Mission Profile Evaluation for Automotive Applications

An Anthology of Best Practices

Semyra Vasquez-Borucki
Infineon Technologies AG

Mission Profile Evaluation for Automotive Applications

Mission Profile Evaluation for Automotive Applications
Infineon at a glance

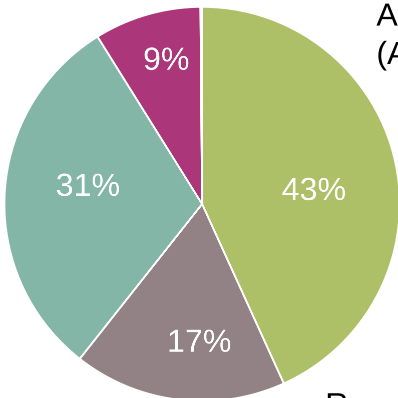
Business Segments

Digital Security Solutions (DSS)

Power Management & Multimarket (PMM)

Industrial Power Control (IPC)

Automotive (ATV)

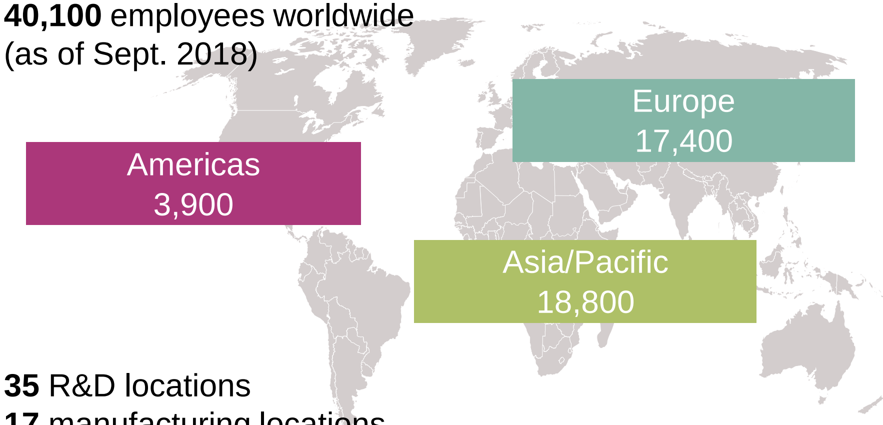


Revenue FY 2018

Further information in the [Annual Report 2018]

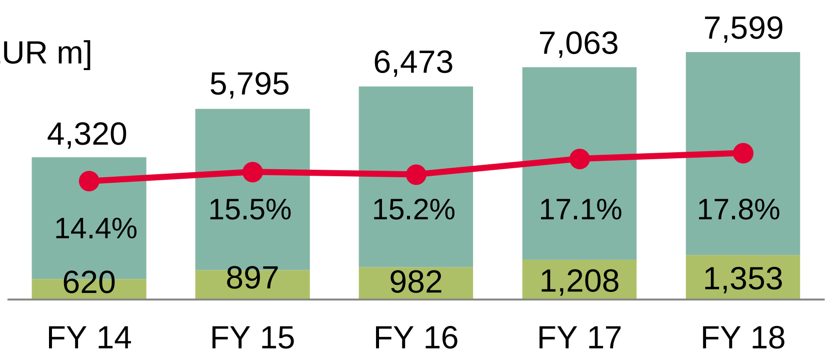
Employees

40,100 employees worldwide (as of Sept. 2018)



35 R&D locations
17 manufacturing locations

Financials



Market Position

Automotive	Power	Security ICs
		
# 2	**# 1**	**# 2**
Strategy Analytics, April 2019	IHS Markit, Technology Group, September 2019	ABI Research September 2019

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High Reliability (HiRel) Semiconductor Solutions from Infineon

Some applications need a high level of reliability!

Infineon (former Siemens Semiconductor) is an expert in handling special requirements and has an excellent reputation in the space community for over 40 years!

- Infineon world wide customers value the high quality of the devices and appreciate the expertise in development and production.
- The space heritage covers more than 1500 Satellites/Missions. Lifetime up to 15 years without any failure
- There are already more than 200 000 Infineon HiRel components in Space.
- The product range covers Radiation Hard PowerMOS Transistor MW-Transistors, Diodes and PIN–Diodes
- **Link to webpage: www.infineon.com/space**

Slide provided from W. Kuebler

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AEC Q100 Rev. H

- Failure Mechanism Based Stress Test Qualification for Integrated Circuits
- Connect operating mission profile to a temperature grade
- Introduce section "Method to Assess a Mission Profile"
  - Demanding loading profile
  - Extended service lifetime requirement
  - More stringent failure rate target over lifetime

1.3.4 Definition of Part Operating Temperature Grade

The part operating temperature grades are defined in Table 1 below:

Table 1: Part Operating Temperature Grades

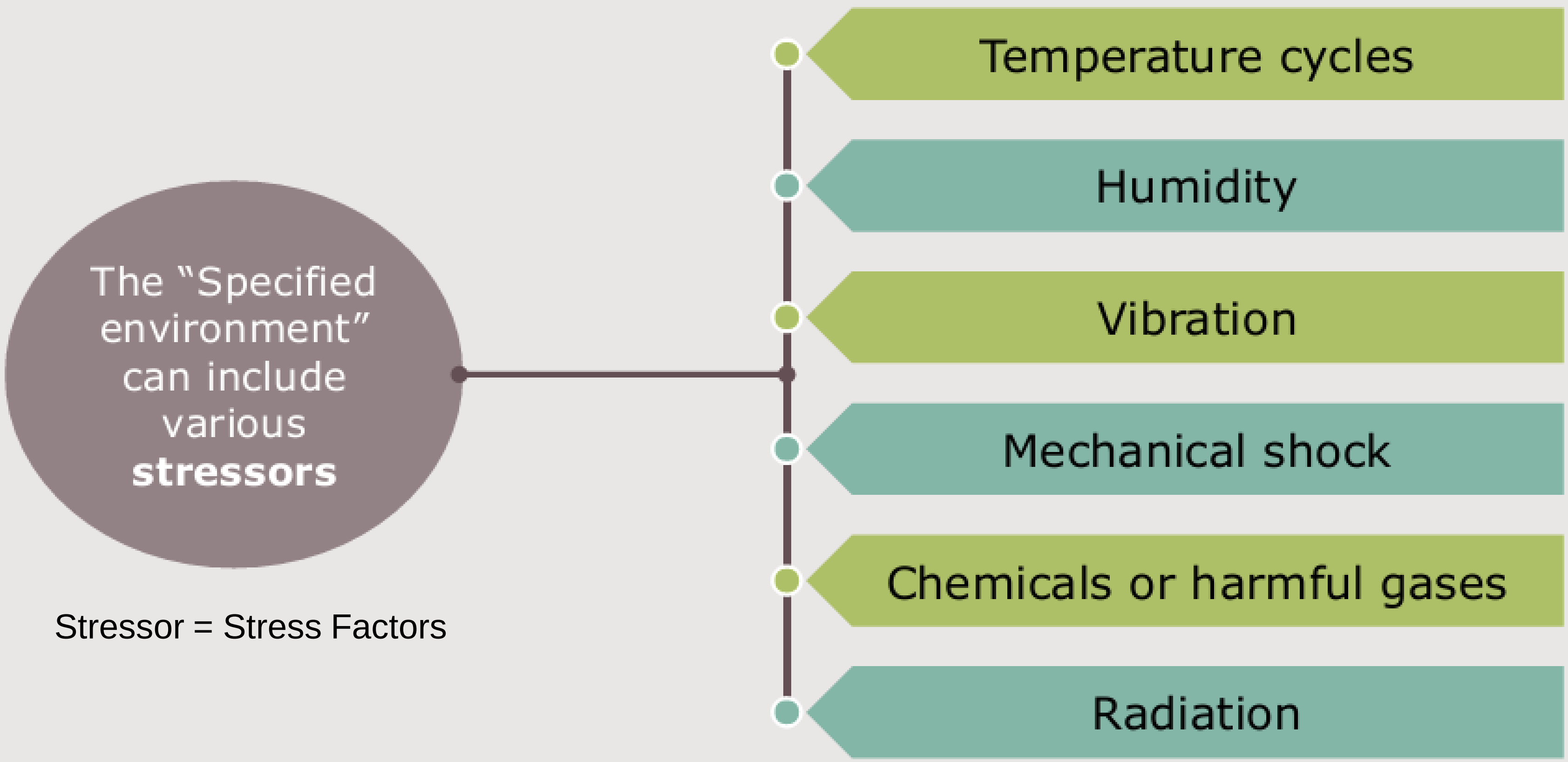
Grade	Ambient Operating Temperature Range
0	-40°C to +150°C
1	-40°C to +125°C
2	-40°C to +105°C
3	-40°C to +85°C

The endpoint test temperatures for hot and cold test, if required for that stress test, must be equivalent to those specified for the particular grade. If accounting for junction heating during powered test, hot test endpoint test temperature can be greater.

For Test Group B – Accelerated Lifetime Simulation Tests: High Temperature Operating Life (HTOL), Early Life Failure Rate (ELFR) and NVM Endurance, Data Retention, and Operational Life (EDR), the junction temperature of the device during stressing should be equal to or greater than the hot temperature for that grade.

Mission Profile Definition

Customer specifies environment conditions for our product!



Stressor = Stress Factors

A mission profile is a description of all conditions, in which the IC will be exposed in a defined application.

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Automotive Applications Requirements

Basic lifetime requirements for passenger vehicles today	
Lifetime	15 years
Operation Time	8.000 hours
Mileage	300.000 Km

Please note:

- These requirements apply to the (passenger) vehicle in a more or less private use
- Subsystems and ECUs within the vehicle already today face different lifetime requirements.
- A different user profile may result in totally different lifetime requirements. Commonly, sources for that kind of requirements are commercial vehicles and trucks.

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Automotive Applications Requirements

Extended Mission Profiles Today

Example:

Microcontroller for **use in a battery charging system**

Lifetime (same like vehicle): 15 years

- Op. Ambient Temp. Range: -40 °C to 125 °C
- Non-operating time: 91,400 hours
- Operating time: 40,000 hour

Is an AEC-Q100 qualification covering the lifetime?

Customer Mission Profile*

$T_{ambient}$ [°C]	Time [h]
Operating	
125	400
120	3,200
76	26,000
23	8,000
-40	2,400
Non Operating	
85	914
80	7,312
60	59,410
23	18,280
-40	5,484

*) Arbitrary chosen, corresponding to "Automotive Application Questionnaire for Electronic Control Units and Sensors", ZVEI, October 2006

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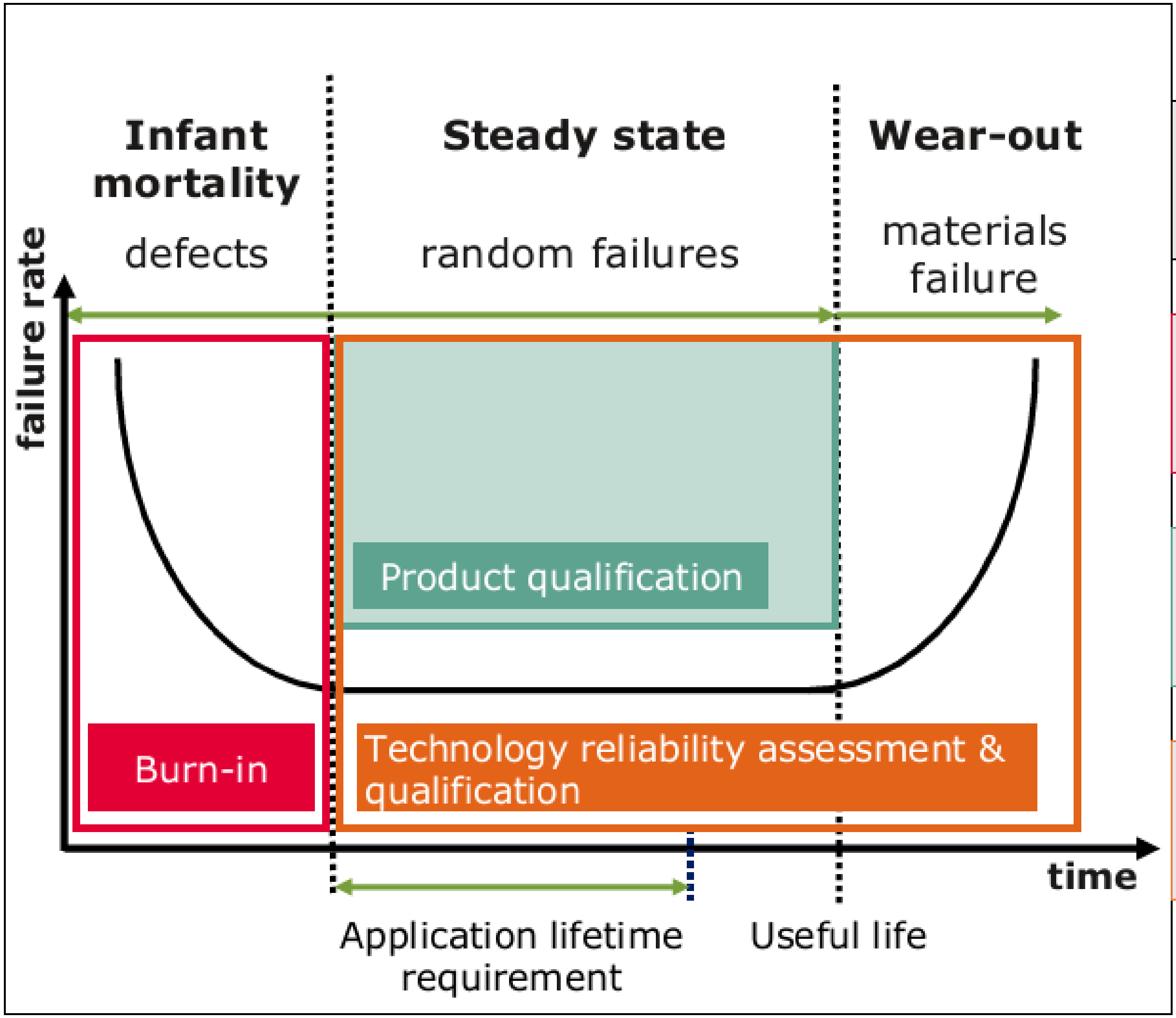
Reliability Basics



Bathtub curve: failure rate of a product over lifetime

Failures at early stage: defects causing a weak point in the product

Constant failure rate: mix of latent defects & statistical early wear-out failures

Wear-out failures: intrinsic limitation of used materials and design

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Acceleration Models

› A first glimpse at lifetime models

Conversion of test time at test conditions to equivalent application time at use conditions:

$t_{use} = AF \cdot t_{stress}$ AF is called acceleration factor

Stressor	Model	Equation
Temperature Thermal processes	Arrhenius	$AF\ (T) = \exp\left\{\frac{Ea}{kB}\left(\frac{1}{Tuse} - \frac{1}{Tstress}\right)\right\}$
Temperature Cycling Thermal mechanical processes	Coffin-Manson	$AF(\Delta T) = \left(\frac{\Delta Tstress}{\Delta Tuse}\right)^{B}$
Temperature and Humidity Corrosion	Peck	$AF(T, RH) = \exp\left\{\frac{Ea}{kB}\left(\frac{1}{Tuse} - \frac{1}{Tstress}\right)\right\} \cdot \left(\frac{RHstress}{RHuse}\right)^{p}$

E_a: apparent thermal activation energy
k_B : Boltzmann constant
= $8{,}617 \cdot 10^{-5}$ eV/K

T : temperature (K)
V : voltage (V)
RH : relative humidity (%)

ΔT : temperature interval (°C or K)
B = Coffin-Manson coefficient
p = Peck's factor

Arrhenius Model

- Assumption
  - An IC-device shall run 8000h operation hours in 15 years in a given mission profile
- Problem Statement
  - The IC device shows an increase of the T_j of 15°C at V_{max}.
  - What is the minimum equivalent stress time when running HTSL and HTOL stress tests at T_{amb} = 150°C (oven temperature) in order to cover the given mission profile?

HTSL

Ambient temperature	Operating hours	Calculated temperature	Stress temperature	Equivalent Stress time, (E_a=0.7eV)	Equivalent Stress time, (E_a=1.0 eV)
T_{amb} [°C]	t_op [h]	$T_j = T_{amb}$ [°C] + ΔTj	$T_{stress} = T_{oven}$ [°C]	t_stress [h]	t_stress [h]
-20	832	-5	150	0	0
35	2333.6	50	150	6	0
95	3750.4	110	150	505	214
120	833.6	135	150	412	304
140	250.4	155	150	313	345
13	123400	13	150	13	0
sum	8000+123400 = 131400			**1249**	**864**

Non Operating

After cool down

- E_a = 0.7eV (typical gate oxide failure mechanism); E_a = 1.0 eV (package effects)
- Consider passive time up to 15 years at an average temperature, e.g. 13°C

HTSL = High Temperature Storage Life

Examples of Mission Profile Evaluation

Arrhenius Model

HTOL

– E_a = 0.7eV (typical)

Ambient temperature	Operating-hours	Calculated temperature	Stress temperature	Equivalent Stress time, E_a=0.7eV
T_a [°C]	t_{op} [h]	T_j [°C]	$T_{jstress}$ [°C]	t_{stress} [h]
-20	832	-5	165	0
35	2333.6	50	165	3
95	3750.4	110	165	262
120	833.6	135	165	213
140	250.4	155	165	162
∑	8000		T_{oven} = 150°C	641

Ambient temperature	Operating-hours	Calculated temperature	Stress temperature	Equivalent Stress time, E_a=0.7eV
T_a [°C]	t_{op} [h]	T_j [°C]	$T_{jstress}$ [°C]	t_{stress} [h]
-20	832	-5	150	0
35	2333.6	50	150	6
95	3750.4	110	150	505
120	833.6	135	150	412
140	250.4	155	150	313
∑	8000		T_{oven} = 135°C	1237

HTOL = High Temperature Operating Life

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Examples of Mission Profile Evaluation

› Sensibility Analysis

Activation Energy, E_a [eV]		0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.25	1.5
HTOL at T_a = 150°C	Total Equivalent Stress time [h]	2923	2015	1453	1080	823	**641**	509	411	338	221	156
HTOL at T_j = 150°C		3526	2671	2115	1727	1446	**1237**	1078	957	864	715	640

- Most of known failure mechanisms
- Robustness margin

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Examples of Mission Profile Evaluation

› Coffin Manson

- Mission profile arbitrary chosen, corresponding to “Automotive Application Questionnaire for Electronic Control Units and Sensors”, ZVEI, October 2006
- TC test runs within -55°C and 150°C
- ΔTj in operation is 15°C
- 11000 cycles (number of engine on/off cycles over 15 years of use, **2 cold starts per day**

Operation-hours [%]	Delta-T_{op} [°C]	Amount of cycles	Coffin-Manson Coefficient 2	3	4	5	6
21	**30**	2310	49.5	7.2	1.1	0.2	0.0
41	50	4510	268.3	65.4	16.0	3.9	0.9
27	70	2970	346.3	118.2	40.4	13.8	4.7
11	90	1210	233.2	102.4	45.0	19.7	8.7
	∑	11000	897	293	**102**	38	14

› Peck

Table A7.1: Basic Calculations for AEC-Q100 Stress Test Conditions and Durations (continued)

Extract AEC Q100

Loading	Mission Profile Input	Stress Test	Stress Conditions	Acceleration Model (all temperatures in K, not in °C)	Model Parameters	Calculated Test Duration	Q100 Test Duration
Humidity (Option 2)	t_u = 131,400 hr (average on/off time over 15 yr of use) RH_u = 74% (average relative humidity in use environment) T_u = 32°C (average temperature in use environment: 9% @ 87°C - time on and 91% @ 27°C - time off)	Highly Accelerated Steam Test (HAST)	RH_t = 85% (relative humidity in test environment) T_t = 130°C (ambient temperature in test environment)	Hallberg-Peck $A_f = \left(\frac{RH_t}{RH_u}\right)^p \bullet \exp\left[\frac{E_a}{k_B} \bullet \left(\frac{1}{T_u} - \frac{1}{T_t}\right)\right]$ Also applicable for Temperature Humidity Bias (THB) and Unbiased Humidity Steam Test (UHST). See Notes.	p = 3 (Peck exponent, 3 is to be used for bond pad corrosion) E_a = 0.8 eV (activation energy; 0.8 eV is to be used for bond pad corrosion) $k_B = 8.61733 \times 10^{-5}$ eV/K (Boltzmann's Constant)	T_t = 53 hr $t_t = \frac{t_u}{A_f}$	96 hr

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Summary and Perspective

- Acceleration models well known over 30 years
- Challenges for applying acceleration models to new technologies
  - Cu wires (AEC 006)
- Accurate computational methods, e.g. cohesive finite element simulations.

Increasing reliability knowledge is striving for quality!

Thank you!

Part of your life. Part of tomorrow.

Infineon