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INDI4.0

# **PNOZmulti - Programming and Service**

## **Chapter 1 „Machinery Directive“**

**PILZ**  
THE SPIRIT OF SAFETY

# ► Machinery Directive „MD”



PILZ | 01-4

## Machinery Directive

ProdSG / BetrSichV

Harmonized standards

EN ISO 13849-1

Control categories

V-Model

Exercises

## Chronicle of MD

- 1989: Decree of Council of the EUROPEAN Community's Directive, as the MD (89/392/EEC) was known.
- 1995: Directive must be applied in all Member States of the EC.
- 1998: Publication of the now find valid MD (98/37/EC).



## Current Machinery Directive 2006/42/EG Gültig seit 29.12.2009

- Valid from 29.12.2009.
- Must be applied. Is a European law "EU27"!
- National implementation in GPSG.
- Is the key to the single market.
- Brings legal certainty.
- Protection from unsafe products cheap.

# ► Machinery Directive „MD”



PILZ | 01-4+

## Machinery Directive

ProdSG / BetrSichV

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Control categories

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Exercises

## Chronicle of MD

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- 1998: Publication of the now find valid MD (98/37/EC).



Current Machinery Directive 2006/42/EG Valid since 29.12.2009

Plant/machinery (EU Economic Area) may only be sold with:

- Declaration of conformity
- CE mark

"Communauté Européene" => European Community





PILZ | 01-9

Machinery Directive

**ProdSG / BetrSichV**


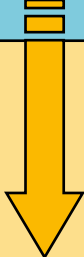

Harmonized standards

EN ISO 13849-1

Control categories

V-Model

Excercises

|   | Manufacturer   | Operator  |
|---|--|---|
| <br><br> | <ul style="list-style-type: none"> <li>▶ CE directives                             <ul style="list-style-type: none"> <li>▶ e.g.: Machinery Directive</li> </ul> </li> </ul>   | <ul style="list-style-type: none"> <li>▶ Directives                             <ul style="list-style-type: none"> <li>▶ e.g.: Work Equipment Directive</li> </ul> </li> </ul>  |
|   | <ul style="list-style-type: none"> <li>▶ ProdSG<br/>                             “<b>Device and Product Safety Law</b>”                             <ul style="list-style-type: none"> <li>▶ 01.12.201 Came into force.</li> <li>▶ Replaces GPSG Device and Product Safety Law</li> </ul> </li> <li>▶ Responsible for:                             <ul style="list-style-type: none"> <li>▶ National law for the manufacture of machinery and products</li> <li>▶ Considers:                                     <ul style="list-style-type: none"> <li>- European and</li> <li>- National legislation.</li> </ul> </li> </ul> </li> </ul> | <ul style="list-style-type: none"> <li>▶ BetrSichV<br/>                             “<b>Industrial Safety Regulations</b>”                             <ul style="list-style-type: none"> <li>▶ 03.10.2002 Came into force.</li> <li>▶ Replaces around 10 domestic regulations.</li> </ul> </li> <li>▶ Responsible for:                             <ul style="list-style-type: none"> <li>▶ Occupational health and safety of employees in the workplace.</li> <li>▶ All types of work equipment, machinery and products.</li> <li>▶ Installations subject to monitoring.</li> </ul> </li> </ul> |



PILZ | 01-15

Machinery Directive

ProdSG / BetrSichV

**Harmonized standards**

EN ISO 13849-1

Control categories

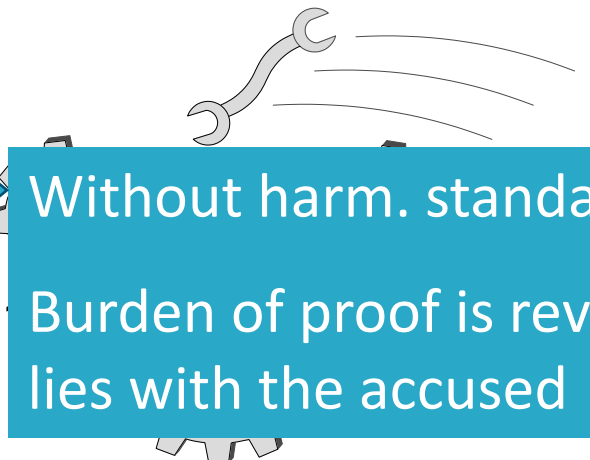
V-Model

Exercises

No legal obligation to comply with standards, even harmonised standards.

Compliance with harmonised standards:

- Provides presumption of conformity
- Burden of proof lies with the authorities, courts or prosecutors.
- Represented in Germany by DIN EN e.g.: DIN EN 60204 or DIN EN ISO 13849-
- Listed in the MD



Without harm. standards:  
Burden of proof is reversed,  
lies with the accused

► Reasons for complying with the harmonised standards?

- Compliance triggers the presumption that the essential requirements of the European directives have been met (presumption of conformity).
- European standards are used to define in detail what are sometimes very general statements within the European directives.
- When acquiring machinery, the purchaser specifies the need to comply with harmonised EU standards.
- Simplifies the area of product liability.

# ► Risk assessment in accordance with DIN EN ISO 13849-1



PILZ | 01-18+

Machinery Directive

ProdSG / BetrSichV

Harmonized standards

**EN ISO 13849-1**

Control categories

V-Model

Excercises

## S = Severity of injury:

- Cuts and bruises, without complications
- Amputations or death

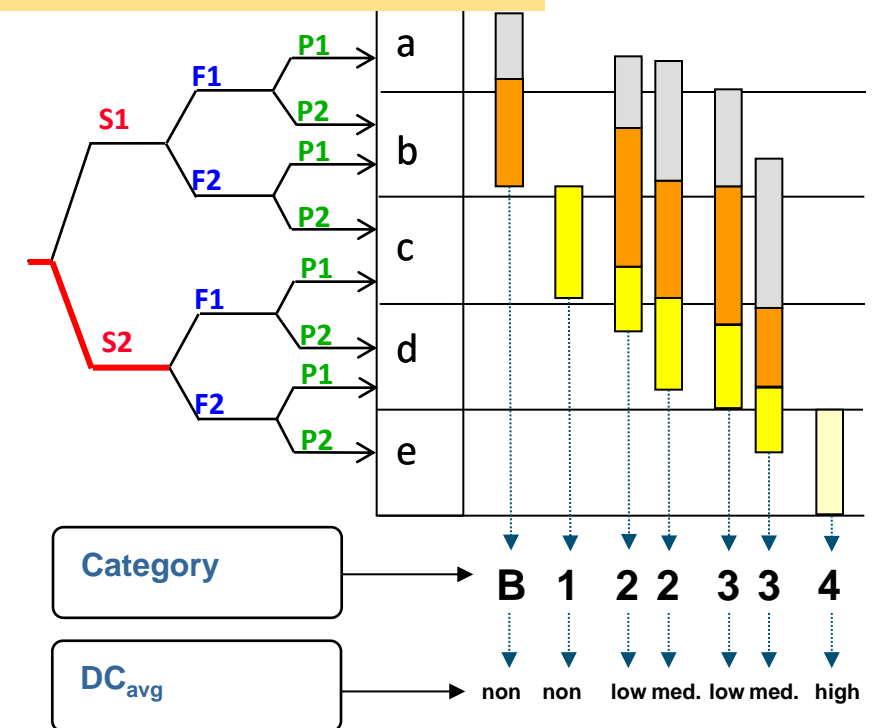
## F = Frequency/exposure to hazard:

- F1 = Seldom to quite often and/or the exposure time is short
- F2 = Frequent to continuous and/or the exposure time is long

## P = Possibility of avoiding hazard:

- P1 = Possible under specific conditions
- P2 = Scarcely possible

S1 may only be selected if no irreversible injury is anticipated.



- MTTF<sub>D</sub> = low 3 – 10 J
- MTTF<sub>D</sub> = med. 10 – 30 J
- MTTF<sub>D</sub> = high 30 – 100 J
- MTTF<sub>D</sub> = high 30 – 2500 J



| DC <sub>avg</sub> | Percent       |
|-------------------|---------------|
| non               | < 60 %        |
| low               | 60 % ... 89 % |
| med.              | 90 % ... 98 % |
| high              | ≥ 99 %        |

# ► Risk assessment in accordance with DIN EN ISO 13849-1



PILZ | 01-18+

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Harmonized standards

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V-Model

Excercises

## S = Severity of injury:

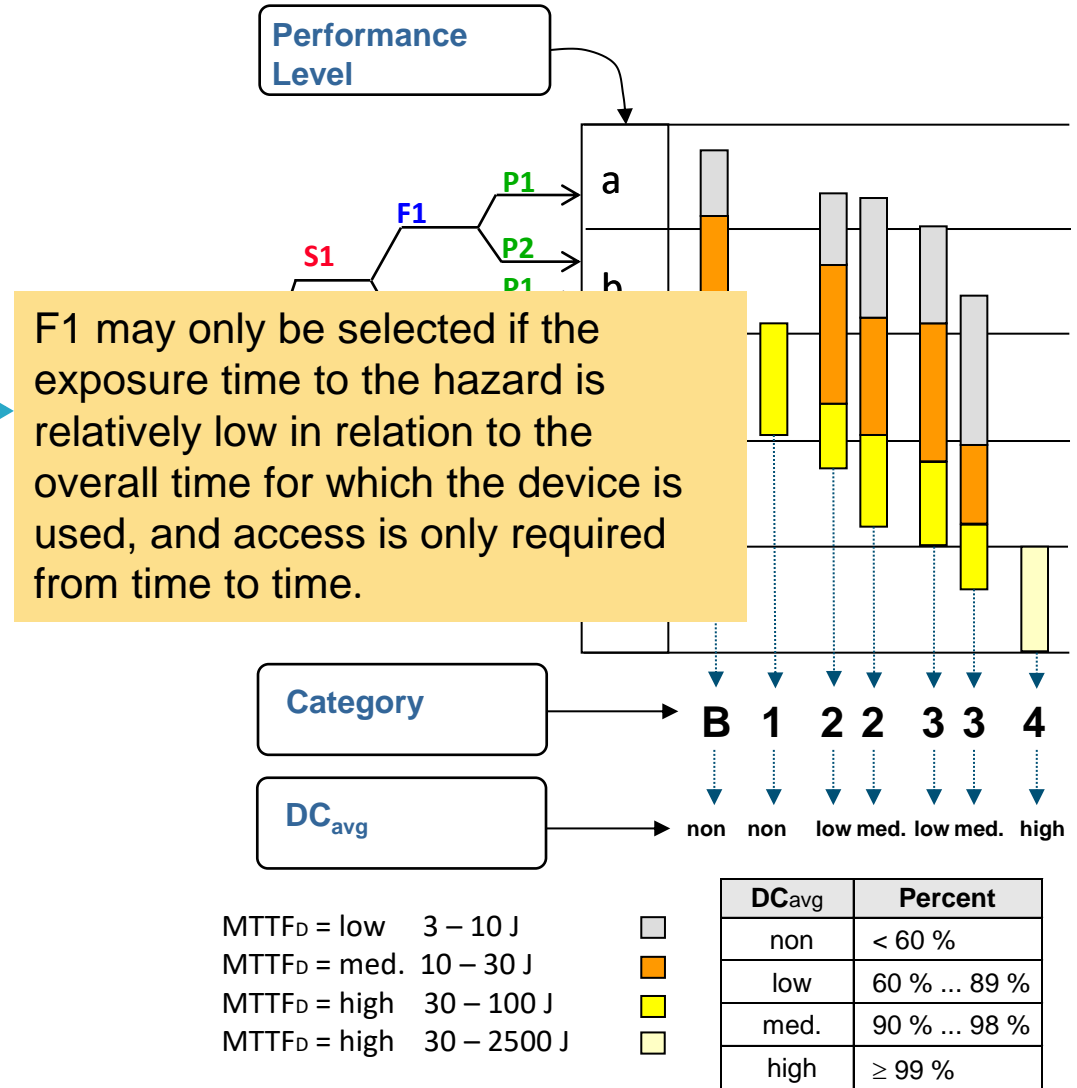
- S1 = Slight injury
- S2 = Serious injury including death

## F = Frequency/exposure to hazard:

- Consideration of the need for access to the hazardous area:
  - Normal operation
  - Maintenance
  - Service

## P =

- Type of access:  
E.g.: manual material feed
- The time, frequency and number of persons spent in the danger zone.



# ► Risk assessment in accordance with DIN EN ISO 13849-1



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Excercises

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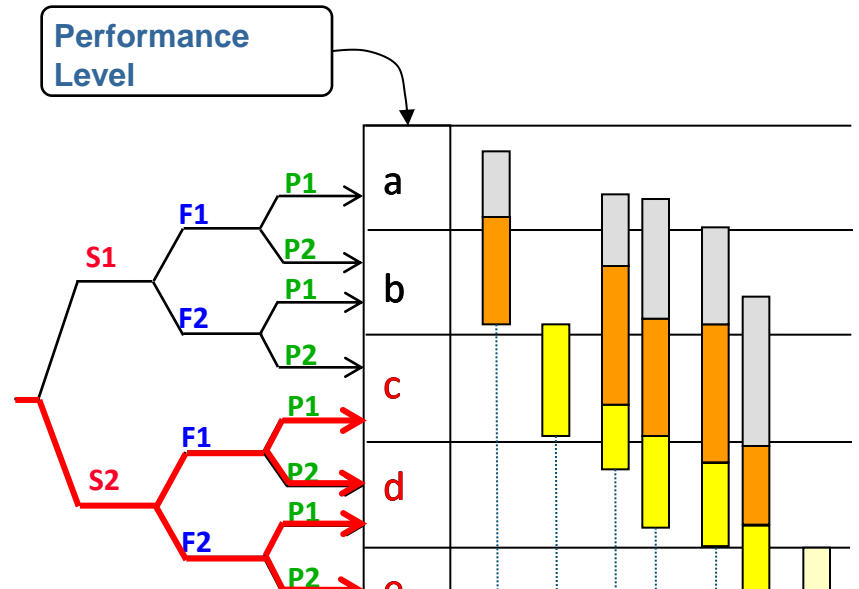
- S1 = Slight injury
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## F = Frequency/exposure to hazard:

- F1 = Seldom to quite often and/or the exposure time is short
- F2 = Frequent to continuous and/or the exposure time is long

## P = Possibility of avoiding hazard:

- Speed with which the hazard occurs
- Ability to escape or third party intervention
- Trained specialised staff
- Is the hazard detected without special displays/measuring devices
- Operation supervised or unsupervised



P1 may only be selected if, when a hazardous condition occurs, there is a realistic chance of avoiding an accident or considerably reducing its effects.

MTTF<sub>D</sub> = low 3 – 10 J  
 MTTF<sub>D</sub> = med. 10 – 30 J  
 MTTF<sub>D</sub> = high 30 – 100 J  
 MTTF<sub>D</sub> = high 30 – 2500 J



| DC <sub>avg</sub> | Percent       |
|-------------------|---------------|
| non               | < 60 %        |
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V-Model

Excercises

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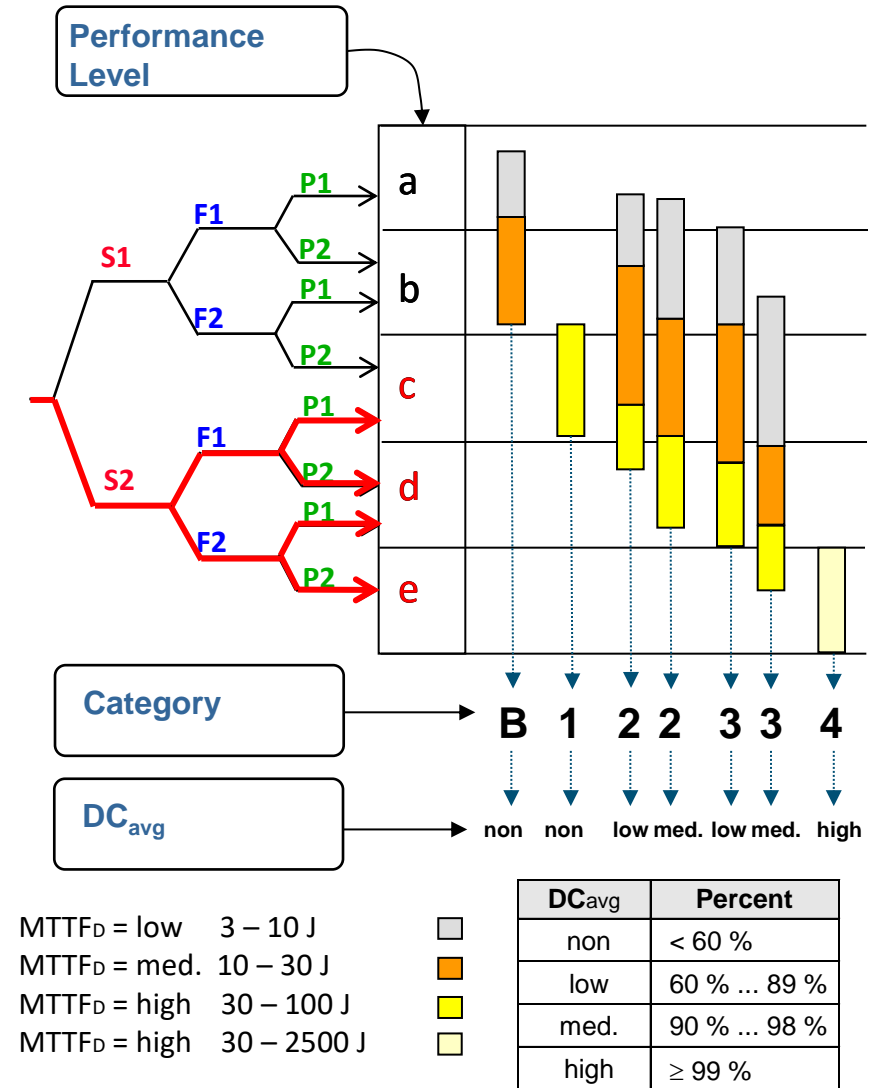
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$$MTTF_D = B10_D / 0,1 \times n_{op}$$



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Excercises

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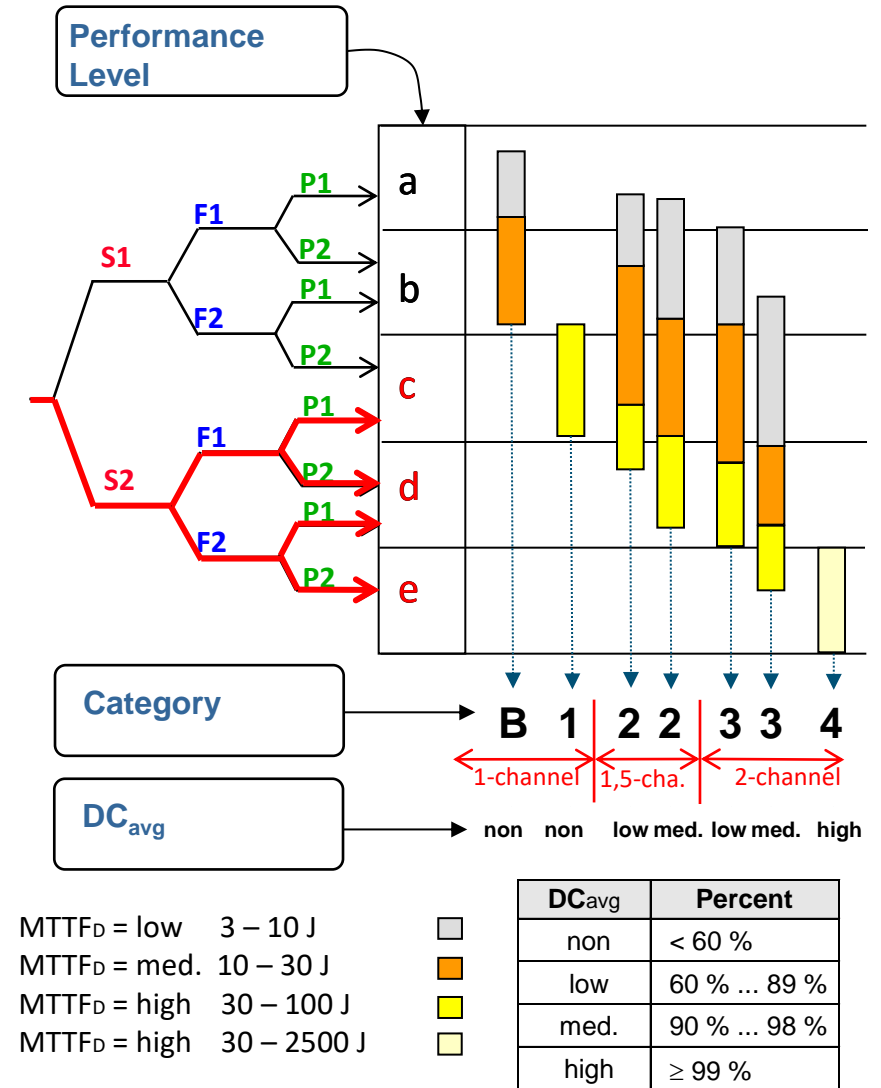
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Control categories

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Excercises

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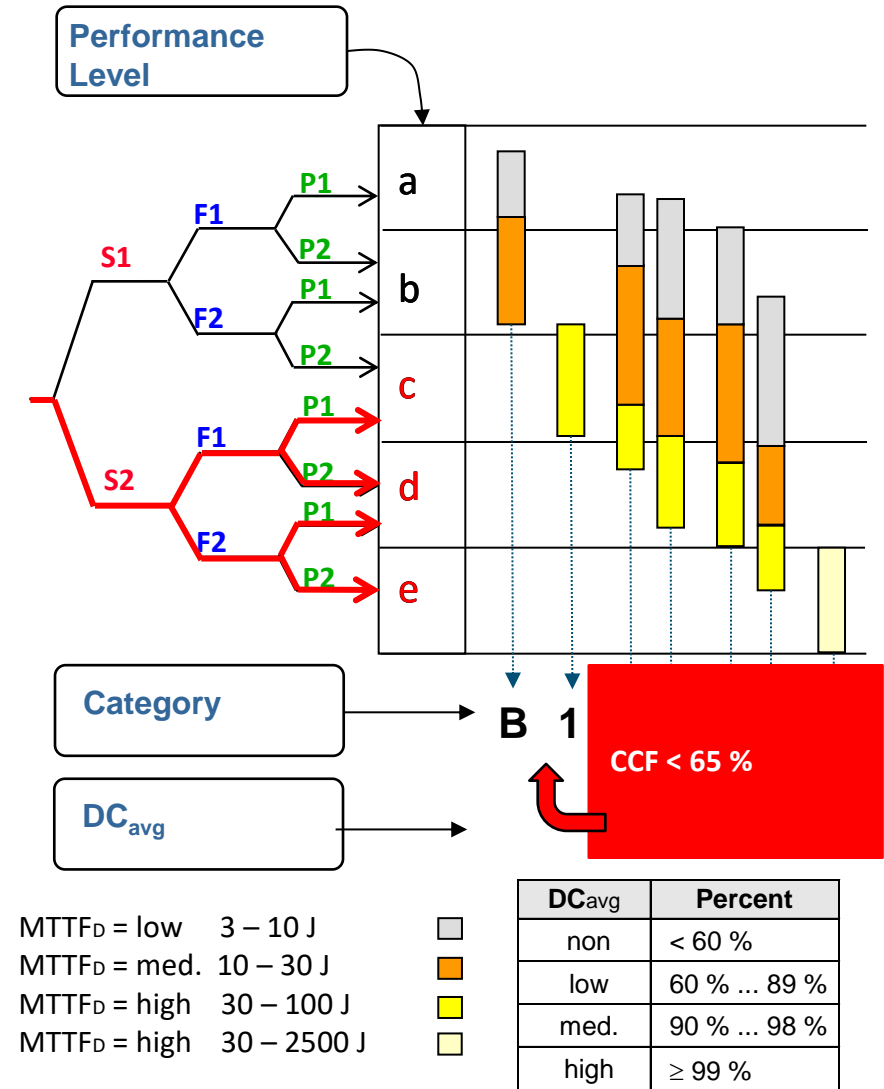
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- F1 = Seldom to quite often and/or the exposure time is short
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## P = Possibility of avoiding hazard:

- P1 = Possible under specific conditions
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# ► Risk assessment in accordance with DIN EN ISO 13849-1



PILZ | 01-19+

Machinery Directive

ProdSG / BetrSichV

Harmonized standards

**EN ISO 13849-1**

Control categories

V-Model

Exercises

MTTF<sub>d</sub>: Mean Time to Failure, Dangerous

DC<sub>avg</sub>: Diagnostic Coverage, average

CCF: Common Cause Failure

| Nr. | Action  | Points |   |
|-----|---|--------|---|
| 1   | <b>Separation / segregation</b>   | 15     | ▲ |
|     | Physical separation between the signal paths:<br>a) Separation of the wiring/piping,<br>b) Detection of short circuits and open circuits in cables by dynamic testing;<br>c) separate shielding of the signal path of each channel;<br>d) e.g. sufficient clearance and creepage distances on printed circuits. |        |   |
| 2   | <b>Diversity</b>  | 20     | ▼ |
|     | Different technologies are used.<br>Different design or principles are used.<br>Components of different manufacturers are used.   |        |   |

# ► Risk assessment in accordance with DIN EN ISO 13849-1



PILZ | 01-19+

Machinery Directive

ProdSG / BetrSichV

Harmonized standards

**EN ISO 13849-1**

Control categories

V-Model

Exercises

MTTF<sub>d</sub>: Mean Time to Failure, Dangerous

DC<sub>avg</sub>: Diagnostic Coverage, average

CCF: Common Cause Failure

| Nr. | Action   | Points |   |
|-----|--|--------|---|
| 3   | <b>Design / application / experience</b>   |        | ▲ |
|     | Protection against overvoltage, overpressure, overcurrent, etc.  | 15     |   |
|     | Components used are well-tried   | 5      |   |
| 4   | <b>Assessment / analysis</b>   |        | ▼ |
|     | Für jedes Teil von sicherheitsbezogenen Teilen eines Steuerungssystems wurde eine Fehlermöglichkeits- und Einflussanalyse durchgeführt und deren Ergebnisse berücksichtigt, um Ausfälle infolge gemeinsamer Ursache bei der Gestaltung zu vermeiden. | 5      |   |

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Excercises

MTTF<sub>d</sub>: Mean Time to Failure, Dangerous

DC<sub>avg</sub>: Diagnostic Coverage, average

CCF: Common Cause Failure

| Nr. | Action   | Points |   |
|-----|--|--------|---|
| 5   | <b>Competence / training</b>   |        | ▲ |
|     | Have developers been trained to understand and avoid the causes and consequences of common cause failures?                 | 5      |   |
| 6   | <b>Environmental influences</b>  |        |   |
|     | Prevention of contamination (hydraulic and pneumatic) and EMC influences considered and tested?                            | 25     |   |
|     | Are the requirements for immunity to temperature, shock, vibration and humidity considered (compliance with product data)? | 10     |   |
|     |  |        | ▼ |

# ► Description of Category „B“



PILZ | 01-22

Machinery Directive

ProdSG / BetrSichV

Harmonized standards

EN ISO 13849-1

**Control categories**

V-Model

Excercises

| Category | Description   |
|----------|---|
| <b>B</b> | <p><u>Requirements:</u></p> <p>In accordance with the relevant standards and the <b>application of fundamental safety principles</b>, the SRP/CS must be able to withstand the following:</p> <ul style="list-style-type: none"><li>➤ Operating stresses</li><li>➤ Influence of the processed material</li><li>➤ External influences</li></ul> <p><u>System behaviour:</u></p> <p>The occurrence of a fault can lead to the loss of the safety function</p> <p><u>Structure:</u></p> <p>Single-channel safety circuit</p> |

# ► Description of Category „1“



PILZ | 01-22

Machinery Directive

ProdSG / BetrSichV

Harmonized standards

EN ISO 13849-1

**Control categories**

V-Model

Excercises

| Category | Description |
|----------|-------------|
|----------|-------------|

# 1

## Requirements:

In addition to Category B, the SRP/CS of Category 1 must be designed and constructed by use of **well-ried components** and **well-ried safety principles**:

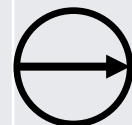
- forced guided contacts
- positively opening contacts

## System behaviour:

The occurrence of a fault can lead to the loss of the safety function. The reliability of the safety function is higher than in Category B.

## Structure:

Single-channel safety circuit



Force guided contacts



PFH-Wert

Forcibly Guided Contacts





# ► Description of Category „2“



PILZ | 01-23

Machinery Directive

ProdSG / BetrSichV

Harmonized standards

EN ISO 13849-1

## Control categories

V-Model

Excercises

| Category | Description   |
|----------|---|
| 2        | <p><u>Requirements:</u></p> <p>In addition to Category B and well-tried principles of Category 1, SRP/CS of Category 2 must be designed so that their functions are <b>checked by the machine control system at appropriate intervals</b>. Testing of the safety function(s) must be carried out:</p> <ul style="list-style-type: none"><li>➤ When the machine is started up</li><li>➤ Prior to the initiation of any hazardous situation</li></ul> <p><u>System behaviour:</u></p> <p>The occurrence of a fault to lead to the loss of the safety function between tests, the loss of the safety function to be detected by the test.</p> <p><u>Additional measures are:</u></p> <ul style="list-style-type: none"><li>➤ Request rate <math>\leq 1/100</math> of the test rate (Typical assumptions according Sect. 4.5.4)<ul style="list-style-type: none"><li>- If <math>\geq 1/100</math> cannot be met, then <math>\geq 1/25</math></li><li>- Immediately upon demand of the safety function (Time for error detection less than Time to reach the danger point)</li></ul></li><li>➤ Mastering of CCF</li></ul> <p><u>Structure:</u></p> <p>Single-channel safety circuit and Test equipment with output (OTE)</p> |

# ► Description of Category „2“



PILZ | 01-23

Machinery Directive

ProdSG / BetrSichV

Harmonized standards

EN ISO 13849-1

### Control categories

V-Model

Excercises

| Category | Description  |
|----------|--|
| 2        | <p><u>Block diagram:</u></p> <pre>graph LR; I[I] --&gt; L[L]; L[L] --&gt; O[O]; TE[TE] --&gt; OTE[OTE*]; TE[TE] -.-&gt; I; TE[TE] -.-&gt; O; L[L] -.-&gt; TE[TE];</pre> <p>* For PL d, a warning signal is not sufficient. Thus, a second shutdown path is required.</p> |

# ► Description of Category „3“



PILZ | 01-23+

Machinery Directive

ProdSG / BetrSichV

Harmonized standards

EN ISO 13849-1

**Control categories**

V-Model

Excercises

| Category | Description   |
|----------|---|
| 3        | <p><u>Requirements:</u></p> <p>In addition to Category B and well-tried principles of Category 1, SRP/CS of Category 3 must be designed so that <b>a single fault does not lead to loss of the safety function</b>. Whenever reasonably practicable, the single fault shall be detected at or before the next demand upon the safety function.</p> <p><u>System behaviour:</u></p> <p>Category 3 system behaviour allows:</p> <ul style="list-style-type: none"><li>➤ some but not all faults to be detected</li><li>➤ the accumulation of undetected faults can lead to the loss of the safety function</li><li>➤ Mastering of CCF</li></ul> <p><u>Structure:</u></p> <p>Dual-channel safety circuit</p> |

# ► Description of Category „3“



PILZ | 01-24

Machinery Directive

ProdSG / BetrSichV

Harmonized standards

EN ISO 13849-1

## Control categories

V-Model

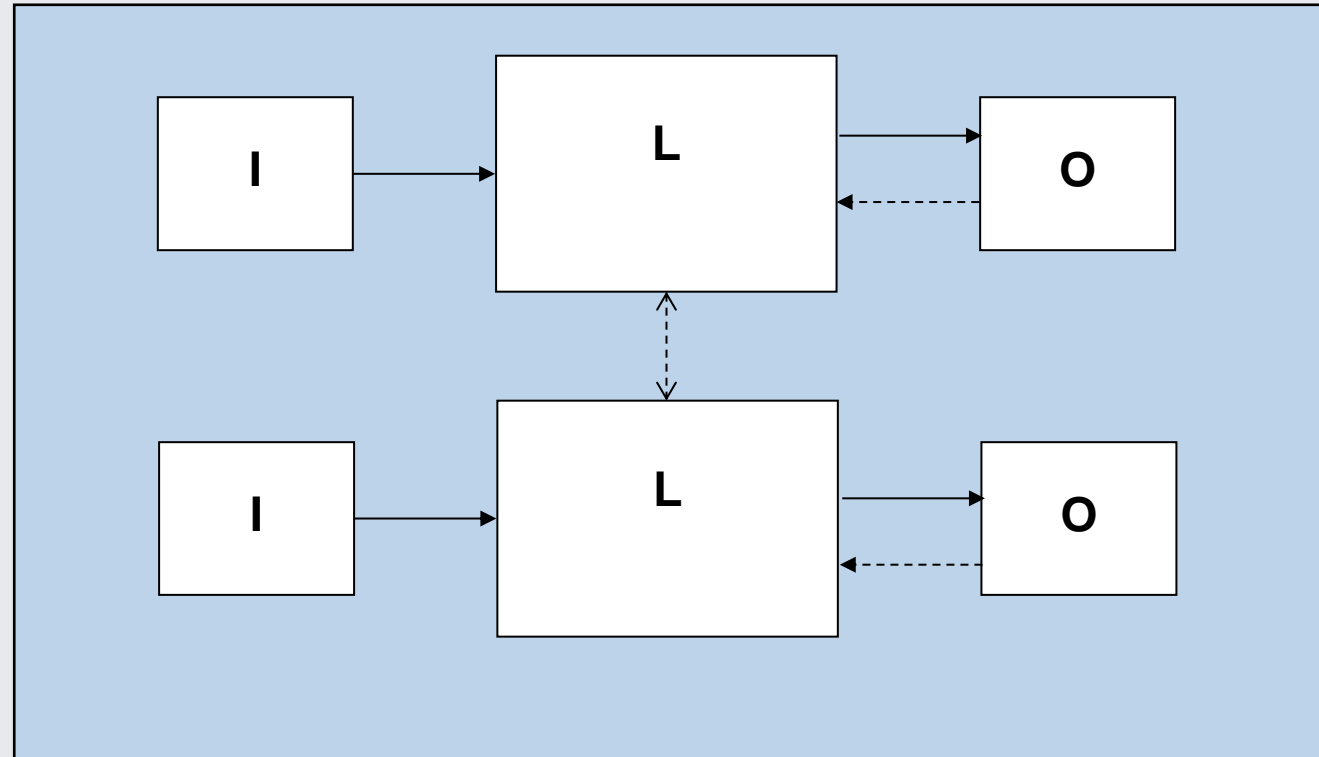
Excercises

Category

Description

3

## Block diagram



# ► Description of Category „4“



PILZ | 01-24

Machinery Directive

ProdSG / BetrSichV

Harmonized standards

EN ISO 13849-1

**Control categories**

V-Model

Excercises

| Category | Description  |
|----------|--|
| 4        | <p><u>Requirements:</u></p> <p>In addition to Category B and well-tried safety principles of Category 1, SRP/CS of Category 4 must be designed so that a single fault in any of these safety-related parts does not lead to the loss of the safety function, and that <b>the single fault shall be detected at or before the next demand upon the safety function.</b></p> <p><u>System behaviour:</u></p> <p>Category 4 system behaviour demands that:</p> <ul style="list-style-type: none"><li>➤ The safety function is always performed when a single fault occurs,</li><li>➤ Faults are detected in time to prevent the loss of the safety function,</li><li>➤ Accumulations of undetected faults are taken into account</li><li>➤ Comparison of channels, such as detection of shorts across contacts (DCavg of HIGH)</li><li>➤ Mastering of CCF</li></ul> <p><u>Structure:</u></p> <p>Dual-channel safety circuit</p> |

# ► Description of Category „4“



PILZ | 01-24

Machinery Directive

ProdSG / BetrSichV

Harmonized standards

EN ISO 13849-1

## Control categories

V-Model

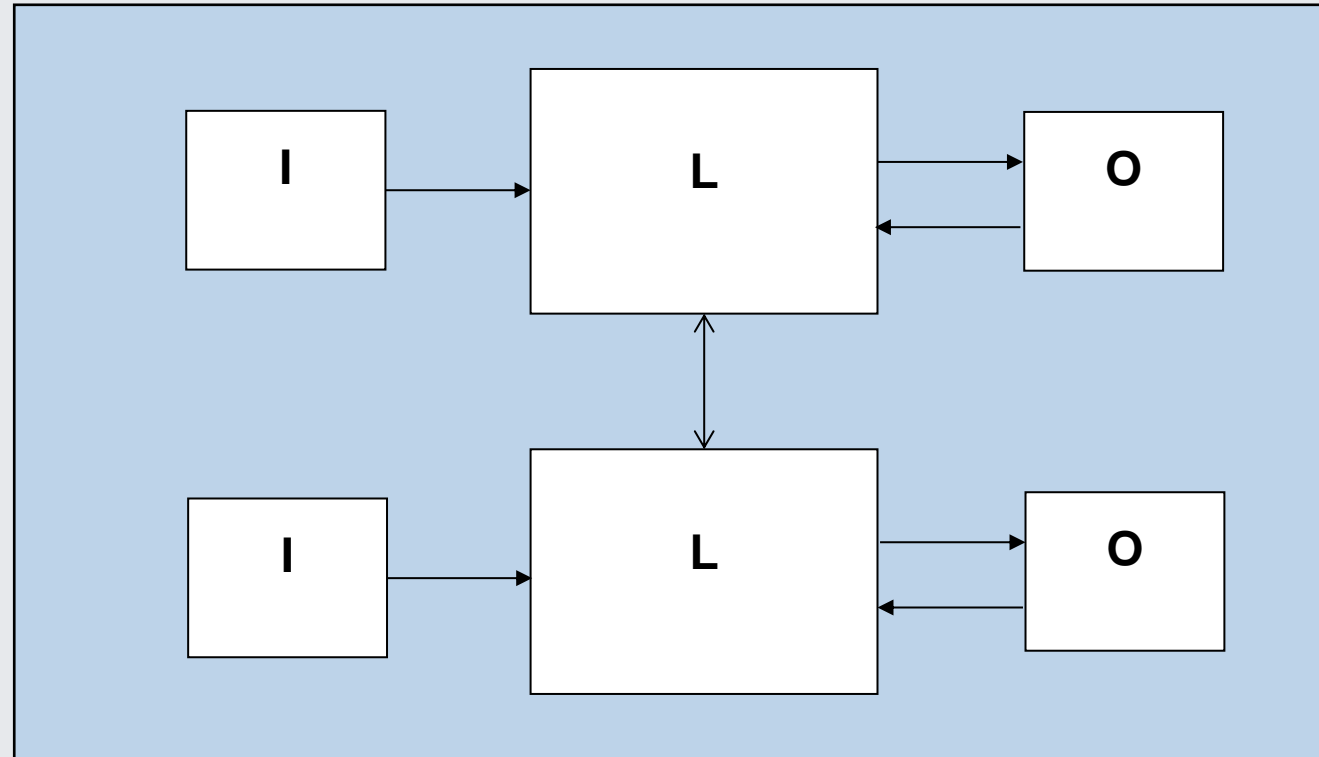
Excercises

Category

Description

4

Prinzipschaltbild:



# ▶ Table 11 simplified procedure



## Simplified procedure for calculating the value PL

PILZ | 01-25

Machinery Directive

ProdSG / BetrSichV

Harmonized standards

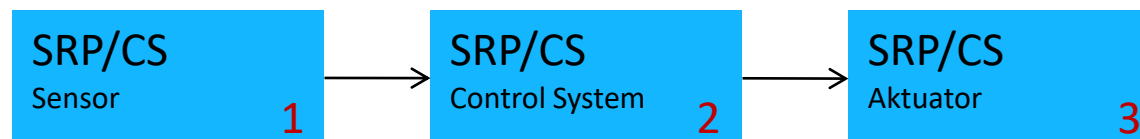
EN ISO 13849-1

### Control categories

V-Model

Excercises

| PL <sub>low</sub> | Quantity of PL <sub>low</sub> | Overall PL          |
|-------------------|-------------------------------|---------------------|
| <b>a</b>          | > 3                           | <b>Not allowed!</b> |
|                   | ≤ 3                           | <b>a</b>            |
| <b>b</b>          | > 2                           | <b>a</b>            |
|                   | ≤ 2                           | <b>b</b>            |
| <b>c</b>          | > 2                           | <b>b</b>            |
|                   | ≤ 2                           | <b>c</b>            |
| <b>d</b>          | > 3                           | <b>c</b>            |
|                   | ≤ 3                           | <b>d</b>            |
| <b>e</b>          | > 3                           | <b>d</b>            |
|                   | ≤ 3                           | <b>e</b>            |



# ▶ Table 11 simplified procedure



PILZ | 01-25

Machinery Directive

ProdSG / BetrSichV

Harmonized standards

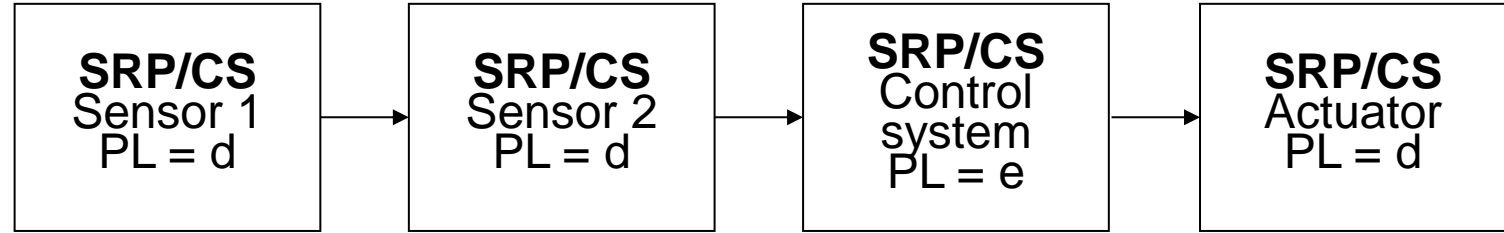
EN ISO 13849-1

### Control categories

V-Model

Excercises

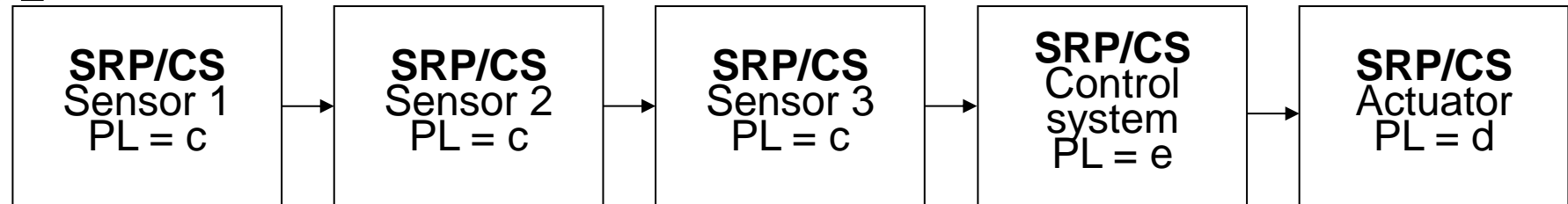
## Example 1



Overall PL



## Example 2



Overall PL







PILZ | 01-26

Machinery Directive

ProdSG / BetrSichV

Harmonized standards

EN ISO 13849-1

**Control categories**

V-Model

Excercises

| SIL<br>(IEC 61508) | PFH<br>(IEC 61508 and ISO 13849-1) | PL<br>(ISO 13849-1) |
|--------------------|------------------------------------|---------------------|
| -                  | $10^{-4} \dots 10^{-5}$            | <b>a</b>            |
| <b>1</b>           | $10^{-5} \dots 3 \times 10^{-6}$   | <b>b</b>            |
| <b>1</b>           | $3 \times 10^{-6} \dots 10^{-6}$   | <b>c</b>            |
| <b>2</b>           | $10^{-6} \dots 10^{-7}$            | <b>d</b>            |
| <b>3</b>           | $10^{-7} \dots 10^{-8}$            | <b>e</b>            |



PILZ | 01-26

Machinery Directive

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Harmonized standards

EN ISO 13849-1

Control categories

**V-Model**

Excercises

Aim:

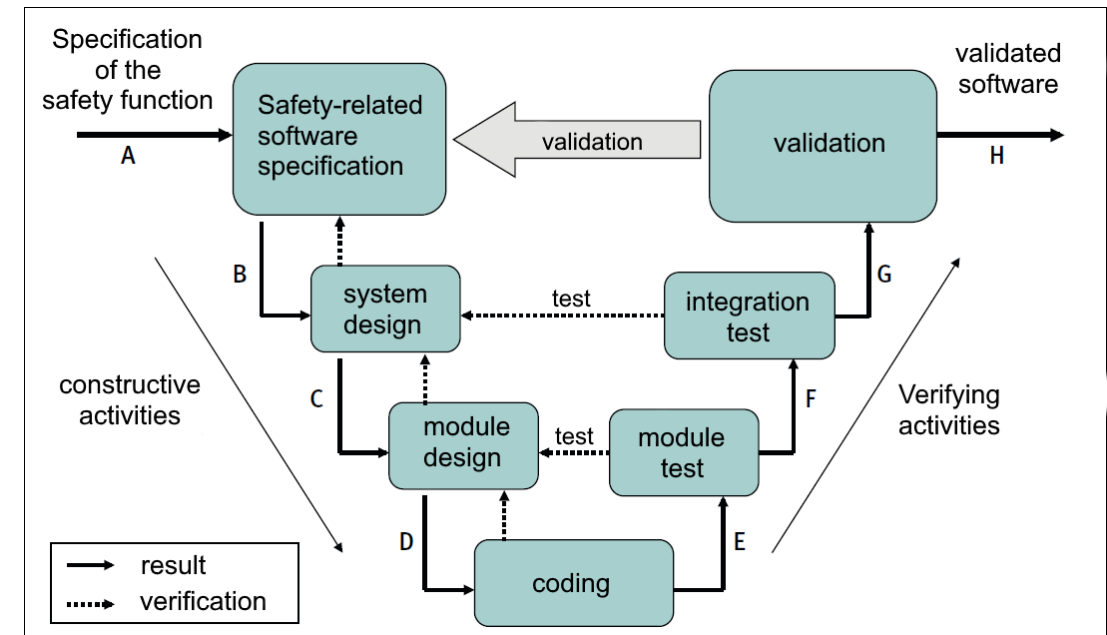
- ▶ Creating software that is readable, comprehensible, testable and maintainable
- ▶ Timely consideration of specification errors and draft errors
- ▶ Error prevention

▶ Defensive programming

Basic measures

- ▶ Modular program structure
- ▶ Comprehensible presentation
- ▶ Simple functions (avoiding indirect addressing)
- ▶ Clear naming of variables
- ▶ Comprehensible comments
- ▶ Testability of the program modules

V-Modell





PILZ | 01-30

Machinery Directive

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EN ISO 13849-1

Control categories

V-Model

**Exercises**

**1. Which of these statements about compliance with standards are correct?  
Place a cross next to the correct answers and then count up the points awarded for the correct answers:**

|  | Richtig                             | Punkte |
|--|-------------------------------------|--------|
| 1. The machine manufacturer is liable to prosecution if he does not comply with the standards that are applicable nationally.  | <input type="radio"/>               | 3      |
| 2. When acquiring machinery, the purchaser specifies the need to comply with harmonised EU standards.  | <input checked="" type="checkbox"/> | 4      |
| 3. The machine manufacturer is liable to prosecution if he does not comply with the EU standards that exist for the respective safeguard, even if the measures he has taken are effective in protecting personnel. | <input type="radio"/>               | 5      |
| 4. European standards are used to define in detail what are sometimes very general statements within the European directives.  | <input checked="" type="checkbox"/> | 10     |
| 5. Simplifies the area of product liability, as the adversary is forced to present a reasoned justification for the alleged safety deficiencies.   | <input checked="" type="checkbox"/> | 30     |
| 6. Compliance with EU standards is European law. Manufacturers in Europe must comply with these standards.   | <input type="radio"/>               | 50     |
| 7. Compliance triggers the presumption that the essential requirements of the European directives have been met (presumption of conformity).   | <input checked="" type="checkbox"/> | 400    |
| 8. Compliance with ISO and IEC standards is international law. Manufacturers all over the world must comply with these standards.  | <input type="radio"/>               | 500    |

**The telephone number for technical support  
or Hot-Line at Pilz is:**

**0711/3409-.....444.....**



PILZ | 01-31

Machinery Directive

ProdSG / BetrSichV

Harmonized standards

EN ISO 13849-1

Control categories

V-Model

**Exercises**

## 2. Please select one or more categories / performance levels (DIN EN ISO 13849-1) that apply for the particular statement (multiple choice "n from 5").

1. High-risk danger zones (irreversible harm), which only maintenance staff need to access. The danger can be averted because the relevant requirements, such as safely reduced speed for example, are met.

| PL a                  | PL b                  | PL c                                | PL d                  | PL e                  |
|-----------------------|-----------------------|-------------------------------------|-----------------------|-----------------------|
| <input type="radio"/> | <input type="radio"/> | <input checked="" type="checkbox"/> | <input type="radio"/> | <input type="radio"/> |

2. High-risk danger zones (serious injury), where people are very often present. The danger cannot be averted because the speed is too high.

| PL a                  | PL b                  | PL c                  | PL d                  | PL e                                |
|-----------------------|-----------------------|-----------------------|-----------------------|-------------------------------------|
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input checked="" type="checkbox"/> |

3. What performance level can be achieved with Category 1 and an  $MTTF_d$  of 77.15 years?

| PL a                  | PL b                  | PL c                                | PL d                  | PL e                  |
|-----------------------|-----------------------|-------------------------------------|-----------------------|-----------------------|
| <input type="radio"/> | <input type="radio"/> | <input checked="" type="checkbox"/> | <input type="radio"/> | <input type="radio"/> |

4. What performance level can be achieved with Category 3 and DCavg LOW with an  $MTTF_d$  of 30.15 years?

| PL a                  | PL b                  | PL c                  | PL d                                | PL e                  |
|-----------------------|-----------------------|-----------------------|-------------------------------------|-----------------------|
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input checked="" type="checkbox"/> | <input type="radio"/> |

Automatisierungs-  
technik



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