signals (forcibly guided contacts) of both contactors	

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3.2 Evaluation safety function 1

Table 3-4 Parameters for evaluation

Parameters	Component	Value	Rule
PFH_D (3TK)	3TK2845	$6{,}86 * 10^{-9}$	Siemens AG

Table 3-5 Result

	EN 62061			
	SIL CL		PFH_D	
Detection	3	Hardware failure tolerance: HFT = 1 Safe failure fraction: SFF ≥ 0.99 (99 %)	$1{,}2 * 10^{-10}$	Architecture: Basic subsystem architecture D
Evaluation	3	Specified by manufacturer	$6{,}86 * 10^{-09}$	Specified by manufacturer
Response	3	Hardware failure tolerance: HFT = 1 Safe failure fraction: SFF ≥ 0.99 (99 %)	$9{,}4 * 10^{-10}$	Architecture: Basic subsystem architecture D
Result	3	The SIL CL of all tasks of the supplementary safety function is at least 3. PFH_D (= $7.91 * 10^{-09}$) of the total supplementary safety function complies with SIL 3.		

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3.2.2 Evaluation according to ISO 13849-1:2006

Table 3-6 Parameters for calculating MTTFd for "Detection 1" (emergency stop) and "Response" (contactor)

Parameters	Value	Reason	Rule
B10		Specified by manufacturer	Siemens AG
Emergency stop	$1 * 10^5$		
Contactor	$1 * 10^6$		
Dangerous failure fraction		Specified by manufacturer	
Emergency stop	0,2	(20 %)	
Contactor	0,75	(75 %)	
d_{op}		Assumption:	User
Average operating time in days per year	365 days per year	Operations are performed on all days in the year.	
h_{op}			
Average operating time in hours per day	24 hours per day		
t_{cycle} Mean time between the beginning of two consecutive cycles of the component		Assumption:	
Emergency stop	168 h / cycle	Operating cycles of emergency stop (test emergency stop) occur at intervals of one week (7 * 24 hours).	
Contactor	8 h / cycle	Operating cycles of the contactors occur at intervals of 8 hours (one shift).	

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Table 3-7 Interim results (In this example, the interim results for emergency stop and contactor are identical)

Interim result		Reason
$MTTF_d$	high	$MTTF_d \geq 30$ years
DC	high	DC = 99 % Discrepancy evaluation on emergency stop; evaluation of the read-back signals (positively driven contacts) of both contactors
Measures against CCF	condition met	It is assumed that the user has taken the necessary measures.
Category	4	System behavior: One failure does not result in the loss of the safety function. The individual failure is detected. $MTTF_d$: high, DC: high, measures against CCF: condition met

Table 3-8 Parameters for evaluation

Parameters	Component	Value	Rule
PFH_D (3TK)	3TK2845	$6,86 * 10^{-9}$	Siemens AG

Table 3-9 Result

	ISO 13849-1:2006	
	PL	**Average probability of a dangerous failure per hour**
Detection	e	$2,47 * 10^{-08}$ (from Appendix K; see Note)
Evaluation	e	$6,86 * 10^{-09}$
Response	e	$2,47 * 10^{-08}$ (from Appendix K; see Note)
Result	e	The PL of all tasks of the supplementary safety function is at least e. Number of tasks is less than or equal to 3.

Note: The $MTTF_d$ for each channel is limited to a maximum of 100 years!

3.2.3 Summary safety function 1

Table 3-10

	EN 62061		ISO 13849-1:2006	
	SIL CL	**PFH_D**	**PL**	**Average probability of a dangerous failure per hour**
Detection	3	$1,2 * 10^{-10}$	e	$2,47 * 10^{-08}$
Evaluation	3	$6,86 * 10^{-09}$	e	$6,86 * 10^{-09}$
Response	3	$9,4 * 10^{-10}$	e	$2,47 * 10^{-08}$

Result	SIL 3	PL e

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3.3 Evaluation safety function 2

3.3.1 Evaluation according to EN 62061

Table 3-11 Parameters for calculating PFH_D for "Detection 2" (position switch) and "Response" (contactor)

Parameters	Value	Reason	Rule
B10 Position switch Contactor	 $1 * 10^6$ $1 * 10^6$	 Specified by manufacturer	Siemens AG
Dangerous failure fraction Position switch Contactor	 0,2 0,75	Specified by manufacturer (20 %) (75 %)	
T1 Service life	175,200 h (20 years)	Specified by manufacturer	
C Number of operations of the position switches Number of operating cycles of the contactors	 0.125 / h 0.125 / h	Assumptions: One operating cycle occurs per shift, that is, once every 8 hours. Operations are performed on all days in the year (365 days).	User
T2 Diagnostics test interval position switch Diagnostic test interval contactor	 8 h 8 h	 On opening the protective door, a defective contact is detected in the 3TK. It is operated once per shift, that is, every 8 hours (see "C"). A defective contactor is detected in the 3TK on operation. It is operated once per shift, that is, every 8 hours (see "C").	
β (CCF factor) Susceptibility to common-cause failures	0,1	In the case of installation according to EN 62061, a CCF factor of 0.1 (10 %) can be assumed. This value puts the calculation on the safe side ("conservative value").	
DC Diagnostics coverage	0,99 (99 %)	Discrepancy evaluation on emergency stop; Evaluation of the read-back signals (positively driven contacts) of both contactors	

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3.3 Evaluation safety function 2

Table 3-12 Parameters for evaluation

Parameters	Component	Value	Rule
PFH_D (3TK)	3TK2845	$6{,}86 * 10^{-9}$	Siemens AG

Table 3-13 Result

	EN 62061			
	SIL CL		PFH_D	
Detection	3	Hardware failure tolerance: HFT = 1 Safe failure fraction: SFF ≥ 0.99 (99 %)	$2{,}5 * 10^{-10}$	Architecture: Basic subsystem architecture D
Evaluation	3	Specified by manufacturer	$6{,}86 * 10^{-09}$	Specified by manufacturer
Response	3	Hardware failure tolerance: HFT = 1 Safe failure fraction: SFF ≥ 0.99 (99 %)	$9{,}4 * 10^{-10}$	Architecture: Basic subsystem architecture D
Result	3	The SIL CL of all tasks of the supplementary safety function is at least 3. PFH_D (= $8.04 * 10^{-09}$) of the total supplementary safety function complies with SIL 3.		

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3.3.2 Evaluation according to ISO 13849-1:2006

Table 3-14 Parameters for calculating MTTFd for "Detection 2" (position switch) and "Response" (contactor).

Parameters	Value	Reason	Rule
B10 Position switch Contactor	 $1 * 10^6$ $1 * 10^6$	Specified by manufacturer	Siemens AG
Dangerous failure fraction Position switch Contactor	 0,2 0,75	Specified by manufacturer (20 %) (75 %)	
d_{op} Average operating time in days per year	365 days per year	Assumption: Operations are performed on all days in the year.	User
h_{op} Average operating time in hours per day	24 hours per day		
t_{cycle} Mean time between the beginning of two consecutive cycles of the component Position switch Contactor	 8 h / cycle 8 h / cycle	Assumption: The protective door is opened and the contactors are operated at intervals of 8 hours (one shift).	

Table 3-15 Interim results (In this example, the interim results for emergency stop and contactor are identical)

Interim result		Reason
$MTTF_d$	high	$MTTF_d \geq 30$ years
DC	high	DC = 99 % Discrepancy evaluation for the position switches; evaluation of the read-back signals (positively driven contacts) of both contactors
Measures against CCF	condition met	It is assumed that the user has taken the necessary measures.
Category	4	System behavior: One failure does not result in the loss of the safety function. The individual failure is detected. $MTTF_d$: high, DC: high, measures against CCF: condition met

Table 3-16 Parameters for evaluation

Parameters	Component	Value	Rule
PFH_D (3TK)	3TK2845	$6,86 * 10^{-9}$	Siemens AG

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Table 3-17 Result

	ISO 13849-1:2006	
	PL	**Average probability of a dangerous failure per hour**
Detection	e	2,47 * 10^{-08} (from Appendix K; see Note)
Evaluation	e	6,86 * 10^{-09}
Response	e	2,47 * 10^{-08} (from Appendix K; see Note)
Result	e	The PL of all tasks of the safety function is at least e. Number of tasks is less than or equal to 3.

Note: The $MTTF_d$ for each channel is limited to a maximum of 100 years!

3.3.3 Summary safety function 2

Table 3-18

	EN 62061		ISO 13849-1:2006	
	SIL CL	**PFH_D**	**PL**	**Average probability of a dangerous failure per hour**
Detection	3	2,5 * 10^{-10}	e	2,47 * 10^{-08}
Evaluation	3	6,86 * 10^{-09}	e	6,86 * 10^{-09}
Response	3	9,4 * 10^{-10}	e	2,47 * 10^{-08}

Result	SIL 3	PL e

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3.4 Evaluation safety function 3

3.4.1 Evaluation according to EN 62061

Table 3-19 Parameters for calculating PFH_D for "Response 2" (lock, spring-locked)

Parameters	Value	Reason	Rule
B10 Lock	$1 * 10^6$	Specified by manufacturer	Siemens AG
Dangerous failure fraction Lock	0,2	Specified by manufacturer (20 %)	
T1 Service life	175,200 h (20 years)	Specified by manufacturer	
C Number operating cycles of the lock	0.125 / h	Assumptions: One operating cycle occurs per shift, that is, once every 8 hours. Operations are performed on all days in the year (365 days).	User
DC Diagnostics coverage	0,90 (90 %)	The feedback signal is permanently monitored by the feedback circuit input of the safety monitor.	

Table 3-20 Parameters for evaluation

Parameters	Component	Value	Rule
PFH_D (3TK)	3TK2845	$6,86 * 10^{-9}$	Siemens AG
PFH_D (3TK)	3TK2810-0	$1,49 * 10^{-9}$	Siemens AG

Table 3-21 Result

	EN 62061			
	SIL CL		PFH_D	
Evaluation	3	Specified by manufacturer	$8,35 * 10^{-09}$	Specified by manufacturer
Response	2	Hardware failure tolerance: HFT = 0 Safe failure fraction: SFF ≥ 0.90 (90 %) (SIL CL is limited to SIL 2; because of fault short-circuit, breakage of the separate actuator)	$2,5 * 10^{-10}$	Architecture: Basic subsystem architecture C
Result	2	The SIL CL of all tasks of the safety function is at least 2. PFH_D (= $8.6 * 10^{-09}$) of the total safety function complies with SIL 2.		

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3.4.2 Evaluation according to ISO 13849-1:2006

Table 3-22 Parameters for calculating $MTTF_d$ for "Response" (lock, spring-locked)

Parameters	Value	Reason	Rule
B10 Lock	$1 * 10^6$	Specified by manufacturer	Siemens AG
Dangerous failure fraction Lock	0,2	Specified by manufacturer (20 %)	
d_{op} Average operating time in days per year	365 days per year	Assumption: Operations are performed on all days in the year.	User
h_{op} Average operating time in hours per day	24 hours per day		
t_{cycle} Mean time between the beginning of two consecutive cycles of the component Lock	8 h / cycle	Assumption: The protective door is opened at intervals of 8 hours (one shift).	

Table 3-23 Interim results

Interim result		Reason
$MTTF_d$	high	$MTTF_d \geq 30$ years
DC	Average	DC = 90 % The feedback signal is permanently monitored by the feedback circuit input of the safety monitor.
Measures against CCF	condition met	It is assumed that the user has taken the necessary measures.
Category	2	System behavior: A single failure can result in the loss of the safety function. The loss of the safety function will be detected by the test. $MTTF_d$: high, DC: medium, measures against CCF: condition met.

Table 3-24 Parameters for evaluation

Parameters	Component	Value	Rule
PFH_D (3TK)	3TK2845	$6,86 * 10^{-9}$	Siemens AG
PFH_D (3TK)	3TK2810-0	$1,49 * 10^{-9}$	Siemens AG

Table 3-25 Result

	EN ISO 13849-1:2006	
	PL	**Average probability of a dangerous failure per hour**
Evaluation	e	$8,35 * 10^{-09}$
Response	d	$2,29*10^{-07}$ (from Appendix K; see Note)
Result	d	The PL of all tasks of the safety function is at least d. Number of tasks is less than or equal to 3.

Note: The $MTTF_d$ for each channel is limited to a maximum of 100 years!

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3.4.3 Summary safety function 3

Table 3-26

	EN 62061		EN ISO 13849-1:2006	
	SIL CL	**PFH_D**	**PL**	**Average probability of a dangerous failure per hour**
Evaluation	3	$8{,}35 * 10^{-09}$	e	$8{,}35 * 10^{-09}$
Response	2	$2{,}5 * 10^{-10}$	d	$2{,}29 * 10^{-07}$

Result	SIL 2	PL d

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4 References

4.1 References

This list does not claim completeness and merely reflects a selection of suitable literature.

Table 4-1

	Topic	Title
/1/	Brochure	**Functional Safety of Machines and Systems Easy Implementation of the European Machinery Directive** (Order No.: E20001-A230-M103-V1-7600)
/2/	Technical book	Patrick Gehlen **Funktionale Sicherheit von Maschinen und Anlagen Umsetzung der Europäischen Maschinenrichtlinie in der Praxis** (in German) (Publicis Corporate Publishing, ISBN: 3895782815)

4.2 Internet links

This list does not purport to be complete and merely reflects a selection of suitable information.

Table 4-2

	Topic	Title
\1\	Reference to the entry	http://support.automation.siemens.com/WW/view/en/51446399
\2\	Siemens I IA/DT Customer Support	http://support.automation.siemens.com
\3\	Safety Evaluation Tool	http://www.siemens.de/safety-evaluation-tool
\4\	Safety Integrated	http://www.siemens.com/safety-integrated

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5 History

Table 5-1

Version	Date	Revision
V1.0	22.07.2011	First edition
V2.0	21.09.2012	Typical circuit diagram replaced in Ch. 2.2; In Table 2.1 hardware component multifunction device (3TK2845-1FB41) added

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