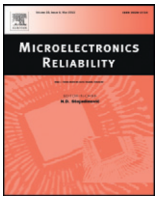
Microelectronics Reliability 55 (2015) 2484–2492

Contents lists available at ScienceDirect

Microelectronics Reliability

journal homepage: www.elsevier.com/locate/mr



Setting stress conditions that qualify application expectations

William J. Roesch

Qorvo, 2300 N.E. Brookwood Parkway, Hillsboro, Oregon 97124-5300, United States

ARTICLE INFO

Article history:
Received 29 July 2015
Received in revised form 7 September 2015
Accepted 23 September 2015
Available online 9 October 2015

Keywords:
Qualification
Acceleration
Application
Stress
Conditions
Knowledge

ABSTRACT

This is a demonstration that blends failure mechanism information and application expectations in order to set goals and make predictions that can be used in setting guidelines or requirements for qualification methods, sample sizes, and durations which are relevant to intrinsic and extrinsic reliability. This information is required to fill in the gaps for new types of knowledge-based and application-specific qualification requirements. Instead of generalizing requirements for convenience and uniformity, as with 29 year old stress-driven qualification methods, specific information can be used to pinpoint needs for one type of device — assuming failure mechanism, degradation distribution, and acceleration factor information is known and exists in the public domain. For illustration, a Power Amplifier Module is demonstrated. The overall synthesis of proper qualification requirements for this type of semiconductor module will result in efficient stressing to protect customers and allow for the completion of meaningful qualifications efficiently.

1. Introduction

Development of an application specific Power Amplifier Module (PAM) qualification requires a thorough understanding of failure mechanisms, acceleration factors, application environments, and prediction models for stress and lifetimes. Characterization of failure distributions and knowledge of statistics, probability, and sampling theory are also needed for calculations that govern accelerated stress aging to make them relevant to application situations and qualification goals.

2. Purpose

The intent of this work is to provide a general discussion on relationships between standards, requirements, and expectations for these types of qualification methodologies…

- Stress-Test-Driven (STD)
- Failure-Mechanism-Driven (FMD)
- Knowledge-based qualification (KBQ)
- Physics-of-Failure (PoF)
- Use-Condition-Based (UCB)
- Application Specific Qualification (ASQ)

To illustrate the discussion, PAM failure mechanism examples will be correlated to known acceleration factors. Example reliability goals for failure rates, and accumulated fallout will be used as generic representations of application models to show how stresses, application models, and acceleration factors can be used to tailor reliability qualification requirements to goals and expectations for reliability. The synthesis of example qualification requirements for efficient stressing to protect customers and complete qualifications efficiently will be demonstrated.

3. History — why the interest in failure mechanisms and application models?

The JEDEC committee on compound semiconductor quality and reliability (JC-14.7) has been working on PAM qualification for about 15 years [1]. A 2009 survey of the JC-14.7 committee, of PAM suppliers, and of PAM customers, identified specific needs for qualifications. A compendium of applicable and unique failure mechanisms was one of the first needs identified [2]. Application models were discussed and suggested as a key expectation for the acceptance of JESD 236. (Note: full JEDEC and SEMATECH standards titles are provided in a section prior to the references.) But the most important desire voiced by the Task Group participants was that the qualification tests must “mean something.” In other words, the team wanted to exclude arbitrary tests that weren't relevant or applicable to the failure mechanisms of compound semiconductor technologies most often utilized in PAM products for mobile phones.

Based upon inputs from participating companies, the top area selected by the Power Amplifier Module Task Group was… “Quantifying PAM differences in failure mechanisms and acceleration factors, (similar to JEP122) for both common mechanisms and unique Compound Semiconductor mechanisms.” The failure mechanism background was tabled by the Task Group until a RF biased stress method, and an overall PAM qualification document were established. The failure mechanism

---

E-mail address: bill.roesch@qorvo.com.

http://dx.doi.org/10.1016/j.microrel.2015.09.022

information was postponed until the research could be completed and published to maintain a synergy of applicability between the three document types. In 2013–14, the basic science work regarding failure mechanisms was discussed. However, the Task Group settled on a compromise of adopting a Stress-Test-Driven approach and finding the lowest common acceptable sample sizes and durations in order to launch a PAM qualification document that could be molded and developed by the expectations of the Task Group.

4. Expectations for qualifications

One purpose of qualifying a product for reliability is to evaluate functionality within a usage situation over the product's expected lifetime. There are at least six different types of Reliability Qualification methods described in various JEDEC documents. Regardless of the name or type of qualification, the interaction between the actual application (or use) conditions, the applied stress, and the understanding of the failure mechanisms is needed in order to make predictions or assessments about reliability. The formative components to define a reliability qualification are shown in Table 1.

5. Finding a level playing field

In order to discuss pros and cons of qualification types, a common vocabulary is useful. Typically, reliability professionals will revert back to the bathtub curve to begin the discussion. One version of the bathtub curve is shown in Fig. 1.

Transformation of the bathtub curve to make it more inclusive of defects and quality aspects may be useful. One option to generalize the bathtub is to change the dependent variable to “fallout” instead of “failure rate.”[4] There are several reasons for blurring the meaning of the vertical axis. We would like to graphically represent both wearout and early life measurement units. We would also like to compare both instantaneous failure rates and the accumulation of fallout over time. In this context, “fallout” can represent unreliability in terms of raw counts, percentages, fractions, or yields as well as failure rates for any arbitrary units or characterizations. The use of “fallout” is intended to get all engineering disciplines communicating and theorizing a cross-functional discussion about the intent of qualification testing.

Whether fallout or failure rate is measured, the determination of those reliability parameters relative to overall lifetimes is a useful technique to compare qualification types. For example, the general categorization of “capability tests” will intentionally apply stress levels and durations to measure actual fallout or failure rates, preferably through the wearout region and including the empirical determination of median lifetimes. So, the capability test is capable of measuring the fallout or failure rate if the stress and duration is adequate to induce and/or characterize the intrinsic reliability. Whereas “success tests” are favored when no fallout or failure rate is desired to be known and none are expected to be measurable with reasonable stress durations and small sample sizes. In other words, success tests are designed to measure “regions of goodness” where failures do NOT occur. Success can be claimed as “good enough” if degradation is not detected, no failures arise, nor any fallout occurs… resulting in a “pass.”

Table 1
Four components of a qualification that “means something.” [3]

Key components	Examples (pick all that apply)
Qualification type:	Standard-based, failure-mechanism driven, knowledge-based, Physics of failure, JESD 236 PAM Qual
Failure mechanism descriptions:	JEP 122 (Silicon), failure mechanism survey publications, compound semiconductor publications that characterize a particular failure mechanism
Stress method:	General method documents, MIL-STD-883, JESD22 series of environmental stresses, JESD226 RFBL
Application model:	JESD94

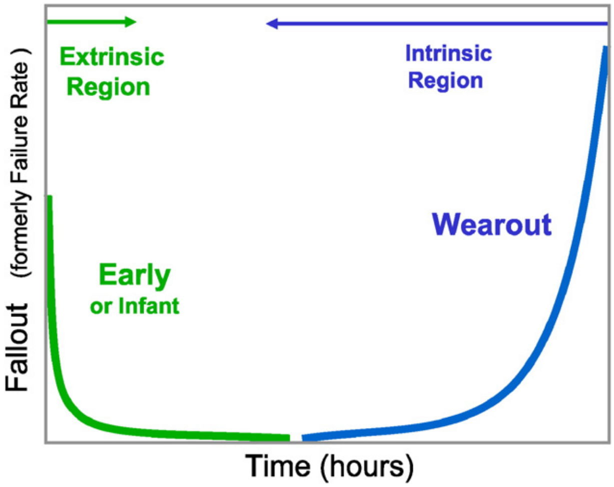


Fig. 1. Historical bathtub curve [4].

Note: customers prefer to see no failures regardless of the duration or meaning of the test, whereas the reliability professional seeks deterministic data on when degradation will occur, what form the degradation will take and how it affects the entire population of devices and the identification of margin between use and wearout.

6. Comparing qualification types

6.1. Standards-based testing

Stress-based qualifications, also known as “standards,” or “success tests,” or “acceptance tests” are documents that describe stress methods and may prescribe a regimen of sample sizes and stress durations. The mother of all standardized qualification is the combination of two documents: MIL-STD-883, which is a compilation of test methods, and MIL-M-38510 which describes the qualification process. Of course, MIL-HDBK-217 is the associated reliability prediction cookbook for electronic equipment and larger systems. These dinosaurs have been translated into sleeker non-military documents such as the Automotive Electronics Council's — *Stress Test Qualification for Integrated Circuits*; AEC-Q100, and Telecordia's Network Equipment System specification — *Generic Requirements for Assuring Component Reliability*; GR-357, and JEDEC's — *Stress-Test-Driven Qualification of Integrated Circuits*; JESD47. These younger qualification “standards” are the most popular approaches for both system level and component level assessments. Both customers and suppliers agree that stress-based methods offer a uniform approach to qualification because a consistent sample size of components are subjected to the same set of stresses and durations for decades. The stress-based approach allows components and suppliers to be compared — but only if the capability of the devices is challenged by the stress regimen. Continued use of the “standard,” uniform suite of stresses over time can also contribute to a historical library of information. The relative uniformity of the stress and durations and the historical value are strengths of the acceptance test approach.

The standards-based approach also has some issues. The most glaring drawback of this type of qualification is that the stress conditions and durations are completely arbitrary. To be meaningful, reliability stresses would need to accelerate environmental and bias conditions expected in the intended applications. For example, reliability stressing needed to qualify a semiconductor for use in an automobile would differ considerably from the stresses needed to evaluate the use in an environmentally controlled office or a data center. Likewise, the lifetime expectations would vary considerably between a “free” upgradeable mobile