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UNDERSTANDING ELECTRICAL OVERSTRESS - EOS

Contents

Introduction ... iii
I.1 Purpose ... iii
I.2 Traditional Perceptions of EOS ... iv
I.3 Industry Council Worldwide Survey ... iv
I.4 New Definition of EOS Incorporating AMR and EIPD ... v
I.5 EOS Root Causes ... vii
I.6 EOS Root Cause Diagnostics ... viii
I.7 EOS Case Studies and IC Designs ... ix
I.8 EOS Mitigation and Communication ... x
I.9 Summary ... x
I.10 Outlook ... x

1 Scope ... 1

2 References ... 1

3 Terms and Definitions ... 7

4 History of EOS ... 9
4.1 Outline of History of Relevant Professional Societies ... 11
4.2 EOS – A Brief History ... 11
4.3 Transition to Present ... 14

5 EOS Damage in the Factory and Field ... 15
5.1 Motivation for Field Returns Analysis of Failures Exhibiting EOS Damage ... 15
5.2 Transients ... 16
5.3 EOS Survey for Gathering Data on EOS Damage ... 17
5.4 Impact of EOS Damage ... 32
5.5 Failure Reports of Products Exhibiting EOS Damage ... 33

6 The Definition of EOS – Finding Common Understanding ... 34
6.1 Existing Documentation Practices of AMR Values ... 35
6.2 Unified Understanding of AMR and EOS ... 37
6.3 Additional Comments on Usage of the Term “EOS” ... 38
6.4 Conclusion ... 38

7 EOS Root Causes ... 39
7.1 Root Cause Categories ... 39
7.2 EOS Damage during Unpowered Handling ... 40
7.3 EOS during Powered Handling ... 43
7.4 EOS Damage during AC Operation and Switching ... 47
7.5 Analysis of Electrically Induced Physical Damage and Conclusions on EOS Events ... 48

8 Case Studies on EOS ... 50
8.1 Case 1: Incorrect ESD Qualification Leading to EOS ... 51
8.2 Case 2: EOS Due to Misapplication ... 54
8.3 Case 3: EOS due to Hot Plugging ... 57
8.4 Case 4: EOS due to Intermittent Battery Ground Connection ... 61
8.5 Case 5: EOS due to Ground Offset ... 63
8.6 Case 6: EOS Case Study "Automotive Knock Sensor" ... 65
8.7 Case 7: EMI – Transient Surge ... 70
8.8 Case 8: EMI – Board Design ... 73
8.9 Case 9: Supply Capacitor Switching ... 76
8.10 Case 10: CBE in DSP IC ... 78
8.11 Case 11: Reliability Testing ... 83
8.12 Lessons Learned ... 88
8.13 Conclusions ... 88

9 EOS Analysis and Diagnosis - "Techniques and Methods for Dealing with Electrically Induced Physical Damage" 89
9.1 Optimal Customer and Supplier Failure Symptom Information Exchange and Device Handling 89
9.2 EOS FA Challenges 90
9.3 High Level Preparation Guidelines for Diagnosing the Cause of EOS 92
9.4 Failure Analysis Techniques and Procedures 92
9.5 Analysis of Damage Mechanisms for EOS 102
9.6 Overstress Power vs. Time 107
9.7 Final Diagnosis of the Cause and Conclusion 108

10 Minimization and Mitigation of EOS 112
10.1 Lessons Learned to Minimize EOS Damage 112
10.2 Automotive Studies 117
10.3 Integrated Circuit Trends and EOS Effects 122
10.4 Communication with Customers 134
10.5 Recommendations for EOS Minimization and Mitigation 136
10.6 Conclusions 137

11 Summary and Conclusions 138

Annex A: EOS Survey Form 140

Annex B: The Dwyer Curve and EOS Damage at a Temperature Threshold 146
B.0 Background and 1-Dimensional Heat Flow 146
B.1 Heat Flow as an RC Transmission Line 147
B.2 Thermal Impedance and the Jacobi Theta4 Function 148
B.3 The Analytic Dwyer Curve Approximation 150
B.4 Utility of the Dwyer Curve and Thermal Impedance Approximations 155

Annex C: Frequently Asked Questions 156

Foreword

Damage signatures from Electrical Overstress (EOS) are the leading reported cause of returns in integrated circuits and systems that have failed during operation. Solutions to this problem are hindered by a prevailing misconception in the electronics industry that insufficient robustness to electrostatic discharge (ESD) is a primary cause of EOS. This document, White Paper 4, (WP) has been carefully compiled by the Industry Council on ESD Target Levels to foster a unified global understanding of what constitutes EOS and how EOS damage signatures can result from a wide variety of root causes.

The paper begins by outlining a brief history of EOS. It then presents the results of an industry-wide EOS survey. This survey gathered information on the types of EOS problems experienced by over 80 different companies, the relative importance of EOS to their overall business, and the methods assigned by these companies to address EOS issues. The survey provides a combined picture from which a more comprehensive definition of EOS can be made. The numerous categories and sub-categories of EOS root causes are explored in an attempt to understand how to create better specifications which will reduce their occurrence. In addition to the survey results, this paper studies many field returns with EOS damage signatures to establish the underlying root causes of damage and offers the respective identified solutions.

The survey and the case studies both show that successful failure analysis (FA) depends on careful communication between customer and supplier from the time a failure occurs until its cause has been discovered. Detailed investigation into manufacturing and handling processes is often necessary to accurately identify the root cause. This paper outlines a basic summery of the typical process flow for component electrical failure analysis.

The key point is that EOS issues can be mitigated when the proper understanding of IC design, factory and field environments, and system implementation is combined with effective communication across all these areas.

Introduction

In this introduction the Industry Council will address the most important electrical overstress (EOS) issues and conclusions of White Paper 4. Further details can be found in the various clauses of the document.

I.1 Purpose

This purpose of this white paper will be to introduce a new perspective about EOS to the electronics industry. As failures exhibiting EOS damage are commonly experienced in the industry, and these severe overstress events are a factor in the damage of many products, the intent of the white paper is to clarify what EOS really is and how it can be mitigated once it is properly comprehended. It is very clear that EOS is predominantly a matter of what customers do with devices, and in which applications the semiconductor specifications are exceeded causing destruction of the device. This white paper will describe those phenomena and explain the most important facts so that the involved partners in the industry have the opportunity to understand and recognize helpful steps for analysis and avoidance of EOS events.

I.1 Introduction (cont'd)

EOS is defined in terms of its impact inside applications. We focus on exceedance of specifications but not on how an exact specification was originally created. We focus instead on when and how the specifications are exceeded to cause EOS damage.

It is intended that this document be disseminated throughout the semiconductor industry for the benefit of those persons whose positions are concerned with the real nature of EOS. It is intended to serve as a foundational reference document for existing and future technologies.

I.2 Traditional Perceptions of EOS

Through the years, a high incidence of failures exhibiting EOS damage has been reported in most market segments of electronics and related industries, such as the automotive industry. This damage has often been mislabeled as "EOS Failure", implying that these malfunctions are solely a result of a phenomenon or stress called EOS. Understanding EOS as a "stress" has led many customers to incorrectly assume a device experiencing EOS is "weak". This misperception has led to requests to "improve" a device in regards to EOS.

Another incorrect assumption has been that EOS can be avoided by making devices more ESD robust to both the human body model (HBM) and the charged device model (CDM). This misconception has been addressed in JEDEC publications JEP155 [1], and JEP157 [2] where it is convincingly shown that the incidence of EOS is independent of the level of HBM and CDM robustness.

I.3 Industry Council Worldwide Survey

In preparation for this white paper, the Industry Council conducted a worldwide survey of the electronics industry concerning EOS. Results confirmed the long held view that EOS is consistently one of the "high bars" on product failure Pareto charts. Looking at the EOS survey, respondents reported greater than 20% of total failures being EOS-related or 30% of total electrical failures being EOS-related, making EOS the largest bar on the Pareto chart of that responder's known causes of returns. One glaring revelation was the critical need for a better industry-wide understanding of EOS to address its issues.

Looking at the EOS survey further, misapplication (powered handling) stands out as the highest cause of EOS damage, with over 40% of respondents indicating EOS damage which occurred in the field as the most common location. Damage signatures associated with EOS often can involve package and silicon damage and are more extensive in a product than failure signatures resulting from events in the measurable ESD regimes. The main findings of the EOS Survey were:

1) **Powered Handling**: This stands out as the most widely reported root cause, involving a significant (over 20%) percentage of reported returns exhibiting EOS damage. Powered handling can include overvoltage, improper insertion, power supply sequencing, and incorrect biasing during use.
2) **Absolute Maximum Rating (AMR):** A number of returns exhibiting EOS damage were attributed to applied voltages exceeding the specified AMR voltage, indicating that incomplete or unclear maximum ratings may be an issue and that AMR characterization and improved AMR information on the datasheets is important to minimize the risk of EOS.
3) **ESD Related**: System level events, discharges from charged devices, and ESD controls in manufacturing which are not compliant with handling ESDS devices are additional root causes for EOS damage. Charged board events (CBE) and cable discharge events (CDE) also contribute.
4) **Miscellaneous Causes**: There were other miscellaneous causes reported that ranged from weak printed circuit board (PCB) designs to mishandling.