Reliability of Printed Circuit Boards

Webinar December 6th 2016

Speaker: Andreas Schilpp
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1. Reliability

2. Life cycle of a printed circuit board

3. How to set the screws to design robust PCBs
Content

1. Reliability

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3. How to set the screws to design robust PCBs
Reliability – a Definition

„the ability of a system or component to perform its required functions under stated conditions for a specified time.“ (DIN 40041:1990-12)
Design Chain electronic system development

“a pcb is a complex construction made out of many different materials, produced using a variety of processes for getting tailored functionality!“

stated conditions ➔ Specification
Classification according IPC

- **Class 1** — includes *limited life products* suitable for applications where the requirement is function of the completed product.

- **Class 2** — includes products where *continued performance and extended life is required*; and for which uninterrupted service is desired but not critical.

- **Class 3** — includes products where continued *high performance or performance-on-demand is critical*, product down-time cannot be tolerated, and the product must function when required.
Content

1. Reliability
2. Life cycle of a printed circuit board
3. How to set the screws to design robust PCBs
Life Cycle of a Printed Circuit Board

- Specification
- Production
- Component Assembly Packaging Test final assembly
- Usage
Life Cycle of a Printed Circuit Board

Specification

- Functionality
- Time, loads
- Operating conditions

- Material
- Technology
- Components and assembly
- Solder surface
- Design Rules
- Mechanical Construction
- Thermal Management
- ..... 

- Test and Qualification
Life Cycle of a Printed Circuit Board

Production

- according IPC-A-600
  - class 2 (Standard, Industry)
  - class 3 (high reliability)
- Material acc. IPC-4__
  - IPC4101 rigid materials
  - IPC4102/03/04 flexible material
- IPC-SM-840 solder mask

- qualified Processes

- Electrical Test, Impedance Testing
- Certificate of Conformance (CoC)
- First Article Inspection Report (FAIR)
- PPAP (Production Part Approval Process)
Life Cycle of a Printed Circuit Board Production

Material- und Process Qualification

- micro sections, optical inspection of thicknesses and material integrity
- dimensional accuracy
- solder mask
  - adhesion
  - isolation
  - resistance against solvents
  - surface energy
- copper adhesion surface / PTH
- registration of layers
- Tg / delta Tg
- CTE(z)
- solderability, Test acc. JEDEC-020C
- Solder Dip Test
- cleanliness
- .....
Reliability Testing for Qualification of Material and Processes

- Solder shock test
- Hot storage 1000 h @ 125°C
- Temperature Cycling, i.e.
  - Rapid cycling 1000 Cycles
  - IST 200 Cycles
- Moisture resistance Test – Isolation Test
Life Cycle of a Printed Circuit Board Production

IST – Interconnect Stress Test

specified in IPC-TM650.2.6.26
Life Cycle of a Printed Circuit Board Production
Life Cycle of a Printed Circuit Board
Further Processing

- Component Assembly
- Soldering
  - Wave / Reflow / selectiv / Hand
- Cleaning
- Test
- Separation
- Coating
- Storage
- Transport
Load Types (single, combined)

1. Climate Load (Θ, rF)
2. Mechanical Load
3. Chemical Load, UV, Radiation
4. Dust, Particles, Liquids
5. Electrical Loads (current, Voltage, EMC)

→ Models, Calculations, Simulations
→ Test methods, Test planning

Target:
- reliable statements
- at the same time high acceleration factor (near-term result)
2.6 Environmental Test Methods
IPC-TM-650 2.6 TEST METHODS MANUAL

- 2.6.1E Fungus Resistance Printed Wiring Materials
- 2.6.1.1 Fungus Resistance – Conformal Coating
- 6.2C Moisture Absorption, Flexible Printed Wiring
- 2.6.2.1A Water Absorption, Metal Clad Plastic Laminates
- 2.6.3E Moisture and Insulation Resistance, Printed Boards
- 2.6.3.1D Moisture and Insulation Resistance - Solder Mask
- 2.6.3.4 Moisture and Insulation Resistance – Conformal Coating
- 2.6.3.2B Insulation and Moisture Resistance, Flexible Base Dielectric
- 2.6.3.3A Surface Insulation Resistance, Fluxes
- 2.6.4A Outgassing, Printed Boards
- 2.6.5C Physical Shock, Multilayer Printed Wiring
- 2.6.6B Temperature Cycling, Printed Wiring Board
- 2.6.7A Thermal Shock and Continuity, Printed Board
- 2.6.7.1 Thermal Shock—Polymer Coatings
- 2.6.7.2A Thermal Shock, Continuity and Microsection, Printed Board
- 2.6.7.3 Thermal Shock – Solder Mask
- 2.6.8D Thermal Stress, PTH (Plated-Through-Holes)
- 2.6.8.1 Thermal Stress, Laminate
- 2.6.9A Vibration, Rigid Printed Wiring
2.6.9.1 Test to Determine Sensitivity of Electronic Assemblies to Ultrasonic Energy
2.6.9.2 Test to Determine Sensitivity of Electronic Components to Ultrasonic Energy
2.6.10A X-Ray (Radiography), Multilayer Printed Wiring Board Test Methods
2.6.11 Hydrolytic Stability Solder Mask
2.6.11.1 Hydrolytic Stability – Conformal Coating
2.6.12 Temperature Testing, Flexible Flat Cable
2.6.13 Assessment of Susceptibility to Metallic Dendritic Growth: Uncoated Printed Wiring
2.6.14 C Resistance to Electrochemical Migration, Solder Mask
2.6.14.1 Electrochemical Migration Resistance Test
2.6.15B Corrosion, Flux
2.6.16 Pressure Vessel Method for Glass Epoxy Laminate Integrity
2.6.16.1 Moisture Resistance of High Density Interconnection (HDI) Materials Under High Temperature and Pressure (Pressure Vessel)
2.6.17 Hydrolytic Stability, Flexible Printed Wiring
2.6.18A Low Temperature Flexibility, Flexible Printed Wiring Materials
2.6.19 Environmental and Insulation Resistance Test of Hybrid Ceramic Multilayer SubstrateBoards
2.6.23 Test Procedure for Steam Ager Temperature Repeatability
2.6.26 DC Current Induced Thermal Cycling Test
Reliability Testing „Bare Board“

- always with „Pre Conditioning“
  - Drying
  - Reflow / Wave / selectiv / Hand
- High Temp storage (1.000h @ 125°C)
- Thermal Cycling (-40°C …. 125 / 140 / 150°C)
- IST / single via test
- Humidity storage (60°C @ 90% r.F.)
- E-Corrosion (100V / 40°C / 93% r.F.)
- SIR (Surface Isolation Resistance)
- CAF (Cathothic Anodic Filament)
- Salt Spray Test
- Corrosive gas
- Radiation (i.e. UV- , radioaktive)
- Outgassing under Vacuum
Life Cycle of a Printed Circuit Board

Usage

System Reliability Testing

Quelle: Daimler AG
Life Cycle of a Printed Circuit Board Usage

System Reliability Testing

- EMC
- Heat management, hot spot Analysis
- Software
- Repair
- Shock, Vibration
Life Cycle of a Printed Circuit Board Usage

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Falling Test from 50cm height on concrete slab
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How to set the screws
Reliability engineering

- best way of co-operation

Cooperation of all participants of the value-added chain is necessary

- Quality and reliability must be planned
  - Design-to-cost
  - Design-for-manufacturing
  - Testability (homogeneous System!)

- Listings and permits, i.e. UL

  ➔ There are a lot of dependencies and feedbacks!
How to set the screws
robust Design

Basic Design Guide

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**Leiterbahnbreite und Leiterabstände / Track Width and Conductor Spacing**

- **Außenlagen / Outer Layers**
  - Pad ø Innenlagen / Inner Layers
  - Leiterabstand / Spacing
  - Kupferleiterbreite / Track Width
  - Kupferleiterbreite / Track Width
  - ca. 50 µm
  - 70 µm
  - 105 µm
  - ca. 25-30 µm

- **Leiterbahnbreite und Leiterabstände / Track Width and Conductor Spacing**
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**Lötstopmaske / Solder Mask**

- Abstand Lötstopmaske zu Leiter / Solder Mask to Track
  - ca. 50 µm
  - 70 µm
  - 105 µm

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**Durchgehende Vias / Plated Through Hole Via**

- Pad ø
  - 0.35 mm
  - 0.30 mm
  - 0.20 mm

- Abstand zu Leiter / Distance to Track
  - 0.25 mm
  - 0.17 mm

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**Sonstige Design Parameter / Other Design Parameters**

- Abstand Kupfer zu Fräsfortsatz / Copper Clearance to milled edge
  - ≥ 0.25 mm

- Abstand Kupfer zu剧情 / Copper Clearance to Laser Trace
  - ≥ 0.25 mm

- Abstand Kupfer zu NDI Bohrung / Copper Clearance to NDI Hole
  - ≤ 0.25 mm

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**Zusätzliche Design Parameter / Additional Design Parameters**

- **Bestückungs- und Servicedruck Legende / Legend Print (Cu max. 70 µm)**
  - 100 µm
  - 1.0 mm

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*Note: All values are approximations and may vary depending on specific application requirements.*
How to set the screws
Fastening of the pcb

Comparison 4 – 9 fixing points

9 screws:

- 282 Hz
- 680 Hz
- 831 Hz
- 1365 Hz
- 1031 Hz
- 1188 Hz
- 1631 Hz
- 1778 Hz

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How to set the screws
Thermal management / HDI / printed Resistors

The printed circuit board system is used in the gearbox control in “Actros”, the flagship of Mercedes-Benz’s commercial vehicle division.

The use of HDI technology combined with printed resistors made it possible to achieve a significant reduction in the size of the printed circuit board.

At a glance:

- HDI 06_2+2b+2 build up
- Embedded resistors 50 to 50 K, laser trimmed and voltage divider
- Customised heat sink for optimal thermal management, directly mounted on the gearbox
- Operating temperature up to 140 °C, (peak to 150 °C) with TG170 ° material
- Harsh environmental conditions (shock, vibration etc.)
- HDI, printed polymer and thermal management – these three key technologies replace the previous ceramic solution
How to set the screws
Flex-Rigid

- development of a robust, reliable and highly accessible prototype design
- active implant ➔ very restricted volume with complex contours
- no connectors allowed due to area and volume needs
- critical EMC with different high frequency sources (wireless transmission of energy and signals) onboard
  ➔ specific advantage due to integrated flex connection – no solder joints or connectors which could fail
  ➔ specific advantage due to low physical mass in case of shock and vibration
How to set the screws embedded Components

embedding advantages
⇒ high miniaturisation
⇒ protection of components and solder joints
⇒ short signal paths
⇒ improved heat dissipation
Summary

Reliability

- must be planned from the very beginning
- needs all the different disciplines
- starts with system specification
- WE likes to support you in a project
- Please contact us as soon as possible!
Thank you for your attention

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