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Qualification extension of automotive smart power and digital ICs to harsh aerospace mission profiles: Gaps and opportunities

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ABSTRACT

Historically the aerospace market has always chosen high level reliability solutions through customized technologies and processes, in order to cope with the requirement driven by mission profiles and application environment severity.

In parallel, Automotive market required more and more high reliability targets. As a consequence, the qualification activity has evolved, passing from a stress driven approach strictly based on AEC-Q100 standard to a failure mode driven approach oriented to satisfy the robustness criteria required by TIER1 and Car Makers.

Starting from this scenario, new market opportunities for Automotive devices can be identified, since the most reliable of them are today eligible to be sold to aerospace manufacturers with important cost saving thanks to massive production volumes of consolidated technologies.

A gap may still persist and has to be carefully explored. First of all, a study of the different application constraints has to be carried out and the potential failure modes activated by Aerospace cold unbalanced mission profile, atmospheric pressure and radiations have to be analysed.

Experimental evidences have been collected as first step on advanced CMOS technologies, and their extension to the smart-power families, where digital and power coexist together, will be shortly discussed in this paper.

1. Introduction

This work reflects industry trend to combine technological complexity and reliability in advanced products development.

The growing of competition, the reduction of the prices per unit and also the mandatory request of the market in terms of quality per unit, make reliability a fundamental ingredient of products advanced requirements; consequently, it is also becoming a pervasive subject of study for modern industry.

The comparison between Aerospace and Automotive mission profiles, with their related constraints in environmental stress severity, offers an opportunity to discuss about qualification exercise extension of CMOS 90 nm microcontrollers, and analyse the gap between CMOS and Smart Power families in terms of basic failure mechanisms.

In the second and third chapter we will respectively give a brief description of the Aerospace and Automotive qualifications. The fourth paragraph exposes the experimental results obtained from an "extension trial" consisting in accelerated life tests aimed at qualifying an Automotive 90 nm microcontroller IC for Aerospace applications; the differences between the CMOS and the smart power devices in terms of activated failure mechanisms are also discussed. In the fifth paragraph we will identify the gap between two typical mission profiles, and then some conclusions will be shared.

2. Space qualification standards

The life cycle of an IC for Aerospace application consists of a series of phases, culminating with the operative conditions into the Space environment.

For each phase of the component life, a series of accelerated life tests are required, that can be listed as follows:

- Temperature (static + cycling) for life on Earth and in Space
- Humidity exposure for life before the launch
- Vibrations and shocks for the problems that could arise during the launch
- In-vacuum operation for life in Space
- Microgravity for life in Space
- Radiations for life in Space

In Europe the standard is called ECSS [1] and will be analysed and considered in this paper. The European Cooperation for Space Standardization (ECSS) is an initiative established in 1993 to develop a coherent,

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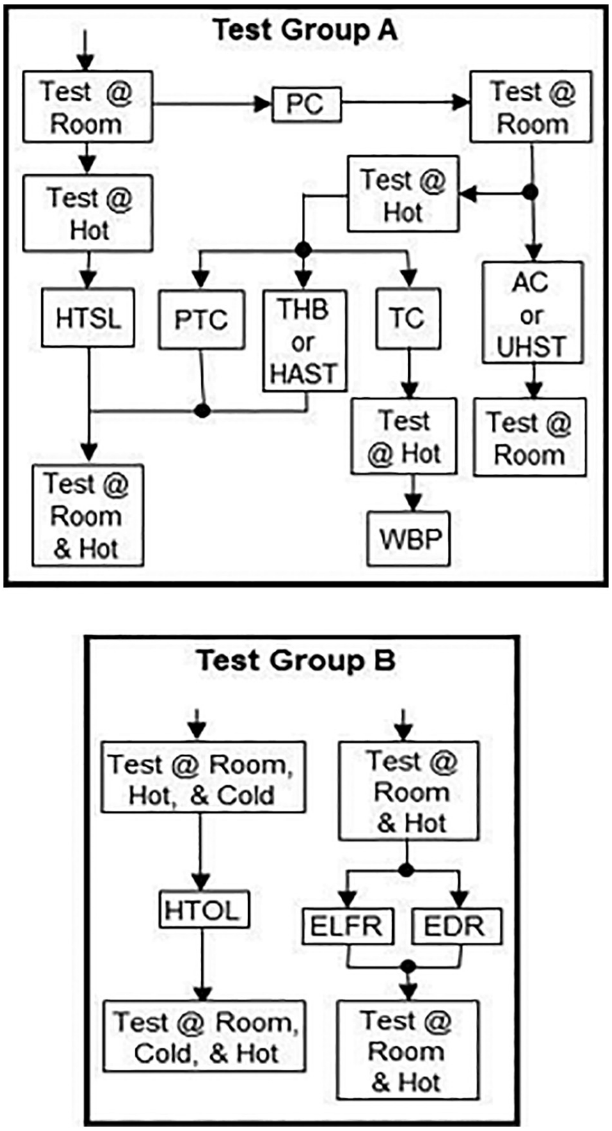

Fig. 1. AEC-Q100 Main Test Groups [3].

single set of user-friendly standards for use in all European Space activities.

This set of Standards is organized in four branches.

The first branch deals with Project Management, the second branch deals with Quality of the devices used for Space, the third one deals with all the engineering activities needed to develop a product used for Space applications, and the last branch, the forth, deals with sustainability.

It is possible to identify some key documents:

ECSS-E-ST-10-04C "Space Environment": this Standard defines the Space as harsh environment. ECSS-Q-ST-60C: this standard defines requirements for selection of Electronic, Electrical Electromechanical components for Space projects.

ECSS-Q-30-08A "Space Product Assurance - Components reliability Data Sources and their use": this Standard defines test methods to be applied for reliability prediction of components.

ECSS-Q-ST-60-02C "Space Product Assurance - ASIC and FPGA development": this Standard defines a comprehensive set of requirements for digital, analog and mixed analog-digital custom designed integrated circuits, such as Application Specific Integrated Circuits (ASICs) and Field Programmable Gate Arrays (FPGAs).

Qualification procedures and subsequent accelerated aging test plan have to be engineered on the basis of the device family (ASIC, RF, Optoelectronic, etc.) and position on the spacecraft. Trials duration has to be planned according to the applicable mission profiles, and stress set-up following the guidelines defined into JEDEC [2] standard for military applications.

Table 1
Automotive Mission profile for microcontroller CMOS 90 nm converted into trial duration by using Arrhenius law and Acceleration Factor in Voltage.

	Tjunction (°C)	Time use (h)	HTSL Equivalent time Tjunction 150 °C Ea = 1,0 eV	HTOL Equivalent time Tjunction 150 °C Ea = 0,6 eV (AFV = 5)
ON	60	656	0.4	1.5
	70	820	1.3	3.5
	80	1998	8.6	15.2
	90	4403	46.8	57.7
	100	6090	152.9	133.5
	110	6135	347.5	219.2
	120	3270	401.1	185.7
	130	1260	322.0	111.2
	140	340	174.7	45.6
	150	30	30	6.0
OFF	40	175,200	11.2	
	Sum	200,202	1497	779

3. Standards and qualification approach in automotive

Automotive products are used in a variety of applications: from multimedia entertainment to power train, from safety systems to driver assistance.

It is evident that in such complex scenario all the activities aimed to reduce the failure rate at customer and final user play a crucial role.

Reliability must be present since the first development phases, starting the implementation of robust approaches directly at design level, and including backups or error recovery solutions. Then it is essential to anticipate the reliability study since the very beginning of the process development through dedicated test chips, in order to validate, update and characterize the initial hypothesis about failure modes and mechanisms. Preventive screening aimed at catching any new or unexpected failure mode is also fundamental, to be later combined with the continuous monitoring on the mass manufacturing in order to react in front of any deviations.

In order to define a common method to qualify semiconductor devices for Automotive market, AEC-Q100/Q101 documents [3,4] have been composed and they are continuously reviewed year over year by the major devices producers and car-makers. AEC documents are designed to serve Automotive electronics industry through eliminating possible sources of misunderstanding between manufacturers and purchasers: Q100 is specific for ICs and Q101 is also considered for Smart Power in case of discrete devices.

Table 2
Automotive Mission profile for microcontroller CMOS 90 nm converted into stress trial duration by using Coffin- Manson's law.

Delta temperature on field (°C)	Number of cycles on field	TC [−50,+150 °C] $n = 4$
52	657	3,0
37	2190	2,6
87	6888	246,6
122	1095	151,6
134	121	24,4
5	300,000	0,1
10	5000	0,0
8	11,000	0,0
29	5000	2,2
15	9000	0,3
Sum	340,951	431

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