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Introduction to Design for Excellence

1.1 Design for Excellence (DfX) in Electronics Manufacturing

Design for Excellence (DfX) is based on the premise that getting product design right–the first time–is far less expensive than finding failure later in product development or at the customer. The book will specifically highlight how using the DfX concepts of Design for Reliability, Design for Manufacturability, Design for the Use Environment, and Design for Life-Cycle Management will not only reduce research and development costs but will also decrease time to market and allow companies to issue warranty coverage confidently. Ultimately, Design for Excellence will increase customer satisfaction, market share, and long-term profits. The Design for Excellence material is critical for engineers and managers who wish to learn best practices regarding product design. Practices need to be adjusted for different manufacturing processes, suppliers, use environments, and reliability expectations, and this DfX book will demonstrate how to do just that.

Design for Excellence is a methodology that involves various groups with knowledge of different parts of the product life-cycle advising the design engineering functions during the design phase. It is also the process of assessing issues beyond the base functionality where base functionality is defined as meeting the business and customer expectations of function, cost, and size. Key elements of a DfX program

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include designing for reliability, manufacturability, testability, life cycle management, and the environment. DfX efforts require the integration of product design and process planning into a cohesive, interactive activity known as *concurrent engineering*.

The traditional product development process (PDP) has been a series of design-build-test-fix (DBTF) growth events. This is essentially a formalized trial-and-error process that starts with product test and then evolves into continuous improvement activities in response to warranty claims. DfX moves companies from DBTF into the realm of assessing and preventing issues beyond the base functionality before the first physical prototype has been made. DfX has further evolved as an improvement of the silo approach where electrical design, mechanical design, and reliability work (among others) were all performed separately. DfX allows for maximum leverage during the design stage. Approximately 70% of a product's total cost is committed by design exit. Companies that successfully implement DfX hit development costs 82% more frequently, average 66% fewer redesigns, and save significant money in redesign avoidance. Practicing DfX allows companies to focus on preventing problems instead of solving them or redesigning them.

Each chapter in this book describes and illustrates a specific core element of a comprehensive DfX program. The chapters provide best practices and real-world case studies to enable effective implementation.

1.2 Chapter 2: Establishing a Reliability Program

The chapter will educate you on the core elements of a reliability program, common analysis pitfalls, performing and reviewing reliability data analysis.

At the end of this chapter, readers will be better prepared to:

- Understand the basic elements of a successful reliability program
- Understand the principles associated with reliability analysis and management of the factors that affect product reliability
- Understand the probability density function (PDF) and the cumulative distribution function (CDF) used in reliability
- Understand the reliability prediction models available

1.3 Chapter 3: Design for Reliability (DfR)

The process of Design for Reliability (DfR) has achieved a high profile in the electronics industry and is part of an overall DfX program. Numerous organizations now offer DfR training and tools (sections, books, etc.) in response to market demand. However, many of these are too broad and not electronics-focused. They place too much emphasis on techniques like failure modes and effects analysis (FMEA) and fault tree analysis (FTA) and not enough emphasis on answers. FMEA and FTA rarely identify DfR issues because of the limited focus on the failure mechanism. And they incorporate highly accelerated life testing (HALT) and failure analysis when HALT is testing, not DfR. In addition, failure analysis occurs too late. This frustration with test-in reliability, even HALT, has been part of the recent focus on DfR.

As the design for philosophy has expanded and spread through the electronics marketplace and has become identified with best practices, a diluted understanding of DfR has occurred. True DfR requires technical knowledge of electronics packaging, discrete components, printed boards, solder assemblies, and connectors and how these aspects of electronics can fail under environmental stresses.

This chapter is designed for engineers and manufacturing personnel who need to fully comprehend the characteristics of DfR and how it applies to their unique applications.

1.4 Chapter 4: Design for the Use Environment: Reliability Testing and Test Plan Development

Scientific principles are based on the understanding that products fail when environmental stress exceeds the material strength.

At the end of this chapter, you will:

- Understand the basic elements of a successful reliability testing program
- Understand how reliability testing can be used for the process, part and assembly qualification
- Understand failure patterns based on the ensemble of environmental stressors chosen

- Have a basic understanding of the concepts of accelerated aging rates and acceleration factors
- Understand the difference between a stress screen and an accelerated life test
- Understand the basics of stress-screening equipment
- Have a basic understanding of frequency analysis and power spectral density for vibration and mechanical shock testing
- Have a basic understanding of setting stress levels based on the step-stress algorithm to establish the product operational and destruct limits
- Know how to use the testing process to drive improved reliability in the products manufactured at every site
- Know how to drive robust product design with the testing process and push product performance to the fundamental limits of the material and device technology

1.5 Chapter 5: Design for Manufacturability (DfM)

This chapter provides a comprehensive insight into the areas where design plays an important role in the manufacturing process. It addresses the increasingly sophisticated printed circuit board (PCB) fabrication technologies and processes, covering issues such as laminate selection, microvias and through-hole formation, trace width and spacing, and soldermask and finishes for lead-free materials and performance requirements. Challenges include managing the interconnection of both through-hole and surface mount at the bare-board level. The soldering techniques discuss pad design, hole design/annular ring, component location, and component orientation. You will have a unique opportunity to obtain first-hand information on design issues that impact both leaded and lead-free manufacturability.

1.6 Chapter 6: Design for Sustainability

The best design is not just reliable and manufacturable; products must also be designed with life-cycle management in mind. Designing products to be both reliable and supportable is a critical step in the process. It is one that must be addressed if customers or end-users have long-life, high-reliability, and repairable systems or products.

Key topics covered in this chapter include:

- Obsolescence management
- Long-term storage issues
- Counterfeit prevention and detection strategies
- Baseline life-cycle cost (estimated total ownership cost)
- Use environment verification
- Corrosion protection and mitigation
- Supplier auditing and vendor maturity and stability

1.7 Chapter 7: Root Cause Problem-Solving, Failure Analysis, and Continual Improvement Techniques

Root cause analysis (RCA) is a generic term for diligent structured problem-solving. Over the years, various RCA techniques and management methods have been developed. All RCA activities are problem-solving methods that focus on identifying the ultimate underlying reason a failure or problem event occurred. RCA is based on the belief that problems are more effectively solved by correcting or eliminating the root causes, rather than merely addressing the obvious symptoms. The root cause is the trigger point in a causal chain of events, which may be natural or man-made, active or passive, initiating or permitting, obvious or hidden. Efforts to prevent or mitigate the trigger event are expected to prevent the outcome or at least reduce the potential for problem recurrence.

Effective failure analysis is critical to product reliability. Without identifying the root causes of failure, true corrective action cannot be implemented, and the risk of repeat occurrence increases.

This chapter outlines a systematic approach to failure analysis proceeding from non-destructive to destructive methods until all root causes are conclusively identified. The appropriate techniques are discussed and recommended based on the failure information (failure history, failure mode, failure site, and failure mechanism) specific to the problem.

The information-gathering process is the crucial first step in any failure analysis effort. Information can be gained through interviews with all the members of the production team, from suppliers, manufacturers, designers, reliability teams, and managers to end-users.

Topics to be covered include:

- Root cause problem-solving methodology
- Root cause failure analysis methodology and approach
- Failure reporting, analysis, and corrective action system (FRACAS)
- Failure mechanisms
- Continuing education and improvement activities

The authors hope this book helps you to manufacture your products with better reliability and greater customer satisfaction.