IEC TR 62380 FIT Rate Scaling for different mission profile

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IEC TR 62380

Model for reliability predictions of electronic components

Commonly used for failure rate estimation used in safety related analysis

TECHNICAL REPORT

IEC TR 62380

First edition
2004-08

**Reliability data handbook –
Universal model for reliability prediction of electronics components, PCBs and equipment**

IEC TR 62380 FIT Rate Analysis for Integrated Circuit

General formula for IEC TR 62380 IC failure rate can be modeled as sum of the die related failure rate and the package related failure rate where

- Die related failure rate formula includes terms for IC type and IC technology, transistor count, thermal mission profile, junction temperature, operating and non-operating lifetime.
- Package related failure rate formula includes terms for mechanical stress due to thermal expansions, thermal cycles, thermal mission profile, package type and package materials.
- EOS failure rate formula includes terms for external interface and electrical environment.

IEC TR 62380 Intrinsic Failure Rate

$$\lambda = \left(\underbrace{\left\{ \lambda_1 \times N \times e^{-0.35 \times a} + \lambda_2 \right\} \times \left\{ \frac{\sum_{i=1}^{y} (\pi_t)_i \times \tau_i}{\tau_{on} + \tau_{off}} \right\}}_{\lambda_{die}} + \left\{ \underbrace{2.75 \times 10^{-3} \times \pi_\alpha \times \left(\sum_{i=1}^{z} (\pi_n)_i \times (\Delta T_i)^{0.68} \right) \times \lambda_3}_{\lambda_{package}} \right\} + \left\{ \underbrace{\pi_I \times \lambda_{EOS}}_{\lambda_{overstress}} \right\} \right) \times 10^{-9} / h$$

Total FIT = Die FIT + Package FIT + EOS FIT

Figure 1: TR 62380 Integrated Circuit Failure Rate Model Equation

NECESSARY INFORMATION:

$(t_{ae})_i$: average outside ambient temperature surrounding the equipment, during the i[th] phase of the mission profile.

$(t_{ac})_i$: average ambient temperature of the printed circuit board (PCB) near the components, where the temperature gradient is cancelled.

λ_1 : per transistor base failure rate of the integrated circuit family. See Table 16.

λ_2 : failure rate related to the technology mastering of the integrated circuit. See Table 16.

N : number of transistors of the integrated circuit.

a : [(year of manufacturing) – 1998].

$(\pi_t)_i$: i[th] temperature factor related to the i[th] junction temperature of the integrated circuit mission profile.

τ_i : i[th] working time ratio of the integrated circuit for the i[th] junction temperature of the mission profile.

τ_{on} : total working time ratio of the integrated circuit. With: $\tau_{on} = \sum_{i=1}^{y} \tau_i$

τ_{off} : time ratio for the integrated circuit being in storage (or dormant). With $\tau_{on} + \tau_{off} = 1$

π_α : influence factor related to the thermal expansion coefficients difference, between the mounting substrate and the package material.

$(\pi_n)_i$: i[th] influence factor related to the annual cycles number of thermal variations seen by the package, with the amplitude ΔT_i .

ΔT_i : i[th] thermal amplitude variation of the mission profile.

λ_3 : base failure rate of the integrated circuit package. See Table 17a and 17b

π_I : influence factor related to the use of the integrated circuit (interface or not).

λ_{EOS} : failure rate related to the electrical overstress in the considered application..

Figure 2: TR 62380 Interated Circuit Failure Rate Model Terms

Scaling IEC TR 62380 Die Fit for different mission profiles

Technology & Transistor information unchanged for different mission profile

Temperatures, durations , Ton and Toff change for different mission profiles.

Delta Tja unchanged for mission profile
Temperature factor pie_t unchanged for mission profile

$$\underbrace{\left\{\lambda_1 \times N \times e^{-0.35 \times a} + \lambda_2\right\} \times \left\{\frac{\sum_{i=1}^{y} (\pi_t)_i \times \tau_i}{\tau_{on} + \tau_{off}}\right\}}_{\lambda_{die}}$$

For mission profile 1:
Lambda die 1 = Tech info x mission profile 1

For mission profile 2:
Lambda die 2 = Tech info x mission profile 2

Tech info is independent of the mission profile
If you know Lambda die 1 for mission profile 1

The Lambda die 2 can be solved by substitution

Lambda die 2 = Lambda die 1 * mission profile 2 / mission profile 1

Scaling IEC TR 62380 Die Fit for different mission profiles

Example: Lambda die fit of 3.5 FIT for Motor Control profile
to be scaled to Passenger Compartment profile

Assume a HV BiCMOS technology A=4640 and Delta Tj of 15 deg C

Technological structure	Temperature factor π_t
MOS BiCMOS (low voltage)	$e^{\left[A\left(\frac{1}{328}-\frac{1}{273+t_j}\right)\right]}$ A=3480 ; (Ea=0.3 eV)
Bipolar BiCMOS (high voltage)	$e^{\left[A\left(\frac{1}{328}-\frac{1}{273+t_j}\right)\right]}$ A=4640 ; (Ea=0.4 eV)

Mission profile phases	Temp. 1		Temp. 2		Temp. 3		Ratios on/off	
Application types	$(t_{ac})_1$ °C	τ_1	$(t_{ac})_2$ °C	τ_2	$(t_{ac})_3$ °C	τ_3	τ_{on}	τ_{off}
Motor control	32	0.020	60	0.015	85	0.023	0.058	0.942
Passenger compartment	27	0.006	30	0.046	85	0.006	0.058	0.942

Delta Tj = Power * Theta Ja = 90mW * 171 C/ W = 15 deg C

See datasheet

See FIT rate report assumptions

Motor Control
Tj 1 = 32C + 15C = 47C pie_t 1= e^(4640 (1/328 – 1/(273+ 47))) = 0.702
Tj 2 = 60C + 15C = 75C pie_t 2= e^(4640 (1/328 – 1/(273+ 75))) = 2.254
Tj 3 = 85C + 15C = 100C pie_t 3= e^(4640 (1/328 – 1/(273+ 100))) = 5.510

3.5 die FIT = (tech info) * ((0.02*0.702 + 0.015 * 2.254 + 0.023 * 5.510) / (0.94 + 0.058)) ; 3.5 die FIT = (tech info) * 0.1746

Passenger Compartment
Tj 1 = 27C + 15C = 42C pie_t 1= e^(4640 (1/328 – 1/(273+ 42))) = 0.5577
Tj 2 = 30C + 15C = 45C pie_t 2= e^(4640 (1/328 – 1/(273+ 45))) = 0.6409
Tj 3 = 85C + 15C = 100C pie_t 3= e^(4640 (1/328 – 1/(273+ 100))) = 5.510

Pass Comp die FIT = (tech info) * ((0.006*0.5577 + 0.046 * 0.6409 + 0.006 * 5.510) / (0.94 + 0.058)) ; Pass Comp die FIT = (tech info) * 0.0659

Pass Comp die FIT = 3.5 FIT * (0.0659 / 0.1746); <u>Passenger Compartment profile die FIT = 1.4 FIT</u>

Scaling IEC TR 62380 Package Fit for different mission profiles

The thermal expansion factor pie_alpha and the package factor fail rate lambda 3 unchanged for different mission profile

Temp Cycle Factors change for different mission profiles.

Delta Tja unchanged for mission profile

$$\left\{ \underbrace{2.75\times10^{-3}\times\pi_{\alpha}\times\left(\sum_{i=1}^{z}(\pi_{n})_{i}\times(\Delta T_{i})^{0.68}\right)\times\lambda_{3}}_{\lambda_{package}} \right\}$$

For mission profile 1:
Lambda package 1 = Package info x mission profile 1

For mission profile 2:
Lambda package 2 = Package info x mission profile 2

Package info is independent of the mission profile
If you know Lambda 1 and mission profile 1

The Lambda 2 can be solved by substitution

Lambda 2 = Lambda 1 * mission profile 2 / mission profile 1

Scaling IEC TR 62380 Package Fit for different mission profiles

Example: Lambda package fit of 1.9 FIT for Motor Control profile
to be scaled to Passenger Compartment profile

Assume world wide climate t_ae and day/night delta_t. Assume Delta Tj of 15 deg C

Mathematical expression of the Influence factor $(\pi_n)_i$	$n_i \le 8760$ Cycles/year	$(\pi_n)_i = n_i^{0.76}$
	$n_i > 8760$ Cycles/year	$(\pi_n)_i = 1.7 \times n_i^{0.60}$
n_i : Annual number of cycles with the amplitude ΔT_i		
For an on/off phase	$\Delta T_i = \left[\frac{\Delta T_j}{3} + (t_{ac})_i\right] - (t_{ae})_i$	
For a permanent working phase, storage or dormant	ΔT_i =average per cycle of the (t_{ae}) variation, during the i[th] phase of the mission profile.	

Mission profile phases	2 night starts		4 day light starts		Non used vehicle	
Application types	n_1 cycles/year	ΔT_1 °C/cycle	n_2 cycles/year	ΔT_2 °C/cycle	n_3 cycles/year	ΔT_3 °C/cycle
Motor control	670	$\frac{\Delta Tj}{3}+55$	1340	$\frac{\Delta Tj}{3}+45$	30	10
Passenger compartment	670	$\frac{\Delta Tj}{3}+30$	1340	$\frac{\Delta Tj}{3}+20$	30	10

Delta Tj = Power * Theta Ja = 90mW * 171 C/ W = 15 deg C

See FIT rate report assumptions   See datasheet

Motor Control
dT1 = 15C/3 + 55C = 60C   pie_n1= 670^0.76 = 140.5
dT2 = 15C /3+ 45C = 50C   pie_n2= 1340^0.76 = 238.0
dT3 = 10C   pie_n3= 30^ 0.76 = 13.3

1.9 package FIT = (Package info) * ((60^0.68 * 140.5) + (50^0.68 * 238.0) + (10^0.68 * 13.3)); 1.9 package FIT = (Package info) * 5741.6

Passenger Compartment
dT1 = 15C/3 + 30C = 35C   pie_n1= 670^0.76 = 140.5
dT2 = 15C /3+ 20C = 25C   pie_n2= 1340^0.76 = 238.0
dT3 = 10C   pie_n3= 30^ 0.76 = 13.3

Pass Comp package FIT = (package info) * ((35^0.68 * 140.5) + (35^0.68 * 238.0) + (10^0.68 * 13.3)); Pass Comp package FIT = (Package info) * 3764.5

Pass Comp package FIT = 1.9 FIT * (3764.5/ 5741.6); Passenger Compartment profile package FIT = 1.3 FIT

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