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GUIDE FOR THE PRODUCTION AND ACQUISITION OF RADIATION-HARDNESS ASSURED MULTICHIP MODULES AND HYBRID MICROCIRCUITS

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Foreword

This document is intended for use by suppliers and users of radiation-hardness-assured (RHA) multichip modules (MCMs) and hybrid microcircuits. It provides guidance as to how to achieve, maintain and ensure the required levels of radiation-hardness given the fact that the constituent dice can have different levels of hardness and hardness assurance. It has been prepared under the direction of JEDEC JC-13.5 (Hybrid, RF/Microwave, and MCM Technology) Committee, and contributions of the JEDEC JC-13.4 (Radiation-Hardness Assurance) Committee and the members of the AF/NASA/DTRA Space Parts Working Group Hardness Assurance Committee and Users Group.

Introduction

The development of radiation-hardened multichip modules and hybrid microcircuits can take place in one of three ways:

- Build-To-Print, where the buyer (also referred to as the original equipment manufacturer, OEM) assumes responsibility for all aspects of the performance of the finished module.
- Build-To-Spec, where the buyer provides the performance specifications, including radiation, to the manufacturer, who then interprets them, and designs, acquires the component parts, assembles, and tests the module.
- A joint effort between the buyer and the manufacturer, with each one taking responsibility for different parts of the development. For example, the buyer could take responsibility for the calculation of the radiation specifications and for the radiation testing. The manufacturer would then be responsible for the design, piece-part procurement, and assembly.

Because this document is primarily for use by the manufacturers, it will present the tasks as though the procurement is a build-to-spec type, where the manufacturer has the responsibility for all of the tasks. We recognize that is not always the case, with the joint effort scheme probably used more often. The development process is a complex undertaking because:

- The dice used for the circuits can come from a wide variety of suppliers ranging from qualified sources of radiation hardened microcircuits or discretes, where the radiation response of their devices is specified, to high volume commercial suppliers that provide no guarantees concerning device hardness.
- The radiation response of an MCM/hybrid must be addressed as a subsystem rather than simply as a collection of dice. That is, it is possible that the within-specification radiation response of a die can result in the malfunctioning of an MCM/hybrid device due to the interaction of the interconnected die.
- In very high dose rate environments, the actual MCM/hybrid structure (lands, grooves, etc.) can become a source of radiation-induced current, further impacting individual die response.
- The actual hybrid/MCM construction methods (e.g., ground connections, die attach, etc.) can influence the overall package and individual die response.

Introduction (cont'd)

This Guide describes how to deal with the various situations that an MCM/hybrid developer, procuring activity or user will encounter. The guidance is intended to supplement that already provided in the two relevant performance specifications: MIL-PRF-38534, General Requirements for Custom Hybrid Microcircuits and MIL-PRF-38535, General Specification for Integrated Circuits (Microcircuits) Manufacturing, as well as MIL-PRF-19500, General Specification for Semiconductor Devices.

This Guide is designed to provide support to several potential user groups, including:

- 1) Government Program Office (PO) personnel, will be able to use the Guide as a metric to:
 - a) quantify the rigor of the hardening effort for the MCM/hybrid devices used in their system or equipment;
 - b) adopt the radiation test data obtained during the characterization of the MCM/hybrid to support radiation hardening and survivability analysis.
- 2) Original Equipment and System Manufacturers (OEMs), who can use the Guide to:
 - a) formulate the details of the acquisition/procurement document used to obtain MCM/hybrid devices concerning radiation response issues, e.g., testing and analysis;
 - b) determine the level of effort required to obtain RHA MCM/hybrids as a function of radiation environment;
 - c) establish a radiation response database to support any subsequent system radiation hardening and survivability analysis or determination.
- 3) MCM/Hybrid Suppliers (Manufacturers):

This Guide should be especially useful to manufacturers that lack experience or expertise in radiation hardening and survivability and RHA since it outlines various issues that must be considered. In addition, for those manufacturers who will use third parties for radiation issues, the document can be used as a guide to identify the relevant concerns and facilitate communications. It will serve to:

- a) formulate the details of any die acquisition/procurement documents with respect to radiation effects and RHA;
- b) assist in the identification of critical requirements and RHA issues;
- c) assist in the implementation of an MCM/hybrid RHA system and identify the level of effort required to provide RHA devices;

Many MCM/hybrid manufacturers do not possess an RHA capability. For them, the document will facilitate their interaction with either third party sources or others, e.g., the system or equipment manufacturer, and will establish a baseline for the activities needed to provide radiation-hardness-assured MCMs and hybrids. This use of the Guide should be especially valuable.

GUIDE FOR THE PRODUCTION AND ACQUISITION OF RADIATION-HARDNESS ASSURED MULTICHIP MODULES AND HYBRID MICROCIRCUITS

(From JEDEC Board Ballot JCB-09-66, formulated under the cognizance of the JC-13.5 Subcommittee on Hybrid, RF/Microwave, and MCM Technology.)

1 Scope

The information contained herein is intended for use with MIL-PRF-38534 for those multichip modules and hybrids that are marked as radiation-hardness-assured parts and produced under the provisions of that document or that are built to a radiation specification. Guidance is provided concerning the design, development, fabrication, acquisition and test of multichip modules and hybrid circuits that have radiation requirements. This document is not intended to provide detailed guidance about how to assure the hardness of the dice, since it is recognized that dice with a wide range of hardness will have to be used. If non-RHA dice are used, the user-developed RHA procedures found in MIL-PRF-38535 should be used. Rather, this document provides guidance as to how to assure the hardness of the entire module, given the wide range of the radiation hardness and level of hardness assurance of the individual dice to be used in the module. Specifically, four types of dice are available (in order of decreasing level of specification controls):

- Radiation hardness-assured QML controlled (or equivalent). Dice of this type can be used with no additional testing.
- Non-hardened QML (or equivalent) change-controlled dice. Such devices require radiation characterization. However once this is done, minimal lot testing would be necessary.
- Inherently radiation hard or non-hard dice that are not under a formally recognized change control system, but supplier support (e.g., change control notice, etc.) is available.
- Commercial grade or other grade die that appear to have adequate radiation tolerance, but where no supplier support is provided for the qualification or radiation-hardness assurance. This presents a worst-case situation and requires the most stringent RHA program to ensure that the radiation performance requirements of all of the modules produced are satisfied.

The use of dice from any of the above noted categories, combined with the various types of MCM/hybrid suppliers, can then lead to the following categories of MCM/hybrid devices.

- Commercial module designs screened for RHA
- Commercial module designs upgraded with radiation-hardened dice
- Standard product RHA modules
- Custom product RHA modules.

The relationships between the various types of dice and finished modules are shown in figure 1. The objective of this Guide is to provide guidance to allow a supplier or user to establish and complement the RHA requirements for any of these MCM/hybrid combinations.

1 Scope (cont'd)

Two acquisition strategies can be inferred from figure 1. The first is where significant knowledge concerning the constituent chips is available. This approach, as exemplified by the right branch of the figure, places emphasis on component acquisition (i.e., screening and characterization) and subsequent analysis (as required) to obtain MCM/hybrid certification and qualification. It would apply to module manufacturers and to users who have access to accurate component lists, design rules, fabrication methods, etc. It is discussed in detail in subsequent sections of this Guide and should result in the most accurate and cost-effective course of action to obtain RHA qualification. The second approach is where little or nothing is known about the constituent chips. This approach, as exemplified by the left branch of the figure, represents a worst-case situation from both a technical and cost a point-of-view. If only input/output information is available, one has no choice but to try to determine the failure or response distribution of the module for each of the applicable radiation environments. This method may be acceptable if a statistically significant sample size can be tested and considerable margin exists with respect to the specified radiation levels. The key issues involved here are: an adequate sample size, the homogeneity of the sample, and the sample correlation to flight components. Thus significant effort must go into the development of the RHA test program for this technique.

If some minimal knowledge of the component types is available (e.g., high speed bipolar, power MOSFET, etc.), it can be used to guide the development of the RHA test program. For example, if it is known that a power MOS circuit is used, emphasis on Single Event Effects (SEE) testing would be appropriate. Conversely, if a module is known to contain only high speed CMOS digital circuits, then neutron testing and enhanced low rate dose sensitivity (ELDRS) testing can be eliminated. Thus, despite a lack of detailed knowledge about the module, some choices can be made about the radiation testing to improve the test coverage and optimize the test effort.

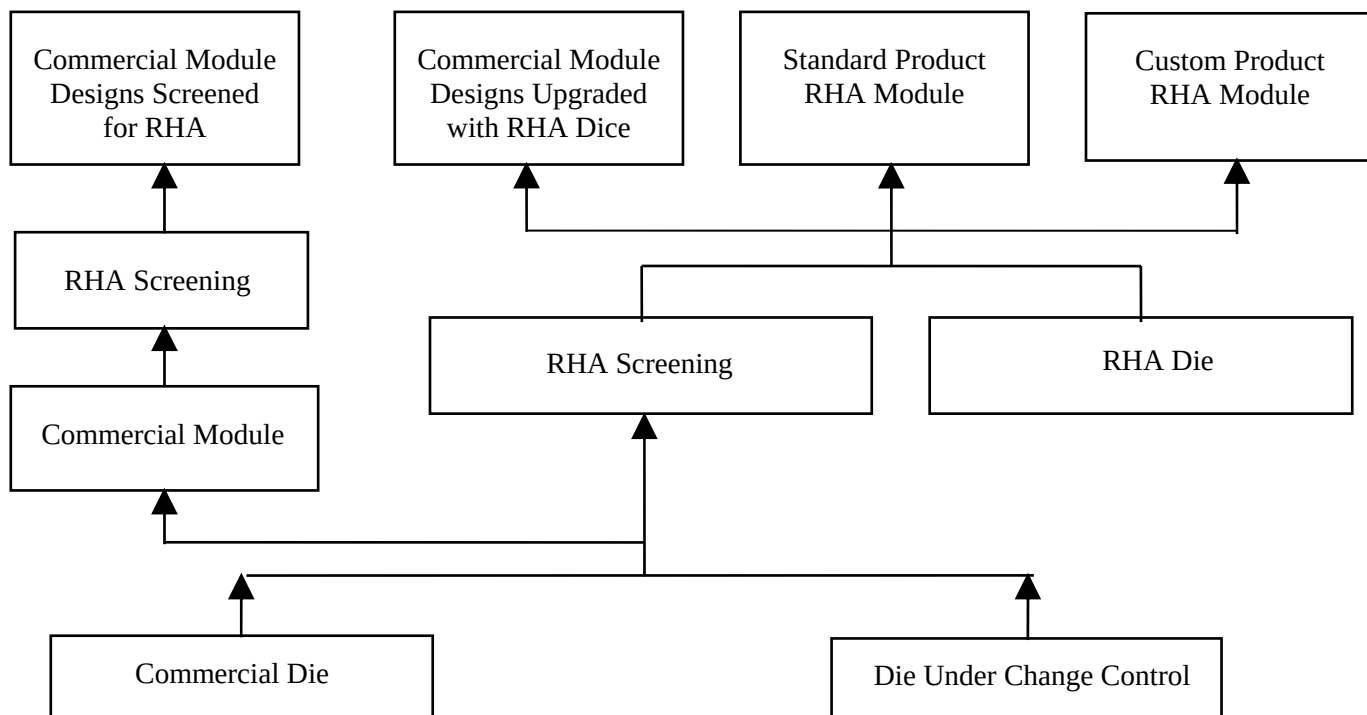


Figure 1 — Makeup and categories of MCM and hybrid devices

2 Normative references

The following standards contain provisions that, through reference in this text, constitute provisions of this Guide. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

MIL-STD-750, *Test Methods for Semiconductor Devices*.

MIL-STD-883, *Test Methods and Procedures for Microelectronics*.

MIL-PRF-38534, *Performance Specification, Hybrid Microcircuits, General Requirements for*.

MIL-PRF-38535, *Performance Specification, Integrated Circuits (Microcircuits) Manufacturing, General Specification for*.

MIL-PRF-19500, *Performance Specification, Semiconductor Devices, General Specification for*.

QML-38534, *Qualified Manufacturers List of Custom Hybrid Microcircuits Qualified under Military Specification MIL-PRF-38534, Custom Hybrid Microcircuits, General Requirements for*.

QML-38535, *Qualified Manufacturers List of Advanced Microcircuits Qualified under Military Specification MIL-PRF-38535, Microcircuits Manufacturing, General Requirements for*.

QPL-19500, *Qualified Products List of Semiconductor Devices Qualified Under Military Specification MIL-PRF-19500, Semiconductor Device, General Specification for*.

EIA/JESD57, *Test Procedures for the Measurement of Single-Event Effects in Semiconductor Devices from Heavy Ion Irradiation*.

JESD89, *Measurement and Reporting of Alpha Particle and Terrestrial Cosmic Ray-Induced Soft Errors in Semiconductor Devices*.

3 Terms and definitions

displacement damage: Displacement of atoms in the silicon lattice caused by their interaction with incident neutrons, protons, or other energetic particles or ions.

dose rate burnout: The catastrophic failure of a circuit caused by the very large currents produced by a high-intensity pulse of ionizing radiation.

dose rate upset: The disruption of a device caused by a high-intensity pulse of ionizing radiation that produces a change in stored data, a change of operating state, or a transient output signal that is large enough to affect other circuit elements.

3 Terms and definitions (cont'd)

enhanced low-dose-rate sensitivity (ELDRS) : For a fixed response, any device characteristic that reflects an increased radiation sensitivity at very low dose rates (i.e., generally at or below 10 mrd(Si)·s⁻¹) than at higher dose rates (i.e., 50-300 rd(Si)·s⁻¹).

NOTE The increased radiation sensitivity may be a result of true dose-rate effects and/or time-dependent effects.

internal electromagnetic pulse (IEMP): An electromagnetic pulse generated by electrons that are ejected from the surfaces interior to an enclosure with conducting walls due to the interaction of a pulse of energetic photons with the surface material(s).

linear energy transfer (LET): The amount of energy per unit length deposited or transferred by radiation traversing a material.

NOTE 1 The energy carried away by the secondary electrons that are produced must be taken into account when calculating the energy deposition.

NOTE 2 The energy deposition or charge transfer mechanism will depend on the type and energy of the radiation, e.g., pair-production, Compton scattering, Bremsstrahlung, collisions, photoelectric effect, and radiative capture.

NOTE 3 LET is strictly defined in terms of energy divided by distance, e.g., MeV/cm, eV/nm, keV/μm. However, since the energy lost is directly proportional to the density of the material traversed, it is useful to divide the LET by the density of the material. For the purposes of this publication, this derived quantity, whose units are typically expressed as MeV•cm²/mg (i.e., MeV/cm divided by mg/cm³), is often also referred to as linear energy transfer (LET).

multiple-bit upset (MBU): Two or more single-event induced bit errors occurring in the same nibble, byte, or word.

NOTE 1 An MBU cannot be corrected by a simple ECC (such as single-bit error correction).

NOTE 2 Single-bit error correction is often used in conjunction with double-bit-error detection (SEC-DED).

qualified manufacturers list (QML): A list of manufacturers whose production lines have been certified and qualified by the Defense Supply Center Columbus (DSCC) for the production of devices used in military or space applications.

qualifying activity: (1) The organizational element that grants certification status; this element may be a part of a) the acquiring activity; b) a quality organization within the manufacturer's company that is independent of the group(s) responsible for the device production, screening, and marketing; or c) an independent third-party organization.

(2) The organizational element of the government that grants certification and QML status.

quality management plan (QMP): A plan presented in military specifications (e.g., MIL-PRF-19500, MIL-PRF-38534, and MIL-PRF-38535) that describes the methods used by a supplier to assure conformance to the applicable requirements, including design, manufacturing, and verification.