Kierunek Elektronika i Telekomunikacja,
Studia II stopnia
Specjalność: Systemy wbudowane

Praktyczne aspekty prognozowania niezawodności systemów elektronicznych -przykłady analiz

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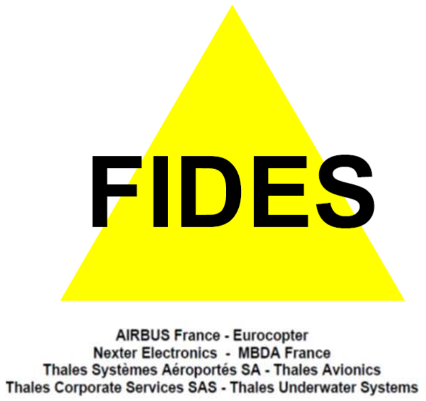
Program wykładu

- Przykład szacowania parametru MTBF zgodnie z metodologiami
  - MIL-HDBK-217
  - FIDES
- Przykład analizy FMEDA (*Failure Modes Effects and Diagnostic Analysis*) i MTBF zgodnie z metodologią SN29500
- http://nomtbf.com/

It is very likely the worst four letter acronym in the reliability engineering profession ☺

Przykładowe metodologie

http://fides-reliability.org/



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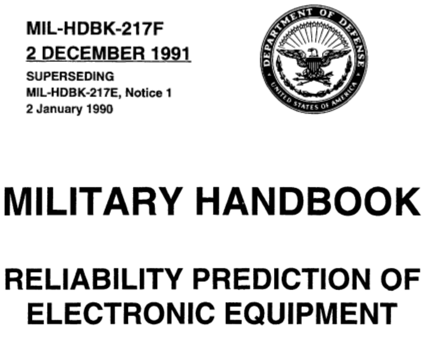
http://www.weibull.com/



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MILITARY HANDBOOK

RELIABILITY PREDICTION OF ELECTRONIC EQUIPMENT

https://www.fides-reliability.org/en/system/files/documents/201305_TC56_Meeting27-56_1512_Presentation_JCL_V1.pdf

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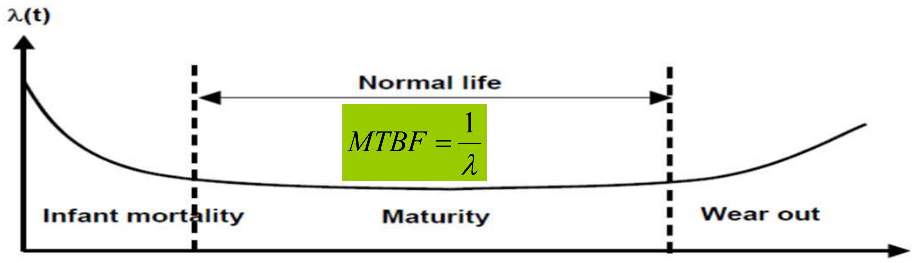
Przykładowy moduł – studencki projekt

Konwerter USB <-> RS232 z izolacją galwaniczną 2,5 kV

Autorzy: Konrad Sierotowicz & Kamil Brzozowski

*Konwerter USB-RS232,
to urządzenie pozwalające na bezpieczną
transmisję między urządzeniem z interfejsem
szeregowym RS232 a portem USB. Urządzenie ma
na celu zapewnić izolację galwaniczną między urządzeniami
w celu uchronienia wrażliwych komponentów komputera przed
uszkodzeniem przy zapewnieniu wysokich prędkości niezakłóconej transmisji*

Analiza MTBF modułu konwertera USB <-> RS232 z izolacją galwaniczną 2,5 kV



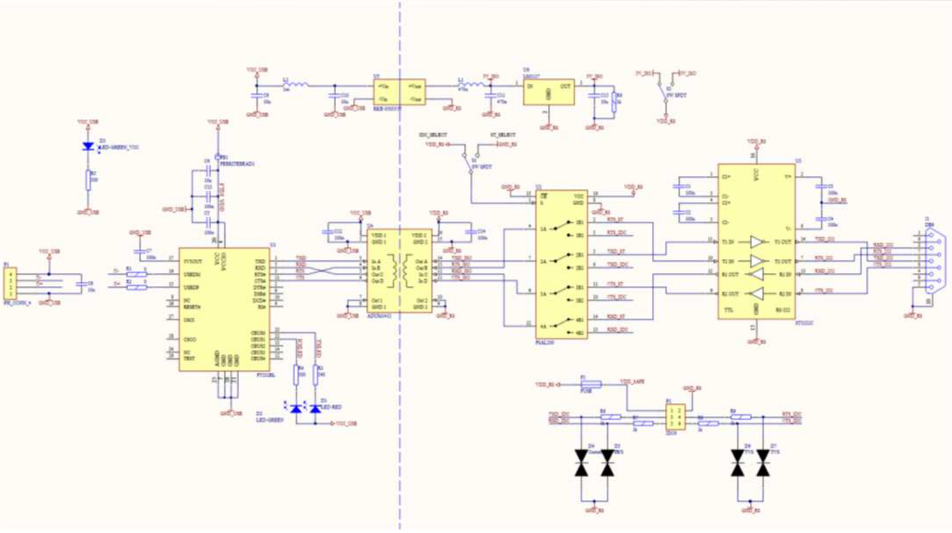
MTBF – **średni czas bezawaryjnej pracy** (ang. ***Mean Time Between Failures***)

λ – **intensywność uszkodzeń** (ang. ***Failure Rate***) (zwykle) jednostka FIT (ang. ***Failure In Time***) 1 FIT = 1 uszkodzenie w 10^9 godzinach pracy

$$\lambda = \sum_{i=1}^{n} \left(\lambda_{ref} \times \pi_I \times \pi_U \times \pi_T \times \pi_? \times \pi_{??} \times ....\right)_i$$

λ_{ref} referencyjna intensywność uszkodzeń
π_U czynnik przyspieszające od napięcia pracy;
π_I czynnik przyspieszające od prądu pracy;
π_T czynnik przyspieszające od temperatury pracy;
$\pi_?$ czynnik przyspieszające od ....
wybranej metodologii ☺ ;

Analiza MTBF modułu konwertera USB <-> RS232 z izolacją galwaniczną 2,5 kV



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λ_p - part failure rate

$$\lambda_p = (C_1\pi_T + C_2\pi_E + \lambda_{CYC})\,\pi_Q * \pi_L \quad \textit{Failures/ } 10^6 \textit{ Hours}$$

C_1 -die Complexity Failure Rate - sekcja 5.1 MILHDBK-217F

π_T -temperature factor - sekcja 5.8 MILHDBK-217F

C_2 -Package Failure Rate for all Microcircuits - sekcja 5.9 MILHDBK-217F

π_E -Environment Factor - sekcja 5.10 MILHDBK-217F

λ_{CYC} -tylko EEPROM - sekcja 5.10 MILHDBK-217F

π_Q -Quality Factors - sekcja 5.10 MILHDBK-217F

π_L -Learning Factor - sekcja 5.10 MILHDBK-217F

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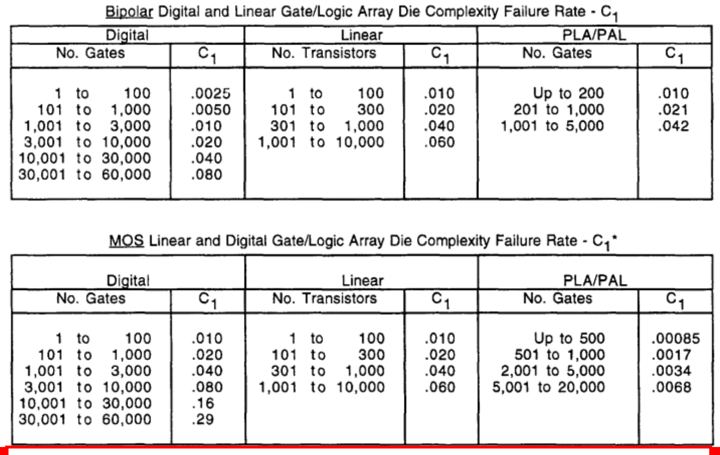
C_1 -die Complexity Failure Rate - sekcja 5.1 MILHDBK-217F



Bipolar Digital and Linear Gate/Logic Array Die Complexity Failure Rate - C_1

Digital		Linear		PLA/PAL	
No. Gates	C_1	No. Transistors	C_1	No. Gates	C_1
1 to 100	.0025	1 to 100	.010	Up to 200	.010
101 to 1,000	.0050	101 to 300	.020	201 to 1,000	.021
1,001 to 3,000	.010	301 to 1,000	.040	1,001 to 5,000	.042
3,001 to 10,000	.020	1,001 to 10,000	.060		
10,001 to 30,000	.040				
30,001 to 60,000	.080				

MOS Linear and Digital Gate/Logic Array Die Complexity Failure Rate - C_1*

Digital		Linear		PLA/PAL	
No. Gates	C_1	No. Transistors	C_1	No. Gates	C_1
1 to 100	.010	1 to 100	.010	Up to 500	.00085
101 to 1,000	.020	101 to 300	.020	501 to 1,000	.0017
1,001 to 3,000	.040	301 to 1,000	.040	2,001 to 5,000	.0034
3,001 to 10,000	.080	1,001 to 10,000	.060	5,001 to 20,000	.0068
10,001 to 30,000	.16				
30,001 to 60,000	.29				

!!!! *NOTE: For CMOS gate counts above 60,000 use the VHSIC/VHSIC-Like model in Section 5.3 !!!!

Układy scalone

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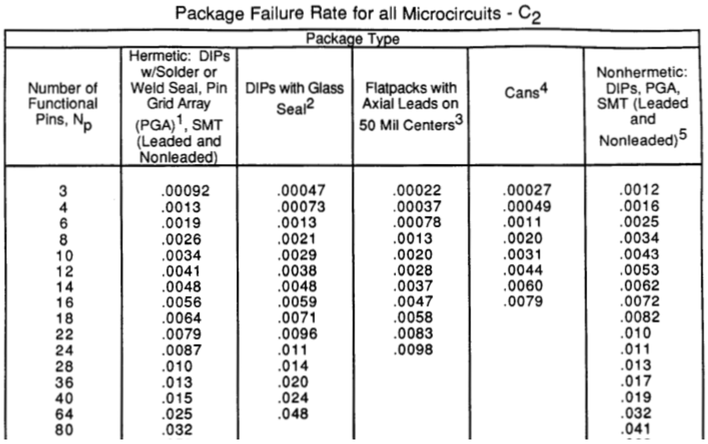
C_2 -Package Failure Rate for all Microcircuits - sekcja 5.9 MILHDBK-217F



Package Failure Rate for all Microcircuits - C_2

Number of Functional Pins, N_p	Package Type				
	Hermetic: DIPs w/Solder or Weld Seal, Pin Grid Array (PGA)^1, SMT (Leaded and Nonleaded)	DIPs with Glass Seal^2	Flatpacks with Axial Leads on 50 Mil Centers^3	Cans^4	Nonhermetic: DIPs, PGA, SMT (Leaded and Nonleaded)^5
3	.00092	.00047	.00022	.00027	.0012
4	.0013	.00073	.00037	.00049	.0016
6	.0019	.0013	.00078	.0011	.0025
8	.0026	.0021	.0013	.0020	.0034
10	.0034	.0029	.0020	.0031	.0043
12	.0041	.0038	.0028	.0044	.0053
14	.0048	.0048	.0037	.0060	.0062
16	.0056	.0059	.0047	.0079	.0072
18	.0064	.0071	.0058		.0082
22	.0079	.0096	.0083		.010
24	.0087	.011	.0098		.011
28	.010	.014			.013
36	.013	.020			.017
40	.015	.024			.019
64	.025	.048			.032
80	.032				.041

Układy scalone

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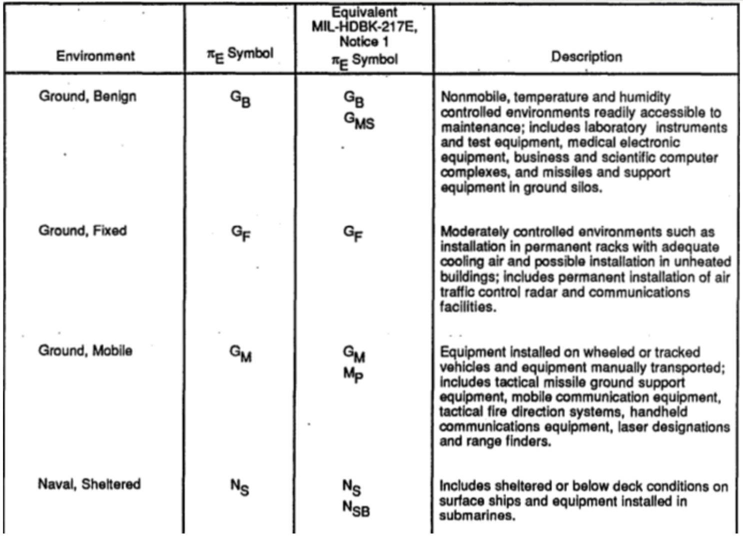
π_E -

Environment Factor

Tabela 3.2



Environment	π_E Symbol	Equivalent MIL-HDBK-217E, Notice 1 π_E Symbol	Description
Ground, Benign	G_B	G_B G_{MS}	Nonmobile, temperature and humidity controlled environments readily accessible to maintenance; includes laboratory instruments and test equipment, medical electronic equipment, business and scientific computer complexes, and missiles and support equipment in ground silos.
Ground, Fixed	G_F	G_F	Moderately controlled environments such as installation in permanent racks with adequate cooling air and possible installation in unheated buildings; includes permanent installation of air traffic control radar and communications facilities.
Ground, Mobile	G_M	G_M M_P	Equipment installed on wheeled or tracked vehicles and equipment manually transported; includes tactical missile ground support equipment, mobile communication equipment, tactical fire direction systems, handheld communications equipment, laser designations and range finders.
Naval, Sheltered	N_S	N_S N_{SB}	Includes sheltered or below deck conditions on surface ships and equipment installed in submarines.

Układy scalone

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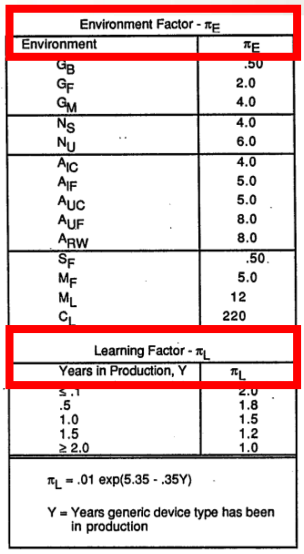
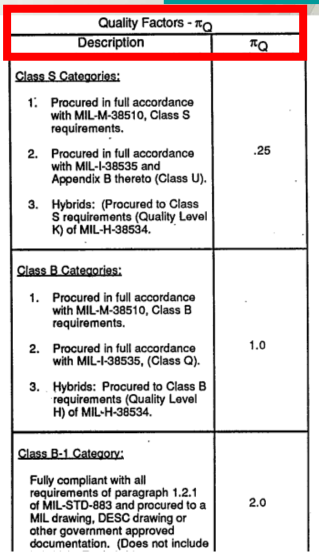


Environment Factor - π_E	
Environment	π_E
G_B	.50
G_F	2.0
G_M	4.0
N_S	4.0
N_U	6.0
A_{IC}	4.0
A_{IF}	5.0
A_{UC}	5.0
A_{UF}	8.0
A_{RW}	8.0
S_F	.50
M_F	5.0
M_L	12
C_L	220

Learning Factor - π_L	
Years in Production, Y	π_L
≤ .1	2.0
.5	1.8
1.0	1.5
1.5	1.2
≥ 2.0	1.0

$\pi_L = .01 \exp(5.35 - .35Y)$

Y = Years generic device type has been in production



Quality Factors - π_Q	
Description	π_Q
<u>Class S Categories:</u> 1. Procured in full accordance with MIL-M-38510, Class S requirements. 2. Procured in full accordance with MIL-I-38535 and Appendix B thereto (Class U). 3. Hybrids: (Procured to Class S requirements (Quality Level K) of MIL-H-38534.	.25
<u>Class B Categories:</u> 1. Procured in full accordance with MIL-M-38510, Class B requirements. 2. Procured in full accordance with MIL-I-38535, (Class Q). 3. Hybrids: Procured to Class B requirements (Quality Level H) of MIL-H-38534.	1.0
<u>Class B-1 Category:</u> Fully compliant with all requirements of paragraph 1.2.1 of MIL-STD-883 and procured to a MIL drawing, DESC drawing or other government approved documentation. (Does not include	2.0

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$$\lambda_{\text{product}} = \left(\sum_{\text{Components}} \lambda_{\text{Components}} + \sum_{\text{PCB}} \lambda_{\text{PCB}} + \sum_{\text{Boards}} \lambda_{\text{COTS boards}} + \sum_{\text{other\_S-A}} \lambda_{\text{Other\_subassemblies}} \right)$$

Component
Off
The
Shelfe

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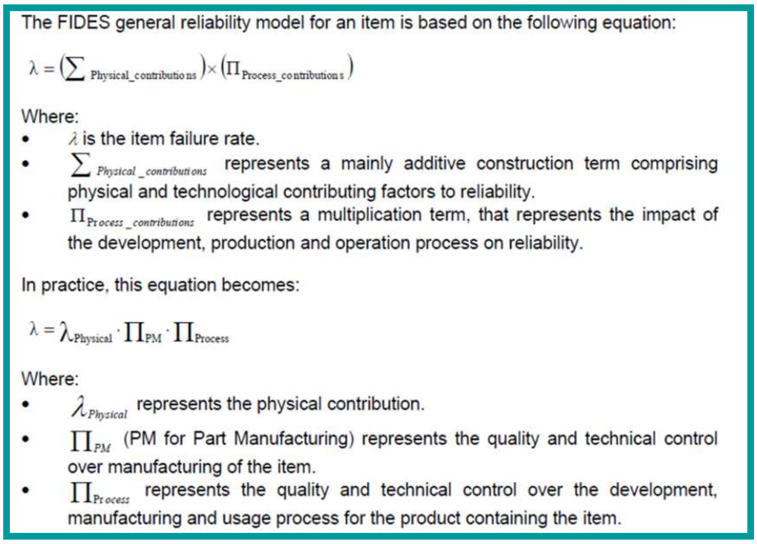

The FIDES general reliability model for an item is based on the following equation:

$$\lambda = \left(\sum_{\text{Physical\_contributions}}\right) \times \left(\Pi_{\text{Process\_contributions}}\right)$$

Where:

- λ is the item failure rate.
- $\sum_{Physical\_contributions}$ represents a mainly additive construction term comprising physical and technological contributing factors to reliability.
- $\Pi_{Process\_contributions}$ represents a multiplication term, that represents the impact of the development, production and operation process on reliability.

In practice, this equation becomes:

$$\lambda = \lambda_{\text{Physical}} \cdot \Pi_{\text{PM}} \cdot \Pi_{\text{Process}}$$

Where:

- $\lambda_{Physical}$ represents the physical contribution.
- Π_{PM} (PM for Part Manufacturing) represents the quality and technical control over manufacturing of the item.
- $\Pi_{Process}$ represents the quality and technical control over the development, manufacturing and usage process for the product containing the item.

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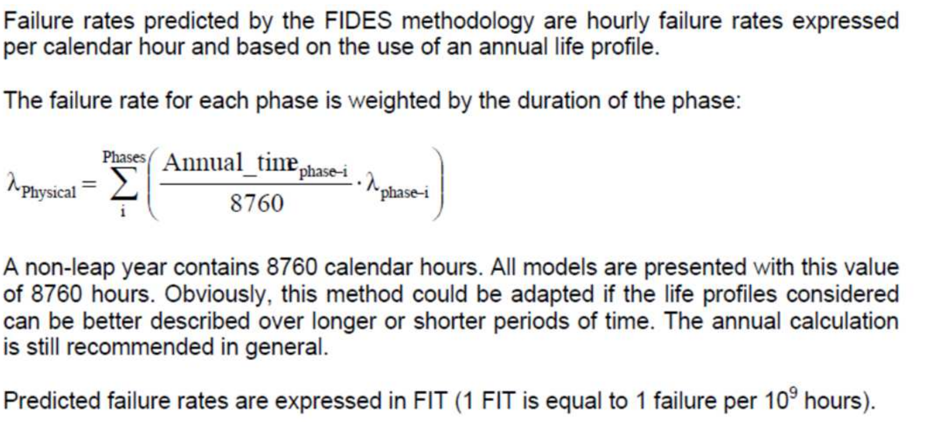

Failure rates predicted by the FIDES methodology are hourly failure rates expressed per calendar hour and based on the use of an annual life profile.

The failure rate for each phase is weighted by the duration of the phase:

$$\lambda_{\text{Physical}} = \sum_{i}^{\text{Phases}} \left(\frac{\text{Annual\_time}_{\text{phase-i}}}{8760} \cdot \lambda_{\text{phase-i}} \right)$$

A non-leap year contains 8760 calendar hours. All models are presented with this value of 8760 hours. Obviously, this method could be adapted if the life profiles considered can be better described over longer or shorter periods of time. The annual calculation is still recommended in general.

Predicted failure rates are expressed in FIT (1 FIT is equal to 1 failure per 10^9 hours).

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$$\lambda_{\text{Physical}} = \left[\sum_{\text{Physical\_Contributions}} \left(\lambda_0 \cdot \Pi_{\text{acceleration}} \right) \right] \cdot \Pi_{\text{induced}}$$

- Thermal:	$\Pi_{Thermal}$
- Electrical:	$\Pi_{Electrical}$
- Temperature cycling:	Π_{TCy}
- Mechanical:	$\Pi_{Mechanical}$
- Humidity:	Π_{RH}
- Chemical:	$\Pi_{Chemical}$

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The Π_{induced} factor represents the contribution of overstresses not listed as such. It is calculated for each phase in the life profile.

It is in the following form:

$$\Pi_{\text{induce-i}} = \left(\Pi_{\text{placement-i}} \times \Pi_{\text{application-i}} \times \Pi_{\text{ruggedising}} \right)^{0,511 \times \text{Ln}\left(C_{\text{sensibility}}\right)}$$

- $\Pi_{\text{Placement}}$ represents the influence of the item placement in the equipment or the system. In this case placement refers to the position of the item or the function in which it is integrated (particularly whether or not it is interfaced).
- $\Pi_{\text{Application}}$ represents the influence of the usage environment for application of the product containing the item. For example, exposure to a mechanical overstress is a priori more important in electronics integrated into a mobile system than in a fixed station system. This factor is variable depending on the life profile phase.
- $\Pi_{\text{Ruggedising}}$ represents the influence of the policy for taking account of overstresses in the product development.
- $C_{\text{sensitivity}}$ represents the coefficient of sensitivity to overstresses inherent to the item technology considered.
- i is the index of the phase considered.

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Contribution associated with the $\Pi_{Placement}$ factor:

	$\Pi_{placement}$
Digital non-interface function	1.0
Digital interface function	1.6
Analogue low level non-interface function	1.3
Analogue low level interface function	2.0
Analogue power non-interface function	1.6
Analogue power interface function	2.5

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Contribution associated with the $\Pi_{application}$ factor:

The $\Pi_{application}$ parameter is evaluated by marking a series of criteria. Each criterion can have three levels corresponding to a favourable, moderate or unfavourable situation. Each criterion has a particular impact on overstresses (P_{OS}):

$$\Pi_{application} = \frac{1}{66} \cdot \sum_{k=Criteria} Pmarks_k \cdot Pos_k$$

Where:

$Pmarks_k$ are weighting factors corresponding to marks assigned to each criterion ($\Pi_{application}$: Table 2).

Pos_k are weights for each criterion ($\Pi_{application}$: Table 1).

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$\Pi_{application}$: **Table 1**

Criterion	Description	Levels	Examples and comments	Weight P_{OS}
User type in the phase considered	Represents the capability to respect procedures, facing operational constraints.	0: Favourable 1: Moderate 2: Unfavourable	The product use and the respect of rules are globally driven by: 0: quality constraints (industrial) 1: cost of the product (general public) 2: success of the mission and operational context (military) Quality, cost, mission constraints exist in all application types, but with different priority.	20
User qualification level in the phase considered	Represents the level of control of the user or the worker regarding an operational context	0: Favourable 1: Moderate 2: Unfavourable	0: Highly qualified 1: Qualified 2: Slightly qualified or with little experience In some phases, the user to be considered is the person who does the maintenance or servicing	10
System mobility	Represents contingencies related to possibilities of the system being moved	0: Non-aggressive 1: Moderate 2: Severe	0: Few contingencies (fixed or stable environment) 1: Moderate contingencies 2: Severe contingencies, large variability (automobile)	4

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Contribution associated with the $\Pi_{Ruggedising}$ factor

The $\Pi_{Ruggedising}$ factor is determined by considering the following questions.

The answers and the justifications provided by the audited person will be used to fix a ***satisfaction***

If the $\Pi_{Ruggedising}$ factor is not evaluated, a default value of 1.7 is suggested. Use of the default value can reduce the accuracy of the final results.

- N3 = the recommendation is globally applied → few risks regarding reliability;
- N4 = the recommendation is fully applied and is described in a procedure → Control of the reliability.

Sheet	Recommendation	Weight
169	Write complete procedures for all product implementation and maintenance operations	7
157	Provide training and manage maintenance of skills for use and maintenance of the product	7
158	Check that procedures specific to the product and rules specific to businesses are respected by an appropriate monitoring system	7
168	Carry out a review of maintenance operations done by the final user and deal with his recommendations	4
156	Check that environmental specifications are complete. Verification criteria for completeness of specifications: analysis, tests, feedback from operations, respect of standards	4

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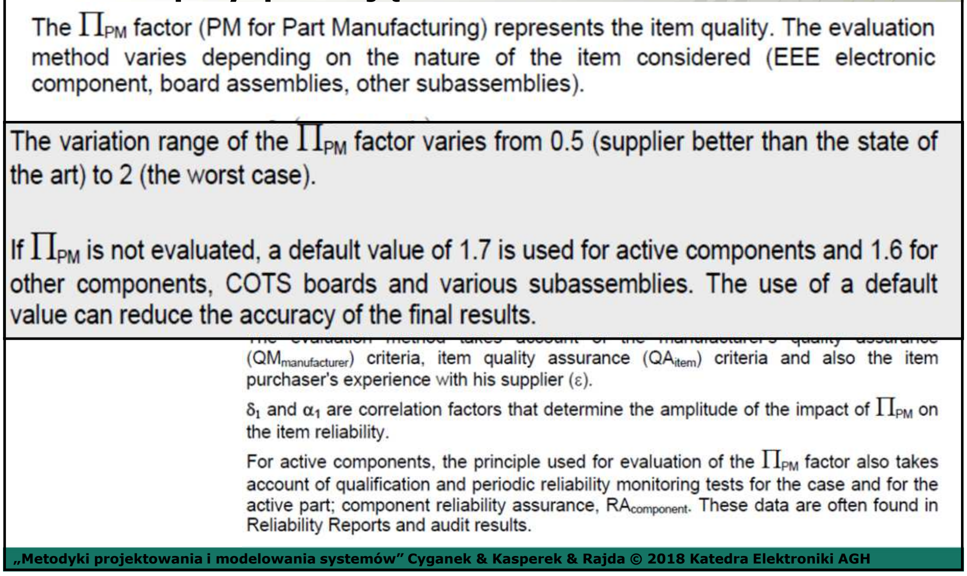

The Π_{PM} factor (PM for Part Manufacturing) represents the item quality. The evaluation method varies depending on the nature of the item considered (EEE electronic component, board assemblies, other subassemblies).

The variation range of the Π_{PM} factor varies from 0.5 (supplier better than the state of the art) to 2 (the worst case).

If Π_{PM} is not evaluated, a default value of 1.7 is used for active components and 1.6 for other components, COTS boards and various subassemblies. The use of a default value can reduce the accuracy of the final results.

($QM_{manufacturer}$) criteria, item quality assurance (QA_{item}) criteria and also the item purchaser's experience with his supplier (ε).

δ_1 and α_1 are correlation factors that determine the amplitude of the impact of Π_{PM} on the item reliability.

For active components, the principle used for evaluation of the Π_{PM} factor also takes account of qualification and periodic reliability monitoring tests for the case and for the active part; component reliability assurance, $RA_{component}$. These data are often found in Reliability Reports and audit results.

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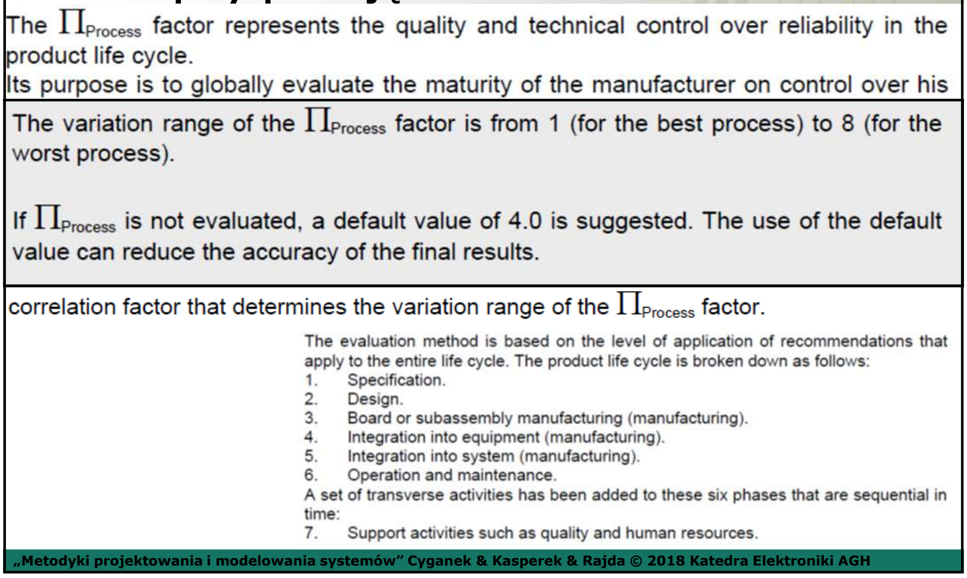

The $\Pi_{Process}$ factor represents the quality and technical control over reliability in the product life cycle.

Its purpose is to globally evaluate the maturity of the manufacturer on control over his

The variation range of the $\Pi_{Process}$ factor is from 1 (for the best process) to 8 (for the worst process).

If $\Pi_{Process}$ is not evaluated, a default value of 4.0 is suggested. The use of the default value can reduce the accuracy of the final results.

correlation factor that determines the variation range of the $\Pi_{Process}$ factor.

The evaluation method is based on the level of application of recommendations that apply to the entire life cycle. The product life cycle is broken down as follows:

1. Specification.
2. Design.
3. Board or subassembly manufacturing (manufacturing).
4. Integration into equipment (manufacturing).
5. Integration into system (manufacturing).
6. Operation and maintenance.

A set of transverse activities has been added to these six phases that are sequential in time:

7. Support activities such as quality and human resources.

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układy scalone - λ

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$\lambda = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$ where:

$$\lambda_{\text{Physical}} = \sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760}\right)_i \times \left(\begin{array}{l} \lambda_{0\,\text{TH}} \times \Pi_{\text{Thermal}} \\ +\lambda_{0\,\text{TCyCase}} \times \Pi_{\text{TCyCase}} \\ +\lambda_{0\,\text{TCySolder joints}} \times \Pi_{\text{TCySolder joints}} \\ +\lambda_{0\,\text{RH}} \times \Pi_{\text{RH}} \\ +\lambda_{0\,\text{Mech}} \times \Pi_{\text{Mech}} \end{array}\right)_i \times \left(\Pi_{\text{Induced}}\right)_i$$

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układy scalone - Π_{PM}

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$$\Pi_{\text{PM}} = e^{1.39\times(1-\text{Part\_Grade})-0.69}$$

where for active parts (integrated circuits, discrete semiconductors, LED, optocouplers):

$$\text{Part\_Grade} = \left[\frac{\left(QA_{\text{manufactuer}} + QA_{\text{component}} + RA_{\text{component}}\right)\times\varepsilon}{36}\right]$$

and for all other items:

$$\text{Part\_Grade} = \left[\frac{\left(QA_{\text{manufactuer}} + QA_{\text{component}}\right)\times\varepsilon}{24}\right]$$

AGH

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układy scalone - Π_{PM}

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Model associated with the *$QA_{manufacturer}$ factor*

This factor is common to all items.

Manufacturer quality assurance level	**Position relative to the state of the art**	**$QA_{manufacturer}$**
Certified ISO/TS16949 V2002	Higher	3
Certified according to one of the following standards: QS9000, TL9000, ISO/TS 29001, EN9100, AS9100, JISQ 9100, AQAP 2110, AQAP 2120, AQAP 2130, IRIS, IEC TS 62239, ESA/ECSS QPL, MIL-PRF-38535 QML, MIL-PRF-19500	Equivalent	2
ISO 9000 version 2000 certified	Lower	1
No information	Very much lower	0

The $QA_{component}$ factor is defined for each item family. It takes account mainly of the qualification methodology without considering the severity of the tests defined in the mentioned standards. Test severities for active components are taken into account by the $RA_{component}$ factor.

Component quality assurance level	**Position relative to the state of the art**	**$QA_{component}$**
Level criteria are defined for each item family	Higher	3
	Equivalent	2
	Lower	1
	Very much lower	0

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Model associated with the *$RA_{component}$ factor*

The $RA_{manufacturer}$ factor is defined for integrated circuits and discrete semiconductors. It is quantified as a function of the results and the severity of tests performed by the manufacturer

	Risk $RA_{component}$
Very reliable level A	**3**
Very reliable level B	**2**
Reliable	**1**
Not reliable	**0**

Description of the risk related to use of this manufacturer	**Value of the ε factor**
Recognised manufacturer: Mature processes for the item considered	4
Recognised manufacturer – Processes not analysed or not mature for the item considered	3
Manufacturer not recognised (for example never audited or audited more than 6 years earlier) or small series productions	2
Previous disqualification or problem with feedback from operations	1

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Basic failure rates associated with the chip

Type	λ_{0TH}
FPGA, CPLD, FPGA Antifuse, PAL	0.166
Analogue and Hybrid circuit (MOS, bipolar, BiCMOS)	0.123
Microprocessor, Microcontroller, DSP	0.075
Flash, EEPROM, EPROM	0.060
SRAM	0.055
DRAM	0.047
Digital circuit (MOS, bipolar, BiCMOS)	0.021

Notes:
- Mixed = analogue and digital.
- For ASICs, refer to the ASIC model.

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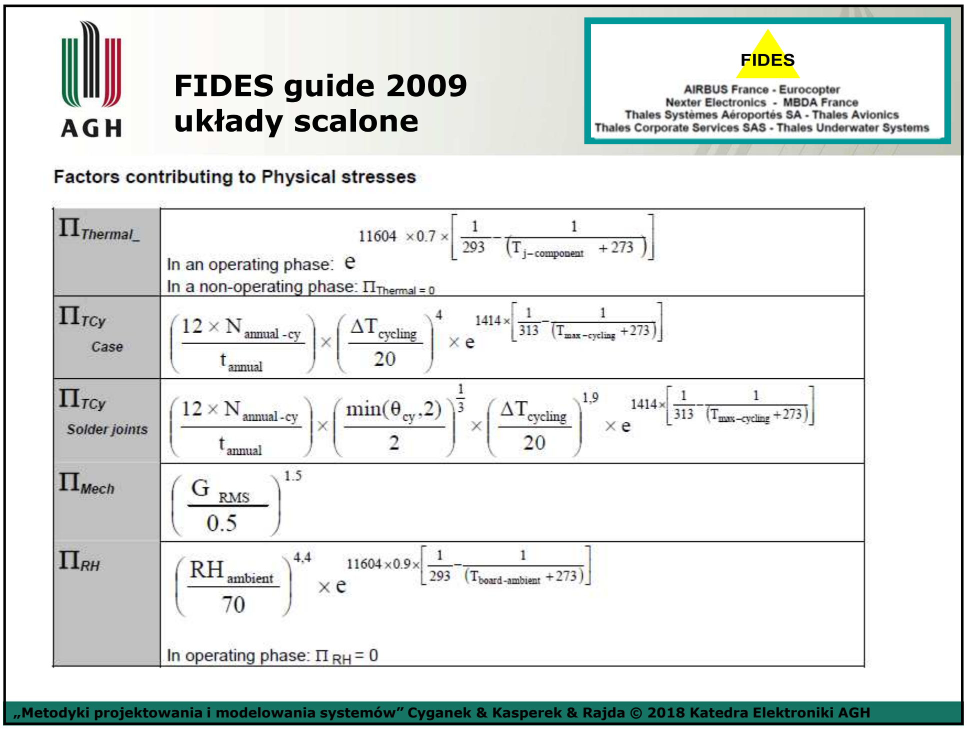
Basic failure rates associated with cases

The basic failure rates for the different physical stresses are obtained by the following equation:

$$\lambda_{0\_Stress} = e^{-a} \times Np^{b}$$

Where:
- a and b are constants that depend on the case type and the number of pins given in the following table.
- Np is the number of pins on the case.

Typical name	Description	Np	λ_{0RH}		λ_{0TCy_Case}		$\lambda_{0TCy\_Solder\ joints}$		$\lambda_{0\ mechanical}$	
			a	b	a	b	a	b	a	b
PDIP. TO116	Plastic Dual In line Package	8 to 68	5.88	0.94	9.85	1.35	8.24	1.35	12.85	1.35
CERDIP. CDIP	Ceramic Dual-In-Line Package	8 to 20 >20 to 48	λ_{0RH}=0		6.77	1.35	5.16 4.47	1.35 1.35	8.38 7.69	1.35 1.35
PQFP	Plastic Quad Flatpack. L lead	44 to 240 >240 to 304	11.16	1.76	12.41	1.46	10.80 10.11	1.46 1.46	14.71 14.02	1.46 1.46
SQFP TQFP. VQFP. LQFP	Plastic Shrink (thickness) Quad Flatpack. L lead Plastic Thin Quad Flatpack. L lead	32 to 120 >120 to 208	7.75	1.13	8.57	0.73	6.96 5.57	0.73 0.73	11.57 10.18	0.73 0.73



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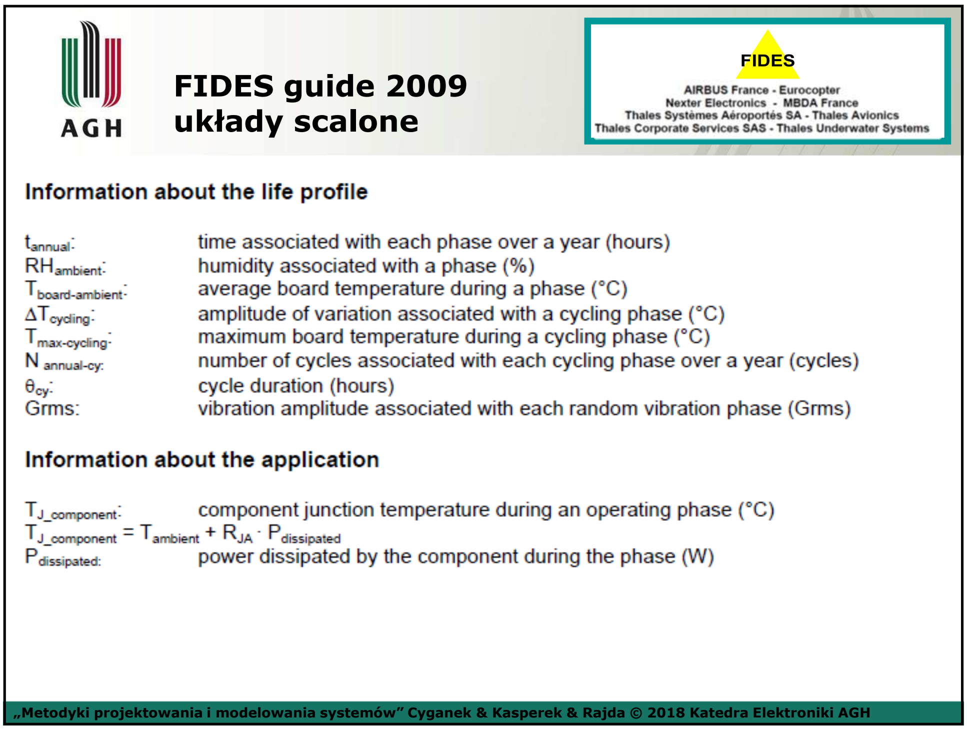
Factors contributing to Physical stresses

$\Pi_{Thermal\_}$	In an operating phase: $e^{11604\times 0.7\times\left[\frac{1}{293}-\frac{1}{(T_{j-component}+273)}\right]}$ In a non-operating phase: $\Pi_{Thermal}=0$
Π_{TCy} Case	$\left(\frac{12\times N_{annual-cy}}{t_{annual}}\right)\times\left(\frac{\Delta T_{cycling}}{20}\right)^{4}\times e^{1414\times\left[\frac{1}{313}-\frac{1}{(T_{max-cycling}+273)}\right]}$
Π_{TCy} Solder joints	$\left(\frac{12\times N_{annual-cy}}{t_{annual}}\right)\times\left(\frac{\min(\theta_{cy},2)}{2}\right)^{\frac{1}{3}}\times\left(\frac{\Delta T_{cycling}}{20}\right)^{1,9}\times e^{1414\times\left[\frac{1}{313}-\frac{1}{(T_{max-cycling}+273)}\right]}$
Π_{Mech}	$\left(\frac{G_{RMS}}{0.5}\right)^{1.5}$
Π_{RH}	$\left(\frac{RH_{ambient}}{70}\right)^{4,4}\times e^{11604\times 0.9\times\left[\frac{1}{293}-\frac{1}{(T_{board-ambient}+273)}\right]}$ In operating phase: $\Pi_{RH}=0$



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Information about the life profile

t_{annual}:	time associated with each phase over a year (hours)
$RH_{ambient}$:	humidity associated with a phase (%)
$T_{board\text{-}ambient}$:	average board temperature during a phase (°C)
$\Delta T_{cycling}$:	amplitude of variation associated with a cycling phase (°C)
$T_{max\text{-}cycling}$:	maximum board temperature during a cycling phase (°C)
$N_{annual\text{-}cy}$:	number of cycles associated with each cycling phase over a year (cycles)
θ_{cy}:	cycle duration (hours)
Grms:	vibration amplitude associated with each random vibration phase (Grms)

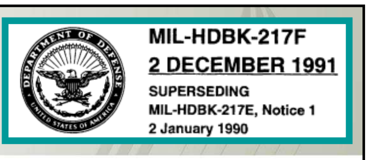
Information about the application

$T_{J\_component}$: component junction temperature during an operating phase (°C)

$T_{J\_component} = T_{ambient} + R_{JA} \cdot P_{dissipated}$

$P_{dissipated}$: power dissipated by the component during the phase (W)

Elementy bierne – rezystory - λ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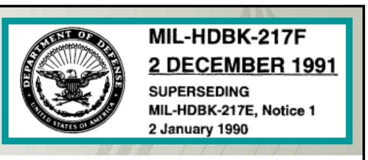
$$\lambda_p = \lambda_b \pi_T \pi_P \pi_S \pi_Q \pi_E \text{ Failures}/10^6 \text{ Hours}$$

Resistor Style	Specification MIL-R-	Description	λ_b	π_T Table Use Column:	π_S Table Use Column:
RC	11	Resistor, Fixed, Composition (Insulated)	.0017	1	2
RCR	39008	Resistor, Fixed, Composition (Insulated) Est. Rel.	.0017	1	2
RL	22684	Resistor, Fixed, Film, Insulated	.0037	2	1
RLR	39017	Resistor, Fixed, Film (Insulated), Est. Rel.	.0037	2	1
RN (R, C or N)	55182	Resistor, Fixed, Film, Established Reliability	.0037	2	1
RM	55342	Resistor, Fixed, Film, Chip, Established Reliability	.0037	2	1
RN	10509	Resistor, Fixed Film (High Stability)	.0037	2	1

+ inne typy....

sekcja 9.1 MILHDBK-217F

Elementy bierne – rezystory - λ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Temperature Factor - π_T

T(°C)	Column 1	Column 2
20	.88	.95
30	1.1	1.1
40	1.5	1.2
50	1.8	1.3
60	2.3	1.4
70	2.8	1.5
80	3.4	1.6
90	4.0	1.7
100	4.8	1.9
110	5.6	2.0
120	6.6	2.1
130	7.6	2.3
140	8.7	2.4
150	10	2.5

Power Factor - π_P

Power Dissipation (Watts)	π_P
.001	.068
.01	.17
.13	.44
.25	.58
.50	.76
.75	.89
1.0	1.0
2.0	1.3
3.0	1.5
4.0	1.7
5.0	1.9
10	2.5
25	3.5

sekcja 9.1 MILHDBK-217F

Elementy bierne – rezystory - λ

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$$S = \frac{\text{Actual Power Dissipation}}{\text{Rated Power}}$$

Power Stress Factor - π_S

Power Stress	Column 1	Column 2
.1	.79	.66
.2	.88	.81
.3	.99	1.0
.4	1.1	1.2
.5	1.2	1.5
.6	1.4	1.8
.7	1.5	2.3
.8	1.7	2.8
.9	1.9	3.4

Environment Factor - π_E

Environment	π_E
G_B	1.0
G_F	4.0
G_M	16
N_S	12
N_U	42
A_{IC}	18
A_{IF}	23
A_{UC}	31
A_{UF}	43
A_{RW}	63

Quality Factor - π_Q

Quality	π_Q
Established Reliability Styles	
S	.03
R	0.1
P	0.3
M	1.0
Non-Established Reliability Resistors (Most Two-Letter Styles)	3.0
Commercial or Unknown Screening Level	10

sekcja 9.1 MILHDBK-217F

Elementy bierne – rezystory

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$\lambda = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$ where:

$$\lambda_{\text{Physical}} = \lambda_{0\_\text{Resistance}} \times \sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760}\right)_i \times \left(\Pi_{\text{Thermo-electrical}} + \Pi_{\text{TCy}} + \Pi_{\text{Mechanical}} + \Pi_{\text{RH}}\right)_i \times \left(\Pi_{\text{Induced}}\right)_i$$

Π***Thermo-electrical***	In an operating phase: $\gamma_{\text{TH-EL}} \times e^{11604 \times 0.15 \times \left[\frac{1}{293} - \frac{1}{\left(T_{\text{board-ambient}} + 273 + A \times \frac{P_{\text{applied}}}{P_{\text{rated}}}\right)}\right]}$ In a non-operating phase: $\Pi_{\text{Thermo-electrical}} = 0$
Π***TCy***	$\gamma_{TCy} \times \left(\frac{12 \times N_{annual-cy}}{t_{annual}}\right) \times \left(\frac{\min(\theta_{cy}, 2)}{2}\right)^{\frac{1}{3}} \times \left(\frac{\Delta T_{cycling}}{20}\right)^{1.9} \times e^{1414 \times \left[\frac{1}{313} - \frac{1}{(T_{max-cycling} + 273)}\right]}$
Π***Mechanical***	$\gamma_{Mech} \times \left(\frac{G_{RMS}}{0.5}\right)^{1.5}$
Π***RH***	$\gamma_{\text{RH}} \times \left(\frac{\text{RH}_{\text{ambient}}}{70}\right)^{4.4} \times e^{11604 \times 0.9 \times \left[\frac{1}{293} - \frac{1}{(T_{\text{board-ambient}} + 273)}\right]}$ In an operating phase: $\Pi_{\text{RH}} = 0$

Elementy bierne – rezystory

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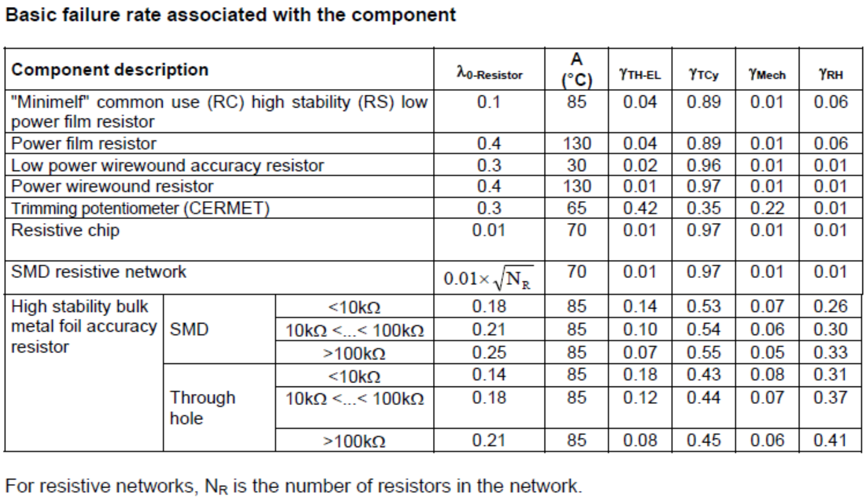

Basic failure rate associated with the component

Component description			$\lambda_{0\text{-Resistor}}$	A (°C)	$\gamma_{TH\text{-}EL}$	γ_{TCy}	γ_{Mech}	γ_{RH}
"Minimelf" common use (RC) high stability (RS) low power film resistor			0.1	85	0.04	0.89	0.01	0.06
Power film resistor			0.4	130	0.04	0.89	0.01	0.06
Low power wirewound accuracy resistor			0.3	30	0.02	0.96	0.01	0.01
Power wirewound resistor			0.4	130	0.01	0.97	0.01	0.01
Trimming potentiometer (CERMET)			0.3	65	0.42	0.35	0.22	0.01
Resistive chip			0.01	70	0.01	0.97	0.01	0.01
SMD resistive network			$0.01\times\sqrt{N_R}$	70	0.01	0.97	0.01	0.01
High stability bulk metal foil accuracy resistor	SMD	<10kΩ	0.18	85	0.14	0.53	0.07	0.26
		10kΩ <...< 100kΩ	0.21	85	0.10	0.54	0.06	0.30
		>100kΩ	0.25	85	0.07	0.55	0.05	0.33
	Through hole	<10kΩ	0.14	85	0.18	0.43	0.08	0.31
		10kΩ <...< 100kΩ	0.18	85	0.12	0.44	0.07	0.37
		>100kΩ	0.21	85	0.08	0.45	0.06	0.41

For resistive networks, N_R is the number of resistors in the network.

Montaż PCB

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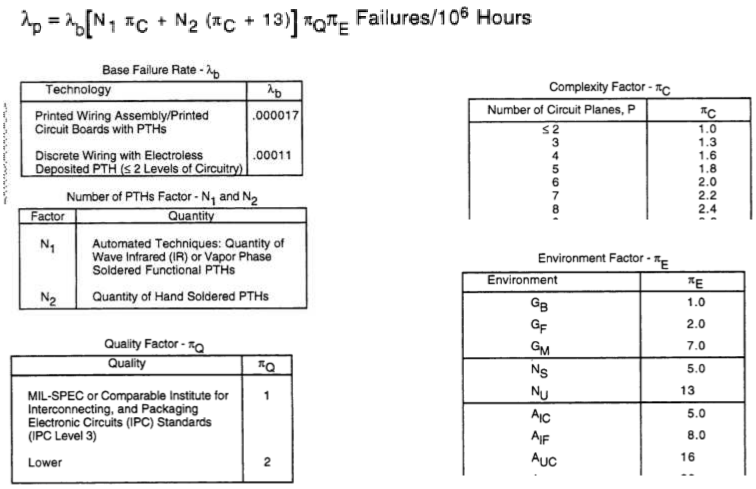

$$\lambda_p = \lambda_b\left[N_1 \pi_C + N_2 (\pi_C + 13)\right] \pi_Q \pi_E \text{ Failures}/10^6 \text{ Hours}$$

Base Failure Rate - λ_b

Technology	λ_b
Printed Wiring Assembly/Printed Circuit Boards with PTHs	.000017
Discrete Wiring with Electroless Deposited PTH (≤ 2 Levels of Circuitry)	.00011

Number of PTHs Factor - N_1 and N_2

Factor	Quantity
N_1	Automated Techniques: Quantity of Wave Infrared (IR) or Vapor Phase Soldered Functional PTHs
N_2	Quantity of Hand Soldered PTHs

Quality Factor - π_Q

Quality	π_Q
MIL-SPEC or Comparable Institute for Interconnecting, and Packaging Electronic Circuits (IPC) Standards (IPC Level 3)	1
Lower	2

Complexity Factor - π_C

Number of Circuit Planes, P	π_C
≤ 2	1.0
3	1.3
4	1.6
5	1.8
6	2.0
7	2.2
8	2.4

Environment Factor - π_E

Environment	π_E
G_B	1.0
G_F	2.0
G_M	7.0
N_S	5.0
N_U	13
A_{IC}	5.0
A_{IF}	8.0
A_{UC}	16

Montaż PCB

$\lambda = \lambda_{\text{Physical}} \times \Pi_{\text{PM}} \times \Pi_{\text{Process}}$ where:

$$\lambda_{\text{Physical}} = \lambda_{0\,\text{PCB}} \times \sum_{i}^{\text{Phases}} \left(\frac{t_{\text{annual}}}{8760} \right)_i \times \left(\Pi_{\text{TCy}} + \Pi_{\text{Mechanical}} + \Pi_{\text{RH}} + \Pi_{\text{Chemical}} \right)_i \times \left(\Pi_{\text{Induced}} \right)_i$$

$\Pi_{\text{Placement}}$ factor:

For PCBs the placement factor is fixed: $\Pi_{\text{Placement}} = 1$

$QA_{\text{component}}$ factor

Component quality assurance level	Position relative to the state of the art	$QA_{\text{component}}$
Qualification according to MIL-PRF-31032 (PCB), MIL-PRF-55110 (PWB), MIL-P-50884, MIL-S-13949, ECSS-Q-ST-70-10 (PCB)	Higher	3
Manufacturer qualification according to IPC-9701 including tests in standard IPC TM 650	Equivalent	2
Know-how approval made according to EN 123 xxx, CECC 23000, NBN EN 61189-1	Lower	1
No information	Much lower	0

Montaż PCB

Basic failure rates associated with the item

$$\lambda_{0\,\text{PCB}} = 5 \cdot 10^{-4} \times \left(N_{\text{layers}} \right)^{\frac{1}{2}} \times \left(\frac{N_{\text{connection}}}{2} \right) \times \Pi_{\text{Class}} \times \Pi_{\text{Techno-PCB}}$$

Information about technical characteristics

N_{layers}: Number of layers in the printed circuit board
$N_{\text{connection}}$: Number of connection points (surface mounted + through holes)

Printed circuit technology identification	Value of $\Pi_{\text{Techno-PCB}}$
Through holes	0.25
Blind holes	0.5
Micro-via technology	1
Pad on via technology	2.5

Minimum conductor width (µm) / Minimum spacing between conductors or pads (µm)	Value of Π_{Class}
800 / 800	1
500 / 500	1
310 / 310	2
210 / 210	3
150 / 150	4
125 / 125	5
100 / 100	6

For a multilayer PCB, the layer with the highest density should be considered. The area with the highest density should be considered in any one particular layer.

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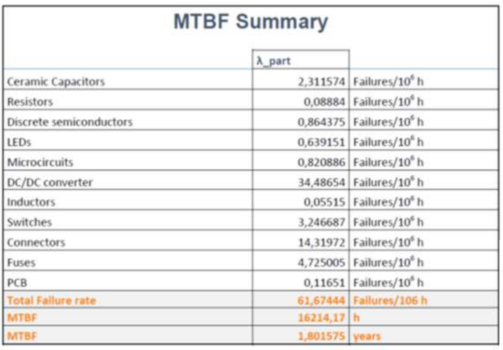
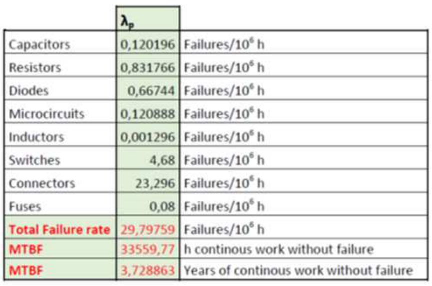


MTBF Summary

	λ_part	
Ceramic Capacitors	2,311574	Failures/10^6 h
Resistors	0,08884	Failures/10^6 h
Discrete semiconductors	0,864375	Failures/10^6 h
LEDs	0,639151	Failures/10^6 h
Microcircuits	0,820886	Failures/10^6 h
DC/DC converter	34,48654	Failures/10^6 h
Inductors	0,05515	Failures/10^6 h
Switches	3,246687	Failures/10^6 h
Connectors	14,31972	Failures/10^6 h
Fuses	4,725005	Failures/10^6 h
PCB	0,11651	Failures/10^6 h
Total Failure rate	61,67444	Failures/106 h
MTBF	16214,17	h
MTBF	1,801575	years



	λ_p	
Capacitors	0,120196	Failures/10^6 h
Resistors	0,831766	Failures/10^6 h
Diodes	0,66744	Failures/10^6 h
Microcircuits	0,120888	Failures/10^6 h
Inductors	0,001296	Failures/10^6 h
Switches	4,68	Failures/10^6 h
Connectors	23,296	Failures/10^6 h
Fuses	0,08	Failures/10^6 h
Total Failure rate	29,79759	Failures/10^6 h
MTBF	33559,77	h continous work without failure
MTBF	3,728863	Years of continous work without failure

Konwerter USB <-> RS232 z izolacją galwaniczną 2,5 kV

Reliability process

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Guide for control and audit of the reliability process

1. Life cycle
2. The process factor
3. Trade recommendations – Reliability control
4. Calculating the process factor
    4.1. Relative influence of phases in the life cycle
    4.2. Recommendation satisfaction level
    4.3.Calibration
    4.4. Calculating the audit mark
    4.5. Calculating the process factor
5. Audit guide

FIDES Presentation

https://www.fides-reliability.org/en/system/files/documents/201305_TC56_Meeting27-56_1512_Presentation_JCL_V1.pdf

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Reliability process

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Metodologia FIDES szacuje cały proces życia produktu na jego niezawodność

Level	Process	$\Pi_{Process}$	Process grade
Very high reliability	Process almost with no weakness	<1.7	> 75%
High reliability	Controlled process, reliability engineering	1.7 to 2.8	50% to 75%
Standard	Usual ISO 9001 version 2000 type quality procedures	2.8 to 4.8	25% to 50%
Unreliable	Reliability problems not taken into account	>4.8	<25%

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Audit process

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Recommendations of the Reliability Process control and audit guide

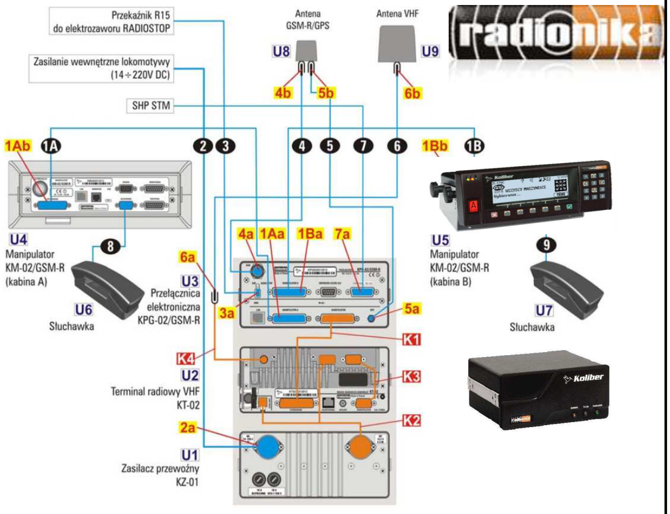
1. Tables of recommendations with weightings.
2. Detailed datasheets for each recommendation.

Specification

Number	Recommendation	Question	Weight
1	Assign resources in terms of personnel and means to reliability studies.	Is there a financing item for reliability studies? Have the necessary means and personnel been identified?	10.7
2	Allocate reliability requirements to subassemblies.	Are global reliability requirements allocated to subassemblies? What allocation method was used?	10.4
26	Completely describe the environment in which the product will be used and maintained.	Is there a description and characterisation of the environment in which the product will be stored, transported, used and maintained?	12.4
28	Define product failure.	What is considered as a product failure?	10.3
29	Define the method of demonstrating product reliability during operational phases.	How is it planned to demonstrate the product reliability?	9.8
31	Define the product life profile for which reliability performances are expected.	Is the usage profile of the product for which reliability performances are expected defined?	9.9
40	Define the context associated with the product reliability requirements.	What is the context associated with product reliability requirements?	8.1
53	Make use of feedback from operations.	Is feedback from operations used to maintain a good level of confidence in achieving reliability performances?	8.5
54	Get the Operating Dependability business to participate in the functional and organisational design of the product.	Are the reliability criteria taken into account in the architecture of the products, and design, industrialisation and support choices?	12.6

Analiza MTBF i FMEDA radiotelefonu pociągowego VHF „Koliber”

Modułowy radiotelefon pociągowy



Analiza MTBF i FMEDA radiotelefonu pociągowego VHF „Koliber”

Metodologia

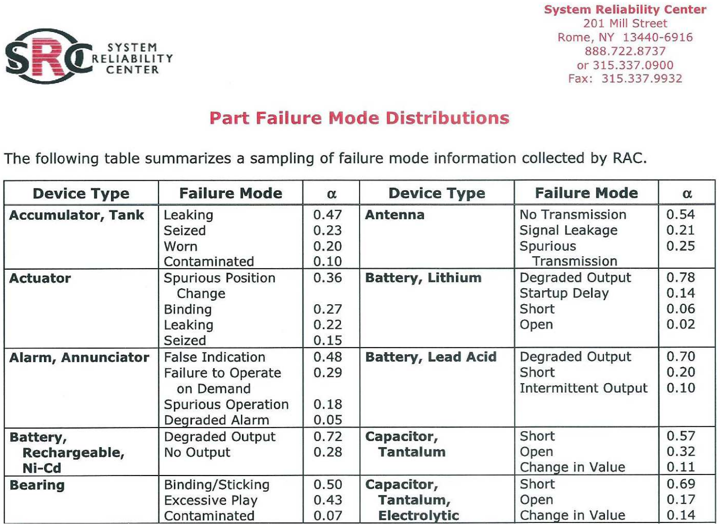
1. Dystrybucja rodzajów uszkodzeń elementów na podstawie dokumentu "*Part Failure Mode Distributions*" **System Reliability Center** z 2001
2. Zestaw norm **Siemens SN 29500** z 08.07.2011
3. Dane producentów podzespołów

Przyjęto założenie o wykonaniu analizy z wykorzystaniem środowiska ALTIUM SCH i generacji BOM z odpowiednio zmodyfikowanymi atrybutami elementów schematu ideowego. Konieczne było przygotowanie biblioteki komponentów SCH gdzie uzupełniono atrybuty w nowe parametry. Dla czytelności zapisu każdy dodany parametr otrzymał nazwę z prefiksem FS_ (ang. *Functional Safety*).

Zestaw modułów Kolibra (KT-01, KM-02, KPG-02) został przeanalizowany pod kątem:

- określenia parametru MTBF ang. *Mean Time Between Failure.*
- analizy realizacji funkcji bezpieczeństwa zdefiniowanej jako "Prawidłowe działanie systemu RADIOSTOP"

Metodyka zgodna z IEC 61508
Component FMEDA – przykłady baz danych



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Part Failure Mode Distributions

The following table summarizes a sampling of failure mode information collected by RAC.

Device Type	Failure Mode	α	Device Type	Failure Mode	α
Accumulator, Tank	Leaking Seized Worn Contaminated	0.47 0.23 0.20 0.10	**Antenna**	No Transmission Signal Leakage Spurious Transmission	0.54 0.21 0.25
Actuator	Spurious Position Change Binding Leaking Seized	0.36 0.27 0.22 0.15	**Battery, Lithium**	Degraded Output Startup Delay Short Open	0.78 0.14 0.06 0.02
Alarm, Annunciator	False Indication Failure to Operate on Demand Spurious Operation Degraded Alarm	0.48 0.29 0.18 0.05	**Battery, Lead Acid**	Degraded Output Short Intermittent Output	0.70 0.20 0.10
Battery, Rechargeable, Ni-Cd	Degraded Output No Output	0.72 0.28	**Capacitor, Tantalum**	Short Open Change in Value	0.57 0.32 0.11
Bearing	Binding/Sticking Excessive Play Contaminated	0.50 0.43 0.07	**Capacitor, Tantalum, Electrolytic**	Short Open Change in Value	0.69 0.17 0.14

Siemens SN 29500 – przykład tabel dla układów pamięci

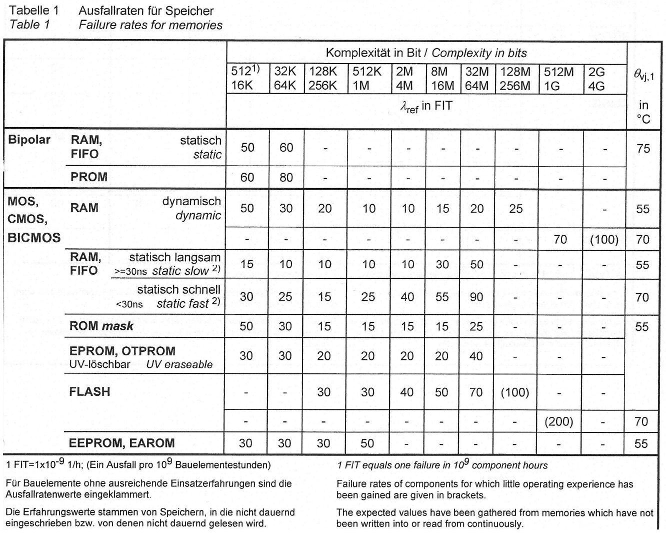


Tabelle 1 Ausfallraten für Speicher
Table 1 Failure rates for memories

		Komplexität in Bit / *Complexity in bits* λ_{ref} in FIT: $512^{1)}$ 16K	32K 64K	128K 256K	512K 1M	2M 4M	8M 16M	32M 64M	128M 256M	512M 1G	2G 4G	$\theta_{vj,1}$ in °C
Bipolar	**RAM, FIFO** statisch *static*	50	60	-	-	-	-	-	-	-	-	75
	PROM	60	80	-	-	-	-	-	-	-	-	
MOS, CMOS, BICMOS	**RAM** dynamisch *dynamic*	50	30	20	10	10	15	20	25		-	55
		-	-	-	-	-	-	-	-	70	(100)	70
	RAM, FIFO statisch langsam >=30ns *static slow* 2)	15	10	10	10	10	30	50	-	-	-	55
	statisch schnell <30ns *static fast* 2)	30	25	15	25	40	55	90	-	-	-	70
	ROM *mask*	50	30	15	15	15	15	25	-	-	-	55
	EPROM, OTPROM UV-löschbar *UV eraseable*	30	30	20	20	20	20	40	-	-	-	
	FLASH	-	-	30	30	40	50	70	(100)	-	-	
		-	-	-	-	-	-	-	-	(200)	-	70
	EEPROM, EAROM	30	30	30	50	-	-	-	-	-	-	55

1 FIT=1x10^{-9} 1/h; (Ein Ausfall pro 10^9 Bauelementestunden)

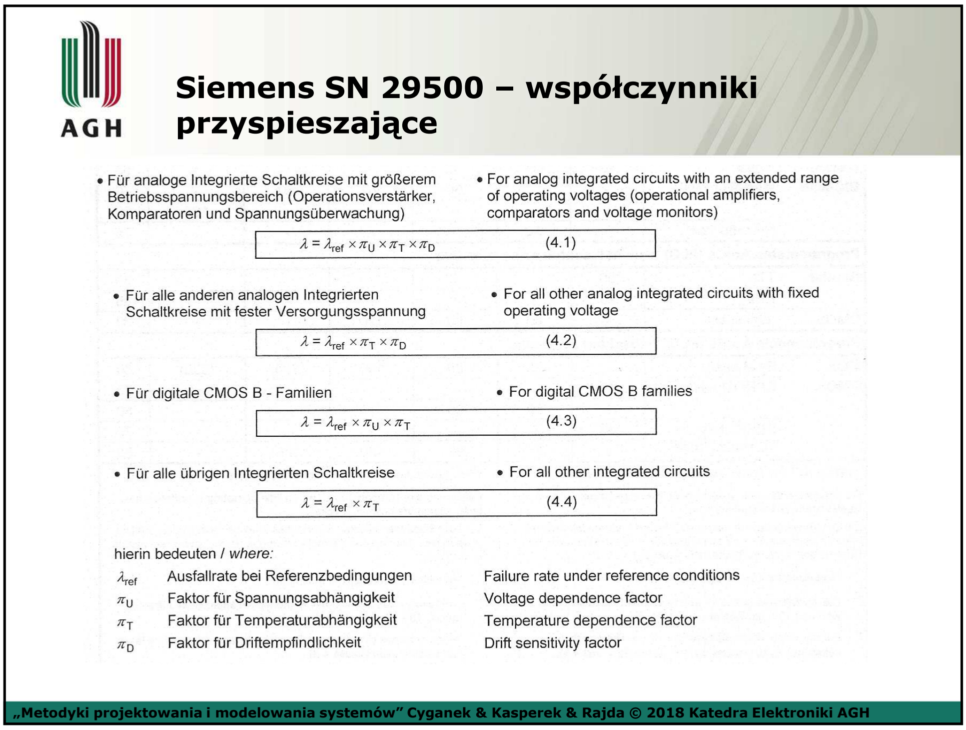
1 FIT equals one failure in 10^9 component hours

Für Bauelemente ohne ausreichende Einsatzerfahrungen sind die Ausfallratenwerte eingeklammert.

Failure rates of components for which little operating experience has been gained are given in brackets.

Die Erfahrungswerte stammen von Speichern, in die nicht dauernd eingeschrieben bzw. von denen nicht dauernd gelesen wird.

The expected values have been gathered from memories which have not been written into or read from continuously.



Siemens SN 29500 – współczynniki przyspieszające

- Für analoge Integrierte Schaltkreise mit größerem Betriebsspannungsbereich (Operationsverstärker, Komparatoren und Spannungsüberwachung)
- *For analog integrated circuits with an extended range of operating voltages (operational amplifiers, comparators and voltage monitors)*

$$\lambda = \lambda_{ref} \times \pi_U \times \pi_T \times \pi_D \qquad (4.1)$$

- Für alle anderen analogen Integrierten Schaltkreise mit fester Versorgungsspannung
- *For all other analog integrated circuits with fixed operating voltage*

$$\lambda = \lambda_{ref} \times \pi_T \times \pi_D \qquad (4.2)$$

- Für digitale CMOS B - Familien
- *For digital CMOS B families*

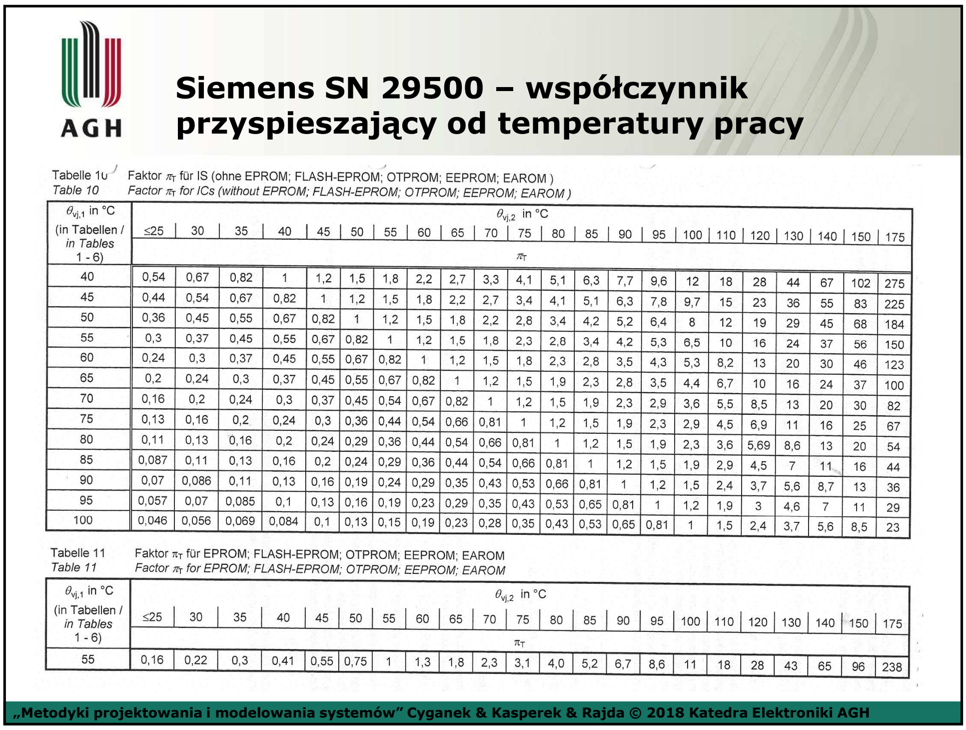
$$\lambda = \lambda_{ref} \times \pi_U \times \pi_T \qquad (4.3)$$

- Für alle übrigen Integrierten Schaltkreise
- *For all other integrated circuits*

$$\lambda = \lambda_{ref} \times \pi_T \qquad (4.4)$$

hierin bedeuten / *where:*

λ_{ref}	Ausfallrate bei Referenzbedingungen	*Failure rate under reference conditions*
π_U	Faktor für Spannungsabhängigkeit	*Voltage dependence factor*
π_T	Faktor für Temperaturabhängigkeit	*Temperature dependence factor*
π_D	Faktor für Driftempfindlichkeit	*Drift sensitivity factor*



Siemens SN 29500 – współczynnik przyspieszający od temperatury pracy

Tabelle 10 Faktor π_T für IS (ohne EPROM; FLASH-EPROM; OTPROM; EEPROM; EAROM)
Table 10 Factor π_T for ICs (without EPROM; FLASH-EPROM; OTPROM; EEPROM; EAROM)

$\theta_{vj,1}$ in °C (in Tabellen / *in Tables* 1 - 6)	$\theta_{vj,2}$ in °C ≤25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	110	120	130	140	150	175
	π_T																					
40	0,54	0,67	0,82	1	1,2	1,5	1,8	2,2	2,7	3,3	4,1	5,1	6,3	7,7	9,6	12	18	28	44	67	102	275
45	0,44	0,54	0,67	0,82	1	1,2	1,5	1,8	2,2	2,7	3,4	4,1	5,1	6,3	7,8	9,7	15	23	36	55	83	225
50	0,36	0,45	0,55	0,67	0,82	1	1,2	1,5	1,8	2,2	2,8	3,4	4,2	5,2	6,4	8	12	19	29	45	68	184
55	0,3	0,37	0,45	0,55	0,67	0,82	1	1,2	1,5	1,8	2,3	2,8	3,4	4,2	5,3	6,5	10	16	24	37	56	150
60	0,24	0,3	0,37	0,45	0,55	0,67	0,82	1	1,2	1,5	1,8	2,3	2,8	3,5	4,3	5,3	8,2	13	20	30	46	123
65	0,2	0,24	0,3	0,37	0,45	0,55	0,67	0,82	1	1,2	1,5	1,9	2,3	2,8	3,5	4,4	6,7	10	16	24	37	100
70	0,16	0,2	0,24	0,3	0,37	0,45	0,54	0,67	0,82	1	1,2	1,5	1,9	2,3	2,9	3,6	5,5	8,5	13	20	30	82
75	0,13	0,16	0,2	0,24	0,3	0,36	0,44	0,54	0,66	0,81	1	1,2	1,5	1,9	2,3	2,9	4,5	6,9	11	16	25	67
80	0,11	0,13	0,16	0,2	0,24	0,29	0,36	0,44	0,54	0,66	0,81	1	1,2	1,5	1,9	2,3	3,6	5,69	8,6	13	20	54
85	0,087	0,11	0,13	0,16	0,2	0,24	0,29	0,36	0,44	0,54	0,66	0,81	1	1,2	1,5	1,9	2,9	4,5	7	11	16	44
90	0,07	0,086	0,11	0,13	0,16	0,19	0,24	0,29	0,35	0,43	0,53	0,66	0,81	1	1,2	1,5	2,4	3,7	5,6	8,7	13	36
95	0,057	0,07	0,085	0,1	0,13	0,16	0,19	0,23	0,29	0,35	0,43	0,53	0,65	0,81	1	1,2	1,9	3	4,6	7	11	29
100	0,046	0,056	0,069	0,084	0,1	0,13	0,15	0,19	0,23	0,28	0,35	0,43	0,53	0,65	0,81	1	1,5	2,4	3,7	5,6	8,5	23

Tabelle 11 Faktor π_T für EPROM; FLASH-EPROM; OTPROM; EEPROM; EAROM
Table 11 Factor π_T for EPROM; FLASH-EPROM; OTPROM; EEPROM; EAROM

$\theta_{vj,1}$ in °C (in Tabellen / *in Tables* 1 - 6)	$\theta_{vj,2}$ in °C ≤25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	110	120	130	140	150	175
	π_T																					
55	0,16	0,22	0,3	0,41	0,55	0,75	1	1,3	1,8	2,3	3,1	4,0	5,2	6,7	8,6	11	18	28	43	65	96	238

Analiza MTBF i FMEDA radiotelefonu pociągowego VHF „Koliber”

Przy analizie skutków danego uszkodzenia przyjęto poniższą interpretację:

- ***Safe Detected*** (*akronim SD*) - operator zestawu Koliber jest informowany przez manipulator urządzenia (akustycznie i przez komunikat na wyświetlaczu) o uszkodzeniu które nie ma wpływu na prawidłowe działanie zdefiniowanej funkcji bezpieczeństwa.
- ***Safe Undetected*** (akronim SU) - operator zestawu Koliber manipulator urządzenia nie jest informowany o uszkodzeniu które nie ma wpływu na prawidłowe działanie zdefiniowanej funkcji bezpieczeństwa.
- ***Dangerous Detected*** (akronim DD) - operator zestawu Koliber jest informowany przez manipulator urządzenia (akustycznie i przez komunikat na wyświetlaczu) o uszkodzeniu które ma wpływ na prawidłowe działanie zdefiniowanej funkcji bezpieczeństwa.
- ***Dangerous Undetected*** (akronim DU) - operator zestawu Koliber nie jest informowany o uszkodzeniu które ma wpływ na prawidłowe działanie zdefiniowanej funkcji bezpieczeństwa.
- ***No Effect*** (akronim NE) - uszkodzenie które nie ma wpływu na prawidłowe działanie zdefiniowanej funkcji bezpieczeństwa.

Uwaga

Jest wysoce problematyczna rozróżnianie uszkodzeń Safe Undetected i No Effect w systemie Kolibra gdzie dla sterowania sygnału RADIOSTOP mamy do czynienia z funkcjonalnością Energize to Trip

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Analiza MTBF i FMEDA radiotelefonu pociągowego VHF „Koliber”
analiza schematu ideowego

Lista dodanych parametrów dla komponentów:

- FS_PART - informacja czy dany komponent bierze udział w realizacji zdefiniowanej funkcji bezpieczeństwa (podczas analizy schematu ideowego wprowadzana wartość YES NO - przy czym wybranie wartości "NO" oznacza nieokreślanie innych danych)
- FS_FM__DEVICE_CLASS - klasyfikacja komponentu zgodna z "Part Failure Mode Distributions" System Reliability Center
- FS_LAMBDA_REF - referencyjne wskaźniki prawdopodobieństwa wystąpienia uszkodzenia na podstawie Siemens SN 29500
- FS_PI_FACTORS - wskaźniki zwiększenia prawdopodobieństwa wystąpienia uszkodzenia z uwagi na rzeczywiste warunki pracy komponentu (czynniki przyspieszające PI - ang. *dependence factor*) na podstawie Siemens SN 29500 (w bibliotece komponentów wprowadzana wartość istotna dla danego typu komponentu)
    - napięcie pracy (ang. *voltage dependence factor*) - obecny znak 'V' w polu FS_PI_FACTORS danego komponentu
    - prąd pracy (ang. *current dependence factor*) - obecny znak 'I' w polu FS_PI_FACTORS danego komponentu
    - temperatura pracy (ang. *temperature dependence factor*) - obecny znak 'T' w polu FS_PI_FACTORS danego komponentu
    - współczynnik obciążenia pracą (ang. *stress dependence factor*) - ten czynnik nie był wprowadzony do analizy - przyjęto założenie o ciągłej dostępności funkcji bezpieczeństwa

Analiza MTBF i FMEDA radiotelefonu pociągowego VHF „Koliber”
analiza schematu ideowego

FS_FM__DEVICE_CLASS - klasyfikacja komponentu zgodna z "Part Failure Mode Distributions" System Reliability Center

FS_FM_******* wartości referencyjne prawdopodobieństwa rodzaju uszkodzeń dla danej klasy komponentu zgodna z "Part Failure Mode Distributions" System Reliability Center. Starano się minimalizować liczbę etykiet parametrów i zbliżone funkcjonalności unifikowano pod wspólną etykietą

- klasa BATTERY RECHARCHEABLE NI CD
  - FS_FM_DEGRADED - obniżone napięcie wyjściowe
  - FS_FM_NO_OUTPUT - brak napięcie wyjściowego
- klasa CAPACITOR CERAMIC
  - FS_FM_LOSS - utrata pojemności (do 50%)
  - FS_FM_OPEN - rozwarcie
  - FS_FM_SHORT - zwarcie
- klasa CAPACITOR TANTALUM
  - FS_FM_LOSS - utrata pojemności (do 50%)
  - FS_FM_OPEN - rozwarcie
  - FS_FM_SHORT - zwarcie
- klasa COIL
  - FS_FM_LOSS - utrata indukcyjności (do 50%)
  - FS_FM_OPEN - rozwarcie
  - FS_FM_SHORT - zwarcie

Analiza MTBF i FMEDA radiotelefonu pociągowego VHF „Koliber”
analiza schematu ideowego

- klasa CONNECTOR
  - FS_FM_OPEN - trwałe rozwarcie
  - FS_FM_POOR - zły kontakt
  - FS_FM_SHORT - trwałe zwarcie
- klasa CRYSTAL QUARTZ
  - FS_FM_OPEN - rozwarcie
  - FS_FM_NO_OUTPUT - brak oscylacji
- klasa DIODE SMALL SIGNAL
  - FS_FM_LOSS - utrata parametrów (do 50%)
  - FS_FM_OPEN - rozwarcie
  - FS_FM_SHORT - zwarcie
- klasa FUSE
  - FS_FM_FAIL2OPEN - kompletne niezadziałanie bezpiecznika
  - FS_FM_PREMATURE - przedwczesne zadziałanie bezpiecznika (do 50%)
  - FS_FM_SLOW2OPEN - zbyt późne zadziałanie bezpiecznika (do 50%)
- klasa HYBRID DEVICE
  - FS_FM_DEGRADED - złe działanie wyjścia
  - FS_FM_NO_OUTPUT - brak działanie wyjścia
  - FS_FM_OPEN - rozwarcie wyjścia
  - FS_FM_SHORT - zwarcie wyjścia

Analiza MTBF i FMEDA radiotelefonu pociągowego VHF „Koliber”

analiza schematu ideowego

klasa MICROCIRCUIT LINEAR
- FS_FM_NO_OUTPUT - brak sygnału na wyjściu
- FS_FM_POOR - złe działanie wyjścia

klasa MICROCIRCUIT DIGITAL MOS
- FS_FM_I_OPEN - rozwarcie wejścia
- FS_FM_O_OPEN - rozwarcie wyjścia
- FS_FM_STUCK_HIGH - wyjście w ciągłym stanie wysokim
- FS_FM_STUCK_LOW - wyjście w ciągłym stanie niskim
- FS_FM_SUPPLY_OPEN - rozwarcie zasilania układu

klasa MICROCIRCUIT INTERFACE
- FS_FM_I_OPEN - rozwarcie wejścia
- FS_FM_O_OPEN - rozwarcie wyjścia
- FS_FM_STUCK_LOW - wyjście w ciągłym stanie niskim
- FS_FM_SUPPLY_OPEN - rozwarcie zasilania układu

klasa MICROCIRCUIT MEMORY
- FS_FM_LOSS - utrata danych
- FS_FM_OPEN - rozwarcie wyjścia
- FS_FM_SHORT - zwarcie wyjścia
- FS_FM_SLOW - zwolniony transfer danych - przyjęto efekt straty danych

klasa OPTOELECTRONIC SENSOR
- FS_FM_OPEN - rozwarcie
- FS_FM_SHORT - zwarcie

Analiza MTBF i FMEDA radiotelefonu pociągowego VHF „Koliber”

analiza schematu ideowego

klasa RESISTOR FIXED
- FS_FM_LOSS - zmiana rezystancji (do 50%)
- FS_FM_OPEN - rozwarcie
- FS_FM_SHORT - zwarcie

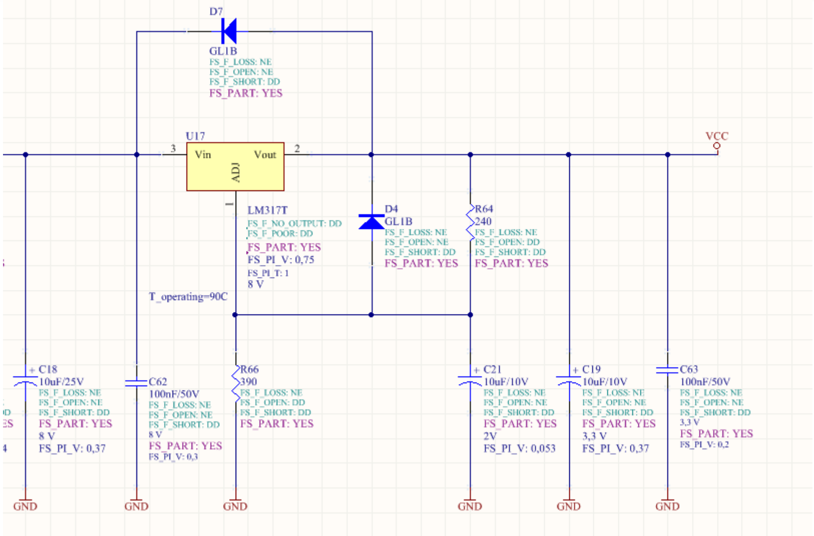
klasa SWITCH TOGGLE
- FS_FM_DEGRADED - złe działanie przełącznika - przyjęto brak działania
- FS_FM_OPEN - rozwarcie
- FS_FM_SHORT - zwarcie

klasa TRANSDUCER
- FS_FM_NO_OUTPUT - brak dźwięku na wyjściu
- FS_FM_POOR - złe działanie dźwięku na wyjściu
- FS_FM_OPEN - rozwarcie
- FS_FM_SHORT - zwarcie

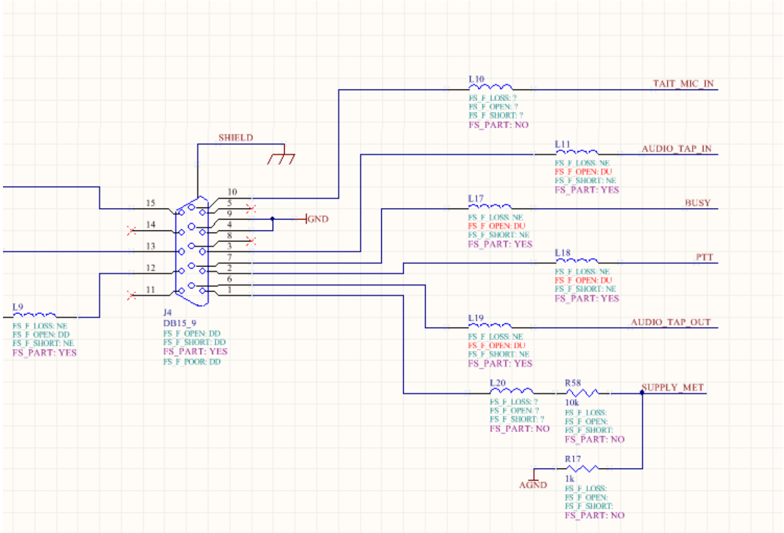
klasa TRANSISTOR BIPOLAR
- FS_FM_OPEN - rozwarcie
- FS_FM_SHORT - zwarcie

klasa TRANSISTOR FET
- FS_FM_LOSS - utrata parametrów (do 50%)
- FS_FM_SHORT - zwarcie
- FS_FM_OPEN - rozwarcie wyjścia
- FS_FM_STUCK_HIGH - wyjście w ciągłym stanie wysokim
- FS_FM_STUCK_LOW - wyjście w ciągłym stanie niskim

Analiza MTBF i FMEDA radiotelefonu pociągowego VHF „Koliber” Przykład komponenetów „NE/DD”



Analiza MTBF i FMEDA radiotelefonu pociągowego VHF „Koliber” Przykład komponenetów „DU”

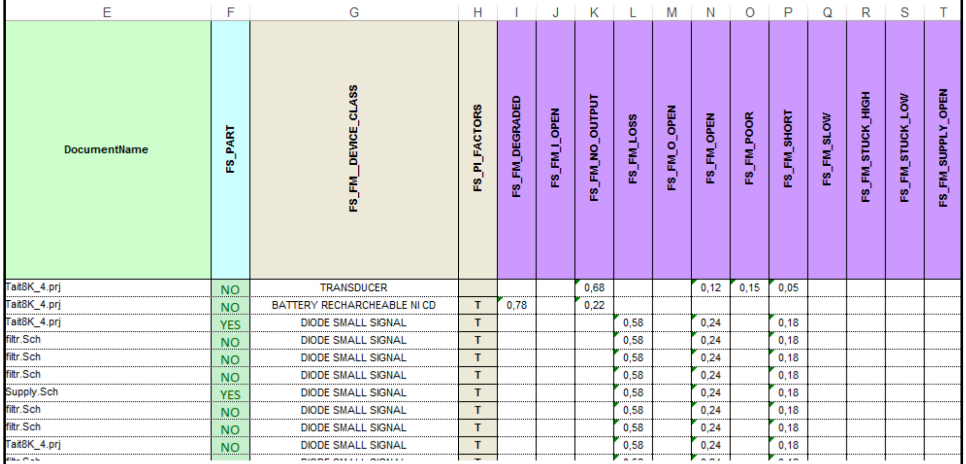


Analiza MTBF i FMEDA radiotelefonu pociągowego VHF „Koliber”
Analiza

Generacja BOM odbywa się na podstawie przygotowanego szablonu w którym znalazły się odpowiednie makropolecenia wyliczające wartości lambda dla określonego elementu – poszczególne role zostały określona podczas analizy schematu ideowego.

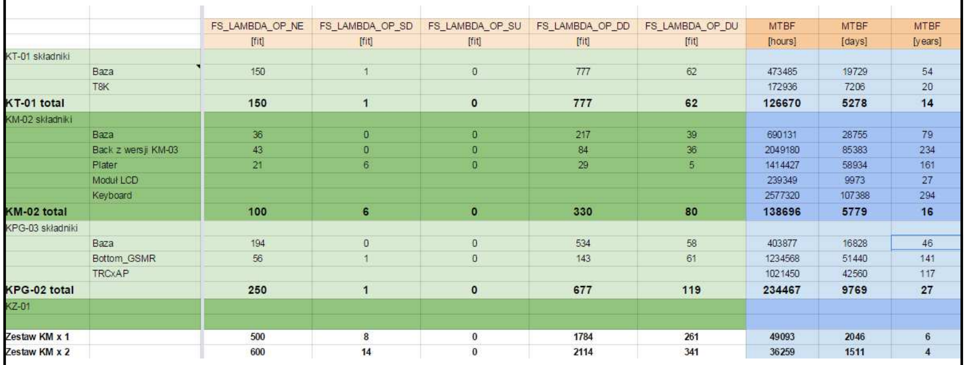
- FS_LAMBDA_OPERATING wskaźniki prawdopodobieństwa wystąpienia uszkodzenia obliczane przez makropolecenie uwzględniające wpływ czynników przyspieszających PI
- FS_LAMBDA_OPERATING_NE wskaźniki prawdopodobieństwa wystąpienia uszkodzenia typu No Effect obliczane przez makropolecenie uwzględniające rolę danego komponentu w realizację zdefiniowanej funkcji bezpieczeństwa.
- FS_LAMBDA_OPERATING_SD wskaźniki prawdopodobieństwa wystąpienia uszkodzenia typu Safe Detected obliczane przez makropolecenie uwzględniające rolę danego komponentu w realizację zdefiniowanej funkcji bezpieczeństwa.
- FS_LAMBDA_OPERATING_SU wskaźniki prawdopodobieństwa wystąpienia uszkodzenia typu Safe Undetected obliczane przez makropolecenie uwzględniające rolę danego komponentu w realizację zdefiniowanej funkcji bezpieczeństwa.
- FS_LAMBDA_OPERATING_DD wskaźniki prawdopodobieństwa wystąpienia uszkodzenia typu Dangerous Detected obliczane przez makropolecenie uwzględniające rolę danego komponentu w realizację zdefiniowanej funkcji bezpieczeństwa.
- FS_LAMBDA_OPERATING_DU wskaźniki prawdopodobieństwa wystąpienia uszkodzenia typu Dangerous Undetected obliczane przez makropolecenie uwzględniające rolę danego komponentu w realizację zdefiniowanej funkcji bezpieczeństwa.

Analiza MTBF i FMEDA radiotelefonu pociągowego VHF „Koliber”
Analiza – straaasznie ☺ rozbudowany arkusz Excell



E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
DocumentName	FS_PART	FS_FM__DEVICE_CLASS	FS_PI_FACTORS	FS_FM_DEGRADED	FS_FM_I_OPEN	FS_FM_NO_OUTPUT	FS_FM_LOSS	FS_FM_O_OPEN	FS_FM_OPEN	FS_FM_POOR	FS_FM_SHORT	FS_FM_SLOW	FS_FM_STUCK_HIGH	FS_FM_STUCK_LOW	FS_FM_SUPPLY_OPEN
Tait8K_4.prj	NO	TRANSDUCER				0,68			0,12	0,15	0,05				
Tait8K_4.prj	NO	BATTERY RECHARCHEABLE NI CD	T	0,78		0,22									
Tait8K_4.prj	YES	DIODE SMALL SIGNAL	T				0,58		0,24		0,18				
filtr.Sch	NO	DIODE SMALL SIGNAL	T				0,58		0,24		0,18				
filtr.Sch	NO	DIODE SMALL SIGNAL	T				0,58		0,24		0,18				
filtr.Sch	NO	DIODE SMALL SIGNAL	T				0,58		0,24		0,18				
Supply.Sch	YES	DIODE SMALL SIGNAL	T				0,58		0,24		0,18				
filtr.Sch	NO	DIODE SMALL SIGNAL	T				0,58		0,24		0,18				
filtr.Sch	NO	DIODE SMALL SIGNAL	T				0,58		0,24		0,18				
Tait8K_4.prj	NO	DIODE SMALL SIGNAL	T				0,58		0,24		0,18				

Analiza MTBF i FMEDA radiotelefonu pociągowego VHF „Koliber” wyniki analizy



		FS_LAMBDA_OP_NE [fit]	FS_LAMBDA_OP_SD [fit]	FS_LAMBDA_OP_SU [fit]	FS_LAMBDA_OP_DD [fit]	FS_LAMBDA_OP_DU [fit]	MTBF [hours]	MTBF [days]	MTBF [years]
KT-01 składniki									
	Baza	150	1	0	777	62	473485	19729	54
	T8K						172936	7206	20
KT-01 total		**150**	**1**	**0**	**777**	**62**	**126670**	**5278**	**14**
KM-02 składniki									
	Baza	36	0	0	217	39	690131	28755	79
	Back z wersji KM-03	43	0	0	84	36	2049180	85383	234
	Plater	21	6	0	29	5	1414427	58934	161
	Moduł LCD						239349	9973	27
	Keyboard						2577320	107388	294
KM-02 total		**100**	**6**	**0**	**330**	**80**	**138696**	**5779**	**16**
KPG-03 składniki									
	Baza	194	0	0	534	58	403877	16828	46
	Bottom_GSMR	56	1	0	143	61	1234568	51440	141
	TRCxAP						1021450	42560	117
KPG-02 total		**250**	**1**	**0**	**677**	**119**	**234467**	**9769**	**27**
KZ-01									
Zestaw KM x 1		**500**	**8**	**0**	**1784**	**261**	**49093**	**2046**	**6**
Zestaw KM x 2		**600**	**14**	**0**	**2114**	**341**	**36259**	**1511**	**4**

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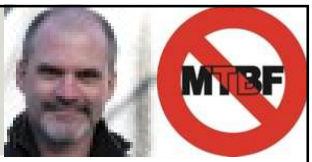

Mistake #1: MTBF and MTTF are erroneously used as projections of product useful life

Let’s take a common example. Electrolytic capacitors can have MTBF (actually should be stated MTTF since they are not repairable) values of 10^8 (one hundred million) or 10^9 (one billion) hours. If one were to divide these numbers by hours in a year to project useful life, this would result in a useful life of 11,415 to 114,155 years! In reality, electrolytic capacitors, if derated and applied properly typically have a useful life of 10 to 20 years. This is because the electrolyte in electrolytic capacitors dissipates, drying up the capacitor, causing significant degradation in performance (capacitance, leakage current, or ESR) or outright open or short failure. This doesn’t mean that electrolytic capacitors are necessarily bad, just that they don’t live for 10,000+ years.

So, how should MTBF and MTTF be used? They should be used as indicators of failure rate during the useful life of the product. So, you take the MTBF or MTTF value and invert it, dividing 1 by it. This gives you the expected failure rate per operating hour for the product during its useful life. So, our electrolytic capacitors that have a MTBF of 10^8 (one hundred million) or 10^9 (one billion) hours actually have an expected failure rate of 1 to 10 x 10^{-9} failures per operating hour. It is possible that they will be very reliable during their 10 to 20 year useful life, but then they are dried out and done.

Using MTBF or MTTF values as projections of product useful life is extremely misleading and will probably get you laughed out of your job. Think about that before you improperly use MTBF or MTTF to claim that a product will last 10,000 years. Somebody may ask for a warranty that long. In writing.

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Mistake #2: MTBF and MTTF assume a constant failure rate during the useful life of the item.

Many products do not exhibit a constant failure rate. Especially if the early failures were not mitigated and the product was not properly maintained. MTBF and MTTF only address the portion of the product's failure population that arise out of random chance and apply a very simplistic "mean" by dividing the total operating time of the product population by the total number of failures. This is then made to look scientific by then stating that this is an exponential distribution whereby the failures that arose in the population were evenly distributed with no proof of even distribution. But the world is not random and failures do not arrive at a constant rate over the life of the product or product population. Most product failures happen in non-exponential distribution, non-random patterns for identifiable reasons. Let's say you have a product population of five products with the following failure times: 98, 99, 100, 101, 102. If you use the standard MTBF averaging, you have a MTBF of 100 hours. But these failures are not randomly distributed with a constant failure rate. They are clustered around 100 hours and there is probably an identifiable reason why. Let's say you have a product population of five products with the following failure times: 10, 10, 10, 235, 235. Again, if you use the standard MTBF averaging, you have a MTBF of 100 hours. It is obvious that there is something going on that caused three products to have a very short life and two products to have a much longer life. Either way, there is probably an identifiable reason why three products failed early and two lived much longer.

Assuming a constant failure rate and using simple averaging of failure times to come up with MTBF or MTTF values is lazy at best. Don't be lazy, investigate failures to find root causes. These root causes will help you determine how to design products to eliminate the failure, mitigate against the failure, or perform proper preventive and predictive maintenance to avoid the failure.

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Mistake #3: MTBF and MTTF are given an assumption of high likelihood that the product will make it to the value.

Even if we do mitigate early life failures and perform proper maintenance, most people assume that the MTBF or MTTF is a value with high statistical likelihood like a B10 life (the point at which 10% of products fail and 90% continue to survive) for bearings. Due to the constant failure rate assumption and underlying statistical distribution, MTBF and MTTF are actually the point at which 63% of products would have failed and only 37% survive. Some high likelihood, — recall that MTBF is the inverse of the failure rate, not a duration.

You can check the math yourself. The probability of survival of a product following the constant failure rate of the exponential distribution is $e^{-(1/MTBF)(Operating\ Time)}$. *So, a product with a MTBF of 200,000 hours will have a probability of survival of* $e^{-(1/200{,}000)(200{,}000)}$ *or 37%.*

Assuming MTBF and MTTF are high likelihood projections is actually almost the exact opposite of how the math really works out. Use MTBF and MTTF with high caution, not high trust.

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Mistake #4: MTBF and MTTF data is assumed to be good and current

Even if you make it past the first three mistakes, this fourth mistake usually throws a wrench in MTBF and MTTF because many of the prediction models and prediction tools being sold are based on outdated information and outdated technologies. One example of this is using a MTBF prediction model for a flash memory device. Most of the data behind prediction tools stopped getting updated when the United States Defense Department transitioned to commercial off the shelf acquisition practices and stopped funding the collection of component operating and failure data. One example is many models for flash memory include devices that have 256K or 512K capacity while the world has moved way past this.

Assuming that the information in prediction models and tools is good and current may lead you to making extremely erroneous predictions of MTBF and MTTF. If you are going to predict MTBF or MTTF, you need to either have collected the operating and failure data yourself and analyzed it properly or make sure that component suppliers are providing good data.

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Reliability professionals in today's world have to understand more and guide product teams to:

- ***Design for Reliability*** for proper application, design margin, and derating.
- ***Design for Maintainability*** to address issues that must be mitigated by maintenance when the needed product life reliability cannot be achieved without maintenance actions.
- ***Failure Mode and Effects Analysis (FMEA) and Fault Tree Analysis (FTA)*** to determine the risks to the product based on severity, occurrence, and detection to drive actions to drive down risk before it becomes realized.

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- ***Reliability Testing*** to aggressively test and discover failures, at what point failures occur, and how much reliability margin the product will have to drive actions to correct the weak links in the design.
- ***Design for Manufacturability*** to preserve the designed in reliability of the product during its manufacture.
- ***Get Good Data*** from your own test and field history and supplier data you can trust instead of relying on generic and often outdated and obsolete prediction data. Data for your products in your customer’s hands tells you the real story of how your products are actually performing in their actual (and sometimes surprising) usage applications and operating environments.

Dziękujemy…