

Use of BERNSTEIN standard inductive sensors in safety applications

Can standard inductive sensors be used in safety technology?

Yes, provided that:

- ✓ Risk analysis was performed
- ✓ The sensors meet the product standard according to EN IEC 60947-5-2
- ✓ MTTF values for the components are available
- ✓ Proven safety principles have been applied according to EN ISO 13849-2
- ✓ Compliance with the required performance level (PLr) is demonstrated

In mechanical and plant engineering, the EN ISO 13849 or EN IEC 62061 standards very often apply to safe control technology. In addition to qualitative measures with corresponding structures and failure-preventing measures, both standards also expect quantitative proof of the safety functions. In order to be able to provide this proof, the failure rates or their reciprocal value, the so-called MTTF (Mean Time To Failure) or $MTTF_d$ (Mean Time To Failure dangerous), of each assembly are usually required. Safety can be achieved in different ways according to the standards. Depending on the required safety level, standard components can also be used in accordance with the EN ISO 13849 and DIN EN 62061¹ standards, which can be used in a safe system architecture purely on the basis of their reliability. To support this approach, BERNSTEIN also supplies the necessary MTTF values for standard components for certain sensor types.

A list of all BERNSTEIN AG inductive sensors that can be used in the sense of this whitepaper can be found from page 7 onwards.

The sensors present in the listing comply with the product standard according to EN IEC 60947-5-2 (see data sheet). All technical specifications of the sensor must also be complied with!

¹ This whitepaper only covers the EN ISO 13849 standard



Basic procedure

The standard components can only be used in safety applications if they comply with the proven safety principles in the application (e.g. over-dimensioning, see EN ISO 13849-2 D.2). The execution of the following steps facilitates use of the sensor in safety-relevant applications.



Hazards and risk analysis

The hazard and risk analysis must always be carried out for a CE declaration of conformity. In the case of machines and systems for which a product standard already exists, this can be used in each case, provided that the system complies with the standard. If the machine or system deviates from this standard or does not have its own product standard, generic standards must be used (e.g. EN 12100).

If there are corresponding risks that can only be mitigated by control measures, EN ISO 13849 must be consulted for this purpose, for example.

Risk rating

The safety objective is determined by the risk assessment according to EN ISO 13849-1 4.3 and this results in a required performance level (PL_r) between 'a' and 'e' for each hazard.

Risk mitigation

To mitigate risk, evaluate the control system for the PL_r using the following criteria:

- Category (ISO 13849-1, 6.1.3)
- MTTFD (ISO 13849-1, 6.1.4)
- DC (ISO 13849-1, 6.1.5)
- CCF (ISO 13849-1, 6.1.6)

- Systematic failures (ISO 13849-1, 6.1.7)
- Basic safety principles (ISO 13849-2)
- Proven safety principles (ISO 13849-2)

And where applicable

- Proven components (ISO 13849-2)
- Software (ISO 13849-1, 7 and Attachment I)

Design

Regardless of the PL_r, the basic safety principles must be fulfilled. The sensors listed from page 7 onwards were developed in accordance with EN IEC 60947-5-2 and can be used in the argumentation for basic safety principles.

Performance Level (PL)

The performance level indicates the safety level. It is divided into five levels from 'a' to 'e', where 'a' is the lowest safety level and 'e' offers the highest safety level.

Categories (Cat.)

The categories are often associated with the architectures. In essence, they are a measure of their fault tolerance. The categories are divided into Cat. B (basic measures), Cat. 1, Cat. 2, Cat. 3 and Cat. 4.

Diagnostic coverage (DC)

From Cat. 2 onwards, the implementation of a diagnosis (DC) is necessary. For this purpose, an average DC (DC_{avg}) is calculated. This value can be simplified as the arithmetic mean of the individual DCs of all components in the function channel. The DC_{avg} is divided into 4 groups: None (< 60%), Low ($\geq 60\%$), Medium ($\geq 90\%$) and High ($\geq 99\%$).

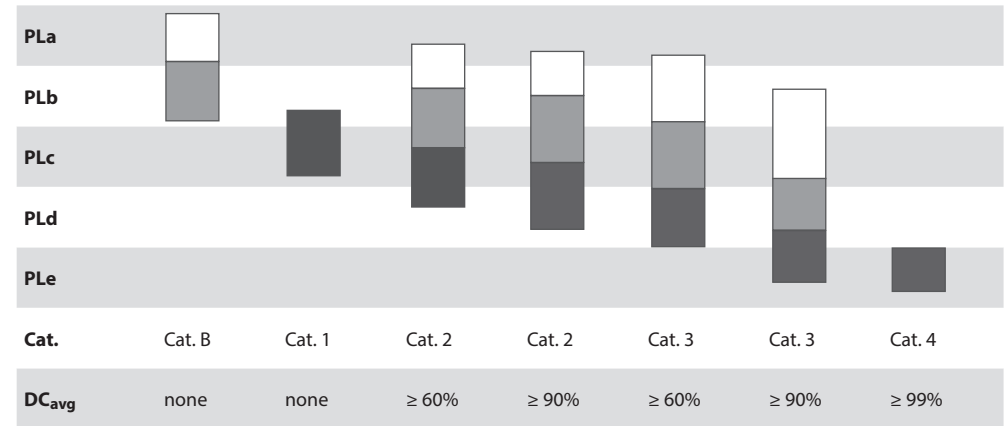
To determine an appropriate DC value, the diagnostic measures must be selected. Table EN ISO 13849-1 E.1 can be used for this purpose. The diagnostic measures of the sensors must be carried out from the control system.

Common Cause Failure (CCF)

The faults that cause all channels in a multi-channel structure to fail simultaneously are called the 'common cause effect' or 'common cause fault'. For this purpose, the CCF is determined according to a point method.

Failure rates and PL

With previously defined safety characteristics, category and DC_{avg} , one of the columns shown below can be selected. At this point, the achievable PL depends only on the $MTTF_D$ of each channel. The $MTTF$ for BERNSTEIN sensors is given. The $MTTF_D$ value can be estimated from $MTTF$ as described in EN ISO 13849 C.5.1. The $MTTF_D$ value of the electrical components is usually assumed to be twice the $MTTF$ value. The other elements of the duct can be taken either from the manufacturer's data, the B_{10} value or from other sources.



$MTTF_D$ of each channel

- White box: $> = 3$ years
- Grey box: $> = 10$ years
- Black box: $> = 30$ years

Figure 1: Relationship between the categories, DC_{avg} , $MTTF_D$ of each channel and PL

Application example

Safety function

Warning when driving off in a truck with extended supports.

Functional description

Loading cranes are supported when loading and unloading trucks with hydraulic or manual support legs to prevent the crane from tipping and ensure stability. For this purpose, the outriggers are hydraulically extended or folded out to the side. The vehicle must not drive off with the supports extended. For this purpose, a warning device that is visible and audible to the driver is switched on in this example as soon as the driver sits down in the driver's seat while the supports are extended. The driver must then retract the supports before driving off.

In the risk analysis, the performance level was assessed as PLc.

Structure

A safe SPS control (S-SPS L1) monitors 3 proximity switches. Switches S1 and S2 are switched by the mechanical system in two channels and monitor the same support leg. Switch S3 is switched when there is an appropriate weight on the driver's seat. When the S3 switch is switched by loading the driver's seat while S1 and S2 are simultaneously switched for extended support legs, the acoustic-optical warning device A1 is activated. In order to get a diagnosis of switch S3, the switching process is plausibilised with S1 and S2. That is, when switches S1 and S2 change their state from retracted support to extended support, the seat switch must be in the unloaded position, otherwise there would already be a warning by error message.

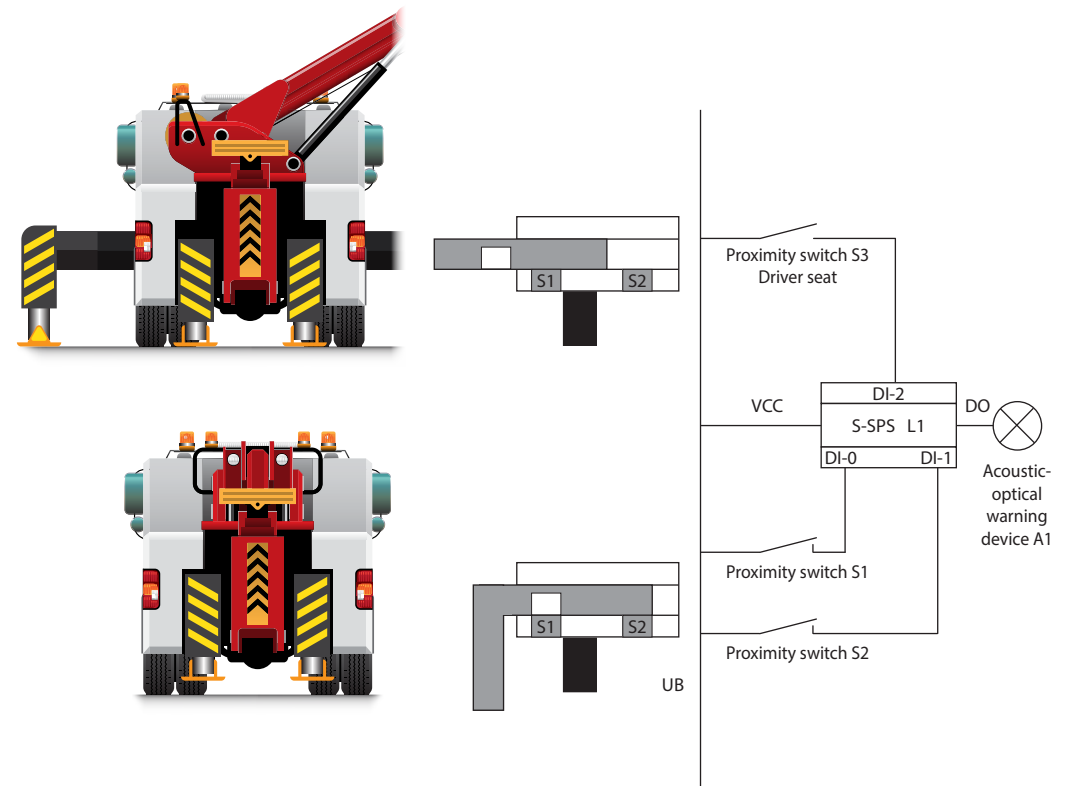


Figure 2: Technical circuit of the safety function

The antivalent combination of switches S1 and S2 can be used for diagnostics. Since the switches have been constructed identically, the dangerous failure of a switch can thus be controlled by the antivalent combination, and the switches fulfil the proven safety principles according to EN ISO 13849-2 clause 9.2.2.c.

Constructive features

- Basic and proven safety principles must be observed.
- Conformity with applicable standards must be maintained.
- The requirements for test frequency from Table 10 in EN ISO 13849-1 must be fulfilled.

Calculation of the probability of default

The safety architecture corresponds to Cat 2. In the risk assessment, it was decided that a fault indication in the event of a failure of the safety function is sufficient.

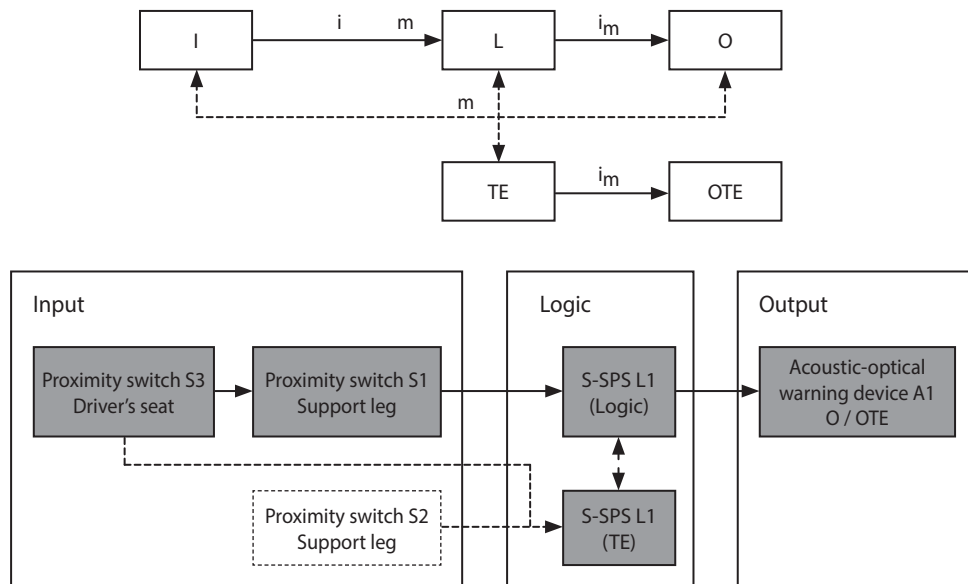


Figure 3: Safety architecture of the safety function

MTTF_D: The BERNSTEIN proximity switches used (S1 and S3) each have an MTTF_D (see Table 1) of 301 years, the S-SPS has one of 200 years and the warning device has one of 40 years as a worst-case value. In total, the MTTF_D for channel 1 is 27.3 years.

According to EN ISO 13849, the MTTF_D value of the diagnostic channel must be greater than half of the functional channel. The MTTF_D value of the diagnostic channel (S2, TE and OTE) here is 30 years.

DC_{avg}: Error detection by the S-SPS leads to DC = 60% for the proximity switch. The warning device has a DC of 99% due to the annual function test. For the S-SPS, the manufacturer specifies a DC = 99%. This results in an average diagnostic coverage DC_{avg} of 91.9% ('medium').

According to EN ISO 13849, the diagnosis must either be 100 times more frequent than the request rate, or the diagnostic check must be performed immediately when the safety function is requested. However, this must also take place within the safety response time. In this application, a safety request is only possible when the support legs are extended. The S2 sensor is diagnosed in this phase.

CCF: The measures against failures due to common causes were considered according to Table F.1 of EN ISO 13849-1. This resulted in 75 points. The measures are rated as sufficient from 65 points upwards.

Result:

Based on the values: MTTF_D: 27.3, DC_{avg}: 91.9% (medium) and category: Cat. 2, PLC can be achieved according to Figure 1. According to EN ISO 13849-K.1, PLC is achieved in this case from MTTF_D > 16 years.

Article no.	Designation	MTTF [a]			
		40°C	50°C	60°C	70°C
6502303006	KIB-M12NS/002-KL7	1484	1014	692	470
6502319002	KIN-T12NS/004-KL0,5S	1484	1014	692	470
6502344004	KIN-M12NS/004-KS12 E	1484	1014	692	470
6502703001	KIB-M12PÖ/002-KL2 E	1484	1014	692	470
6502703002	KIB-M12PÖ/002-KL6	1484	1014	692	470
6502704001	KIN-M12PÖ/004-KL2 E	1484	1014	692	470
6502704002	KIN-M12PÖ/004-KL6 E	1484	1014	692	470
6502743003	KIB-M12PÖ/002-KLS12	1484	1014	692	470
6502743005	KIB-M12PÖ/002-KS12V	1484	1014	692	470
6502744003	KIN-M12PÖ/004-KLS12	1484	1014	692	470
6502744006	KIN-M12PÖ/004-KLSM8V	1484	1014	692	470
6502780001	KIB-Q08PÖ/1,5-K2	1452	986	667	449
6502780002	KIB-Q08PÖ/1,5-KLSM8	1452	986	667	449
6502799010	KIB-Q05PÖ/001-K2PU	1452	986	667	449
6502901004	KIB-M08PS/1,5-KL6	1452	986	667	449
6502901007	KIB-M08PS/1,5-KL3 E	1452	986	667	449
6502903006	KIB-M12PS/002-KL6 E	1484	1014	692	470
6502903013	KIB-M12PS/002-KL2T	1484	1014	692	470
6502903017	KIB-M12PS/002-KL6V	1484	1014	692	470
6502903023	KIB-M12PS/004-KL2VE	1484	1014	692	470
6502904002	KIN-M12PS/004-KL2 E	1484	1014	692	470
6502904005	KIN-M12PS/004-KL6 E	1484	1014	692	470
6502904015	KIN-M12PS/004-KL6V	1452	986	667	449
6502919001	KIN-T12PS/004-KL2 E	1484	1014	692	470
6502942006	KIN-M08PS/002-KLSM8 E	1452	986	667	449
6502942007	KIB-M08PS/1,5-KS12 E	1452	986	667	449
6502942008	KIN-M08PS/002-KS12 E	1452	986	667	449
6502943006	KIB-M12PS/002-KS12V	1484	1014	692	470
6502943008	KIB-M12PS/002-KLSM8V	1484	1014	692	470
6502943012	KIB-M12PS/002-KLS12 E	1484	1014	692	470
6502943015	KIB-M12PS/004-KLS12E	1484	1014	692	470

Article no.	Designation	MTTF [a]			
		40°C	50°C	60°C	70°C
6502944006	KIN-M12PS/004-KS12V	1484	1014	692	470
6502944012	KIN-M12PS/004-KLS12	1484	1014	692	470
6502980002	KIB-Q08PS/1,5-KLSM8	1452	986	667	449
6502980004	KIB-Q08PS/1,5-K2	1452	986	667	449
6502999003	KIB-M05PS/001-KL2PU	1452	986	667	449
6502999007	KIB-M05PS/001-KL6PU	1452	986	667	449
6502999012	KIB-D06PS/1,5-KLSM8 E	1452	986	667	449
6502999013	KIN-D06PS/002-KLSM8	1452	986	667	449
6502999018	KIB-M05PS/001-KLSM8	1452	986	667	449
6502999026	KIB-Q05PS/001-K2PU	1452	986	667	449
6502999041	KIB-Q12PS/004-KLSM8E	1484	1014	692	470
6532101001	KIB-M08NÖ/001-KL2V	1452	986	667	449
6532101002	KIN-M08NÖ/002-KL2V	1452	986	667	449
6532102001	KIB-M08NÖ/001-KL2	1452	986	667	449
6532102002	KIN-M08NÖ/002-KL2	1452	986	667	449
6532103001	KIB-M12NÖ/002-KL2V	1452	986	667	449
6532103002	KIB-M12NÖ/002-KL2	1452	986	667	449
6532104001	KIN-M12NÖ/004-KL2V	1452	986	667	449
6532104002	KIN-M12NÖ/004-KL2	1452	986	667	449
6532105001	KIB-M18NÖ/005-KL2V	1484	1014	692	470
6532105002	KIB-M18NÖ/005-KL2	1484	1014	692	470
6532105003	KIB-M18NÖ/005-KLS12V	1484	1014	692	470
6532105004	KIB-M18NÖ/005-KLS12	1484	1014	692	470
6532106001	KIN-M18NÖ/008-KL2V	1484	1014	692	470
6532106002	KIN-M18NÖ/008-KL2	1484	1014	692	470
6532106003	KIN-M18NÖ/008-KLS12V	1484	1014	692	470
6532106004	KIN-M18NÖ/008-KLS12	1484	1014	692	470
6532107001	KIB-M30NÖ/010-KL2V	1484	1014	692	470
6532107002	KIB-M30NÖ/010-KL2	1484	1014	692	470
6532107003	KIB-M30NÖ/010-KLS12V	1484	1014	692	470
6532107004	KIB-M30NÖ/010-KLS12	1484	1014	692	470

Article no.	Designation	MTTF [a]			
		40°C	50°C	60°C	70°C
6532108001	KIN-M30NÖ/015-KL2V	1484	1014	692	470
6532108002	KIN-M30NÖ/015-KL2	1484	1014	692	470
6532108003	KIN-M30NÖ/015-KLS12V	1484	1014	692	470
6532108004	KIN-M30NÖ/015-KLS12	1484	1014	692	470
6532142001	KIB-M08NÖ/001-KLSM8V	1452	986	667	449
6532142002	KIN-M08NÖ/002-KLSM8V	1452	986	667	449
6532142003	KIB-M08NÖ/001-KLSM8	1452	986	667	449
6532142004	KIN-M08NÖ/002-KLSM8	1452	986	667	449
6532143001	KIB-M12NÖ/002-KLS12V	1452	986	667	449
6532143002	KIB-M12NÖ/002-KLS12	1452	986	667	449
6532144001	KIN-M12NÖ/004-KLS12V	1452	986	667	449
6532144002	KIN-M12NÖ/004-KLS12	1452	986	667	449
6532199001	KIB-D04NÖ/001-KL2	1452	986	667	449
6532199002	KIB-M05NÖ/001-KL2	1452	986	667	449
6532199003	KIB-M05NÖ/001-KLSM8	1452	986	667	449
6532301001	KIB-M08NS/001-KL2V	1452	986	667	449
6532301002	KIN-M08NS/002-KL2V	1452	986	667	449
6532302001	KIB-M08NS/001-KL2	1452	986	667	449
6532302002	KIN-M08NS/002-KL2	1452	986	667	449
6532303001	KIB-M12NS/002-KL2V	1452	986	667	449
6532303002	KIB-M12NS/002-KL2	1452	986	667	449
6532303003	KIB-M12NS/004-KL2EV	1452	986	667	449
6532304001	KIN-M12NS/004-KL2V	1452	986	667	449
6532304002	KIN-M12NS/004-KL2	1452	986	667	449
6532305001	KIB-M18NS/005-KL2V	1484	1014	692	470
6532305002	KIB-M18NS/005-KL2	1484	1014	692	470
6532305003	KIB-M18NS/005-KLS12V	1484	1014	692	470
6532305004	KIB-M18NS/005-KLS12	1484	1014	692	470
6532306001	KIN-M18NS/008-KL2V	1484	1014	692	470
6532306002	KIN-M18NS/008-KL2	1484	1014	692	470
6532306003	KIN-M18NS/008-KLS12V	1484	1014	692	470

Article no.	Designation	MTTF [a]			
		40°C	50°C	60°C	70°C
6532306004	KIN-M18NS/008-KLS12	1484	1014	692	470
6532307001	KIB-M30NS/010-KL2V	1484	1014	692	470
6532307002	KIB-M30NS/010-KL2	1484	1014	692	470
6532307003	KIB-M30NS/010-KLS12V	1484	1014	692	470
6532307004	KIB-M30NS/010-KLS12	1484	1014	692	470
6532308001	KIN-M30NS/015-KL2V	1484	1014	692	470
6532308002	KIN-M30NS/015-KL2	1484	1014	692	470
6532308003	KIN-M30NS/015-KLS12V	1484	1014	692	470
6532308004	KIN-M30NS/015-KLS12	1484	1014	692	470
6532342001	KIB-M08NS/001-KLSM8V	1452	986	667	449
6532342002	KIN-M08NS/002-KLSM8V	1452	986	667	449
6532342003	KIB-M08NS/001-KLSM8	1452	986	667	449
6532342004	KIN-M08NS/002-KLSM8	1452	986	667	449
6532343001	KIB-M12NS/002-KLS12V	1452	986	667	449
6532343002	KIB-M12NS/002-KLS12	1452	986	667	449
6532344001	KIN-M12NS/004-KLS12V	1452	986	667	449
6532344002	KIN-M12NS/004-KLS12	1452	986	667	449
6532399001	KIB-D04NS/001-KL2	1452	986	667	449
6532399002	KIB-M05NS/001-KL2	1452	986	667	449
6532399003	KIB-M05NS/001-KLSM8	1452	986	667	449
6532701001	KIB-M08PÖ/001-KL2VI	1452	986	667	449
6532701002	KIN-M08PÖ/002-KL2VI	1452	986	667	449
6532702001	KIB-M08PÖ/001-KL2I	1452	986	667	449
6532702002	KIN-M08PÖ/002-KL2I	1452	986	667	449
6532703001	KIB-M12PÖ/002-KL2VI	1452	986	667	449
6532703002	KIB-M12PÖ/002-KL2I	1452	986	667	449
6532704001	KIN-M12PÖ/004-KL2VI	1452	986	667	449
6532704002	KIN-M12PÖ/004-KL2I	1452	986	667	449
6532705001	KIB-M18PÖ/005-KL2VI	1484	1014	692	470
6532705002	KIB-M18PÖ/005-KL2I	1484	1014	692	470
6532705003	KIB-M18PÖ/005-KLS12VI	1484	1014	692	470

Article no.	Designation	MTTF [a]			
		40°C	50°C	60°C	70°C
6532705004	KIB-M18PÖ/005-KLS12I	1484	1014	692	470
6532706001	KIN-M18PÖ/008-KL2VI	1484	1014	692	470
6532706002	KIN-M18PÖ/008-KL2I	1484	1014	692	470
6532706003	KIN-M18PÖ/008-KLS12VI	1484	1014	692	470
6532706004	KIN-M18PÖ/008-KLS12I	1484	1014	692	470
6532707001	KIB-M30PÖ/010-KL2VI	1484	1014	692	470
6532707002	KIB-M30PÖ/010-KL2I	1484	1014	692	470
6532707003	KIB-M30PÖ/010-KLS12VI	1484	1014	692	470
6532707004	KIB-M30PÖ/010-KLS12I	1484	1014	692	470
6532708001	KIN-M30PÖ/015-KL2VI	1484	1014	692	470
6532708002	KIN-M30PÖ/015-KL2I	1484	1014	692	470
6532708003	KIN-M30PÖ/015-KLS12VI	1484	1014	692	470
6532708004	KIN-M30PÖ/015-KLS12I	1484	1014	692	470
6532742001	KIB-M08PÖ/001-KLSM8VI	1452	986	667	449
6532742002	KIN-M08PÖ/002-KLSM8VI	1452	986	667	449
6532742003	KIB-M08PÖ/001-KLSM8I	1452	986	667	449
6532742004	KIN-M08PÖ/002-KLSM8I	1452	986	667	449
6532743001	KIB-M12PÖ/002-KLS12VI	1452	986	667	449
6532743002	KIB-M12PÖ/002-KLS12I	1452	986	667	449
6532743003	KIB-M12PÖ/004-KLS12VEI	1452	986	667	449
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6532799001	KIB-D04PÖ/001-KL2I	1452	986	667	449
6532799002	KIB-M05PÖ/001-KL2I	1452	986	667	449
6532799003	KIB-M05PÖ/001-KLSM8I	1452	986	667	449
6532901001	KIB-M08PS/001-KL2VI	1452	986	667	449
6532901002	KIN-M08PS/002-KL2VI	1452	986	667	449
6532902001	KIB-M08PS/001-KL2I	1452	986	667	449
6532902002	KIN-M08PS/002-KL2I	1452	986	667	449
6532903001	KIB-M12PS/002-KL2VI	1452	986	667	449
6532903002	KIB-M12PS/002-KL2I	1452	986	667	449

Article no.	Designation	MTTF [a]			
		40°C	50°C	60°C	70°C
6532903003	KIB-M12PS/004-KL2EVI	1452	986	667	449
6532904001	KIN-M12PS/004-KL2VI	1452	986	667	449
6532904002	KIN-M12PS/004-KL2I	1452	986	667	449
6532904003	KIN-M12PS/004-KL2VI	1484	1014	692	470
6532904003	KIN-M12PS/004-KL2VI	1452	986	667	449
6532905001	KIB-M18PS/005-KL2VI	1484	1014	692	470
6532905002	KIB-M18PS/005-KL2I	1484	1014	692	470
6532905003	KIB-M18PS/005-KLS12VI	1484	1014	692	470
6532905004	KIB-M18PS/005-KLS12I	1484	1014	692	470
6532906001	KIN-M18PS/008-KL2VI	1484	1014	692	470
6532906002	KIN-M18PS/008-KL2I	1484	1014	692	470
6532906003	KIN-M18PS/008-KLS12VI	1484	1014	692	470
6532906004	KIN-M18PS/008-KLS12I	1484	1014	692	470
6532907001	KIB-M30PS/010-KL2VI	1484	1014	692	470
6532907002	KIB-M30PS/010-KL2I	1484	1014	692	470
6532907003	KIB-M30PS/010-KLS12VI	1484	1014	692	470
6532907004	KIB-M30PS/010-KLS12I	1484	1014	692	470
6532908001	KIN-M30PS/015-KL2VI	1484	1014	692	470
6532908002	KIN-M30PS/015-KL2I	1484	1014	692	470
6532908003	KIN-M30PS/015-KLS12VI	1484	1014	692	470
6532908004	KIN-M30PS/015-KLS12I	1484	1014	692	470
6532942001	KIB-M08PS/001-KLSM8VI	1452	986	667	449
6532942002	KIN-M08PS/002-KLSM8VI	1452	986	667	449
6532942003	KIB-M08PS/001-KLSM8I	1452	986	667	449
6532942004	KIN-M08PS/002-KLSM8I	1452	986	667	449
6532943001	KIB-M12PS/002-KLS12VI	1452	986	667	449
6532943002	KIB-M12PS/002-KLS12I	1452	986	667	449
6532943003	KIB-M12PS/004-KLS12VEI	1452	986	667	449
6532943004	KIB-M12PS/004-KLS12EVI	1452	986	667	449
6532944001	KIN-M12PS/004-KLS12VI	1452	986	667	449
6532944002	KIN-M12PS/004-KLS12I	1452	986	667	449

Article no.	Designation	MTTF [a]			
		40°C	50°C	60°C	70°C
6532999001	KIB-D04PS/001-KL2I	1452	986	667	449
6532999002	KIB-M05PS/001-KL2I	1452	986	667	449
6532999003	KIB-M05PS/001-KLSM8I	1452	986	667	449
6602303875	KIB-M12NS/002-KL2,6 E	1484	1014	692	470
6602304195	KIN-M12NS/004-KL3V	1452	986	667	449
6602343366	KIB-M12NS/004-KLSM8E	1484	1014	692	470
6602703023	KIB-M12PS/002-KL2,49S	1484	1014	692	470
6602703356	KIB-M12PÖ/002-KL6V	1484	1014	692	470
6602743112	KIB-M12PÖ/002-KLS12 E	1484	1014	692	470
6602901554	KIB-M08PS/1,5-KL0,31S8 E	1452	986	667	449
6602903148	KIB-M12PS/004-KL5VE	1452	986	667	449
6602903329	KIB-M12PS/002-KL10 E	1484	1014	692	470
6602906108	KIN-M18PS/008-KLS12 E	1484	1014	692	470
6602980004	KIB-Q08PS/1,5-K5T	1452	986	667	449
6602980315	KIB-Q08PS/1,5-K2PU	1452	986	667	449
6602999555	KIB-M05PS/001-KL0,11S8	1452	986	667	449
6932904001	KIN-M12PS/004-KL2 E	1484	1014	692	470
6932942001	KIB-M08PS/1,5-KLSM8 E	1452	986	667	449
6932944001	KIN-M12PS/004-KLS12 E	1484	1014	692	470