General definitions

g 65 Reliability $R(t) = \frac{n(t)}{n_0} = e^{-\int_0^t \lambda(\tau)\, d\tau}$

g 66 Probability to failure $F(t) = 1 - R(t)$

g 67 Failure density $f(t) = -\frac{dR}{dt}$

$= \lambda(t)\, e^{-\int_0^t \lambda(\tau) \cdot d\tau}$

g 68 Failure rate λ $\lambda(t) = \frac{f(t)}{R(t)} = -\frac{1}{R(t)} \cdot \frac{dR}{dt}$

MTTF (mean time to failure)

g 69 $$\text{MTTF} = \int_0^\infty f(t) \cdot t \cdot dt = \int_0^\infty R(t) \cdot dt$$

In systems which can be repaired, MTTF is replaced by the mean time between two errors, the mean failure distance m = MTBF (mean time between failures). Values of MTTF and MTBF are equal.

g 70 $$\text{MTTF} = \text{MTBF} = m = \int_0^\infty R(t) \cdot dt$$

Product rule for the reliability R_s:

When $R_1 \ldots R_n$ are the reliabilities of the single elements 1 … n, the reliability of the whole system becomes:

g 71 $$R_S = R_1 \cdot R_2 \cdot \ldots \cdot R_n = \prod_{i=1}^{n} R_i$$

g 72 $$= e^{-\int_0^t [\lambda_1(\tau) + \lambda_2(\tau) \ldots \lambda_n(\tau)] \cdot d\tau}$$

Note

Expressions for the reliability functions $R(t)$ are the distribution functions $F(x)$ in tables G 4 and G 5 (for calculation use g 66). The exponential distribution, simple to calculate, usually fulfills the requirements ($\lambda = \text{const}$).

$n(t)$: number of elements at the time t
n_0 : number of elements at the beginning

STATISTICS

Reliability; Exponential distribution

Exponential distribution used as reliability function

g 73 Reliability $R(t) = e^{-\lambda t}$

g 74 Probability to failure $F(t) = 1 - e^{-\lambda t}$

g 75 Failure density $f(t) = \lambda \cdot e^{-\lambda t}$

g 76 Failure rate $\lambda(t) = \dfrac{f(t)}{R(t)} = \lambda = \text{const.}$

(Dimension: 1/time)

g 77 Failure distance (MTBF) $m = \int_0^\infty e^{-\lambda t} \cdot dt = \dfrac{1}{\lambda}$

Product rule for the reliability R_S:

g 78 $R_S = e^{-\lambda_1 t} \cdot e^{-\lambda_2 t} \cdot \ldots \cdot e^{-\lambda_n t}$

g 79 $= e^{-(\lambda_1 + \lambda_2 + \ldots + \lambda_n) t}$

g 80 Cumulative failure rate $\lambda_S = \lambda_1 + \lambda_2 + \ldots + \lambda_n = \dfrac{1}{\text{MTBF}}$

For small values the failure rate can be calculated approximately

g 81 $$\lambda = \frac{\text{number of defectives}}{\text{number of elements at the beginning} \times \text{working time}}$$

λ-values are mostly related to working hours

g 82 Unit: 1 fit = 1 failure/10^9 hours

Typical examples for failure rate λ in fit:

IC-digital bipolar (SSI)	10	Resistor-metal	0.2
IC-analog bipolar (OpAmp)	10	Resistor-wire wound	10
Transistor-Si-Universal	5	Small transformer	5
Transistor-Si-Power	100	HF-cool	1
Diode-Si	3	Quartz	10
Tantalum capacitor with liquid electrolyte	10	Light emitting diode (≙ luminous intensity is reduced to 50%)	500
Tantalum capacitor with solid electrolyte	0.5		
Alu-electrolytic capacitor	20	Soldered connection	0.5
Ceramic (multilayer) capacitor	10	Wrapped connection	0.0025
Paper capacitor	2	Crimped connection	0.26
Vulcanite capacitor	1	plug-in contact	0.3
Resistor-carbon ≥ 100 kΩ	5	plug-in socket per used contact	0.4
Resistor-carbon ≤ 100 kΩ	0.5	plug-in switch	5 . . . 30

Note: Specifications for reliability see SN 29 500, part 1 (SIEMENS-Standard), DIN 40 040 and DIN 41 611.