Contents

Preface	7	Other directives	21
Part A: Basics of machine safety – Legal and normative requirements		Low-voltage Directive 2006/95/EC	22
	11	EMC Directive 2004/108/EC ATEX Product Directive 94/9/EC	22 22
		Pressure Equipment Directive 97/23/EC	22
A-1 European directives and national acts	13	Directive on Simple Pressure Vessels 2009/105/EC	23
Directives	14	A-2 Basic standards for functional safety	25
National acts and regulations	14	•	
Standards	14	Structure of international standards for machine safety	25
Requirements of the Machinery Directive and the Use of Work Equipment Directive	14	Standardization organizations Presumption of conformity by harmonized standards	26 27
Scope of the Machinery Directive	15	Consideration of failure probabilities	27
With the Machinery Directive to the Declaration of Conformity	15	Standards for functional safety ISO 12100	27 28
What does the CE mark stand for?	16	IEC 61508	28
Implementation of the Machinery Directive in machinery	17	IEC 61800-5-2	28
Definition	17	IEC 60204-1	28
Implementation	17	IEC 62061	29
Supplied documentation	17	ISO 13849 (replacement of EN 954-1)	29
CE mark	17	History of the standards for functional safety	29
Implementation of the Machinery Directive in partly completed machinery	19	Functional safety – scope of ISO 13849 One control system, several standards	29 30
Definition	19	Global markets and local regulations	31
Implementation	19		
Supplied documentation	19	Part B: 10 steps	
CE mark	19	to performance level	33
Implementation of the Machinery Directive in safety components	20		
Definition Definition	20	B-1 Risk assessment	35
"Safety components" versus "safety-related parts"	20	Basics	35
Implementation	20	Risk assessment as the basis for machine safety	35
Supplied documentation	20	Risk assessment based on standards	37
CE mark	20	Procedure	37
Significant changes in machinery	20	Example	47
Definition	20	Documents for the validation	49
Implementation	21		
New documentation	21		
CF mark	21		



4 Contents

B-2 Identification of the safety functions	51	B-6 Faults and diagnosis	89
Basics	51	Basics	89
Safety functions	51	Consideration of failures (fault list)	89
Procedure	52	Fault exclusion	91
Determination of the safety functions	52	Diagnostic Coverage (DC)	91
Determining the safety-relevant properties		Procedure	95
of the safety functions	52	Example	95
Variants of the safety functions	55	Fault list	95
Partial safety functions of electric drive systems according to IEC 61800-5-2	56	Determining the Diagnostic Coverage (DC) of the components	98
Example	60	Calculation of the DC _{avg}	98
Documents for the validation	61	Documents for the validation	98
B-3 Determination of the PL _r	63	B-7 Determination of the PL	99
Basics	63	Basics	99
Selecting the procedure	64	Reliability (MTTF _d , B _{10d})	101
Determination of the PL _r according to ISO 13849	64	Determination of the performance level (PL _{SRP/CSi})	102
Determination of the PL _r based on IEC 62061	65	Procedure	104
Procedure	65	Example	105
Example	68	Subsystem 1: SRP/CS _{Cat3/4}	105
Identification of the safety function	68	Subsystem 2: SRP/CS _{cert}	108
Determination of the PL _r	68	Determination of the PL _{SF}	108
Comparison with the procedure of ISO 13849	68	Adjustment of the PL _{SF}	108
Documents for the validation	69 ——	Documents for the validation	109
B-4 Category selection	71	B-8 Evaluation of the control system robustness – Failure avoidance	444
Basics	71		111
Relationship between performance level and	71	Basics	111
category Free category selection	71 72	Measures against Common Cause Failures (CCF)	111
Recursive process	73	Basic and well-tried safety principles	113
Properties of the categories	73	Well-tried components	116
Procedure Procedure	75	Systematic failures	117
Example	76	Procedure	119
Documents for the validation	77	Example Example 1: Measures against CCF	120 120
B-5 Modeling the block diagram	 79	Example 1: Measures against COF Example 2: Safety principles	120
		Documents for the validation	123
Basics	79 70	D.O. C-54	400
Analysis	79	B-9 Software requirements	125
Modeling principles	80	Basics	125
Division into subsystems	80	Software-based parameterization	126
Procedure	81	Safety-related application software (SRASW)	126
Example Description of the SBB/CS components	84	Safety-related embedded software (SRESW)	127
Description of the SRP/CS components	84	Procedure	127
Characterisitics of the safety function	85 97	Project-independent preparations	128
Documents for the validation	87	Project-specific activities for SRASW	128

Example	132	2 nd step: Identification of the safety functions	209
Preparation and verification of the		3 rd step: Determination of the PL _r	211
software specification	132	4th step: Category selection	211
Selection of the engineering tools	133	5 th step: Modeling the block diagram	211
Software design	135	6 th step: Faults and diagnosis	215
Combination of safety-related and	135	7 th step: Determination of the PL _{SF}	217
standard programs	136	8 th step: Evaluation of the robustness	219
Software coding	136	9 th step: Software requirements	225
Test Documents for the validation	138	10 th step: Verification and validation	225
B-10 Verification and validation	139	Part D: Appendix	227
Basics	139		
Validation plan	141	D-1 ISO 13849: Machine Safety depends on	
Documentation of the validation process	141	Reliability	229
Validation by analysis	142	Overview	229
Validation by testing	142	Reliability basics	229
Procedure	143	Bathtub curve	229
Documents for the validation	145	Reliability characteristics	230
"Validation" checklist	145	Basis of the statistically based safety technology	231
Explanation	145	State diagram	231
		Characteristics of the statistically based safety technology	232
Part C: Application examples	151	Risk assessment, safety function, performance level (PL)	233
C-1 Example: Machine tool	153	Usability of a component for the functional safety	233
Machine description	154	Methods for determining the reliability characteristics	234
1st step: Risk assessment	155	Calculations of the life cycle	
2 nd step: Identification of the safety functions	155	of electronic components	235
3 rd step: Determination of the PL _r	162	Testing of the life cycle	235
4 th step: Category selection	163	Life cycle analyses of field data	236
5 th step: Modeling the block diagram	164	Failure probability of a safety function	237
6 th step: Faults and diagnosis	167	Reliability model: Block diagram	237
7 th step: Determination of the PL _{SF}	170	Meaning of the MTTF _d value for the safety function Calculation of the dangerous	230
8 th step: Evaluation of the robustness	173	failure probability (PFH _D)	239
9 th step: Software requirements	179	Example of safety characteristics	239
10 th step: Verification and validation	188	Conclusion	240
C-2 Example: Machine tool, pneumatic subsystem	191	D-2 Terms, symbols and abbreviations	241
1 st to 3 rd step to PL	191		
4 th step: Category selection	191	D-3 Bibliography	255
5 th step: Modeling the block diagram	191	Sources used in the book	255
6 th step: Faults and diagnosis	193	Related literature	257
7 th step: Determination of the PL _{SF}	196		
8 th step: Evaluation of the robustness	199	D-4 Alphabetical index	259
9th step: Software requirements	206		
10 th step: Verification and validation	206		
C-3 Example: Injection molding machine	207		

207

208

Machine description

1st step: Risk assessment