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Qualitäts Management Center
im Verband der Automobilindustrie

Quality Management in the Automotive Industry

EOS – Electrical Overstress in the Automotive Industry

Dealing with semiconductor devices showing a signature of electrical overstress

– Contents, documentations and explanations –

1. Edition, January 2020

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Foreword

The percentage of electronic devices in vehicles is continuously increasing and this trend will also grow in the future.

Despite high quality standards in the supply chain, damages of electric/electronic components occur in production and during usage at customers.

Furthermore, the integration and power density of devices is continuously increasing reducing the gap to physical and electrical limits. This has an impact on the robustness of the devices.

Failures showing a signature of electrical overstress play a special role.

The present VDA volume provides a guideline how to deal with damages showing a signature of electrical overstress along the supply chain*. It provides especially an overall approach for such damages and gives guidance for localizing the root cause using examples.

* In this context it is worth reading the following document: ANSI/ESD SP27.1-2018 "Standard Practice for the Recommended Information Flow Regarding Potential EOS Issues between Automotive OEM, Tier 1, and Semiconductor Manufacturers"

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1 Introduction

1.1 Initial Situation

EOS-like damages (EOS = Electrical Overstress) of electronic devices are one of the major problems in the field of electrics/electronics (E/E) of the automotive industry. The new term EIPD (EIPD = Electrically Induced Physical Damage) is used in the following text as designation for the associated physical damages (failure signature); see more on EIPD in chapter 1.2.

A reduction of damages showing EIPD is complicated because of:

- Continuously increasing part of E/E devices
- Increasing operating voltage in the on-board power supply (e.g., 48V, high voltage)
- Increasing functional integration on device and board level
- Further development of process and package technologies to live up with the increasing requirements regarding performance and costs

The lead-time of damages showing EIPD (EIPD cases) is generally much longer than for damages with other signatures and rarely results in a solution of the root cause. Often mentioned reasons are:

- Lack of cooperation between parties involved in the supply chain and missing information exchange
- Missing rules for the classification of damages pointing to the relevant support level
- Missing guidelines on how to proceed in case the location of the root cause within the supply chain cannot be identified

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1.2 Electrically Induced Physical Damage – EIPD

EOS is an event and not suitable for describing a physical damage. Therefore, the new term EIPD was introduced in 2016 and described in “White Paper 4 – Understanding Electrical Overstress – EOS” [1].

EIPD is defined there as damage of a semiconductor device by electrical/thermal stress that the material cannot withstand.

As shown in Figure 1 three basic scenarios exist that can result in EIPD on semiconductor devices.

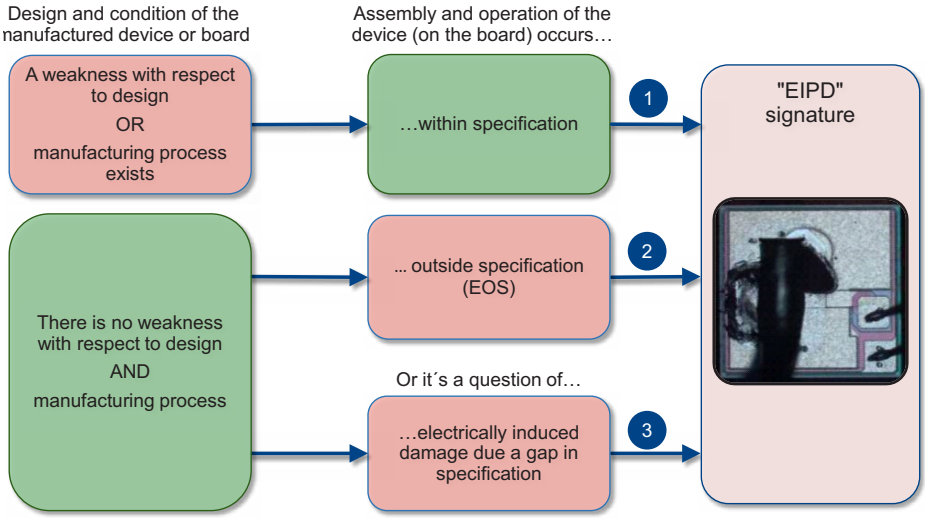


Figure 1: Scenarios resulting in EIPD (see also chapter 6)

A detailed description of the scenarios and possible case studies can be found in chapter 6.

1.3 Scope

The content of this volume deals with processing of claims of semiconductor devices (called devices in the context of this document) assembled in the automotive industry (e.g., diodes, IC´s, sensors) that were damaged by an electrical/thermal stress.

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The content of this volume does not refer to responsibilities of costs.

If a supposedly defective board is sent back to the supplier, an initial analysis is trying to confirm the customer's failure. If this is not possible, the NTF process (NTF = No Trouble Found) as described in the VDA volume "Field Failure Analysis", or similar agreed processes apply.

If the failure is confirmed but the failure signature identified (in an appropriate way) gives no hint for EIPD, the processing is generally done following the 8D method (see also VDA volume "8D - Problem Solving in 8 Disciplines").

Only if the failure signature confirms an EIPD case, the processing follows the method described in the VDA volume in hand (see Figure 2).

Already existing processes and methods (8D, Field Failure Analysis, standardized complaint management) will be complemented by this volume (see Figure 2).

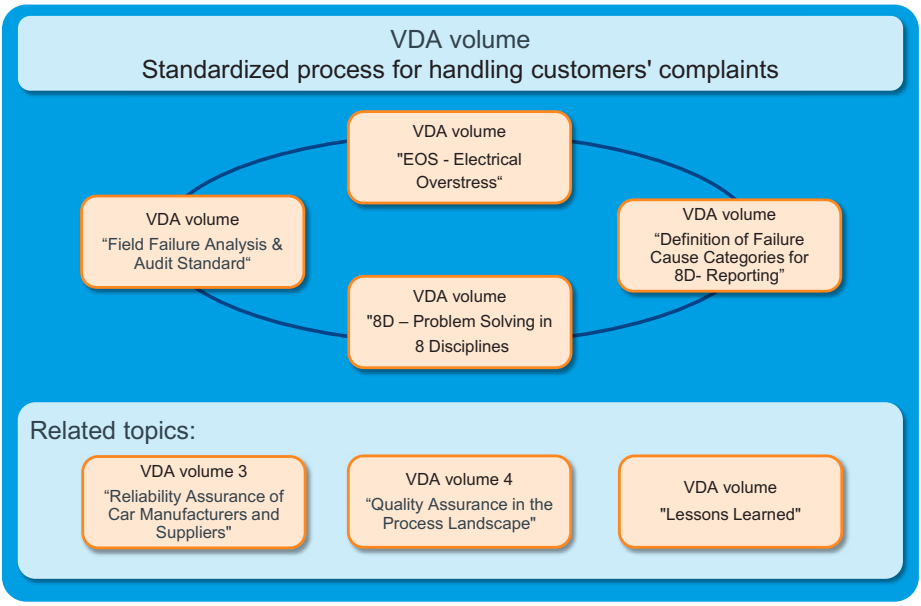


Figure 2: Position of the volume in the complaint process.

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1.4 Phases in the life cycle of devices

Areas to be considered are stations in the life cycle of devices (see Figure 3). This includes production and test of a device in the wafer fab and during package assembly at the semiconductor manufacturer, the processes at the Tiers (placement of devices onto a board, their test and the assembly into a housing), as well as assembly into a vehicle and the test of the vehicle at the car manufacturer. The usage of the vehicle in operation, maintenance, and repair has to be considered as well as the processes the devices will see in case of damage.

In addition, during processes like disassembling from the vehicle, test and desoldering of the device from the board, or test and failure analysis, the device might experience unwanted stress.

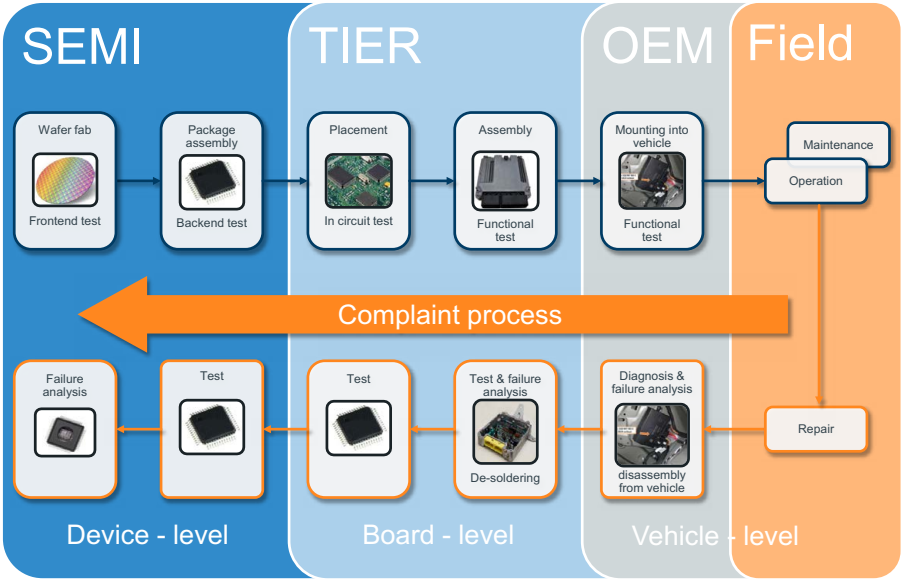


Figure 3: Simplified picture showing the life cycles of a device

A detailed view of the life cycle and the possible root causes for damage of devices can be found in chapter 7.

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1.5 Purpose

Purpose is to define a systematic approach within the supply chain for dealing with EIPD cases.

This should be reached as follows:

- Definition of a two level complaint process to allow to prioritize EIPD cases for relevance and to process the cases as fast as possible
- Definition of simple trigger criteria that can be used to assign the cases to one of the two levels
- Agreement on reaction mechanisms how EIPD cases are to be processed within the supply chain
- Establishing guidelines, what information is provided by the involved parties in the supply chain (incl. catalogue of questions)
- Providing a collection of possible damage locations, EIPD mechanisms, and root causes
- Producing a common view and nomenclature

Achieving the goals above feeds the following expectations:

- Efficient use of available resources to increase the success rate during solving EIPD problems
- Structured communication and processing within the supply chain
- Enhancement of know-how within the supply chain
- Reduction of EOS events and EIPD failure rate
- Minimizing safety risks

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1.6 Terms and Definitions

0km failure	Line failure at OEM (generally the car manufacturer)
8D	Problem solving method with 8 disciplines (steps)
AEC	Automotive Electronics Council
AMR	Absolute Maximum Ratings
Board	Interconnect device populated and processed with devices, e.g., fixed board, flexible board, ceramic, punch scrap
CDM	Charged Device Model, specified ESD discharge model for devices
Device	This volume deals only with semiconductor devices
EIPD	Electrically Induced Physical Damage Damage to an electronic component due to electrical/thermal stress beyond the level which the materials could sustain
EMC	Electromagnetic compatibility
EOL	End-of-Line
EOS	Electrical Overstress An electrical device suffers electrical overstress (EOS) when a maximum limit for either the voltage across, the current through, or the power dissipated in the device is exceeded and causes immediate damage or malfunction, or latent damage resulting in an unpredictable reduction of its lifetime.
ESD	Electrostatic Discharge The fast and spontaneous transfer of electrostatic charge due a high electrostatic field.

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Field failure	Device dismounted in the repair station.
ICT	In Circuit Test ICT is a test method for electronic boards or circuits and assembled boards in electronic assembly. During ICT the focus is the test of device parameters of a populated board or of the electrical connections of a board (no functional test)
ISO	International Standards Organization
LIN	Local Interconnect Network, a serial communication system for a network of sensors and actors, a field bus
MOS	Field effect transistor
NTF	No Trouble Found NTF means that a rejected device is analyzed (standard test and stress test) and no deviation from the specification is found. Hence, the device is declared as ok according to the appraisal, i.e., the complaint could not be confirmed.
OEM	Original Equipment Manufacturer (typically the car manufacturer)
Root cause	The fundamental reason for the occurrence of a problem. Root Cause identifies the part or condition that needs to be changed to prevent reoccurrence

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Safe Launch	Initial manufacturing period, where the product is assembled and tested the first time. The safe launch period is typically defined in a different way for each tier, by a period of time (for example, 3 month) or by a volume of parts produced. Safe launch may include special requirements for additional or extended tests. The safe launch period for the different tiers may not be concurrent.
SEM	Scanning electron microscope
Semi	In the context of this volume: semiconductor manufacturer
SOA	Safe Operating Area Area of safe operation (voltage and current) for devices and boards
Tier	Supplier in the automotive industry; Tier 1, Tier 2, Tier x indicates the position of the supplier in the supply chain starting from OEM.
USCAR	United States Council for Automotive Research
Wafer	A disc made of semiconductor material with integrated circuits
Wafer Lot	A production unit with a fixed number of wafers (typically 25 or 50)

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2 Basic Flow

2.1 Flow of an EIPD/EOS complaint

Typically, the OEM sends damaged boards back to the Tier 1. After confirmation of the failure, the Tier 1 sends the suspected device to the semiconductor manufacturer for analysis.

Up to now, the Tier 1 and/or the semiconductor manufacturer try to duplicate the failure signature by experiments. If the boundary conditions of the failures are not known, finding the root cause is difficult as long as they are single damages. Without good cooperation between the parties involved, the failure signature might be duplicated, but the real damaging stress might hardly be found. This is especially true if the problem occurs only sporadically. In this case, it is very difficult to find the root cause.

To be able to concentrate the available resources effectively on promising problematic cases different support levels for different scenarios are defined requiring different information from the people involved (see details in chapter 2.2).

This document differentiates between:

- cases that can be closed with a simplified procedure (level 1) and
- cases that are introduced to an extended processing in a group of experts with cooperation from at least two parties from the supply chain (level 2).
- Under certain circumstances there can be an upgrade from level 1 to level 2, based on respective argumentation.

Figure 4 shows the flow of an EIPD complaint.

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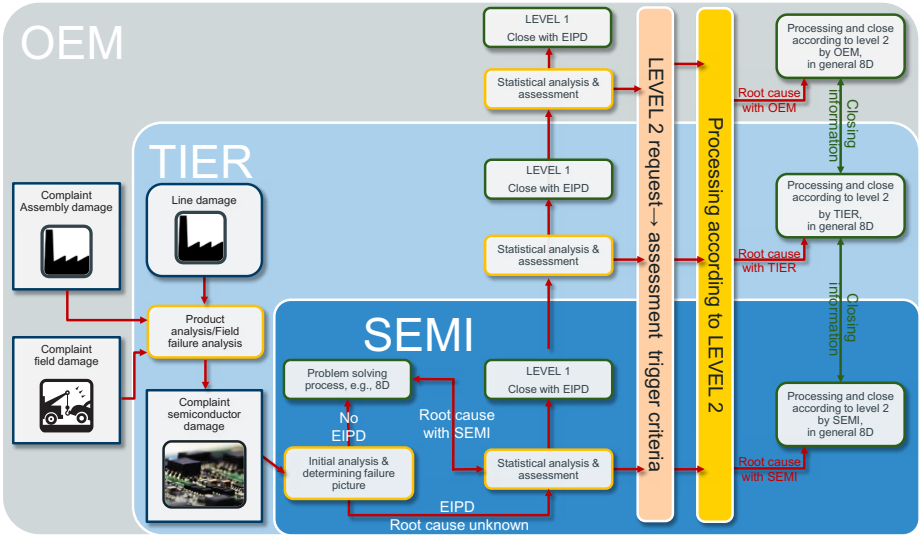


Figure 4: Simplified process flow for an EIPD case

The OEM sends defective boards (from field or 0 km) to the Tier who checks the board during a product analysis.

If devices suspected to be the root cause, they are sent back to the semiconductor supplier (Semi) for failure analysis.

The Tier proceeds in the same way with devices failing in his assembly (line failure).

The semiconductor supplier performs an initial analysis on the devices to determine the failure signature.

For EIPD with unknown root cause, a statistical analysis is done followed by an assessment. If the criteria for level 1, valid for the semiconductor manufacturer, are fulfilled, the case is closed with EIPD as result.

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The Tier receives a report and checks the case, also using a statistical analysis and assessment, and accepts the closing report with level 1. With field and 0 km failures, the Tier reports accordingly to the OEM.

If the statistical analysis followed by an assessment results in acceptance of level 1 also at the OEM, the case is closed with the result EIPD.

The results of the statistical analysis or the following assessment according the trigger criteria in chapter 3 (Semi), 4 (Tier) and 5 (OEM) might require a processing according to level 2. The request for processing according to level 2 comes from the party seeing a need for this.

For requesting a level 2 process the responsible requester needs to answer his specific part of the questionnaire in appendix 1 (chapter 8.1) and to provide it to the partners in the supply chain. With a level 2 process, the parties involved have to provide their part of the questionnaire.

In the questionnaire (chapter 8) some examples are shown. In the context of finding the root cause (reproduction, looking at the process, etc.) it will be necessary to provide more information. Respective questions can be found, e.g., in the document ANSI/ESD SP27.1-2018 of ESDA and USCAR [2].

If the root cause is localized during the level 2 process the case will further be processed by the responsible party.

The parties involved will be informed about the completion.

If the location of damage is not localized during a level 2 process, the requestor has to check whether further investigations are productive. If further investigations are not promising due to missing chances of success, the closing of the level 2 process is documented.

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