Reliability of Printed Circuit Boards

Webinar December 6th 2016

Speaker: Andreas Schilpp

Content

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

Content

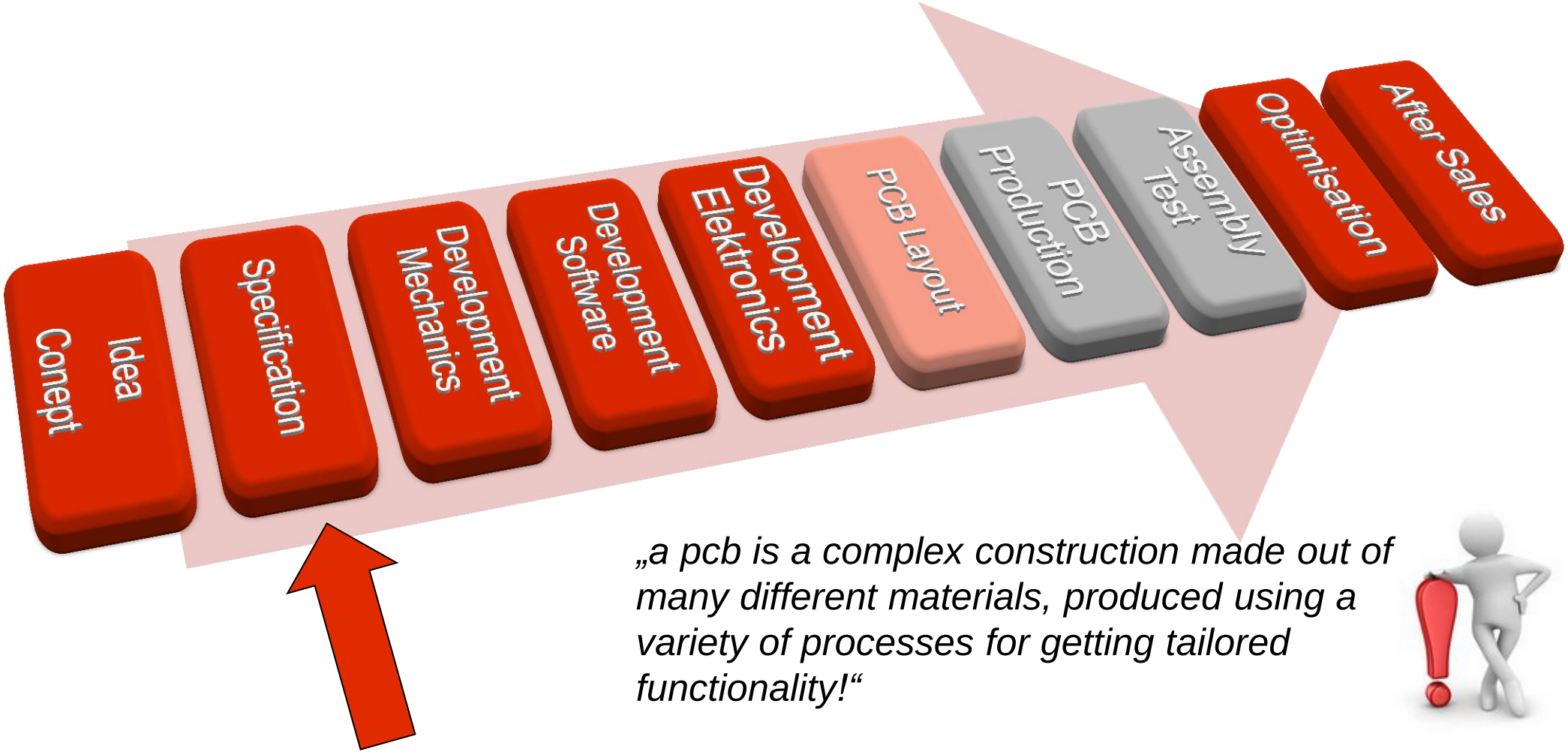
1. **Reliability**
2. Life cycle of a printed circuit board
3. How to set the screws to design robust PCBs

Reliability – a Definition

DIN
Deutsches Institut für Normung

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

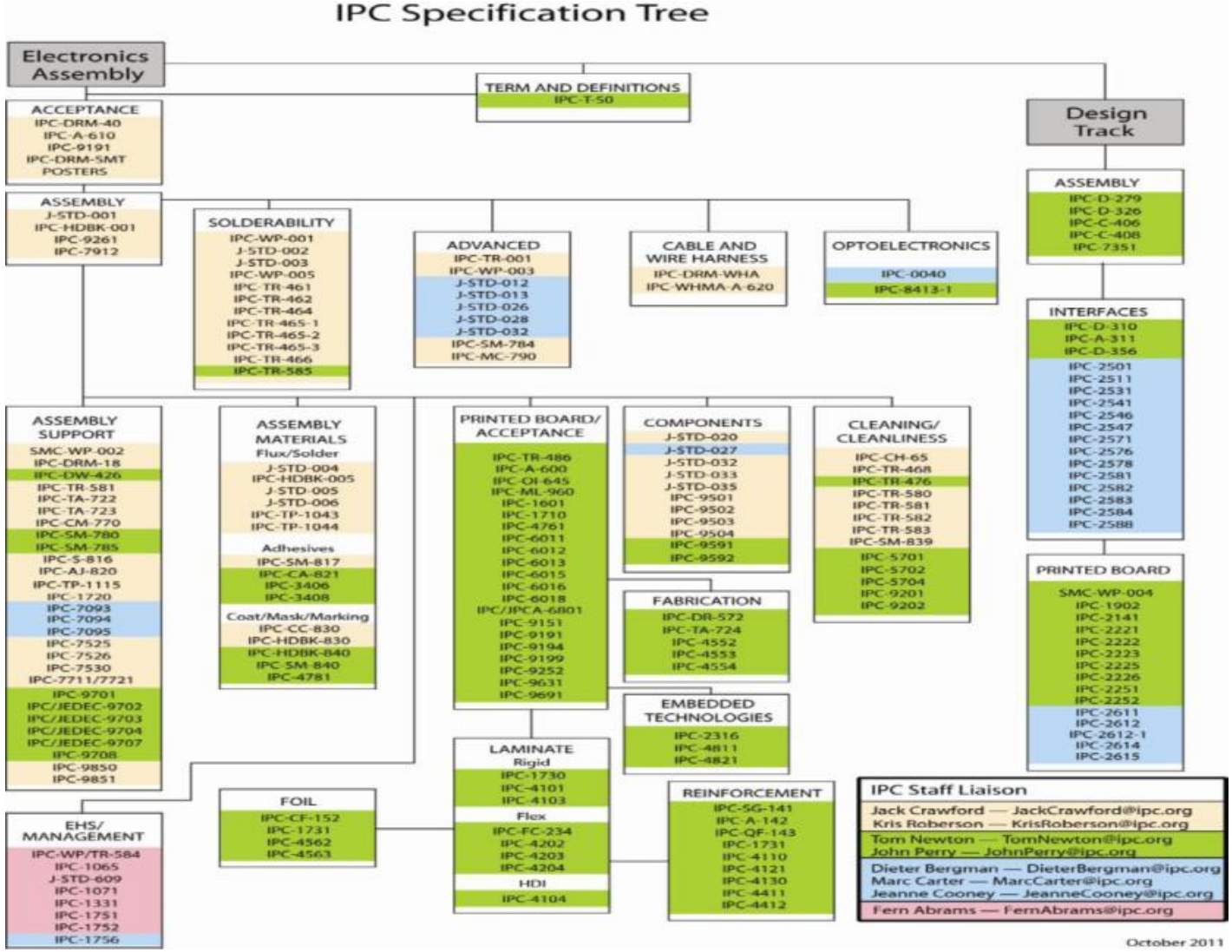
Design Chain electronic system development



„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

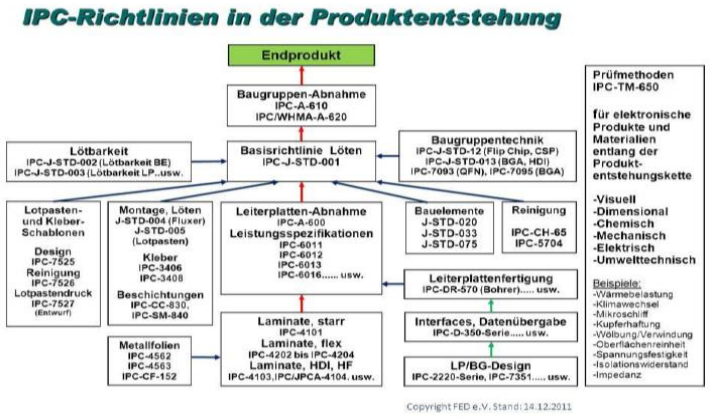
IPC Standards

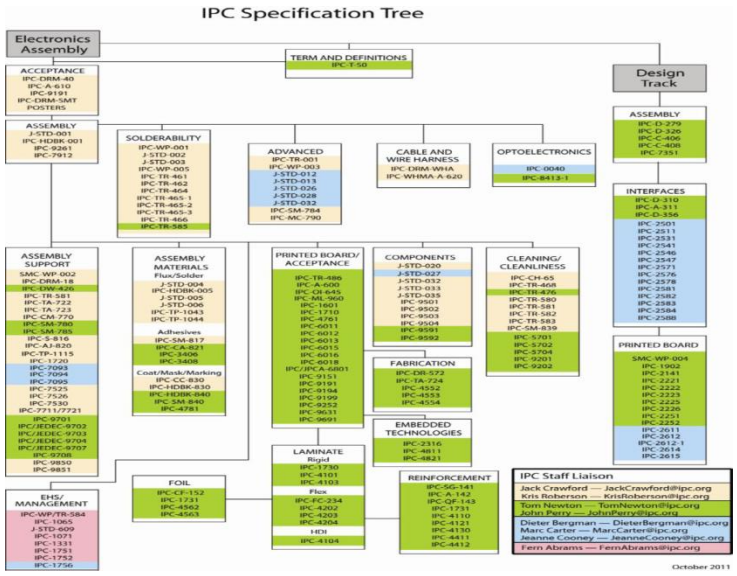


IPC Standards

Classification according IPC

- Class1 — includes **limited life products** suitable for applications where the requirement is function of the cpmpleted 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.

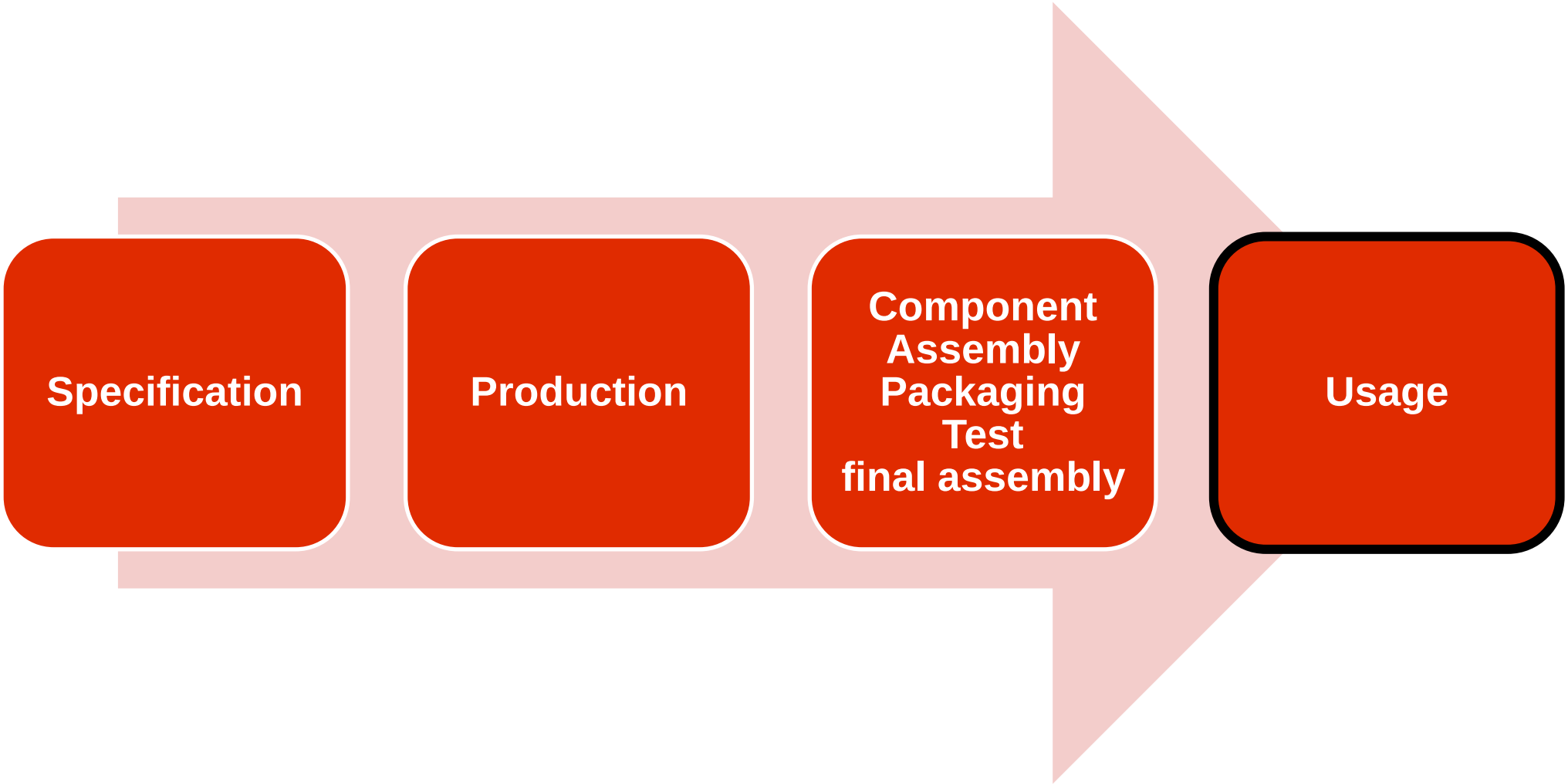


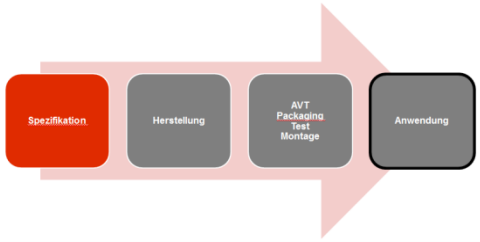


Content

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





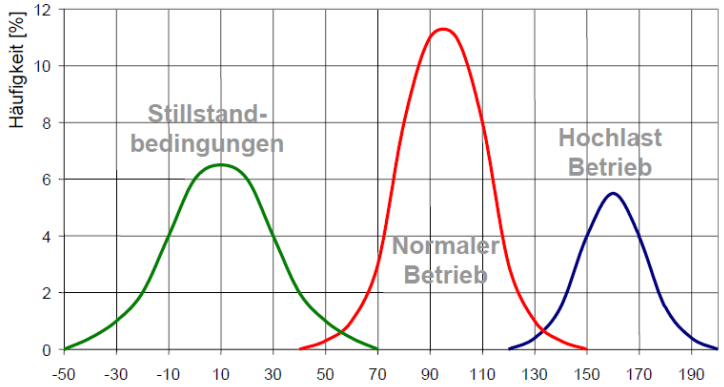
Life Cycle of a Printed Circuit Board

Specification

- Functionality
- Time, loads
- Operating conditions

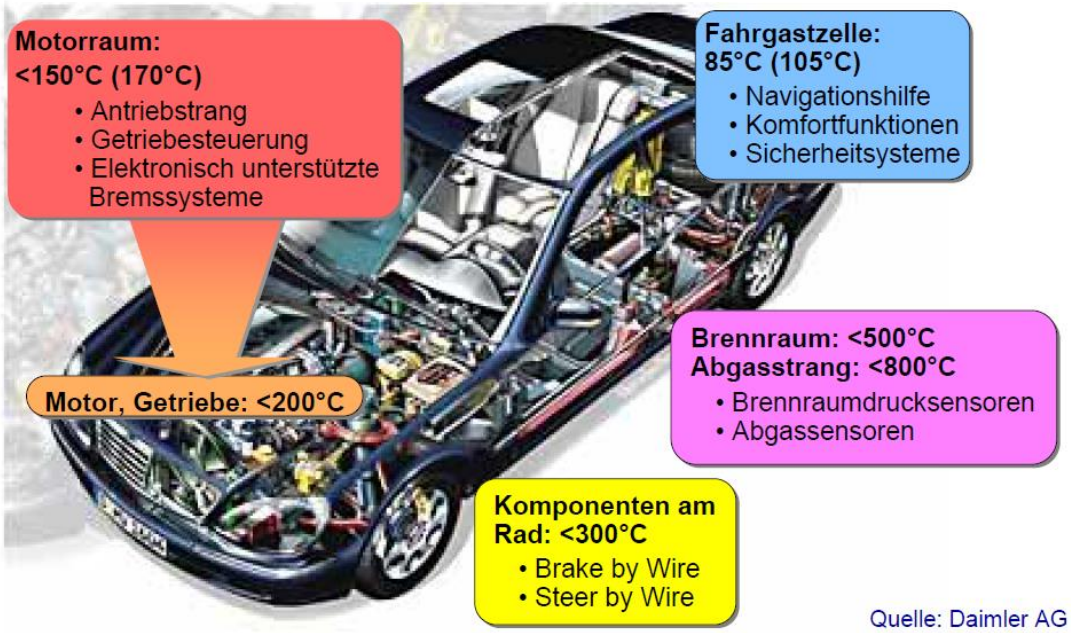
➔ Material
➔ Technology
➔ Components and assembly
➔ Solder surface
➔ Design Rules
➔ Mechanical Construction
➔ Thermal Management
➔ …..

➔ 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



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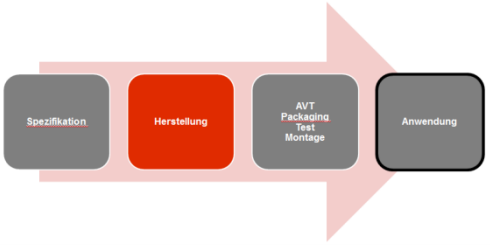


Life Cycle of a Printed Circuit Board

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

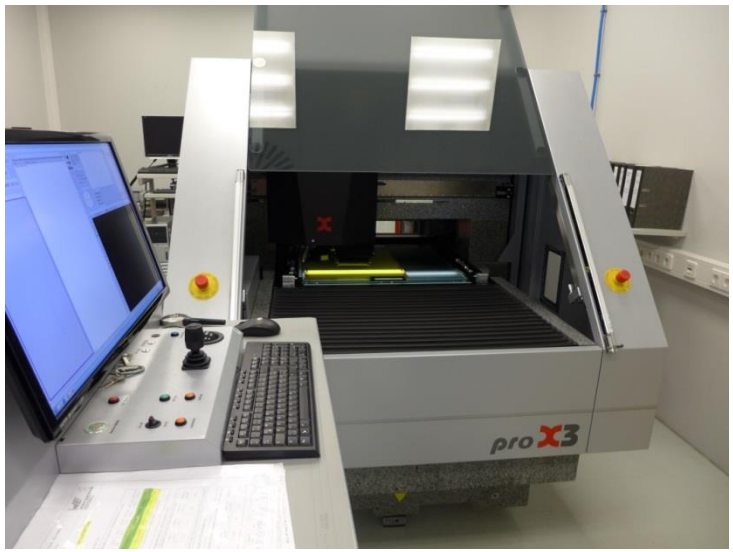
- qualified Processes

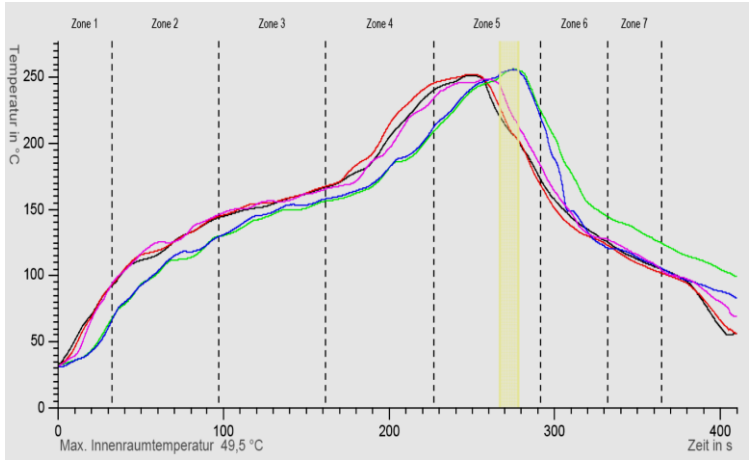
- Electrical Test, Impedance Testing
- Certificate of Conformance(CoC)
- First Article Inspection Report (FAIR)
- PPAP (Production Part Approval Process)

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
- .....

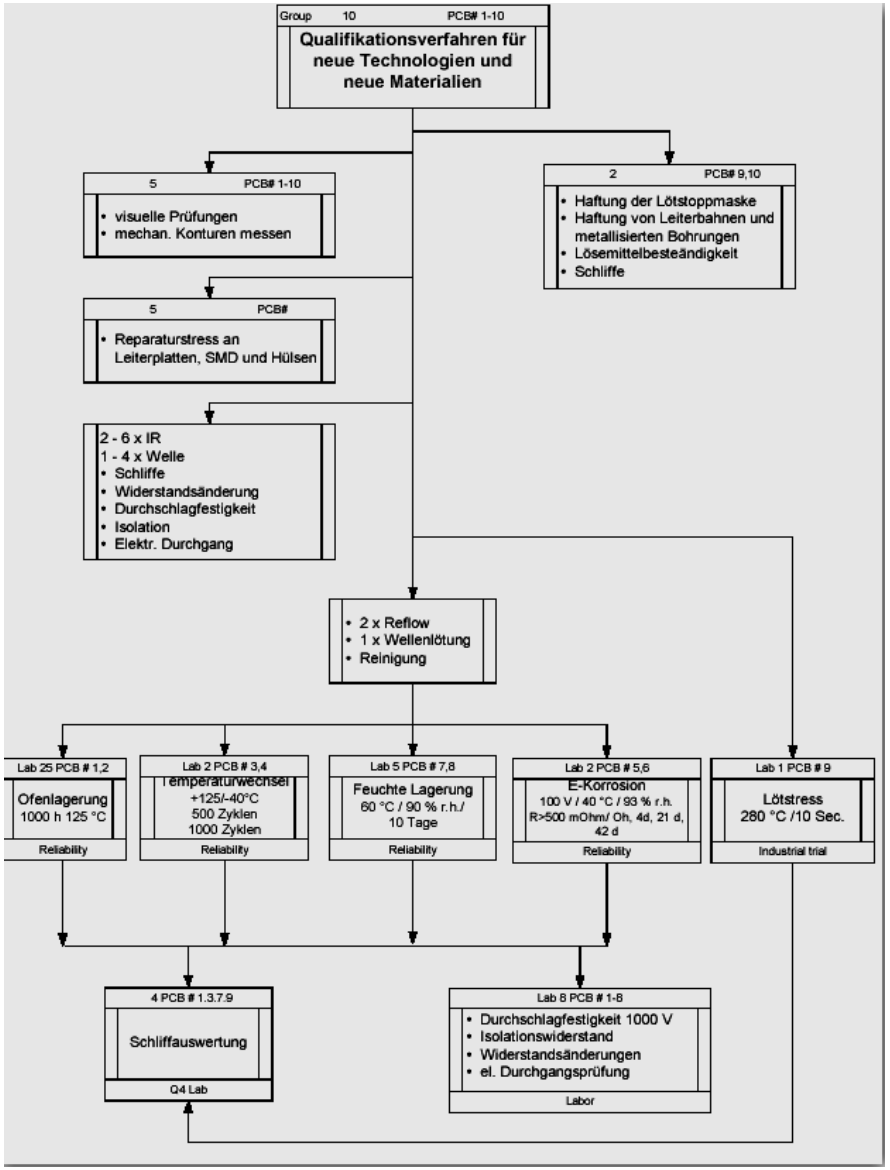




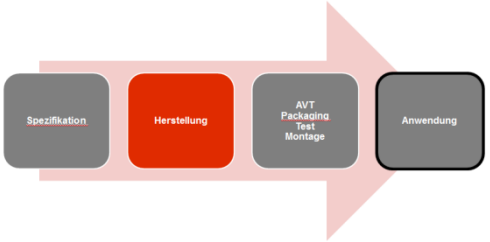
Life Cycle of a Printed Circuit Board Production

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

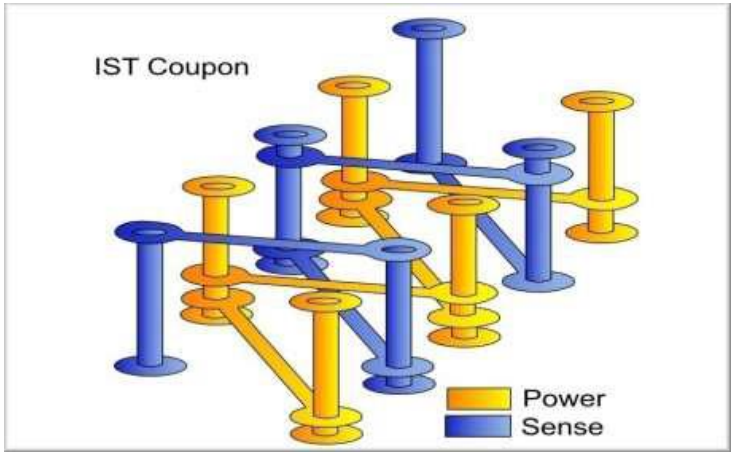


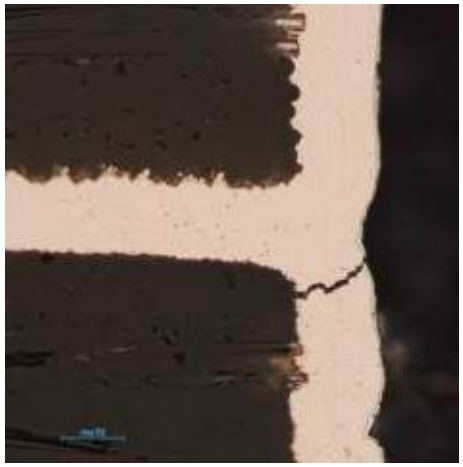
Life Cycle of a Printed Circuit Board Production

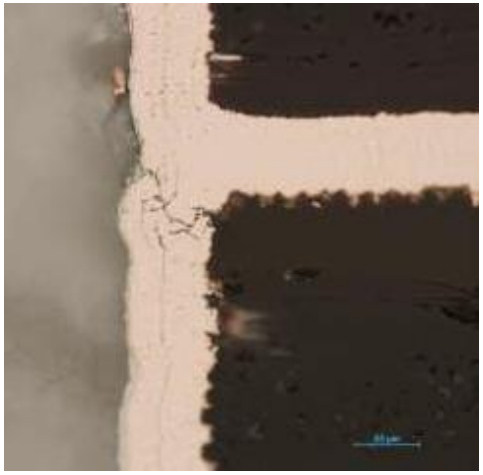


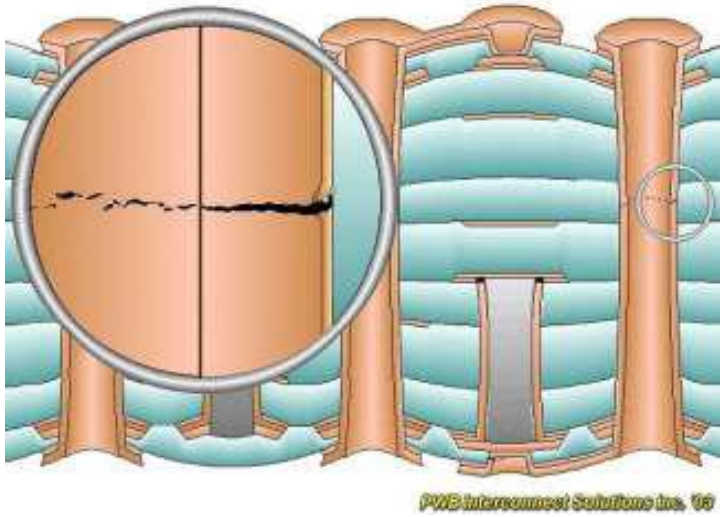
IST – Interconntect Stress Test

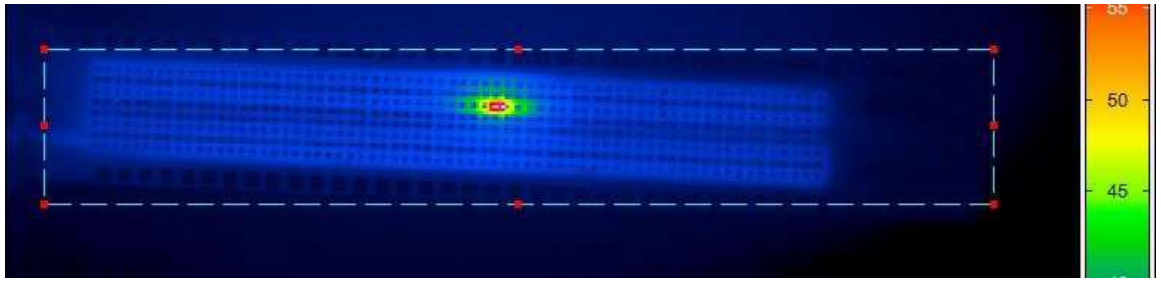
specified in IPC-TM650.2.6.26

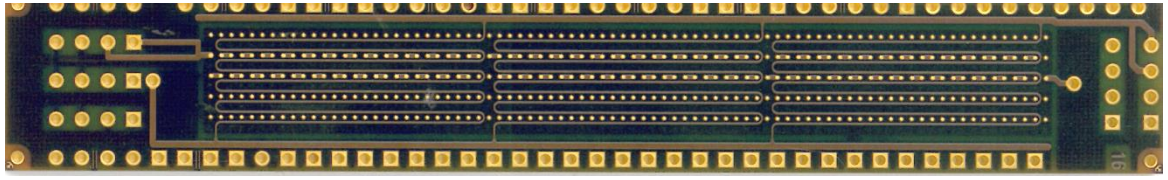




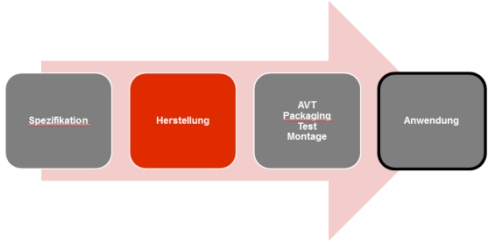


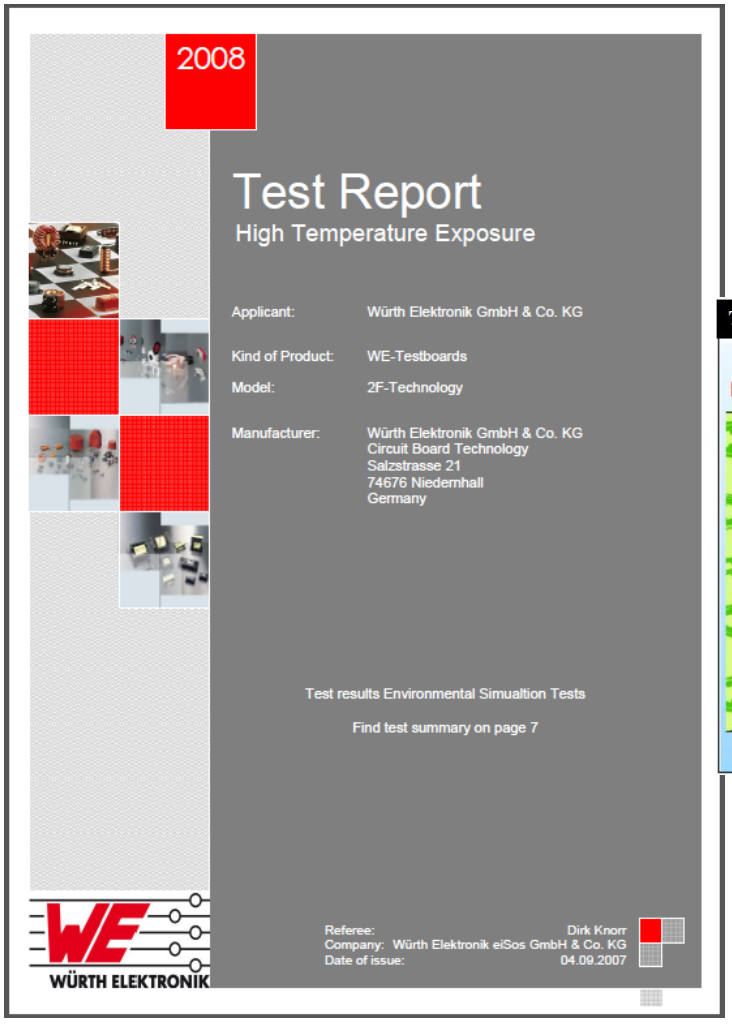


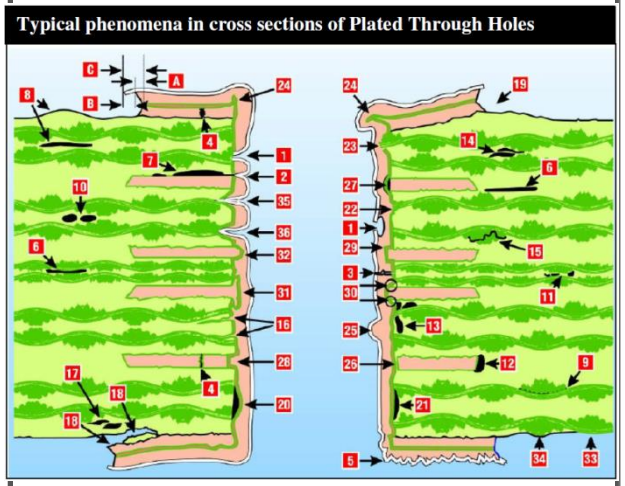


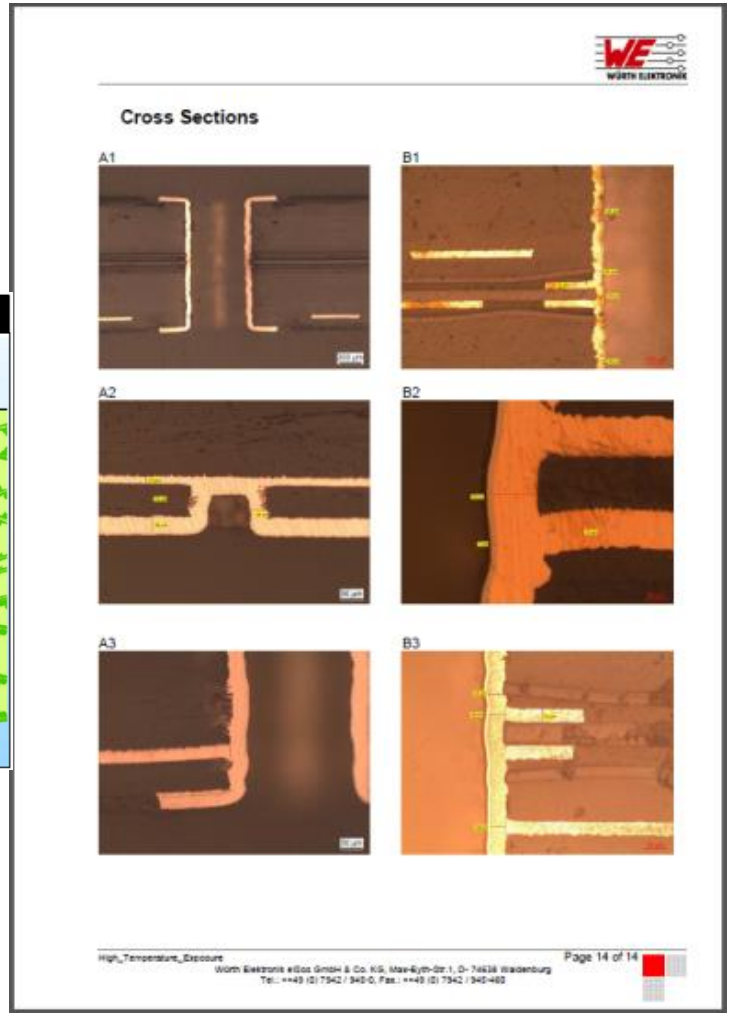


Life Cycle of a Printed Circuit Board Production

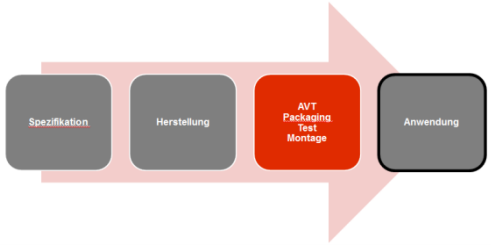




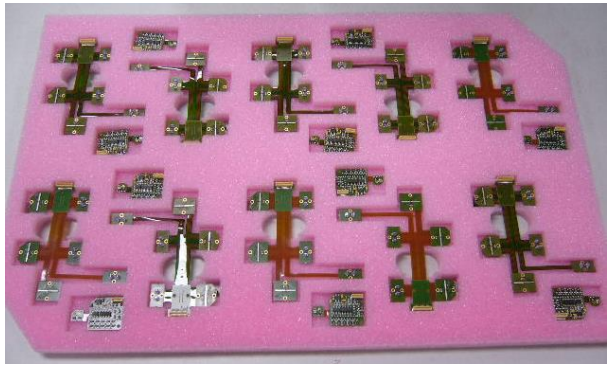


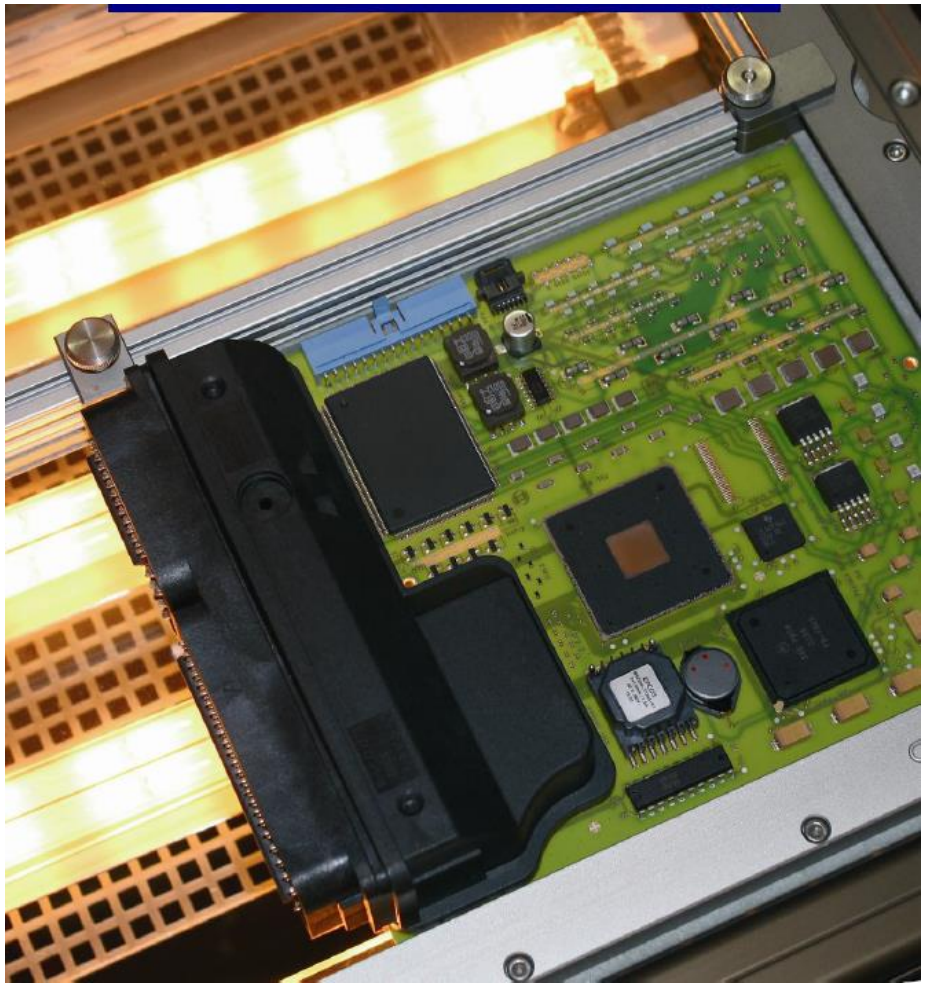


Life Cycle of a Printed Circuit Board
Further Processing

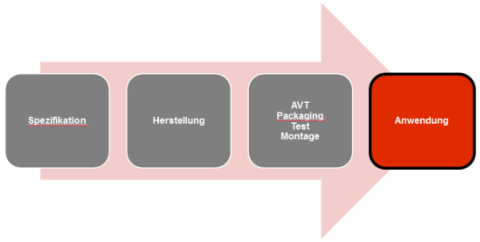


- Component Assembly
- Soldering
  - Wave / Reflow / selectiv / Hand
- Cleaning
- Test
- Separation
- Coating
- Storage
- Transport





Life Cycle of a Printed Circuit Board Usage



WÜRTH ELEKTRONIK

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

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

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

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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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 SubstrateBoards
- 2.6.23 Test Procedure for Steam Ager Temperature Repeatability
- 2.6.26 DC Current Induced Thermal Cycling Test

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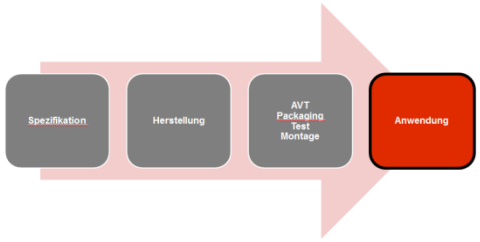
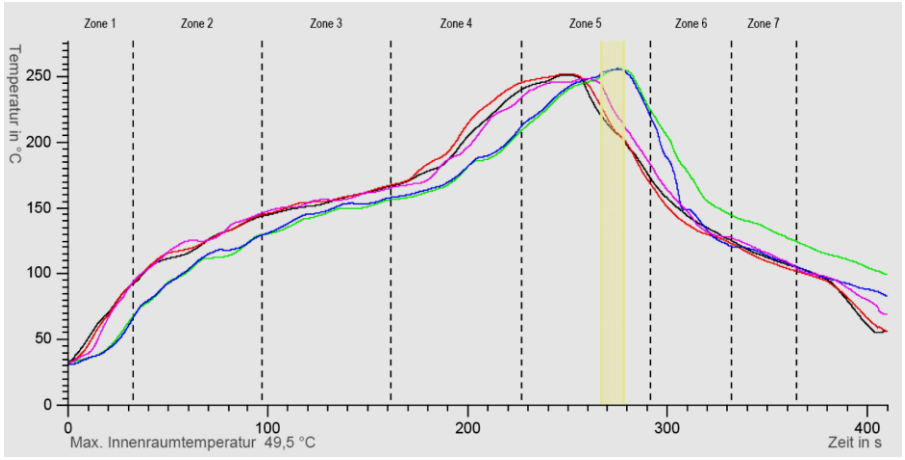
IPC-TM-650
TEST METHODS MANUAL

Life Cycle of a Printed Circuit Board Usage

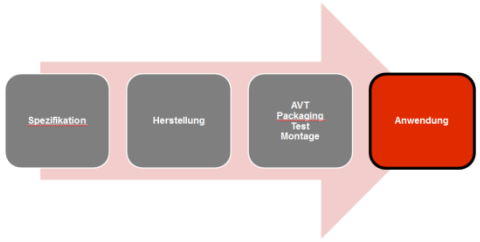


Reliability Testing „Bare Board“

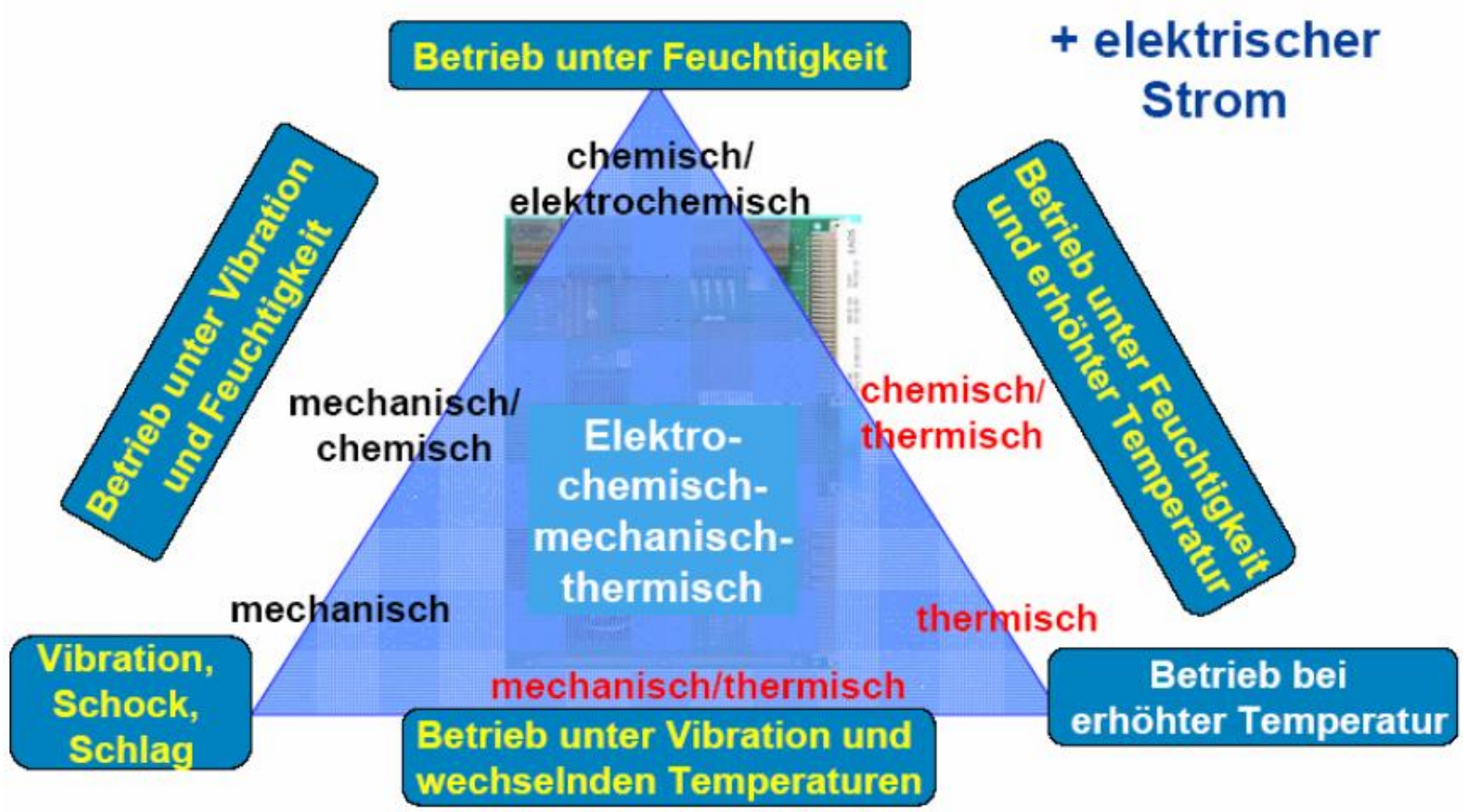


- always with „Pre Conditioning“
  - Drying
  - Reflow / Wave / selectiv / Hand
- High Temp storage (1.000h @ 125°C)
- Thermal Cycling (-40°C …. 125 / 140 / 150°C)
- IST / single via test
- Humidity storage (60°C @ 90% r.F.)
- E-Corrosion (100V / 40°C / 93% r.F.)
- SIR (Surface Isolation Resistance)
- CAF (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

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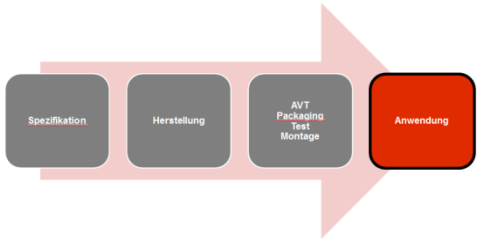
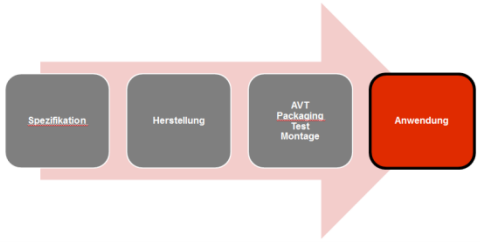


System Reliability Testing

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

Life Cycle of a Printed Circuit Board Usage



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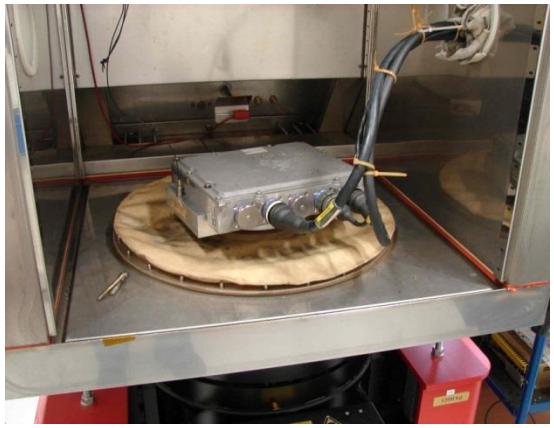

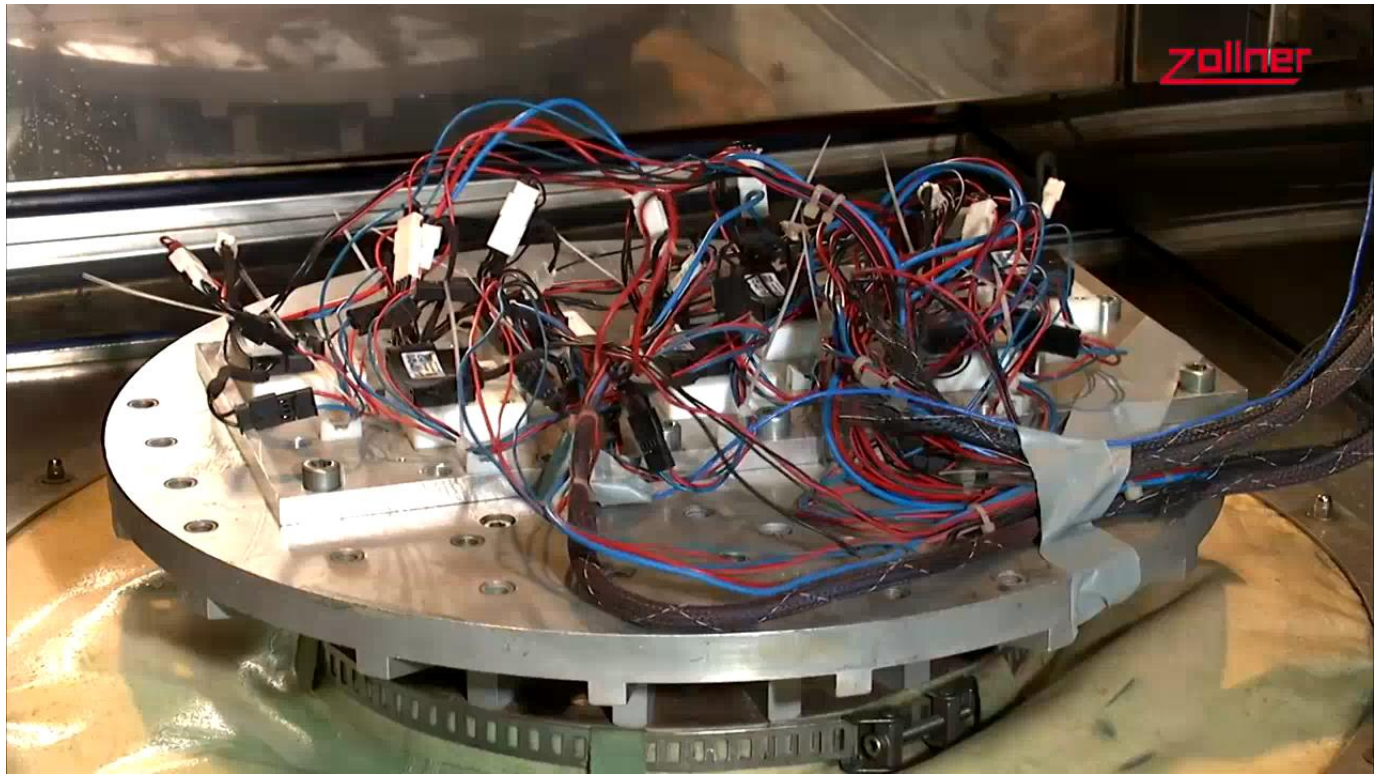

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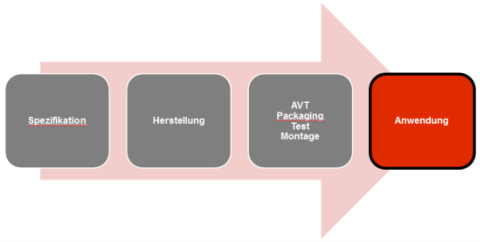

System Reliability Testing

- EMC
- Heat management, hot spot Analysis
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Falling Test from 50cm heigth on concrete slab

Content

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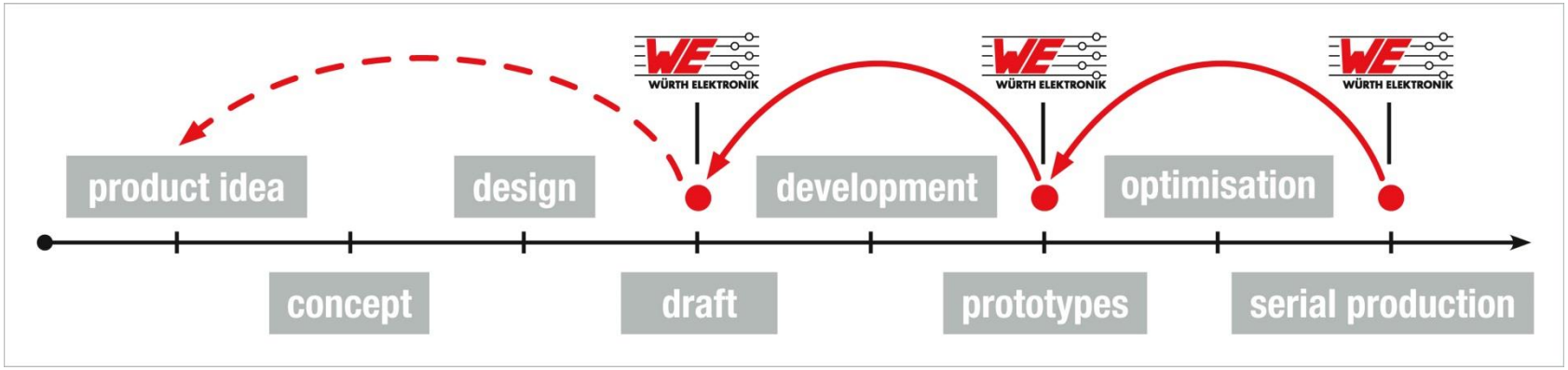
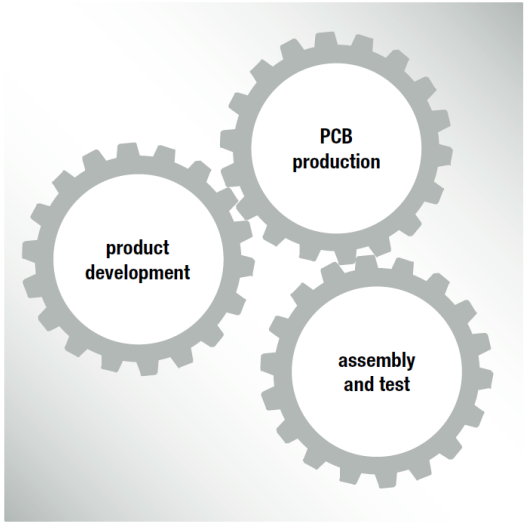
2. Life cycle of a printed circuit board
3. **How to set the screws to design robust PCBs**

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

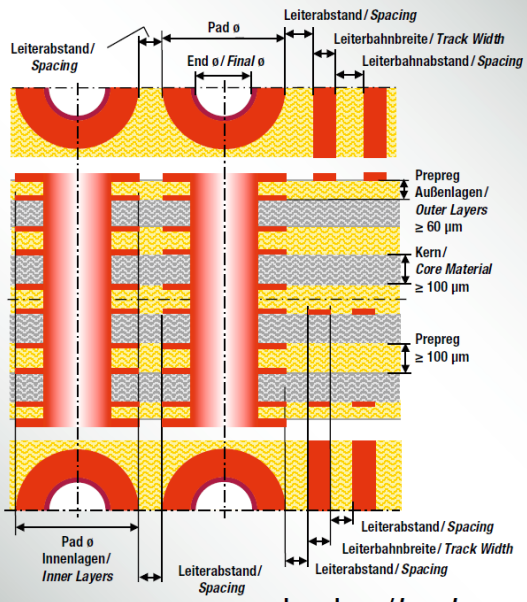


➔ There are a lot of dependencies and feedbacks!

How to set the screws robust Design

Basic Design Guide

Außenlagen / *Outer Layers*



Innenlagen / *Inner Layers*

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

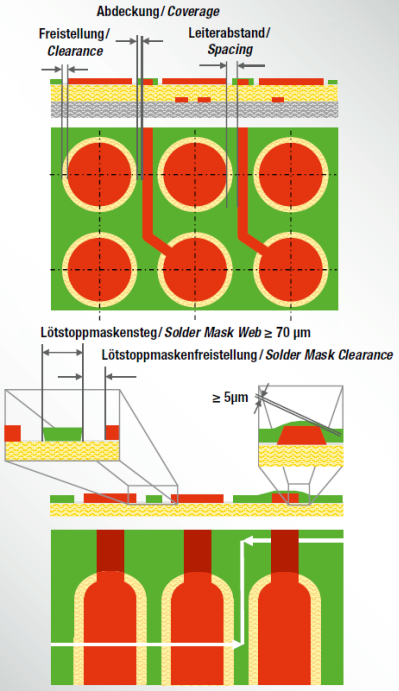
Kupferend-schichtdicke / *Final Copper Thickness*	Leiterbahn-breite / *Track Width*	Leiter-abstand / *Spacing*
ca. 50 µm > 33.4 µm (IPC-6012)	**100 µm**	**100 µm**
70 µm	125 µm	160 µm
105 µm	150 µm	225 µm
ca. 25-30 µm 1)	75 µm 1)	75 µm 1)

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 / ½ oz/ft²	**100 µm** 75 µm 1)	**100 µm** 75 µm 1)
35 µm / 1 oz/ft²	**100 µm**	**100 µm**
70 µm / 2 oz/ft²	125 µm	150 µm
105 µm / 3 oz/ft²	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.

Lötstoppmaske / *Solder Mask*



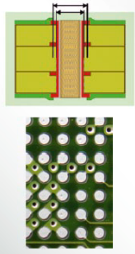
Lötstoppmaske / *Solder Mask*

	Standard	Advanced
Freistellung / *Clearance*	≥ 50 µm	35 µm
Leiterbahn-abdeckung / *Coverage*	50 µm	40 µm
Lötstopp-maskensteg / *Solder Mask Web*	≥ 70 µm	
Viafreistellung / *Via-Opening*	Siehe Tabelle vorherige Seite / *See table previous page*	

Fertigung ohne Viafreistellung 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*	Lötstoppmasken-freistellung / *Solder Mask Opening*
0.60 mm	**Standard / *Preferred***	0.35 mm	**0.25 mm**	+0.10 / -0.05 mm	≥ 0.80 mm	≥ 0.35 mm
0.55 mm		0.30 mm	**0.20 mm**		≥ 0.75 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**		≥ 0.70 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		≥ 0.70 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*	≥ 0.23 mm
Abstand Kupfer zu Kerbfräskontur / *Copper clearance to scored board edge*	≥ 0.45 mm Für LP Dicke 1.60 mm / *For Board Thickness 1.60 mm*
Abstand Kupfer zu NDK Bohrung / *Copper Clearance to NPT Hole*	≥ 0.25 mm Umlaufend / Circumferential

Sonstige Design Parameter / *Other Design Parameters*

Bestückungs- und Servicedruck / *Legend Print* (Cu max. 70 µm)	
Strichstärke / *Line Width*	100 µm
Schrifthöhe / *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

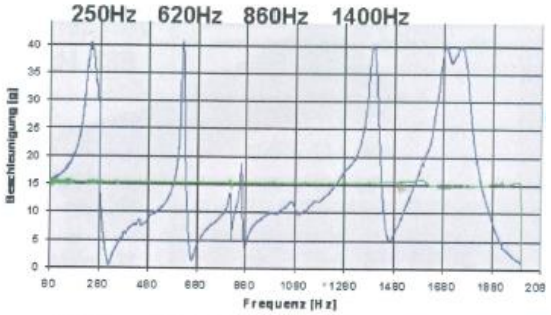


Abbildung 12-15: Experimentell bestimmte Eigenfrequenzen und Modell der simulierten Baugruppe

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.

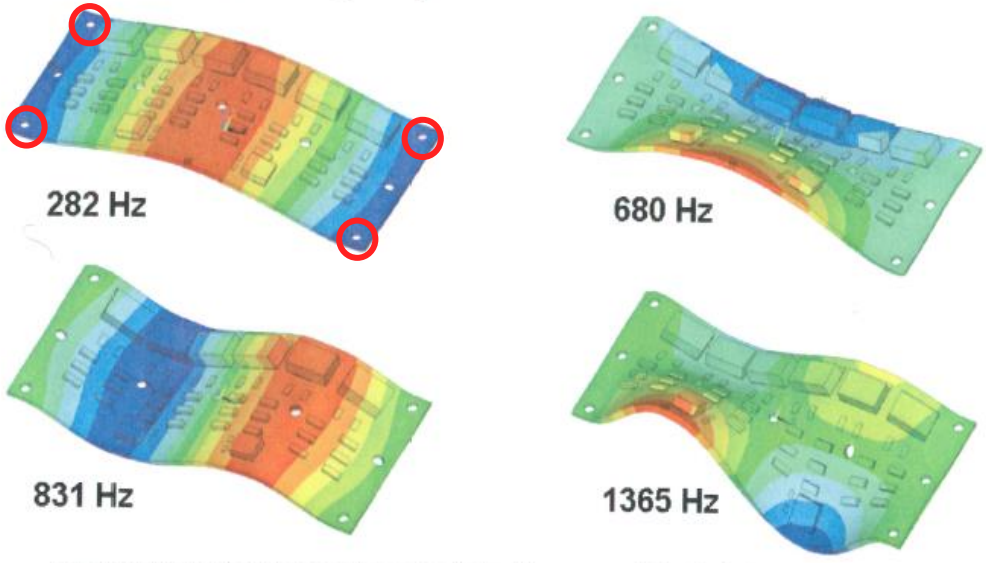
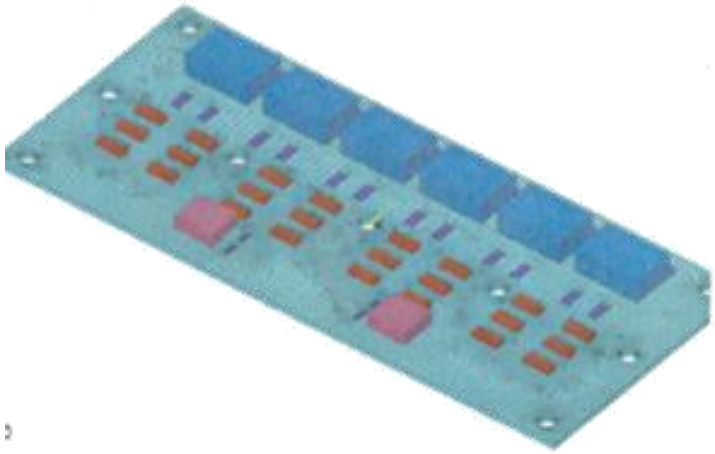


Abbildung 12-16: Eigenfrequenzen der simulierten Baugruppe mit vier Befestigungsschrauben



9 screws:

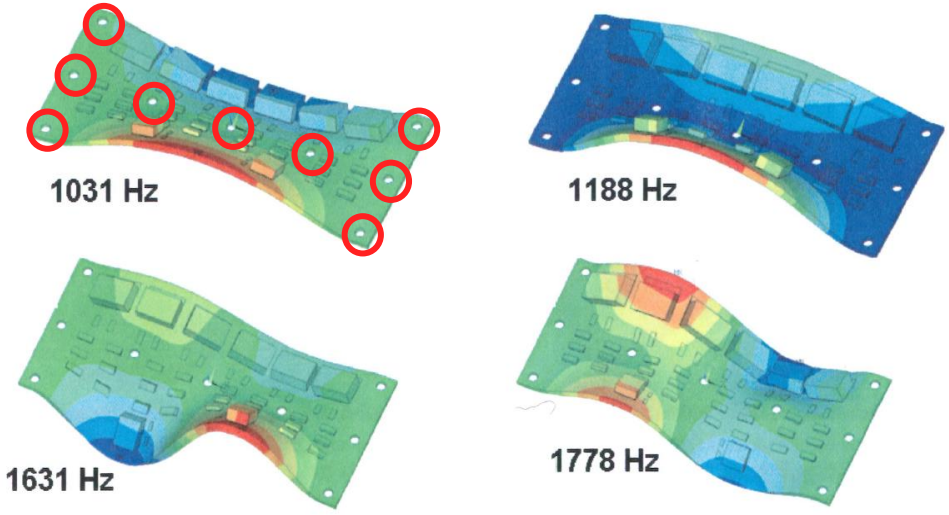
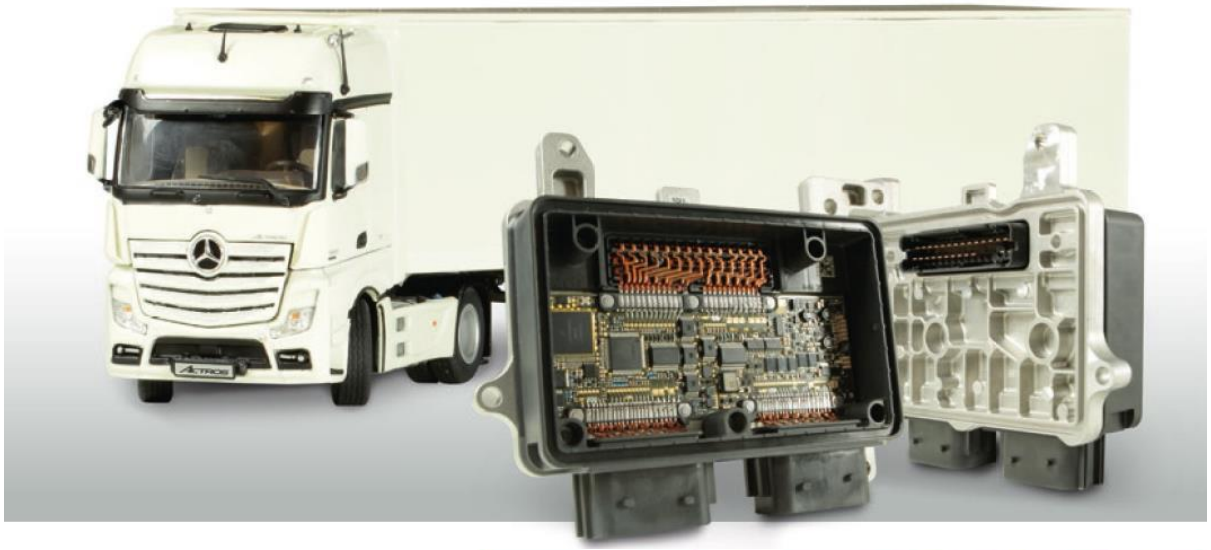


Abbildung 12-18: Berechnung der Eigenfrequenzen der simulierten Baugruppe mit neun Befestigungsschrau-

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

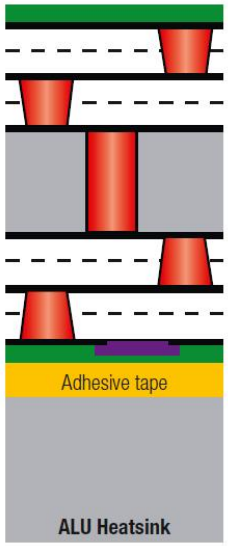
The printed circuit board system is used in the gearbox control in “Actros”, the flagship of Mercedes Benz’s commercial vehicle division.

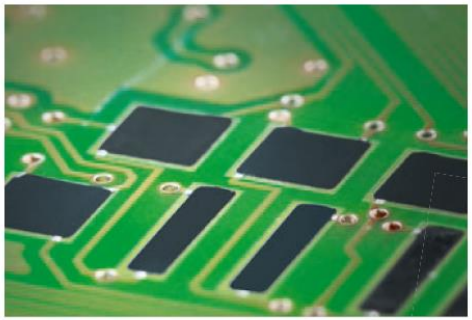
The use of HDI technology combined with printed resistors made it possible to achieve a significant reduction in the size of the printed circuit board.



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

How to set the screws
Flex-Rigid

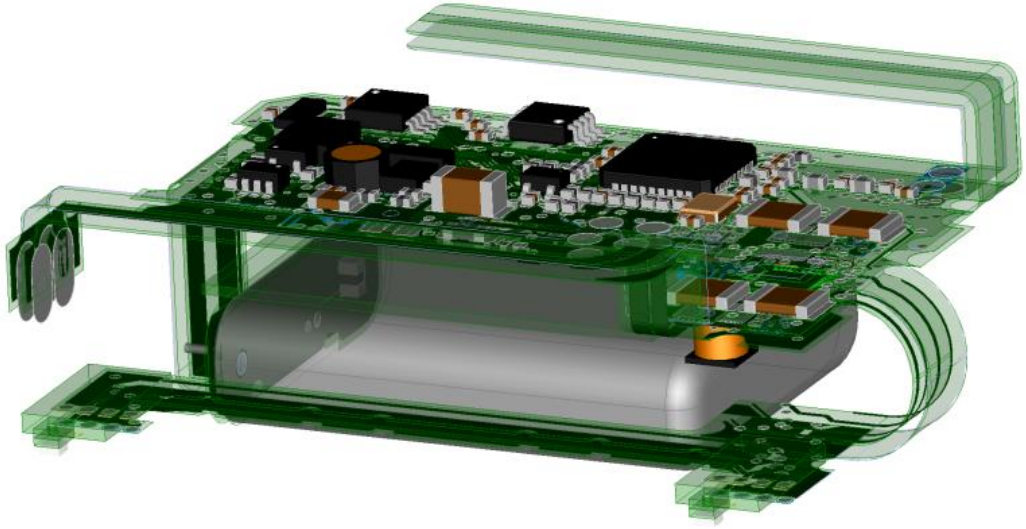
WITTENSTEIN electronics

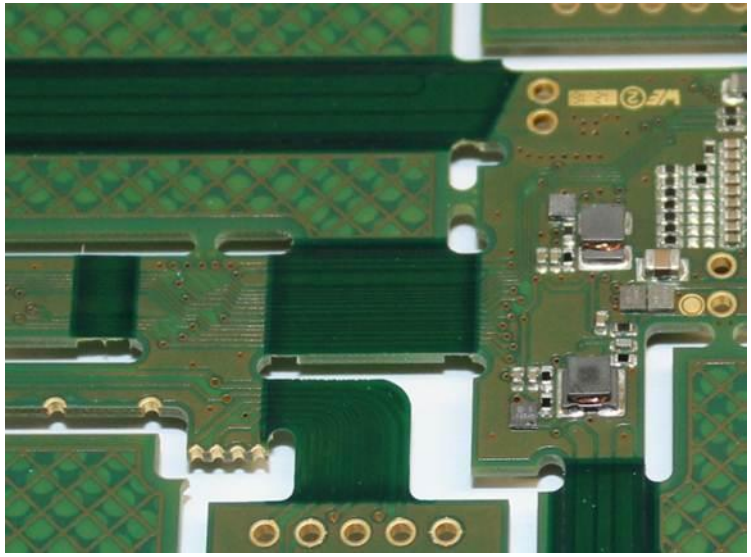
WÜRTH ELEKTRONIK

- 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

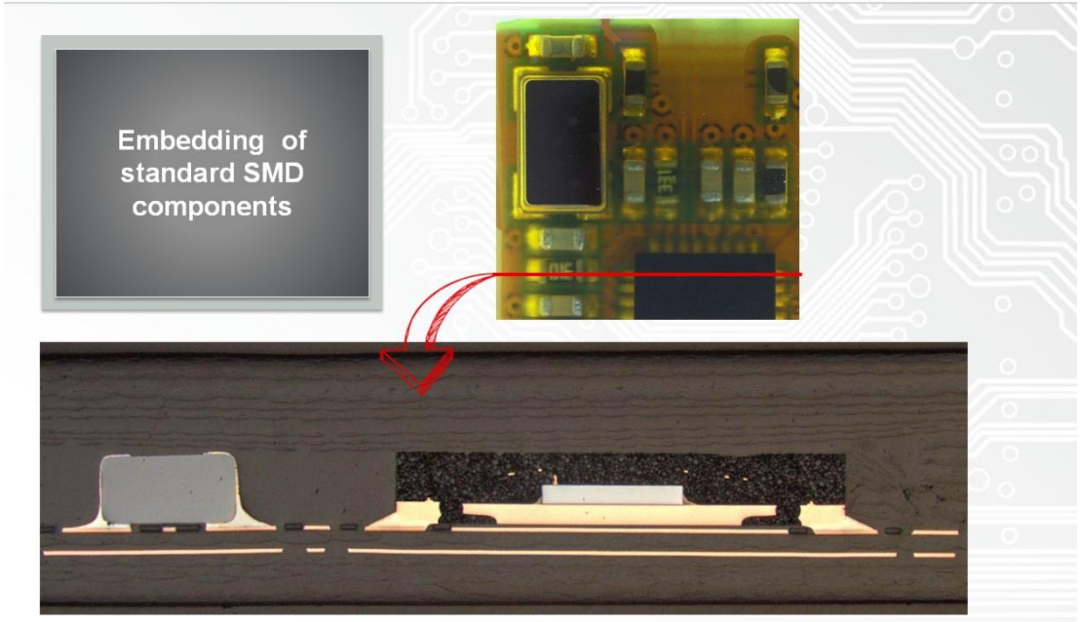
➔ specific advantage due to low physical mass in case of shock and vibration

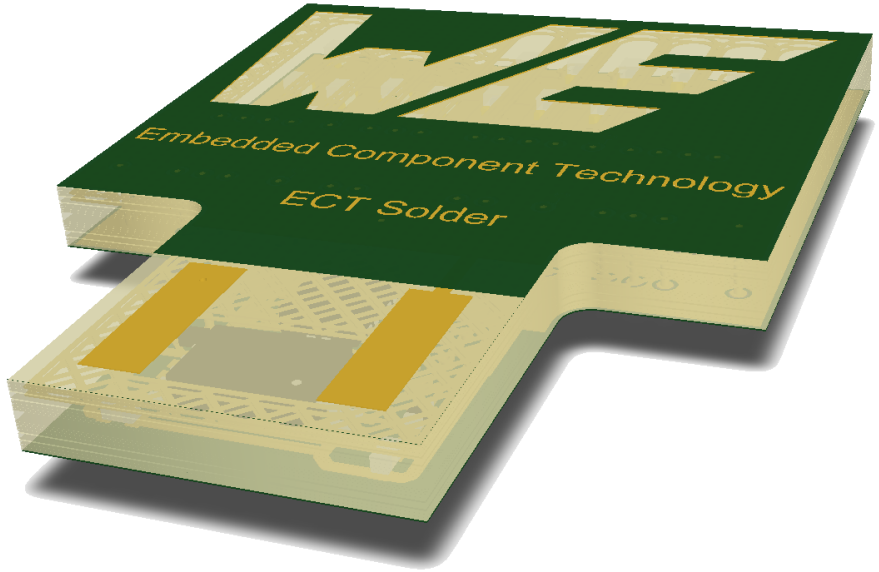




How to set the screws
embedded Components

embedding advantages
- ➔ high miniatrisation
- ➔ 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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