HIGH PERFORMANCE PCB SYSTEM

Miniaturisation: HDI & Thermal Management & **Printed Polymer**

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

HIGHLY RELIABLE PRINTED CIRCUIT BOARDS AND DEVICES IN AUTOMOTIVE ELECTRONICS

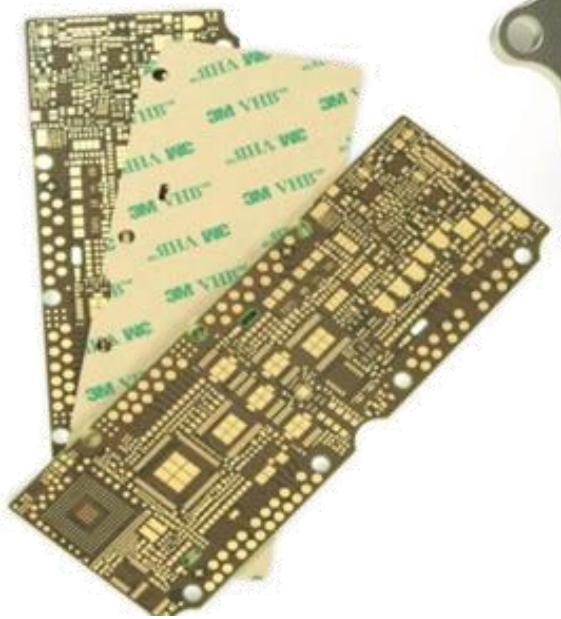
Based on an Example of a High Performance PCB System

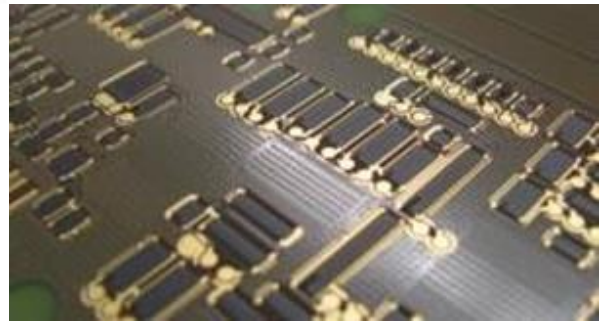
1. Miniaturisation
   - HDI Technology
   - Reliability and Verification by IST

2. **EmbR – printed embedded resistors**
   - **Performance – Tolerances**
   - **Reliability**

3. Thermal Management
   - Thermal vias
   - Heat Sink
   - Thermal Simulation

4. Costs
   - PCB replaces Ceramics





PRINTED RESISTORS

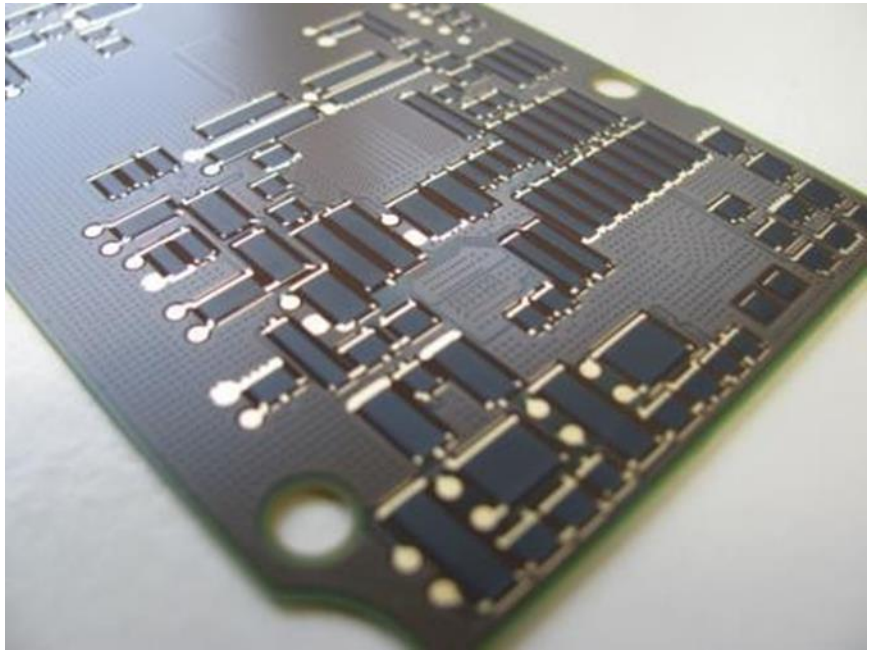
Printed Polymer in General

Applications:

- Pull-up and Pull-down resistors
- Voltage dividers
- General circuit resistors
- High reliability requirements

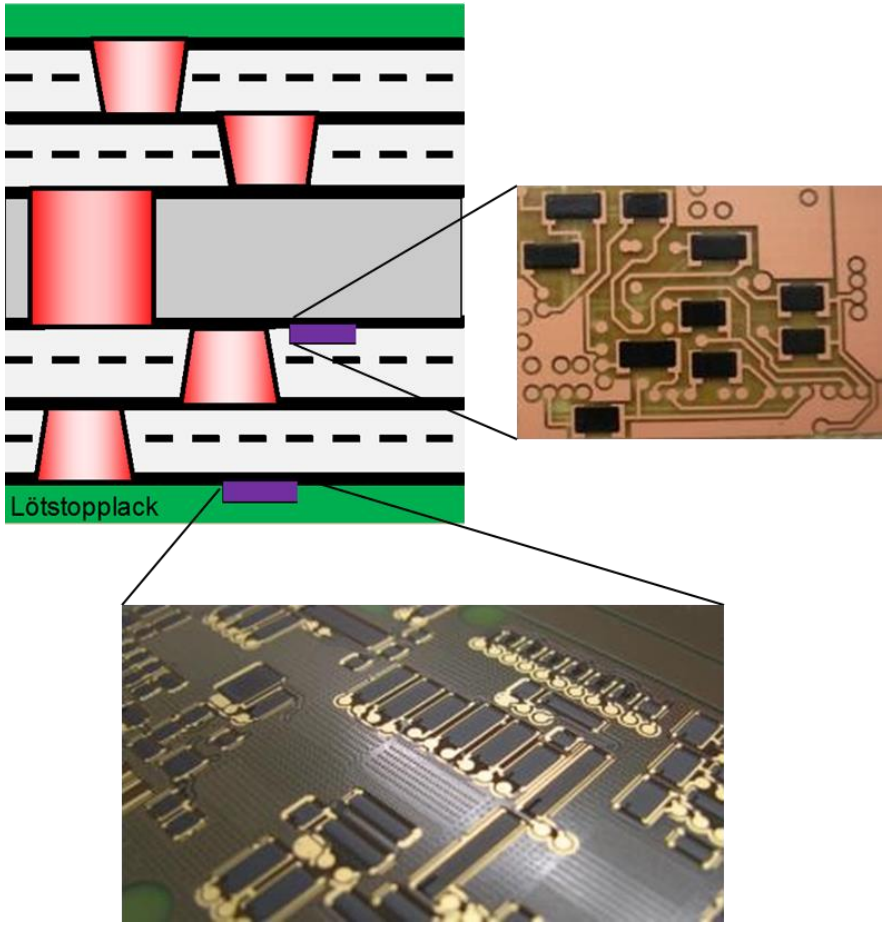
Facts:

- Pastes with different resistance values
- Tolerance printing process R ± 30 % (standard)
- Tolerance after laser trimming ± 5 % for the entire product lifetime
- Resistor values from 50 Ω to 1 MΩ (standard)
- Low temperature coefficient (≙ resistance change) ± 300 ppm/K
- Standard size min. 1,75 mm × 1,25 mm
- Thickness of printed resistors approx. 20 µm
- Design Guide available



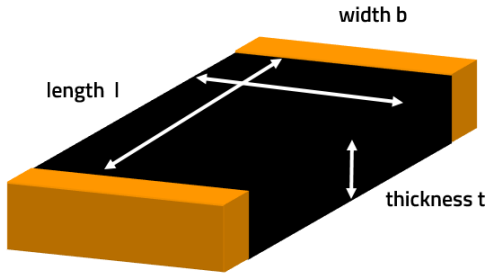
PRINTED RESISTORS

Printed Polymer in General



- Würth Elektronik has many years of experience with printed resistors using polymer pastes (also known casually as "carbon").
- EmbR: Miniaturization potential through embedded resistors
- Reliability advantages
- Dimensioning of the resistors

$$R = \frac{\text{length l}}{\text{width b}} \textbf{ x ink resistance } \rho$$



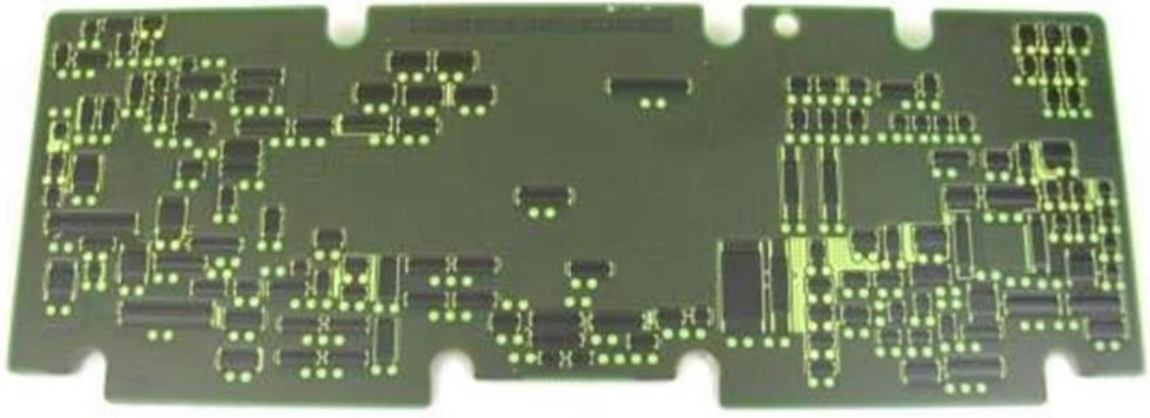
The ink resistance ρ takes into account the square value of the paste and the resistance thickness

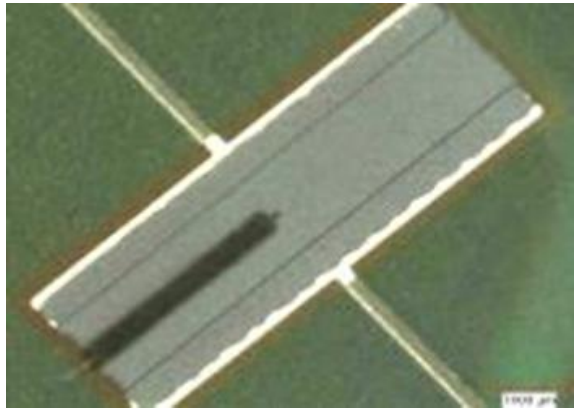
PRINTED RESISTORS

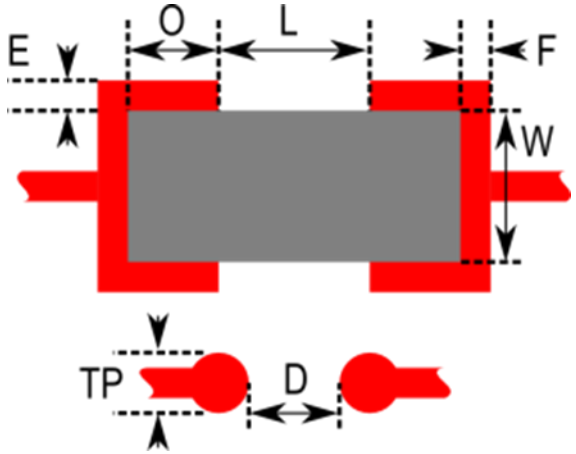
Laser Trimming

Tolerance of resistance value

- Without Laser Trimming maximum ± 30 %
- With Laser Trimming :
  - Up to a maximum of ± 1 % after print
  - Over the entire product lifetime: ± 5 %







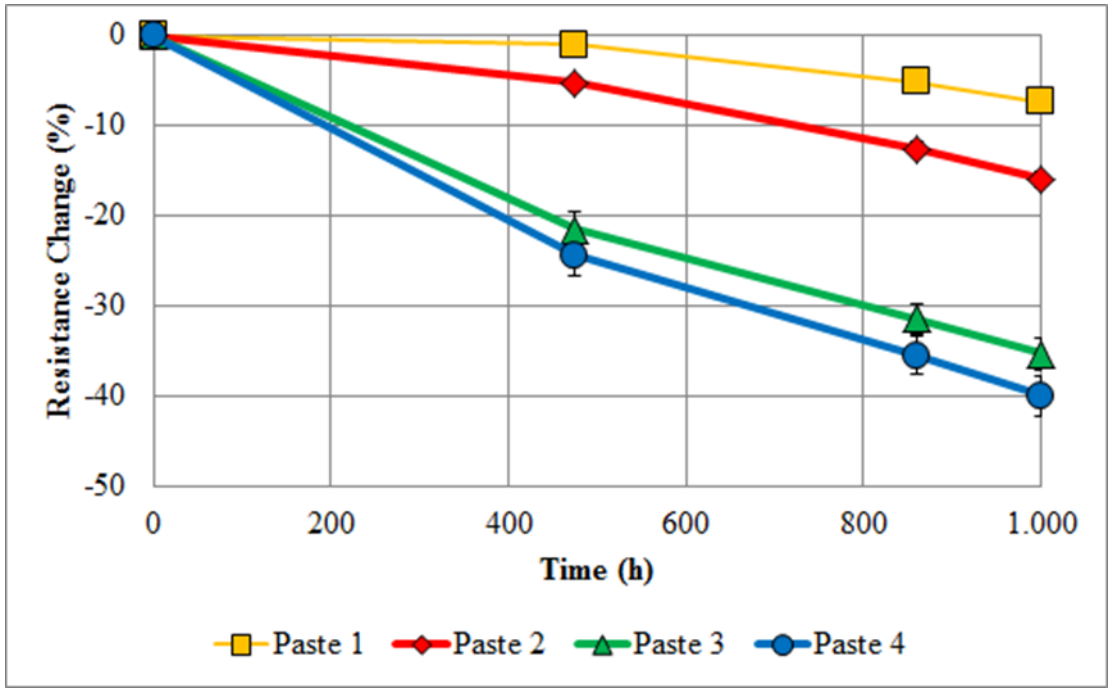
Traceability

- The laser trimming process can also enable perfect traceability by using binary coding on additionally designed resistors.

PRINTED RESISTORS

Choice of Pastes

- Resistance change of 4 pastes @ 155 °C operated with maximum power:



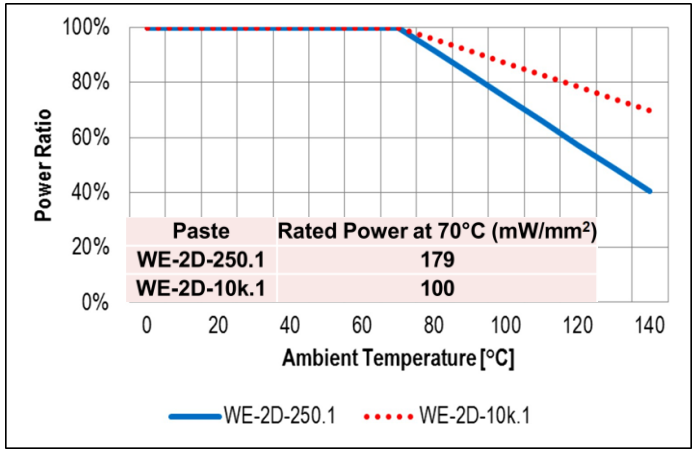
1. Step: Extensive investigations were necessary, in order to determine which pastes could fulfil the demanding requirements of the complete system.

The stability of the resistance values under temperature influence was a particular challenge for many paste systems.

PRINTED RESISTORS

Tests

- Power Derating
  Aim of tests is to determine the maximum electrical load of the resistor, without irreversibly damage the resistor. Currant is constant.



Paste	Rated Power at 70°C (mW/mm²)
WE-2D-250.1	179
WE-2D-10k.1	100

- Result: Even at 140 °C the power dissipation is far above the desired 50 mW/mm²

- TCT Thermal Cycle Test (conventional)
  - -40 °C / +155 °C, 1.000 Cycles
  - Transfer time max. 20 s, dwell time 15 Minuten
  - Resistance change max. 2 %

Results

- Passed 4000 cycles at +125 °C without failure.
  - Thermal expansion is comparable to the base material.

- The performance of the printed resistors is at least as good as comparable soldered resistors or other embedded technologies.

PRINTED RESISTORS

Qualification of the System Resistors and Voltage Dividers

- Extract of the qualification program

Test	Test method	Procedure	Max. Deviation Single Resistor
Temperature Coefficient of Resistance (TCR)	DIN EN 60115-1:2012-04, 4.8	+20 / -40°C ...+20°C / +140°C	- 700 …– 300 ppm/K
High Temperature Exposure (HTE)	MIL-STD-202 Method 108	**1000 h @ T_A = 150° C unpowered**	+/- 3%
Moisture Resistance	MIL-STD-202 Method 106	25°/65°, 95% rH, 3 cycles in 24h, 10 days, unpowered	+/- 2%
Biased Humidity	MIL-STD-202 Method 103	1000 h, 85°C, 85% rH, 10 % of operating power (50 mW/mm²)	+/- 3%
High Temperatur Operating Life (HTOL)	MIL-STD-202 Method 108	1000h HTE, then **1000 h HTOL @ T_A = 140° C at rated power**	+/- 20%
Resistance to Soldering Heat	IPC-TM650	5 times 260 +/- 5 ° C, 10 +/- 1 s	+/- 2 %

- The same tests have been done by customer on the assembled units.

PRINTED RESISTORS

Qualification of the System

- Preparation, measurement setup
  High Temperature Operating Live Test (HTOL)

PRINTED RESISTORS

Annual Re-Qualification of the System Resistors and Voltage Dividers

Requalifizierung: Auswertung HTOL und TWT

WÜRTH ELEKTRONIK

Kopfdaten: Prüfdatum: 27.07.2015

Kunde: WABCO
Typ: TCNG
geprüft von: A. Reeb
Labor SH

Leiterplatte
WE- Nr.: 396638
FA-Nr.: 577887
LK-Nr.: 3013316402

Aluminiumbauteil
Teil-Nr.: 4463533134
Charge / KW: 25 / 30
LS-Nr.: 82513361

PDSS- Spezifikation: PDSS Stand: 10.03.2014

High Temperature Operational Life (HTOL)
1000h bestromt bei 140°C
Toleranz (Max. Änderung)
Einzelwiderstände: +- 20 %
Spannungsteilerverhältnis: +- 0,5 %

Thermal Shock (TWT)
1000 Zyklen bei -40°C/+155°C
Toleranz (Max. Änderung)
Einzelwiderstände: +- 2 %
Spannungsteilerverhältnis: +- 0,5 %

Prüfergebnis HTOL

Getestete Baugruppen: 5
(Panel-ID/PCB-ID)
11 / 9
5 / 17
9 / 10
14 / 5
3 / 13

Fehlerliste:
Widerstände außerhalb der Toleranz

	GUT	FEHLER
Einzelwiderstände:	855	0
Spannungsteiler:	80	0

Resultat:

Einzelwiderstände	Spannungsteiler
i.O.	i.O.

Prüfergebnis TWT

Getestete Baugruppen: 5
(Panel-ID/PCB-ID)
10 / 12
8 / 18
10 / 6
12 / 9
9 / 7

Fehlerliste:
Widerstände außerhalb der Toleranz

	GUT	FEHLER
Einzelwiderstände:	855	0
Spannungsteiler:	80	0

Resultat:

Einzelwiderstände	Spannungsteiler
i.O.	i.O.

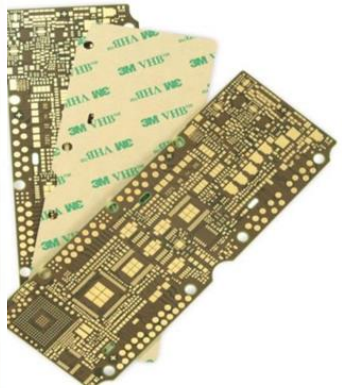
COST COMPARISON

Highly Reliable Printed Circuit Boards and Devices in Automotive Electronics

Ceramics

- High temperature resistance

FR4



- High functionality
- Highest packaging density
- Cost-efficient

COSTS - CIRCUIT BOARD GENERAL

Highly Reliable Printed Circuit Boards and Devices in Automotive Electronics

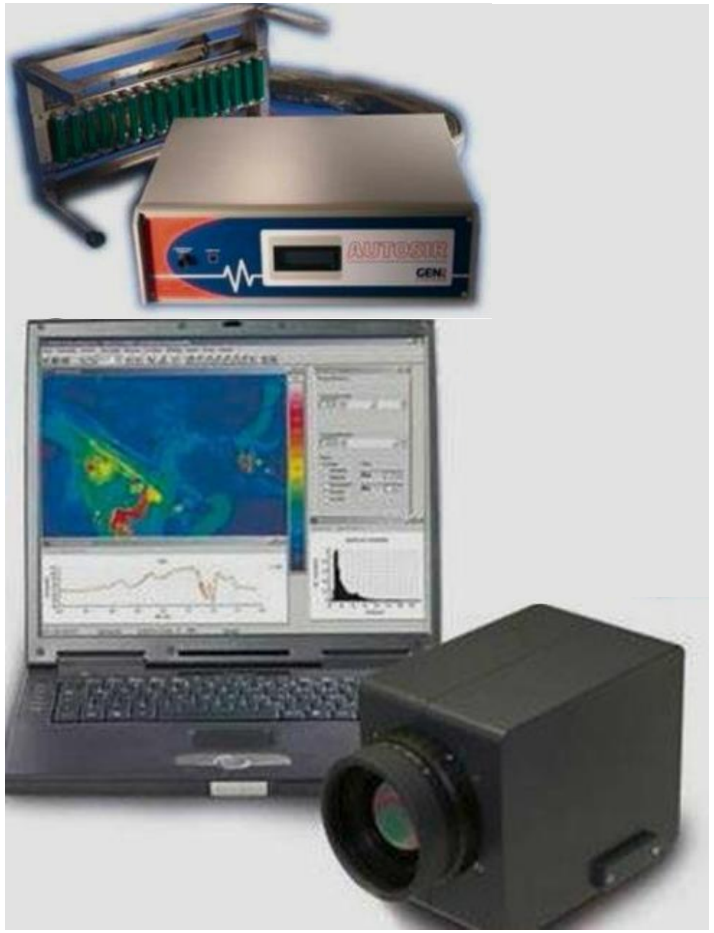
- Main advantage FR4 PCB: Production in the "large" production panel

PCB Cost drivers		FR4 System
PCB size	+	Relatively small size
Unfavourable delivery panel / X-Out	++	Single PCB
Complex build-up	≈	Two lamination processes
Material costs	++	Only one core, four prepregs Tg 170°C
Mechanical drilled Vias	++	Only buried vias in a thin core
Number of plating steps	≈	Only three „simple“ plating processes
Complex contour machining	+	Simple milling contour

REQUIREMENTS TO PCB MANUFACTURER

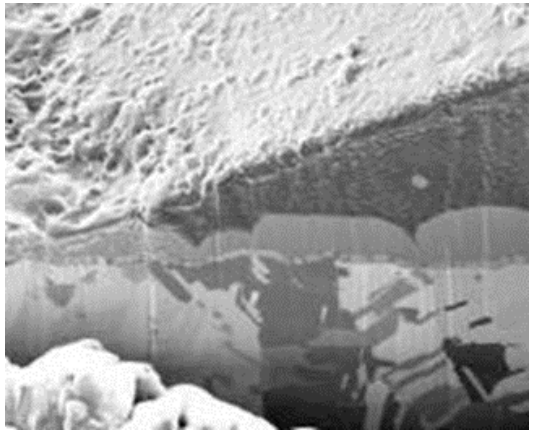
Highly Reliable Printed Circuit Boards and Devices in Automotive Electronics

- Metallurgic analysis
- Inspection acc. to IPC-6012 Class 3
- Stereo/optical microscopy (VIS/UV)
- IR camera
- Ionograph
- CAF Measurement equipment
- Climate test chamber
- Thermal Cycle Test
- IST
- High Current Impulse Test
- Pressure Cooker Test
- **X-Ray fluorescense spectroscopy**
- **Thermal simulation**
- **Testequipment for**
  - **HTOL**
  - **Power Derating**



Collaboration with instituts

- REM/EDX
  (Uni Basel, EMPA Zürich)
- XPS (IGB Stuttgart)
- Wetting tests (ISIT Itzehoe)
- Ultrasonic microscopy
  (ISIT Itzehoe)
- FIB (Uni Basel, EMPA Zürich)



SUMMARY

Highly Reliable Printed Circuit Boards and Devices in Automotive Electronics

- Miniaturisation through
  - HDI Technology
  - Printed resistors (Printed Polymer)
- Highest reliability using a thin HDI build-up without PTH vias
- A technology combination of
  - HDI,
  - Printed resistors and
  - Optimized Thermal Management

  can enable a cost effective substitution of a ceramic solution by a FR4 - PCB.
- A competent and broadly based PCB manufacturer can realize such a task.
- System solutions will be an essential part of collaboration / range of services in the future.

THANKS FOR YOUR ATTENTION

High Performance PCB System
Miniaturisation: HDI & Thermal Management & Printed Polymer