

Reliability of Printed Circuit Boards

Webinar December 6th 2016

Speaker: Andreas Schilpp

A close-up, high-angle photograph of a printed circuit board (PCB) with a red and orange color scheme. The image shows intricate circuit traces and numerous small components. The word 'Reliability' is overlaid in large, bold, white, sans-serif font across the center of the image.

Reliability

Content

1

- **Reliability**

2

- **Life cycle of a printed circuit board**

3

- **How to set the screws to design robust PCBs**

Content

1

- **Reliability**

2

- Life cycle of a printed circuit board

3

- How to set the screws to design robust PCBs

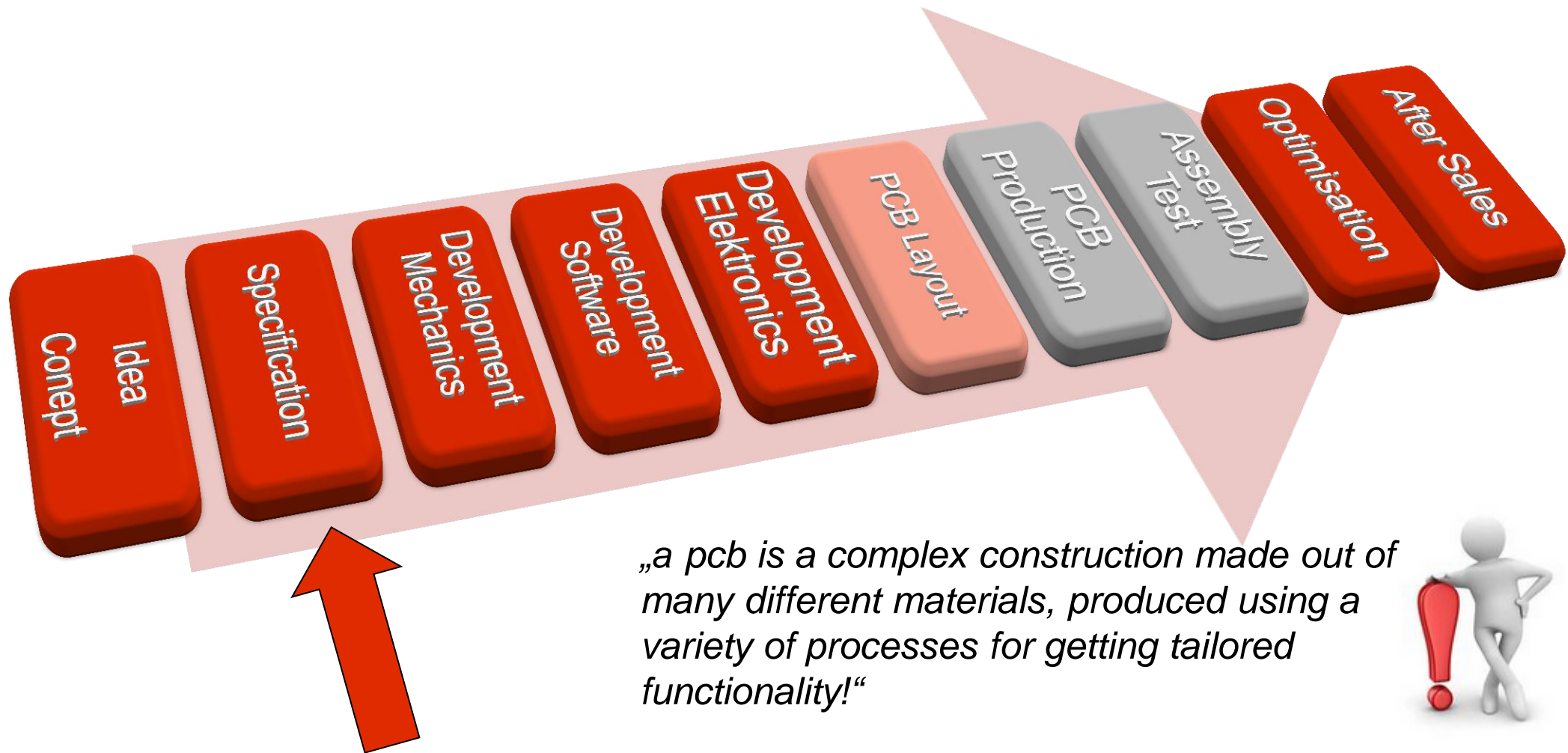
Reliability – a Definition



„ 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

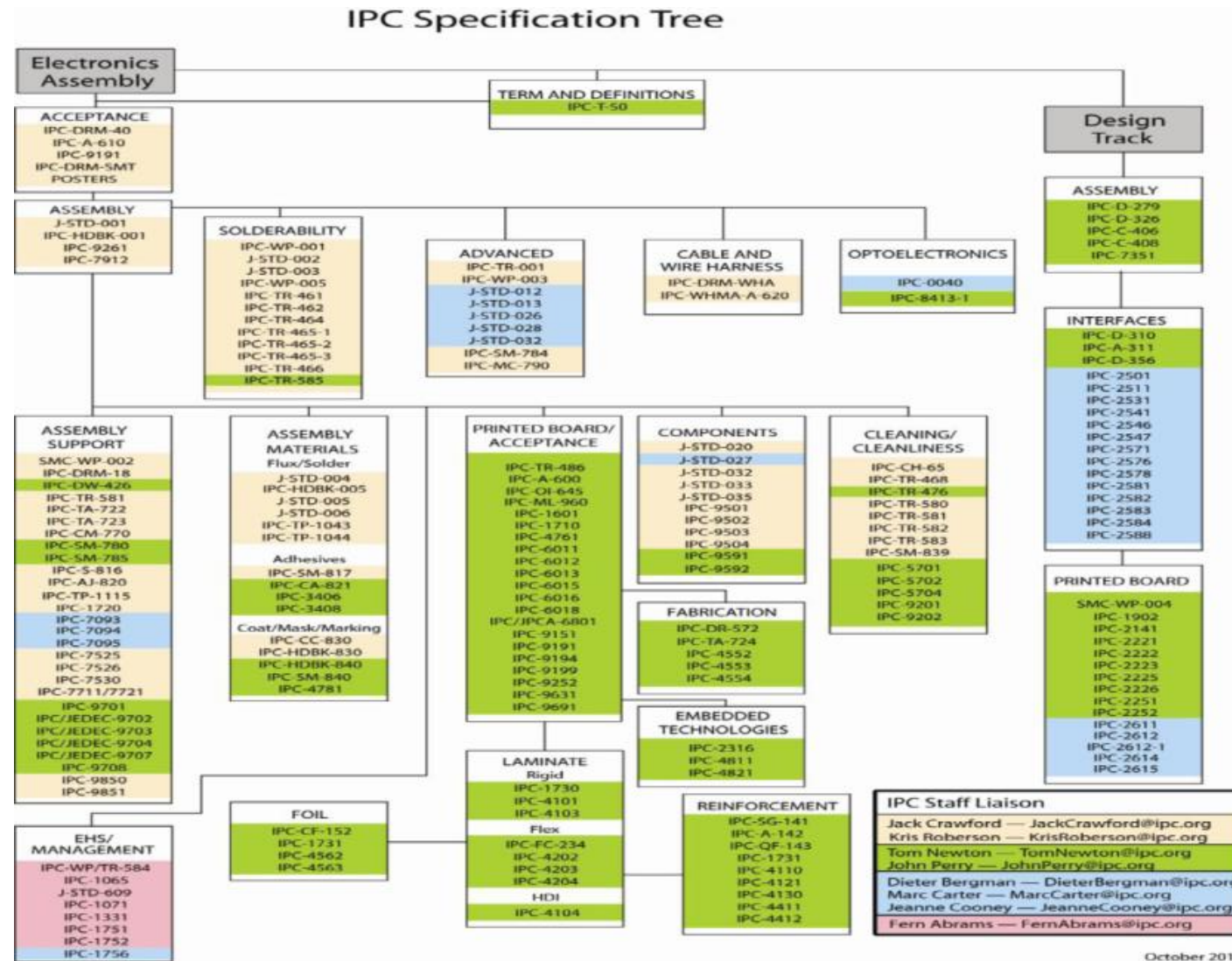


„a pcb is a complex construction made out of many different materials, produced using a variety of processes for getting tailored functionality!“



stated conditions → Specification

IPC Standards



October 2011

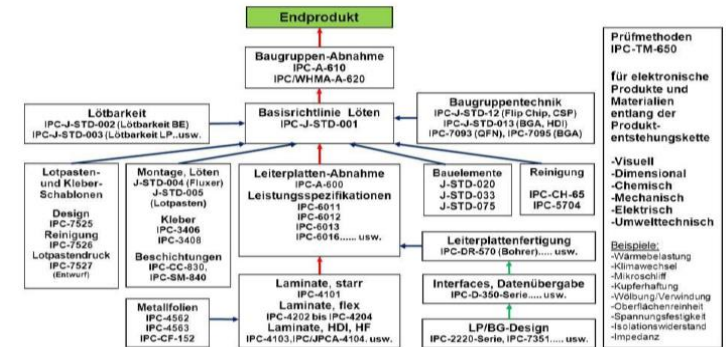


IPC Standards

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.

IPC-Richtlinien in der Produktentstehung



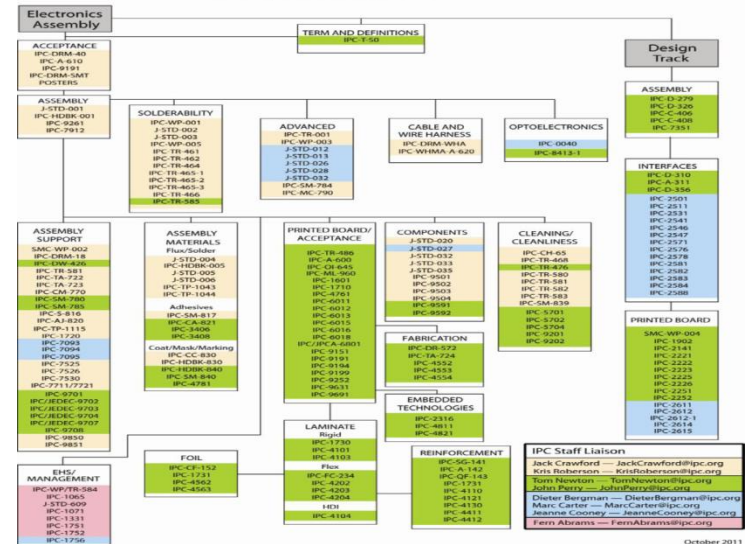
Prüfmethoden
IPC-TM-650
für elektronische Produkte und Materialien entlang der Produktentstehungskette

-Visuell
-Dimensional
-Chemisch
-Mechanisch
-Elektrisch
-Umwelttechnisch

Beispiele:
-Wärmebelastung
-Klimawechsel
-Mikroschleif
-Kupferhaftung
-Vollung/Verwindung
-Oberflächenreinheit
-Spannungsfestigkeit
-Hörschwingenstand
-Impedanz

Copyright FED e.V., Stand:14.12.2011

IPC Specification Tree



October 2011

Content

1

- Reliability

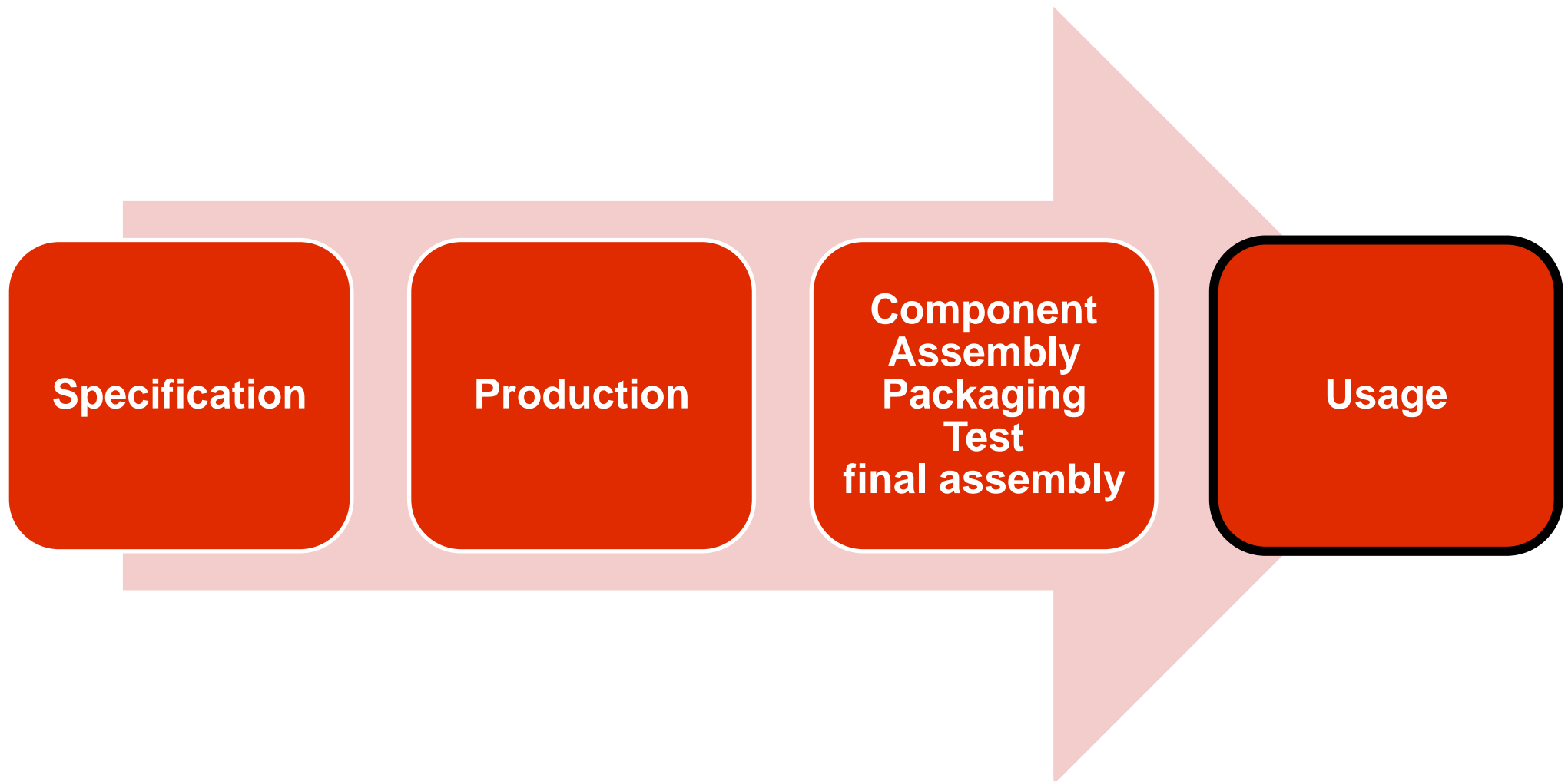
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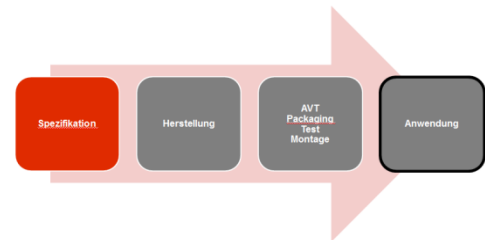
- **Life cycle of a printed circuit board**

3

- How to set the screws to design robust PCBs

Life Cycle of a Printed Circuit Board





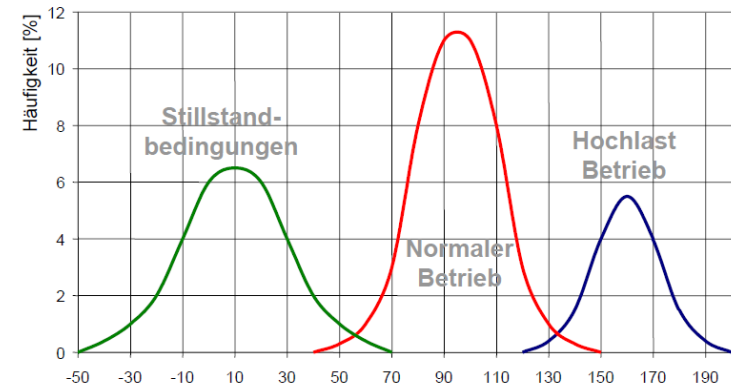
Life Cycle of a Printed Circuit Board

Specification

- **Functionality**
- **Time, loads**
- **Operating conditions**

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

- ➔ **Test and Qualification**



Für Temperatur-, Feuchtigkeits- und mechanische Schwingungsbelastungen sollte ein realistisches Belastungskollektiv mit den Auftrittshäufigkeiten bezogen auf die Betriebszeit aufgestellt werden.

Quelle: Daimler AG

Motorraum:
 <math>< 150^{\circ}\text{C}</math> (170°C)
 • Antriebsstrang
 • Getriebesteuerung
 • Elektronisch unterstützte Bremssysteme

Fahrgastzelle:
 85°C (105°C)
 • Navigationshilfe
 • Komfortfunktionen
 • Sicherheitssysteme

Brennraum: <math>< 500^{\circ}\text{C}</math>
 Abgasstrang: <math>< 800^{\circ}\text{C}</math>
 • Brennraumdrucksensoren
 • Abgassensoren

Motor, Getriebe: <math>< 200^{\circ}\text{C}</math>

Komponenten am Rad: <math>< 300^{\circ}\text{C}</math>
 • Brake by Wire
 • Steer by Wire

Quelle: Daimler AG



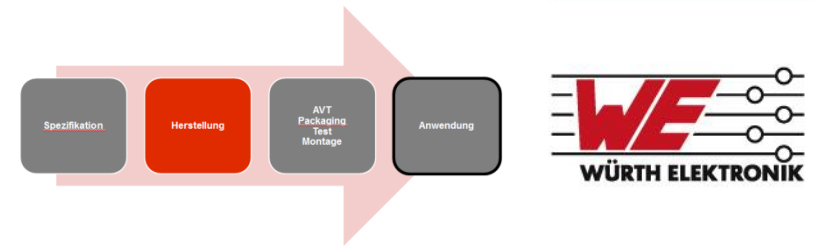
Life Cycle of a Printed Circuit Board

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)

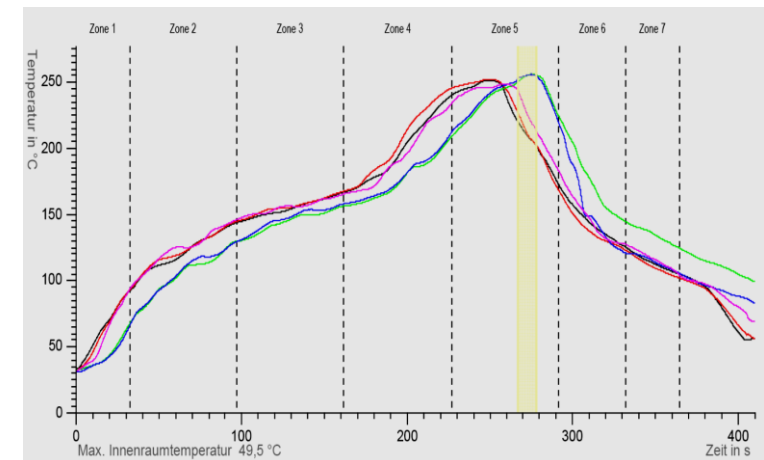
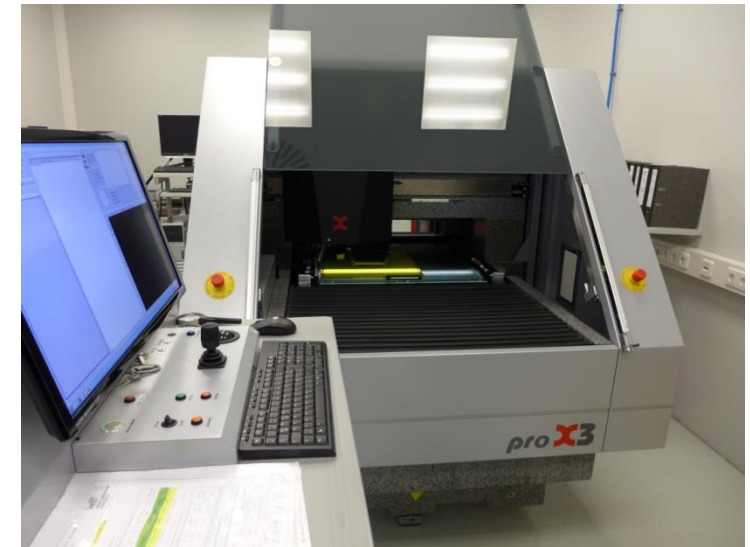


Life Cycle of a Printed Circuit Board Production



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
-

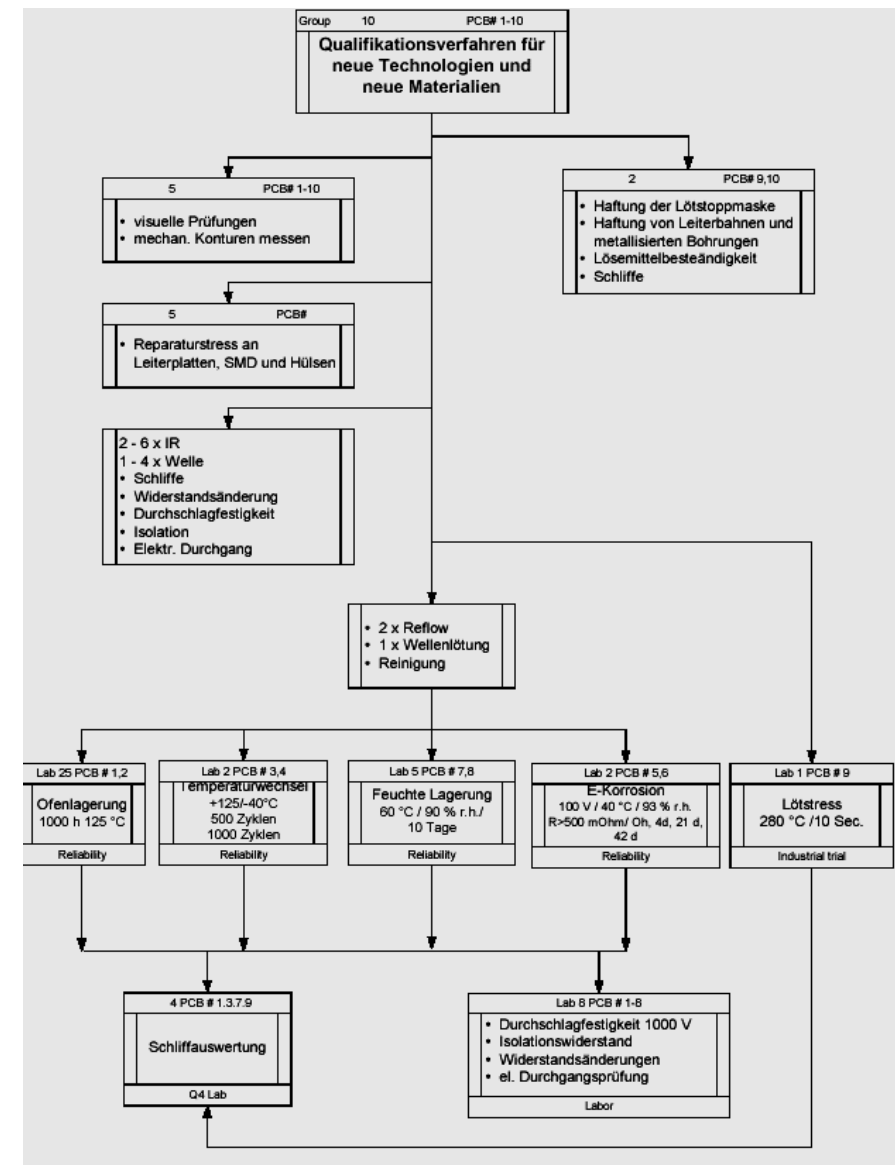


Life Cycle of a Printed Circuit Board Production

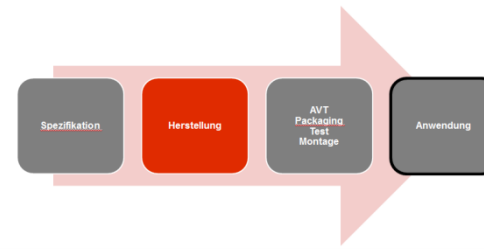


Reliability Testing for Qualification of Material and Processes

- 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

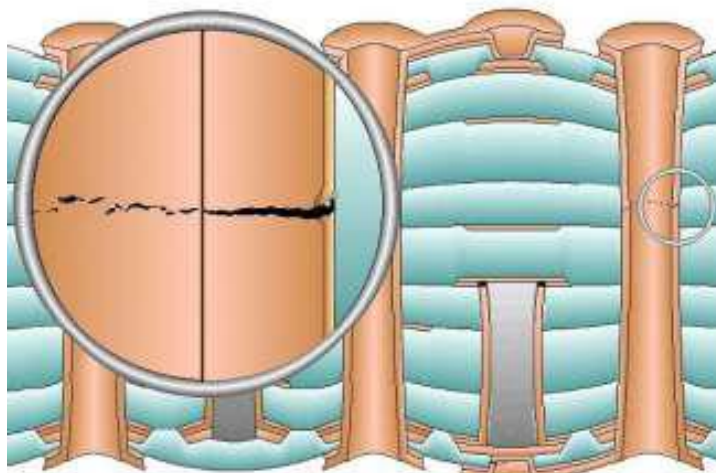
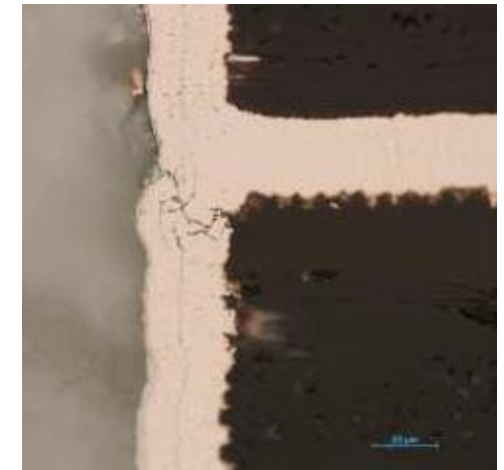
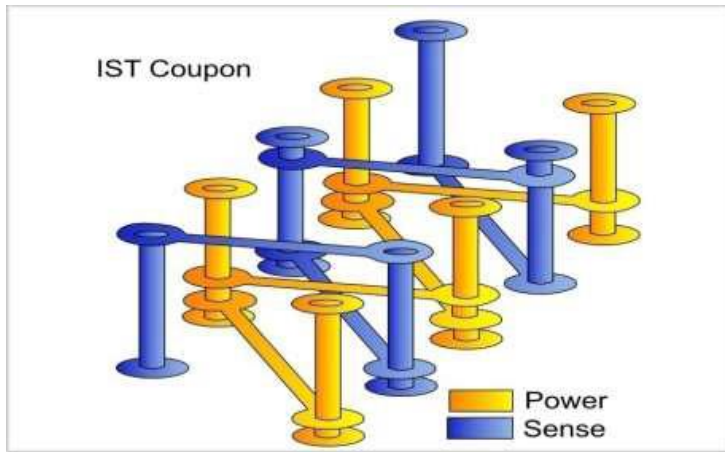


Life Cycle of a Printed Circuit Board Production

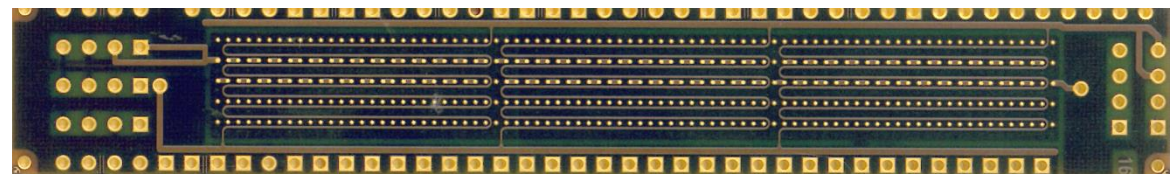
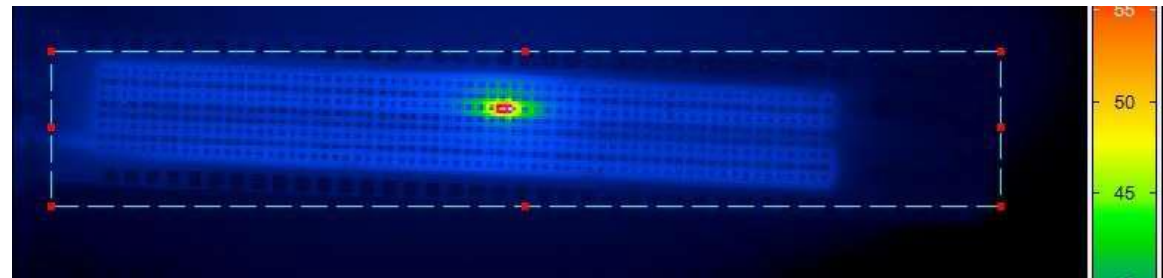


IST – Interconnect Stress Test

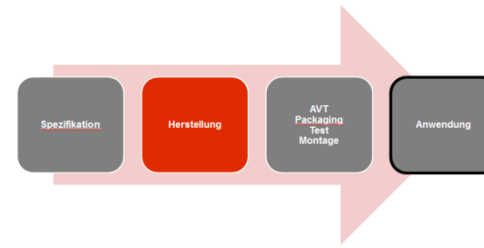
specified in IPC-TM650.2.6.26



PWB Interconnect Solutions Inc. 09



Life Cycle of a Printed Circuit Board Production



2008

Test Report

High Temperature Exposure

Applicant: Würth Elektronik GmbH & Co. KG

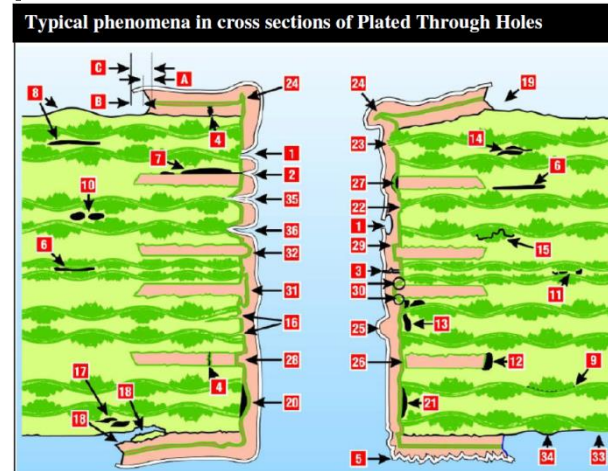
Kind of Product: WE-Testboards

Model: 2F-Technology

Manufacturer: Würth Elektronik GmbH & Co. KG
Circuit Board Technology
Salzstrasse 21
74676 Niedermhall
Germany

Test results Environmental Simulation Tests
Find test summary on page 7

Referee: Dirk Knorr
Company: Würth Elektronik eiSos GmbH & Co. KG
Date of issue: 04.09.2007

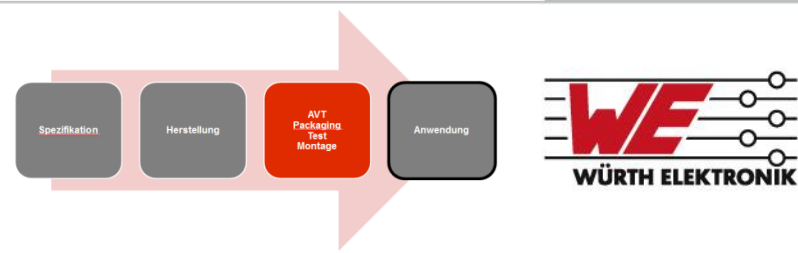


Cross Sections

High_Temperature_Excourt

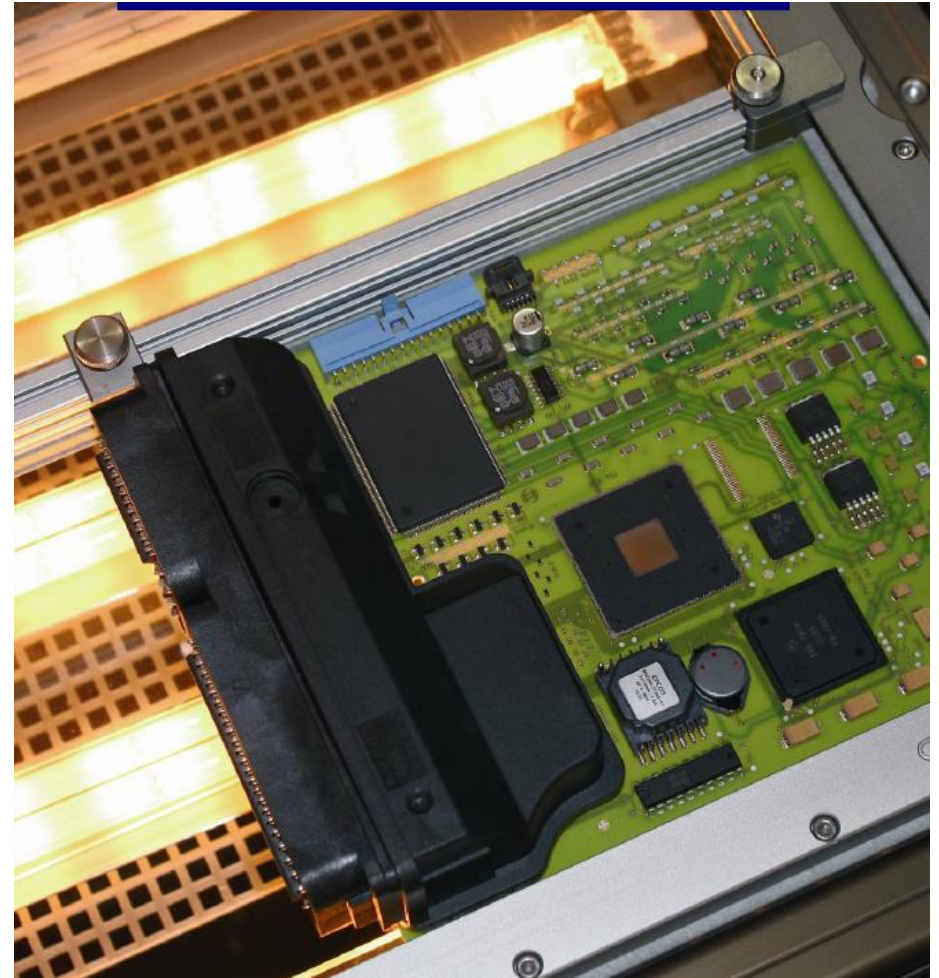
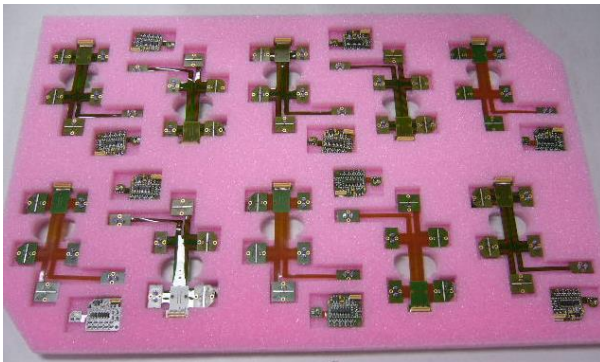
Page 14 of 14

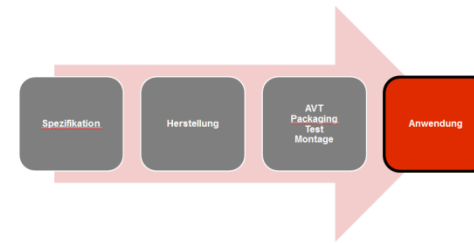
Würth Elektronik eiSos GmbH & Co. KG, Max-Eyth-Str. 1, D-74638 Widdigen
Tel.: +49 (0) 7942 / 340-0, Fax.: +49 (0) 7942 / 340-400



Life Cycle of a Printed Circuit Board Further Processing

- **Component Assembly**
- **Soldering**
 - Wave / Reflow / selectiv / Hand
- **Cleaning**
- **Test**
- **Separation**
- **Coating**
- **Storage**
- **Transport**





Life Cycle of a Printed Circuit Board Usage

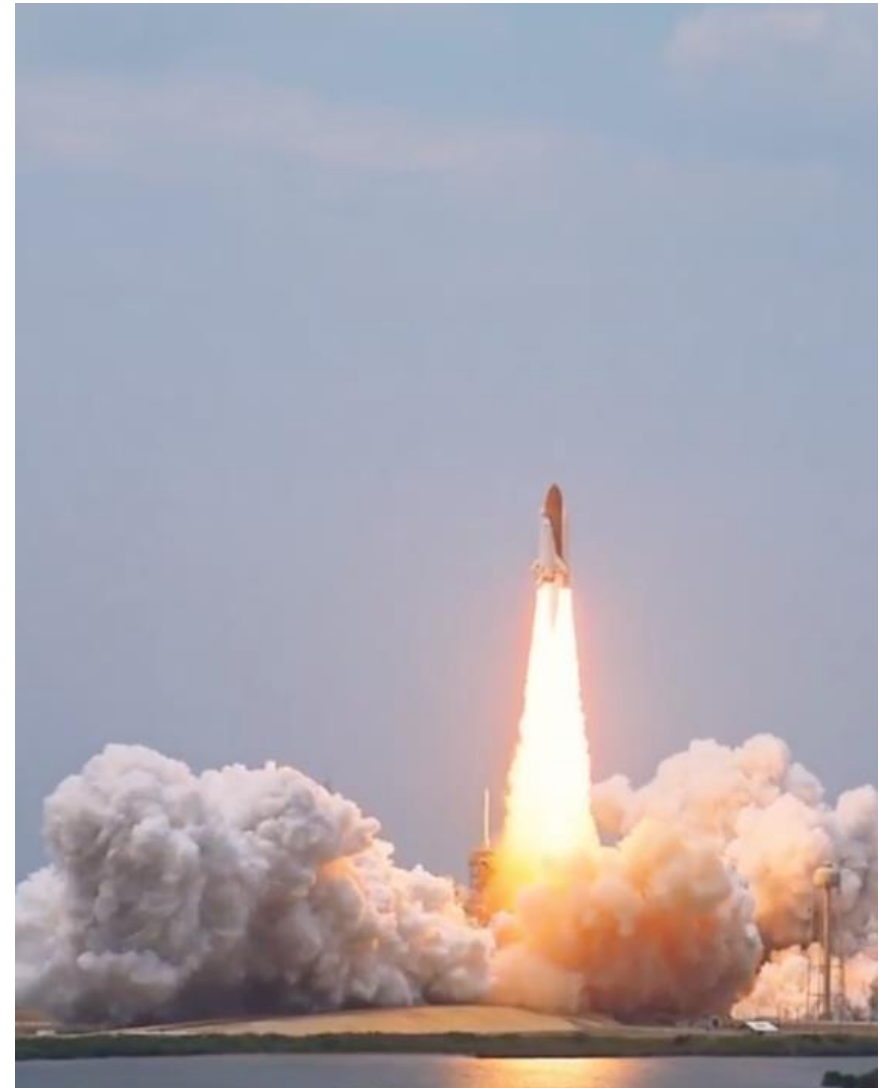
Load Types (single, combined)

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)



IPC-TM-650 2.6 TEST METHODS MANUAL



ASSOCIATION CONNECTING
ELECTRONICS INDUSTRIES

2215 Sanders Road
Northbrook, IL 60062-6135

IPC-TM-650 TEST METHODS MANUAL

- 2.1 Visual Test Methods
- 2.2 Dimensional Test Methods
- 2.3 Chemical Test Methods
- 2.4 Mechanical Test Methods
- 2.5 Electrical Test Methods
- 2.6 Environmental Test Methods

Number 2	
Subject Printed Wiring Board Test Methods	
Date 11/98	Revision
Originating Task Group N/A	

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



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IPC-TM-650 TEST METHODS MANUAL

IPC-TM-650 2.6 TEST METHODS MANUAL

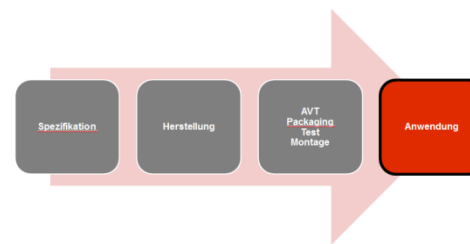
- 2.6.9.1 Test to Determine Sensitivity of Electronic Assemblies to Ultrasonic Energy
- 2.6.9.2 Test to Determine Sensitivity of Electronic Components to Ultrasonic Energy
- 2.6.10A X-Ray (Radiography), Multilayer Printed Wiring Board Test Methods
- 2.6.11 Hydrolytic Stability Solder Mask
 - 2.6.11.1 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 Substrate Boards
- 2.6.23 Test Procedure for Steam Ager Temperature Repeatability
- 2.6.26 DC Current Induced Thermal Cycling Test



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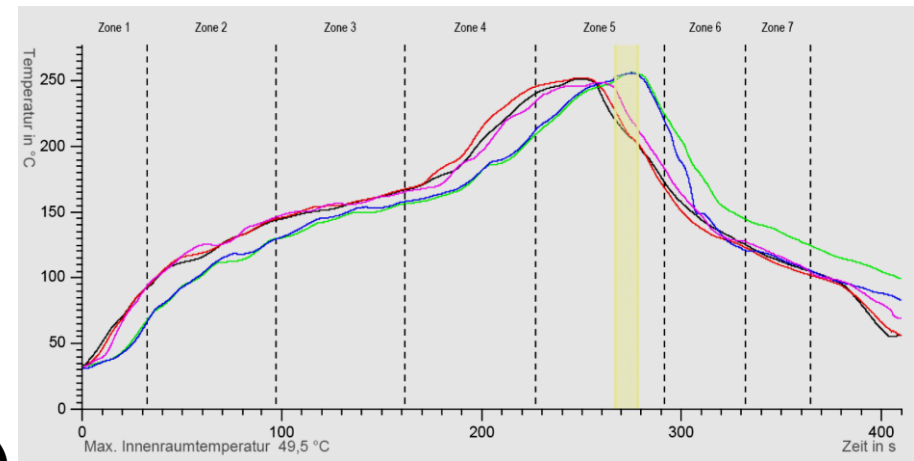
IPC-TM-650 TEST METHODS MANUAL



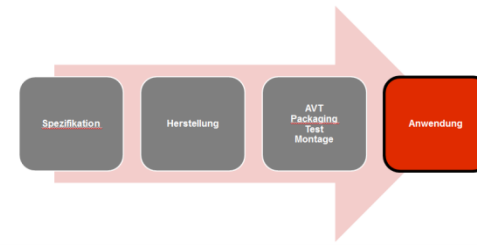
Life Cycle of a Printed Circuit Board Usage

Reliability Testing „Bare Board“

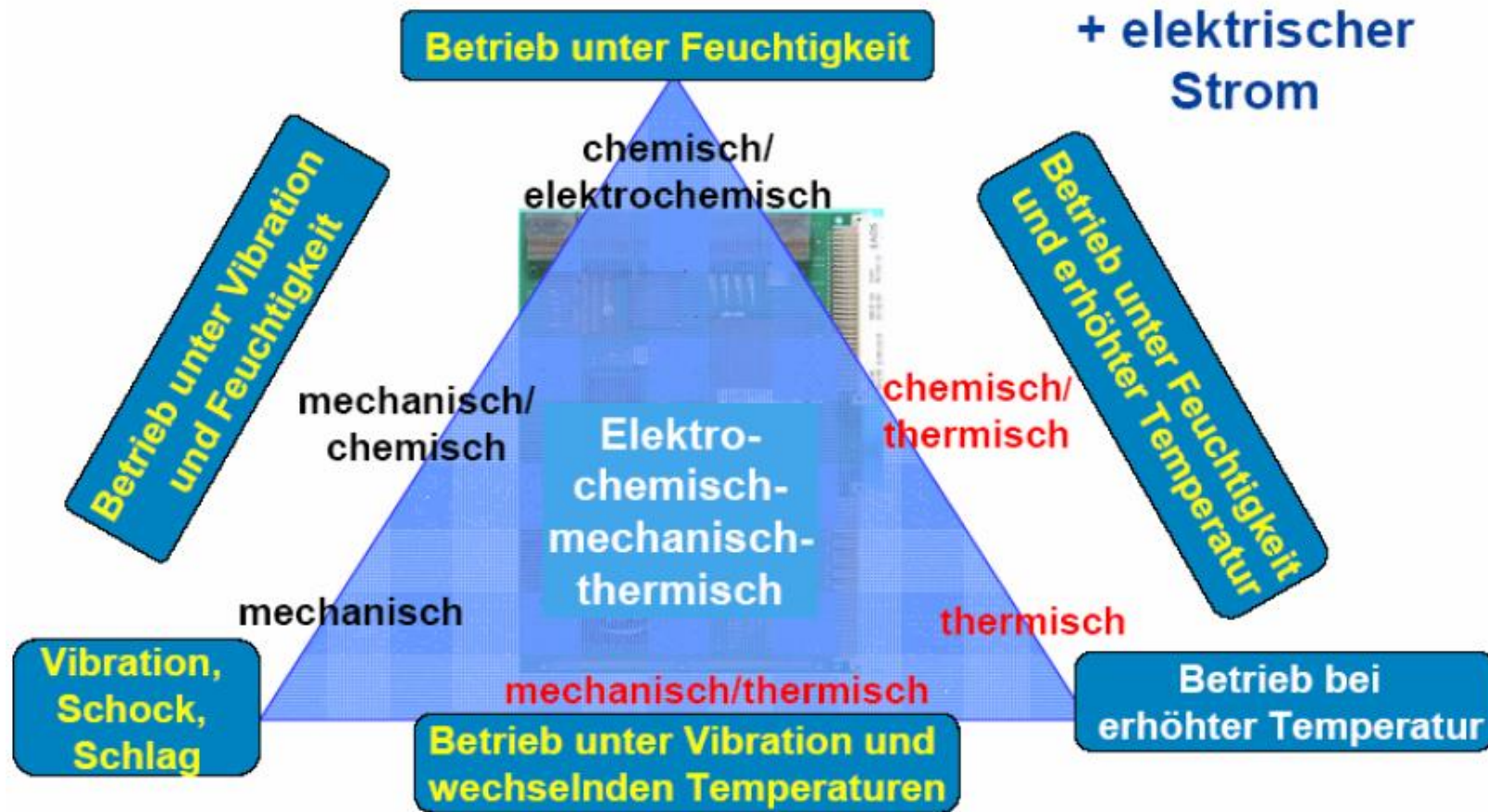
- always with „Pre Conditioning“
 - Drying
 - Reflow / Wave / selectiv / Hand
- High Temp storage (1.000h @ 125°C)
- Thermal Cycling (-40°C 125 / 140 / 150°C)
- IST / single via test
- Humidity storage (60°C @ 90% r.F.)
- E-Corrosion (100V / 40°C / 93% r.F.)
- SIR (Surface Isolation Resistance)
- CAF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



Life Cycle of a Printed Circuit Board Usage

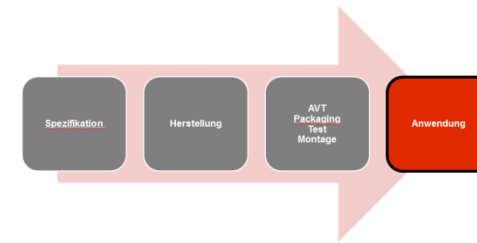


System Reliability Testing



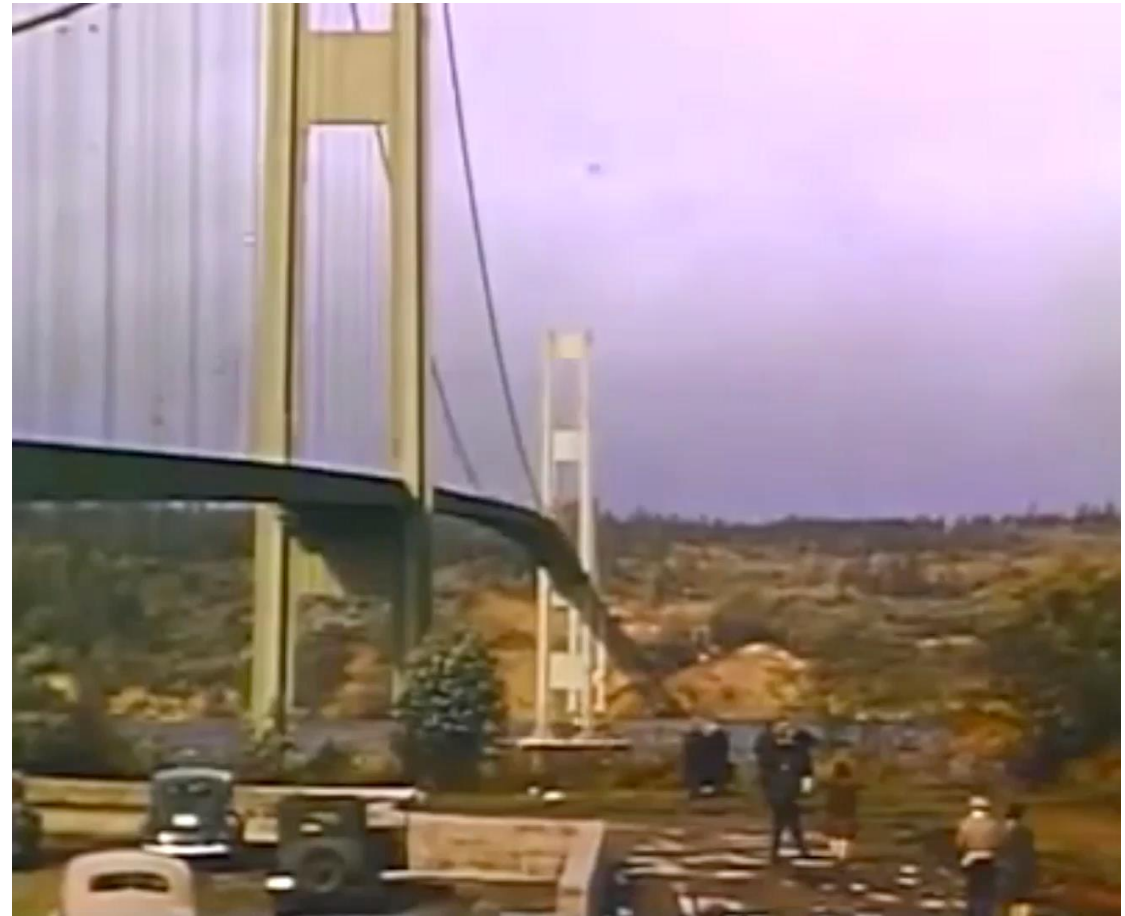
Quelle: Daimler AG

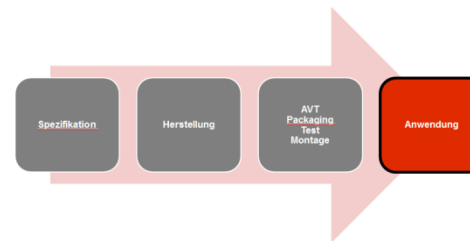
Life Cycle of a Printed Circuit Board Usage



System Reliability Testing

- EMC
- Heat management, hot spot Analysis
- Software
- Repair
- Shock, Vibration

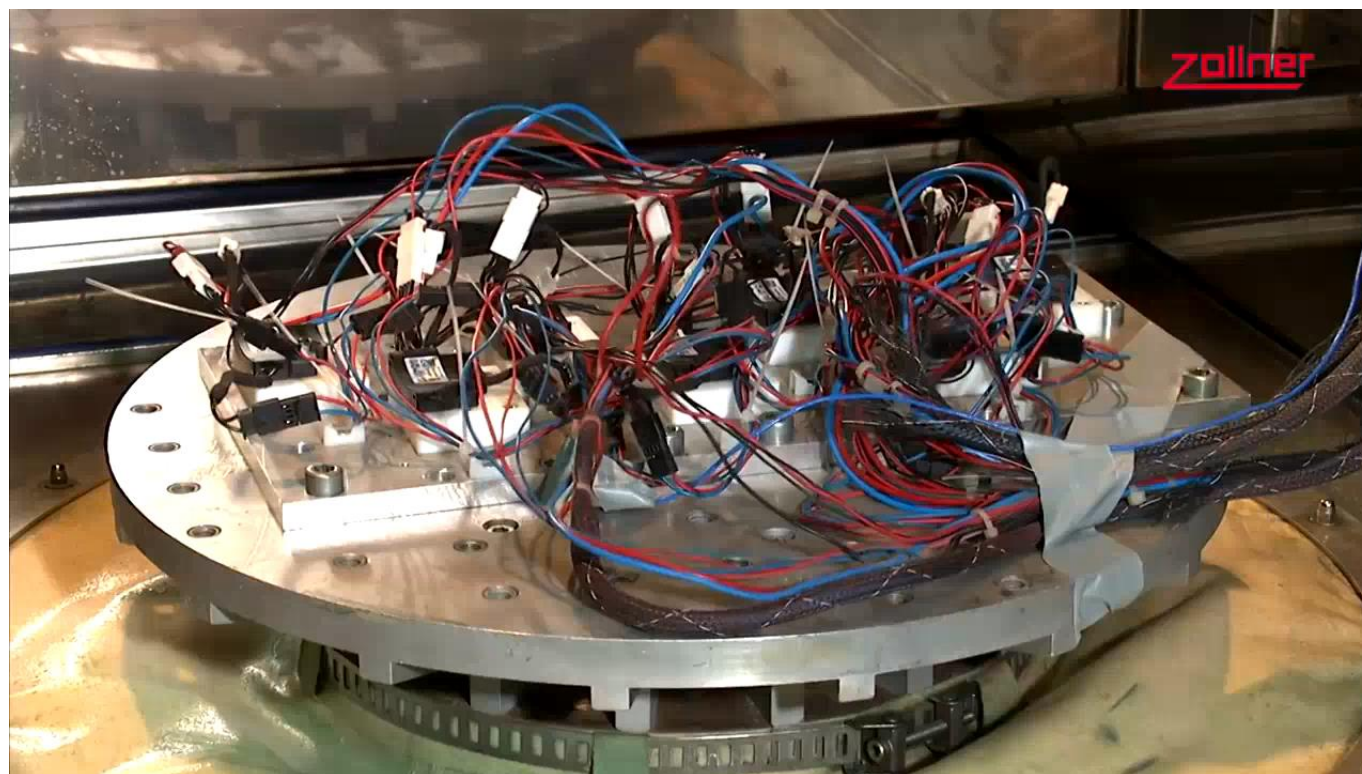
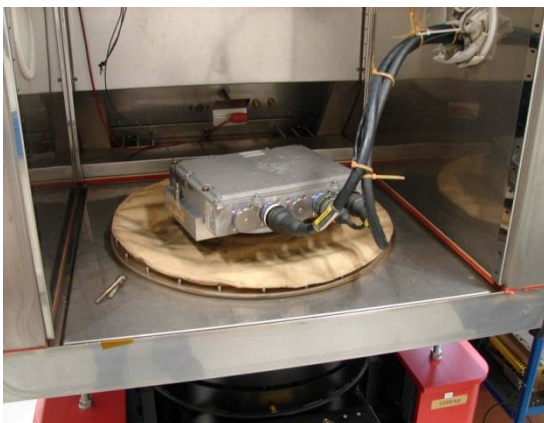




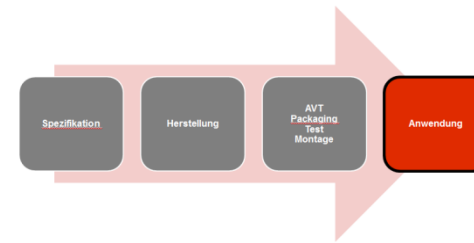
Life Cycle of a Printed Circuit Board Usage

System Reliability Testing

- EMC
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- Software
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Life Cycle of a Printed Circuit Board Usage



System Reliability Testing

- EMC
- Heat management, hot spot Analysis
- Software
- Repair
- Shock, Vibration



Falling Test from 50cm height on concrete slab

Content

1

- Reliability

2

- Life cycle of a printed circuit board

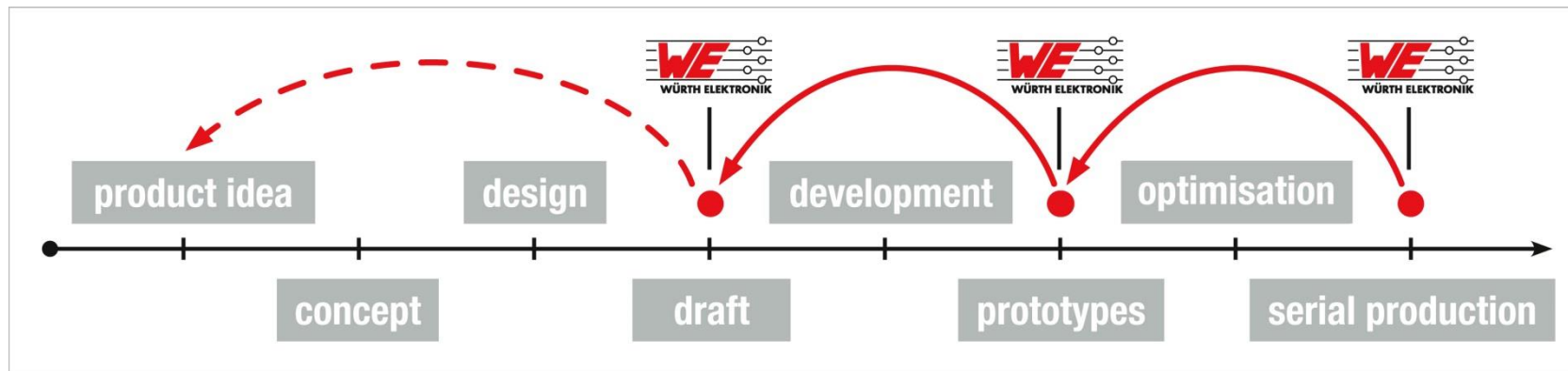
3

- **How to set the screws to design robust PCBs**

How to set the screws

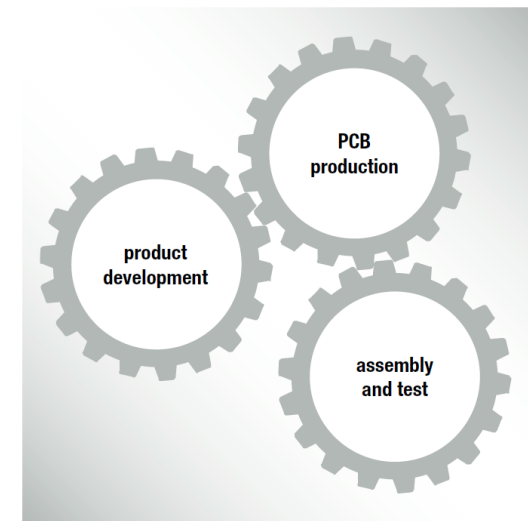
Reliability engineering

- best way of co-operation



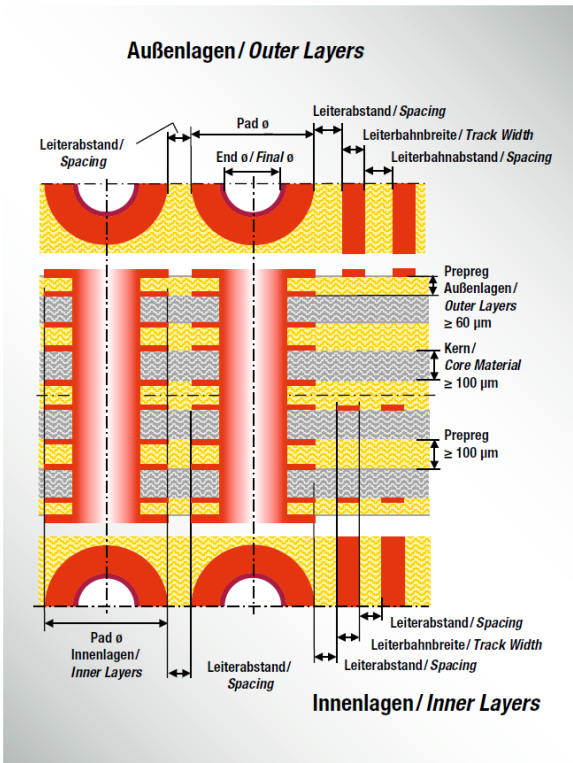
- Cooperation of all participants of the value-added chain is necessary
- Quality and reliability must be planned
 - Design-to-cost
 - Design-for-manufacturing
 - Testability (homogeneous System!)
- Listings and permits, i.e. UL

➔ There are a lot of dependencies and feedbacks!



How to set the screws robust Design

Basic Design Guide



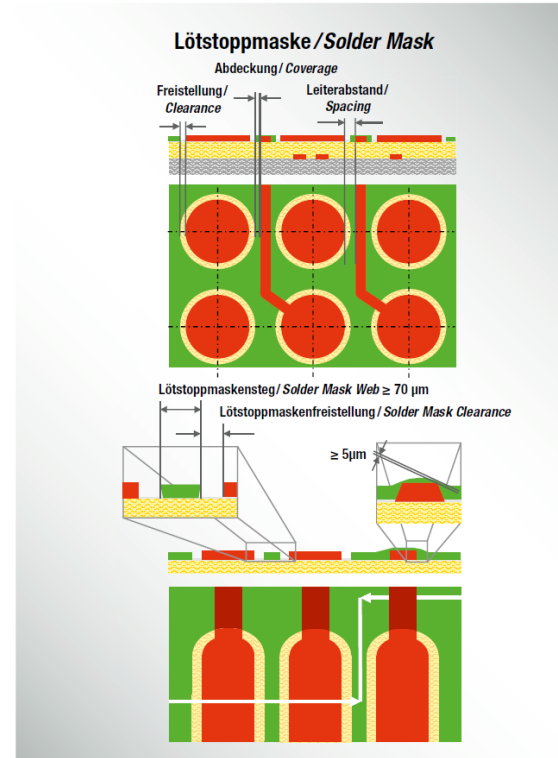
Leiterbahnbreite und Leiterabstände / Track Width and Conductor Spacing Außenlagen / Outer Layers

Kupferend-schichtdicke / Final Copper Thickness	Leiterbahn-breite / Track Width	Leiter-abstand / Spacing
ca. 50 μm > 33,4 μm (P2-0012)	100 μm	100 μm
70 μm	125 μm	160 μm
105 μm	150 μm	225 μm
ca. 25-30 μm ¹⁾	75 μm ¹⁾	75 μm ¹⁾

Leiterbahnbreite und Leiterabstände / Track Width and Conductor Spacing Innenlagen / Inner Layers

Kupferend-schichtdicke / Final Copper Thickness	Leiterbahn-breite / Track Width	Leiter-abstand / Spacing
17,5 μm / 1/2 oz/ft ²	100 μm 75 μm ¹⁾	100 μm 75 μm ¹⁾
35 μm / 1 oz/ft ²	100 μm	100 μm
70 μm / 2 oz/ft ²	125 μm	150 μm
105 μm / 3 oz/ft ²	175 μm	225 μm

¹⁾ Erhöhte Anforderung. Aus Kostengründen nur empfohlen, wo unbedingt erforderlich.
Technically possible. Due to cost reasons only advisable when absolutely necessary.



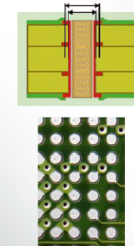
Lötstopmmaske / Solder Mask

	Standard	Advanced
Freistellung / Clearance	$\geq 50 \mu\text{m}$	35 μm
Leiterbahn-abdeckung / Coverage	50 μm	40 μm
Lötstopp-maskensteg / Solder Mask Web	$\geq 70 \mu\text{m}$	
Viafreistellung / Via-Opening	Siehe Tabelle vorherige Seite / See table previous page	

Fertigung ohne Viasfreistellung ist mit Zusatzaufwand verbunden und wird auch aus Qualitätsgründen nicht empfohlen.
Manufacture without solder mask clearances involves additional effort and is not recommended due to quality reasons.

Vias freigestellt gemäß ZVEI Empfehlung / Solder Mask Opening for PTH Vias

Maskenfreistellung = MF
Bohrerdurchmesser + 0,15 mm MF



Durchgehende Vias / Plated Through Hole Vias

Padgröße / Pad Size	Anmerkung / Note	Bohrer / Drill Tool	Enddurchmesser / Final Hole Diameter	Toleranz / Tolerance (Standard)	Kupferfreistellung Innenlagen / Copper Clearance Inner Layers	Lötstoppmaskenfreistellung / Solder Mask Opening
0.60 mm	Standard / Preferred	0.35 mm	0.25 mm	+0.10 / -0.05 mm	$\geq 0.80 \text{ mm}$	$\geq 0.35 \text{ mm}$
0.55 mm		0.30 mm	0.20 mm		$\geq 0.75 \text{ mm}$	0.45 mm
0.50 mm (Cu max. 35 μm)	max. ca. 12 Lagen / Layers max. ca. 1,80 mm LP-Dicke / Board Thickness	0.25 mm	0.15 mm		$\geq 0.70 \text{ mm}$	0.40 mm
0.45 mm (Cu max. 35 μm)	Für weniger komplexe Lagenaufbauten / For stack-ups with lower complexity	0.25 mm (0.20 mm)	0.15 mm		$\geq 0.70 \text{ mm}$	0.35 mm

Genereller Hinweis: Kleinere Parameter sind in vielen Fällen in Absprache möglich! / General Note: Enhanced design rules are often possible with consultation!

Sonstige Design Parameter / Other Design Parameters

Leiterbild / Conductive Pattern	
Abstand Kupfer zu Fräskontur / Copper clearance to routed board edge	$\geq 0.23 \text{ mm}$
Abstand Kupfer zu Kerbfräskontur / Copper clearance to scored board edge	$\geq 0.45 \text{ mm}$ Für LP Dicke 1.80 mm / For Board Thickness 1.80 mm
Abstand Kupfer zu NDK Bohrung / Copper Clearance to NPT Hole	$\geq 0.25 \text{ mm}$ Umlaufend / Circumferential

Sonstige Design Parameter / Other Design Parameters

Bestückungs- und Servicedruck / Legend Print (Cu max. 70 μm)	
Strichstärke / Line Width	100 μm
Schriftgröße / Font Size	1.50 mm
Abstand zu LSM Öffnung / Distance to Solder Mask Opening	100 μm

How to set the screws

Fastening of the pcb

Comparison 4 – 9 fixing points

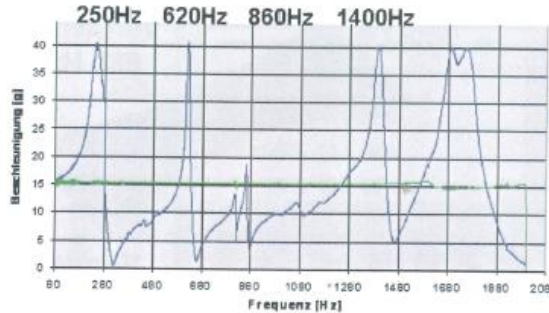


Abbildung 12-15: Experimentell bestimmte Eigenfrequenzen und Modell der simulierten Baugruppe

In einer ersten Berechnung wurden die Bedingungen für eine Befestigung der Baugruppe mit nur vier Schrauben analysiert. Abbildung 12-16 zeigt die berechneten Schwingungsformen für die vier ermittelten Eigenfrequenzen.

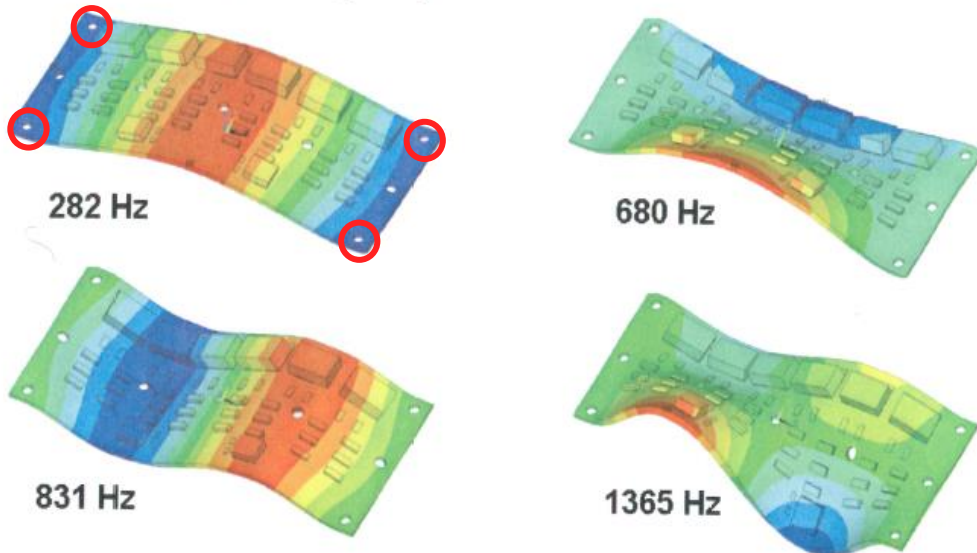
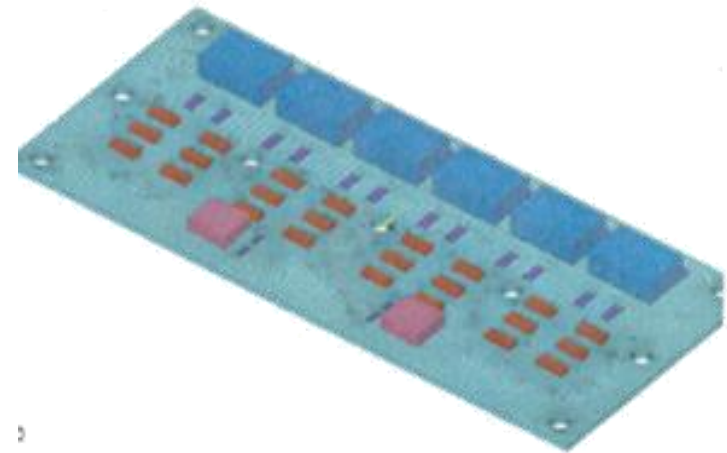


Abbildung 12-16: Eigenfrequenzen der simulierten Baugruppe mit vier Befestigungsschrauben



9 screws:

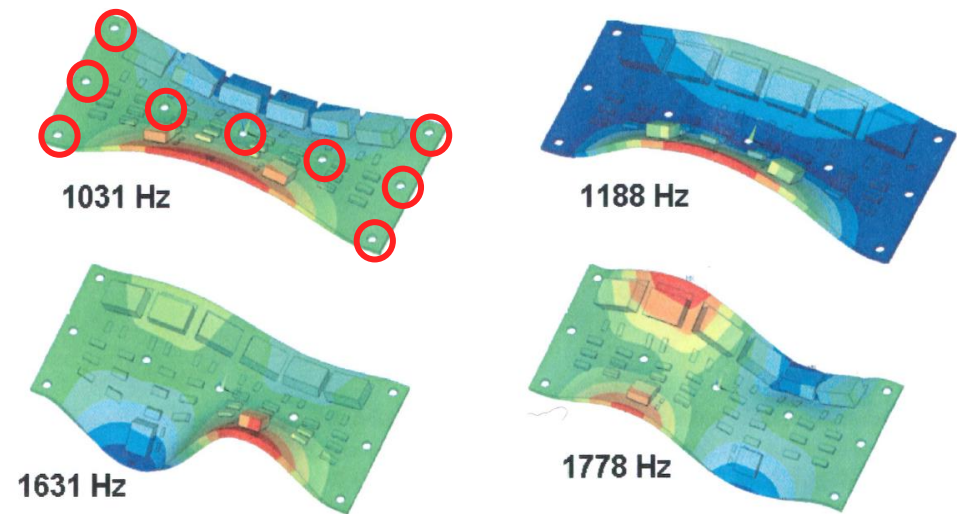


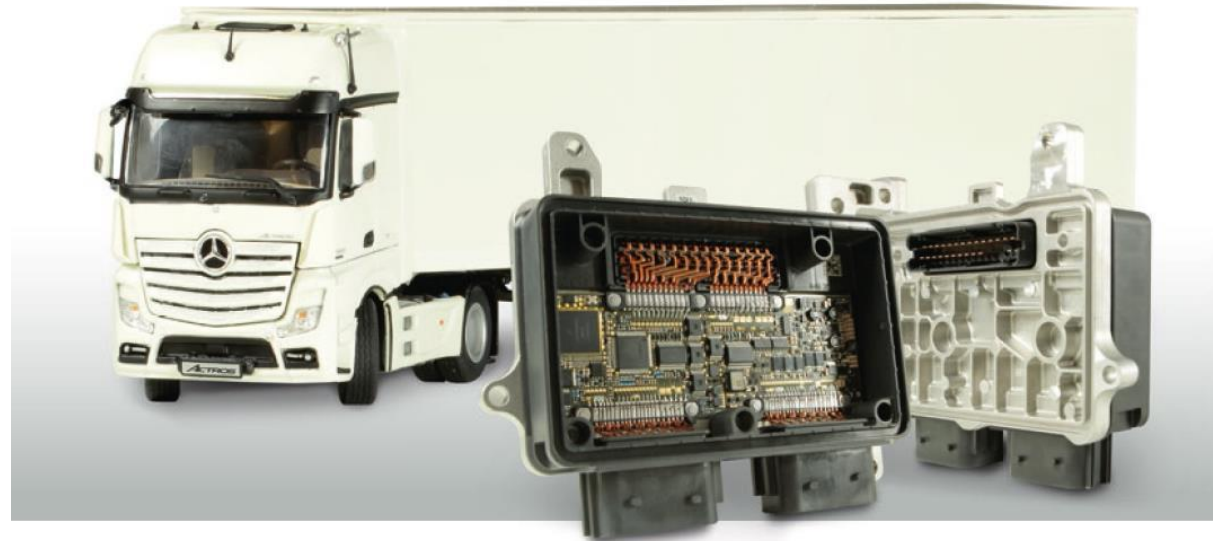
Abbildung 12-18: Berechnung der Eigenfrequenzen der simulierten Baugruppe mit neun Befestigungsschrauben

How to set the screws

Thermal management / HDI / printed Resistors

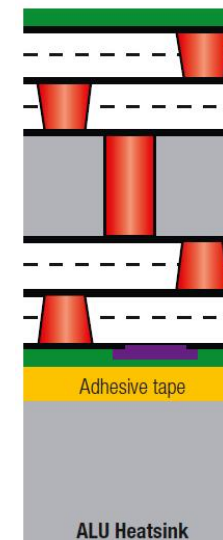
The printed circuit board system is used in the gearbox control in “Actros”, the flagship of Mercedes Benz’s commercial vehicle division.

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



Resistors on the outer layers

ALU Heatsink

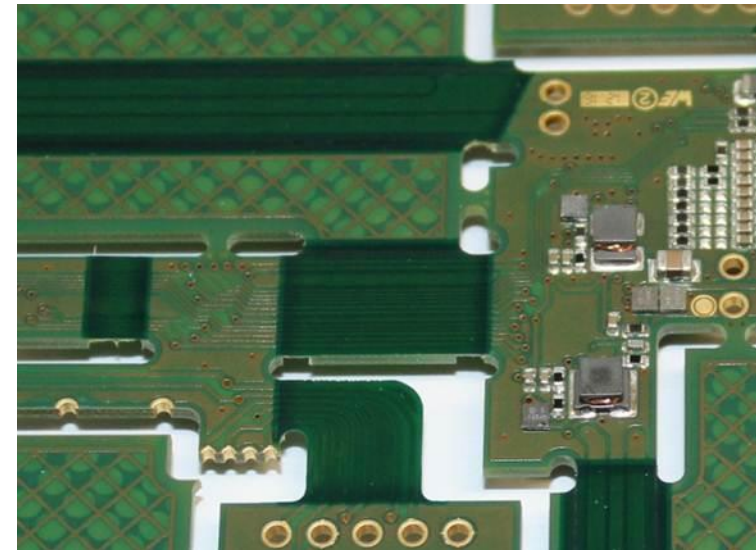
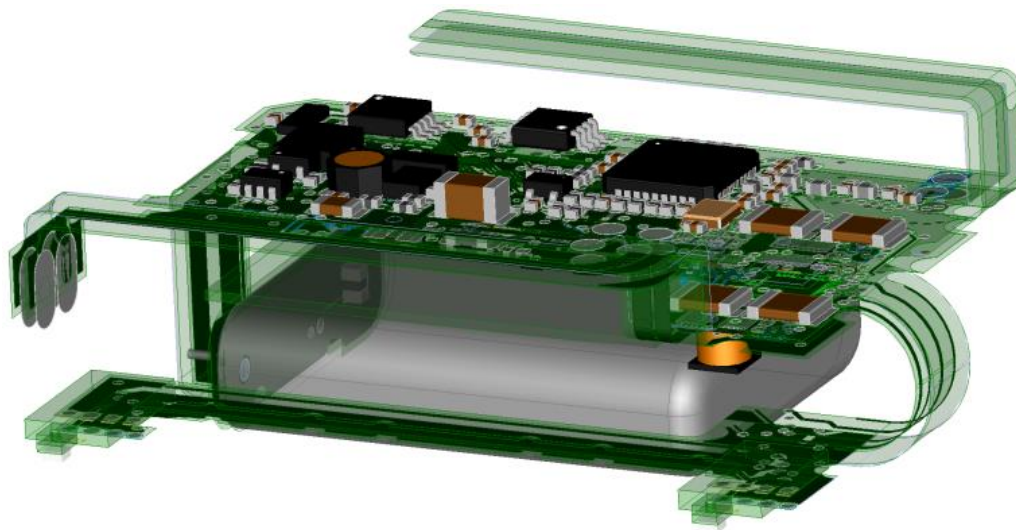


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How to set the screws Flex-Rigid

- 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

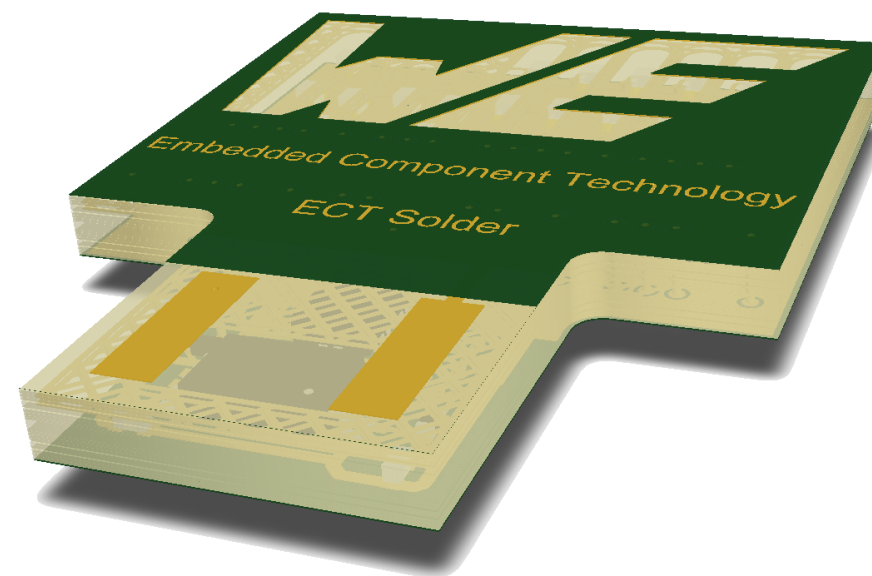
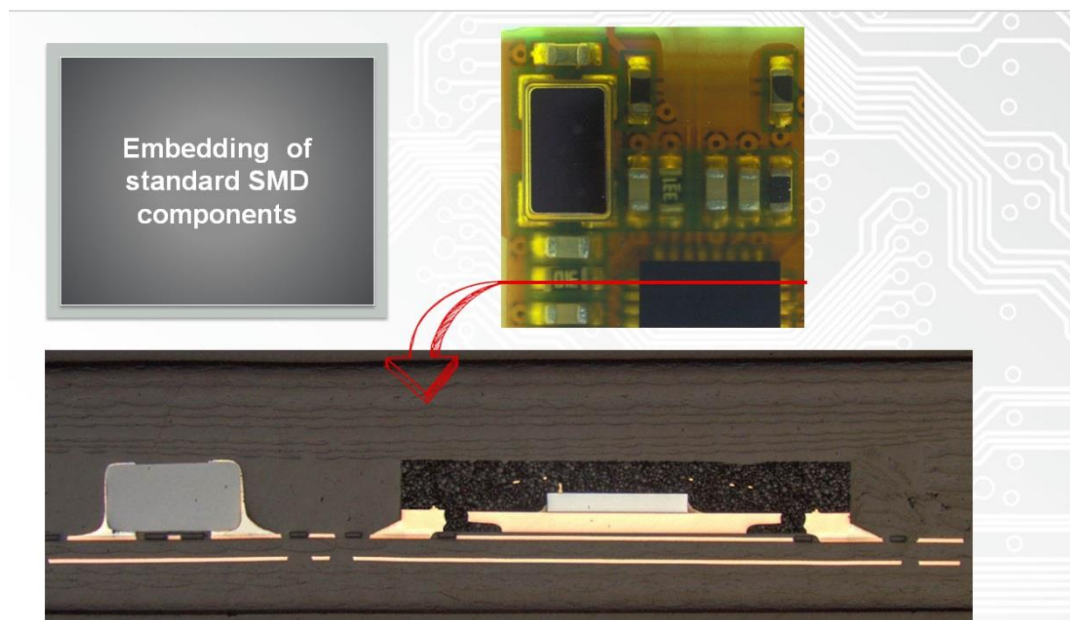


How to set the screws embedded Components



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

The webinar was presented by

