

PCB embedding of Magnetic Material for Inductor-based Applications

iMaps DPC 2020



International Microelectronics
Assembly & Packaging Society

Gerald Weis

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- **Introduction**
- Basics and Aim
- Embedding of magnetic material FR4
- Applications
- Summary and Conclusion

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A world leading high-tech PCB & IC substrates company

High-end interconnect solutions

for
Mobile Devices, Automotive, Industrial,
Medical Applications and Semiconductor
Industry

Outperforming
market growth
over the last
decade

1

high-end PCB producer
worldwide *

Among the top
PCB producers
worldwide

€ 1bn

revenue in
FY 2018/19

~ 10,000
Employees**

Efficient global production
footprint with

6

plants in Europe and Asia

* For CY 2018
Source: Prismark

** For AT&S FY 2018/19

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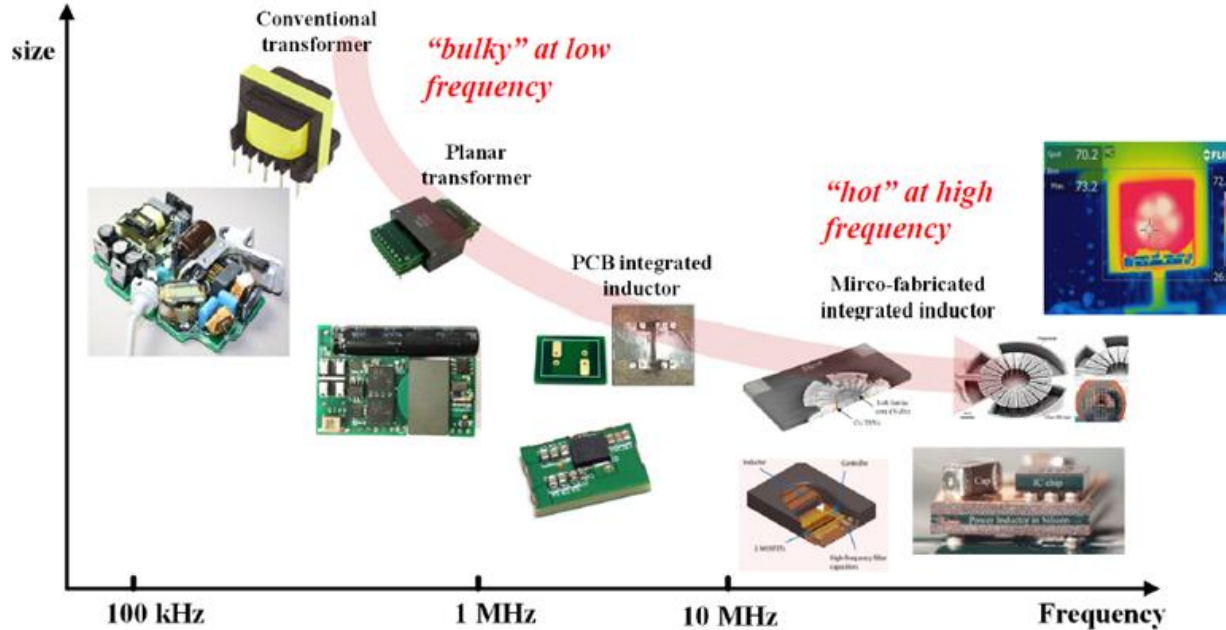
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Evolution of PCB based Inductors or Transformers



Source:

Zo Ouyang, "High Frequency Planar Magnetics for Power Conversion," ECPE Tutorial, Technical University of Denmark, Copenhagen, Sep. 2018.

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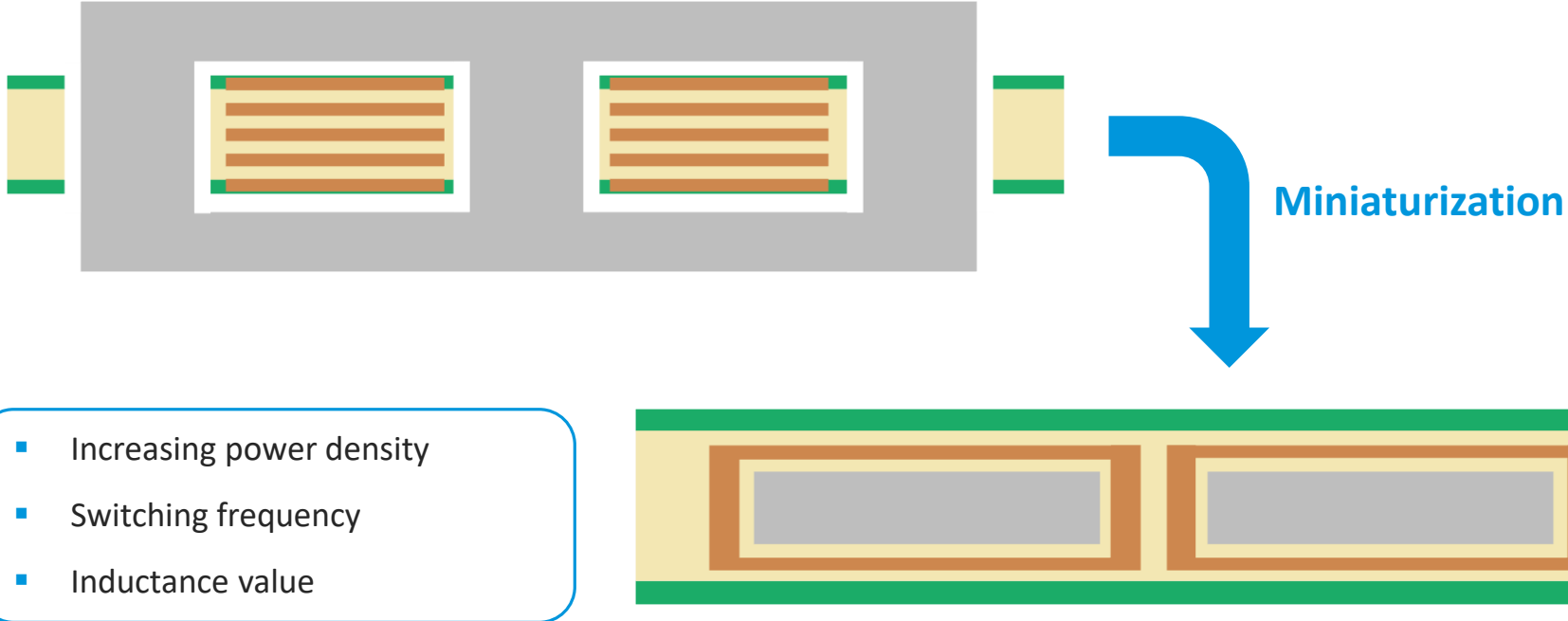
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Why – What is the advantage of this technology?



- Increasing power density
- Switching frequency
- Inductance value

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Part of AT&S Product Portfolio



ECP®: Embedded Component Packaging



Panel level packaging
(embedded component in laminate)

Embedded Component Packaging allows to embed active/passive components (e.g. wafer level dies) within the layers of a PCB – contributes to miniaturization.

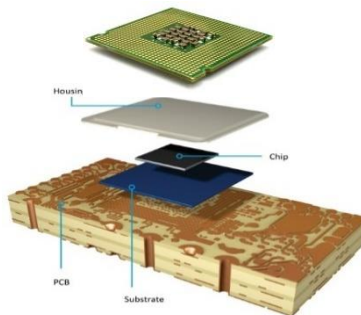
Production site

Leoben, Shanghai

Applications

Devices such as smartphones, tablets, digital cameras and hearing aids

IC substrates

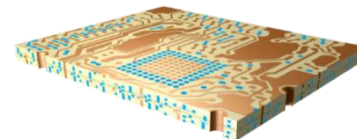


IC substrates serve as interconnection platform with higher density (Line/Space < 15 micron) between semiconductors (Chips) & PCBs.

Chongqing

High-end processors for
Computer, Communication, Automotive, Industrial

Substrate-like printed circuit boards mSAP



Substrate-like PCBs (mSAP technology) are the next evolution of high-end HDI PCBs with higher density: Line/Space < 30 micron.

Chongqing, Shanghai

Mobile applications like smartphones

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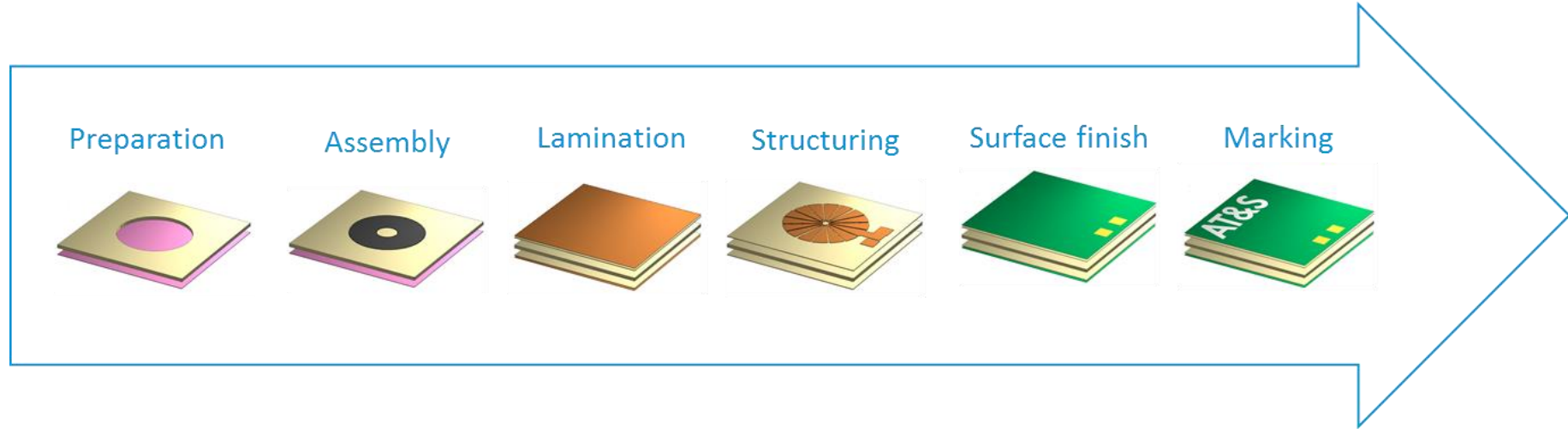
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Embedding Process in Detail



- Qualified process based on the ECP® technology
- Independent from layer count
- Can be applied to every PCB construction

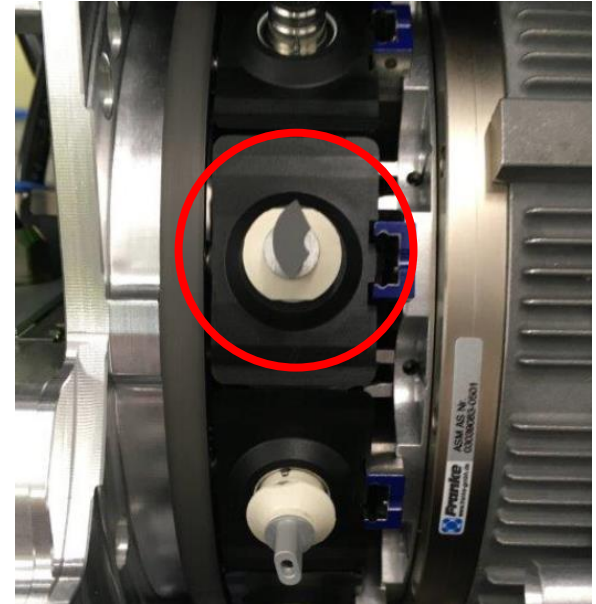
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Fully Automatic Assembly of Inlays (I)

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- Fully automated assembly for high volume production volumes
- Semi-automated setup for fast prototyping
- Assembly from tape and reel as well as tray (small volume)
- Special nozzle to optimize camera alignment and position accuracy

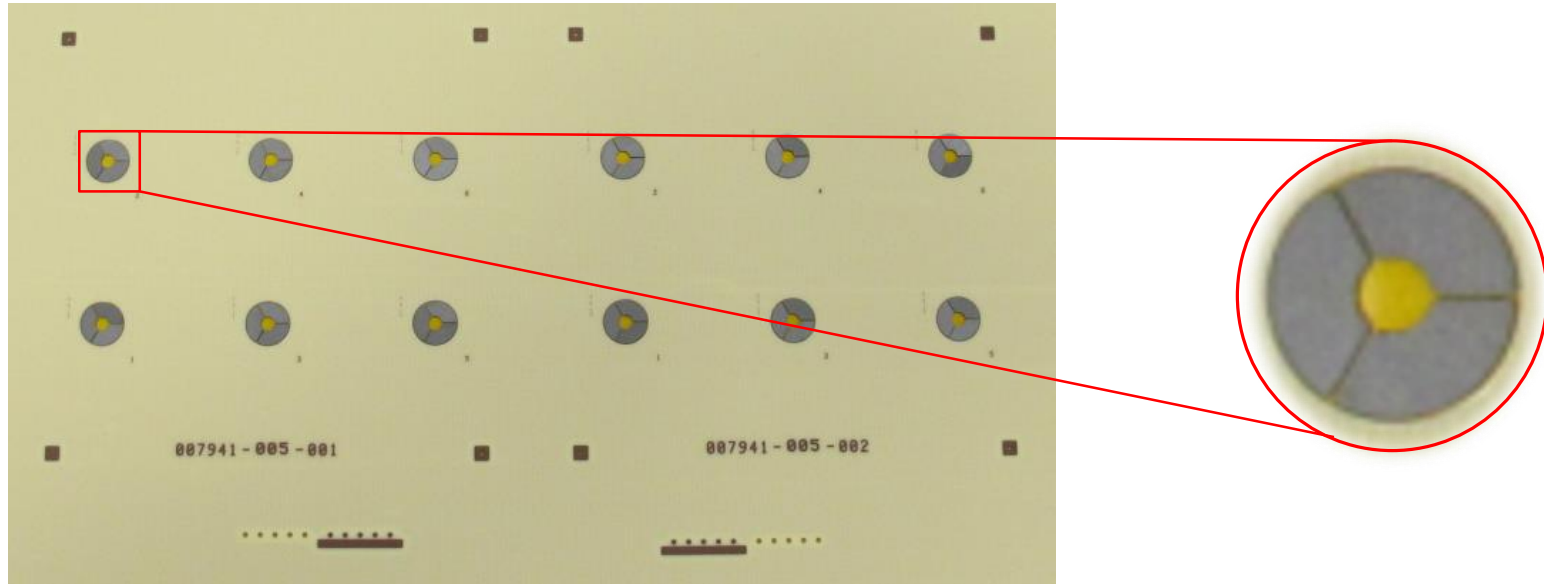


Pick up nozzle with inlay part
on assembly head

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Fully Automatic Assembly of Inlays (II)

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- Inductor demonstrator assembly
- Three parts of magnetic material as well as three air gaps to optimize magnetic behaviour

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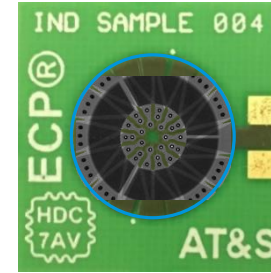
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Application Example: Inductor (I)

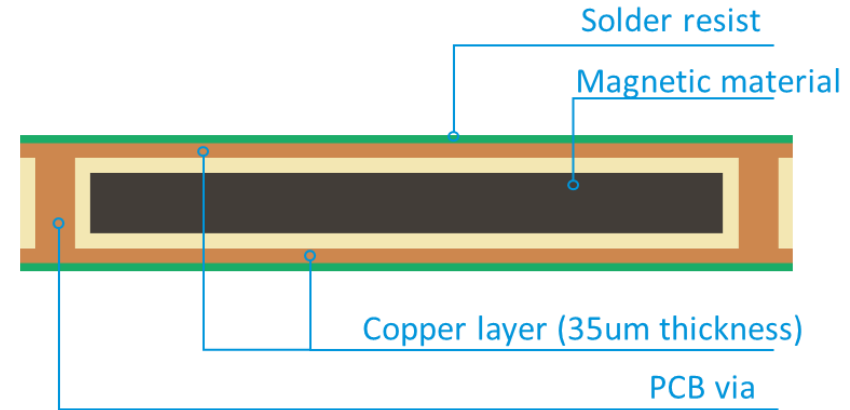
Facts

- Two layer construction
- Different thicknesses possible (used: 300 μm)
- Flexible copper height (used: 35 μm)



Demonstrator with visible X-Ray section

Geometry	Value	Unit
Inner diameter	3	mm
Outer diameter	10.5	mm
Total thickness	0.5	mm
Windings	16	turns
Outer diameter (blue circle)	12.3	mm



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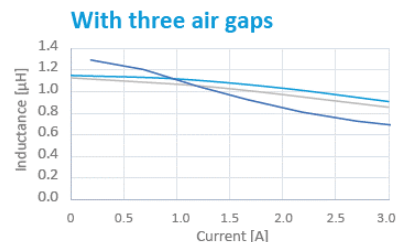
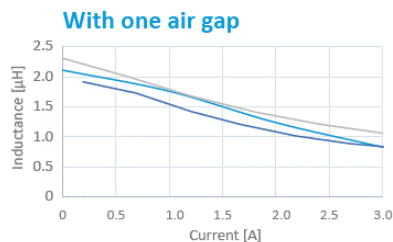
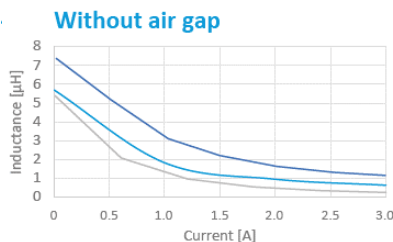
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Application Example: Inductor (II)

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Parameter	Symbol	Without air gap	With 1 air gap	With 3 air gaps	Standard SMD (2)
Inductance	L (@ 1 MHz)	5.7 μH	2.2 μH	1.15 μH	1.2 μH
Saturation current	I_{sat} (1)	300 mA	1.5 A	3.6 A	3.8 A
Rated current (DC)	I_R (@ $\Delta T = 40$ K)		2.0 A		1.9 A
DC Resistance	R_{DC} (@ 0.1 A)		79 m Ω		82 m Ω
Self-resonance frequency	f_{res}	30 MHz	40 MHz	80 MHz	75 MHz
Package size	D_I/D_O		3/10.5 mm		2.5 x 2 mm
Air gap length	l_g	-	500 μm	3 x 170 μm	-
Total thickness	h		500 μm		1 mm



(1) Inductance drops 30% @ I_{sat}
(2) Würth Electronics (74438323012)

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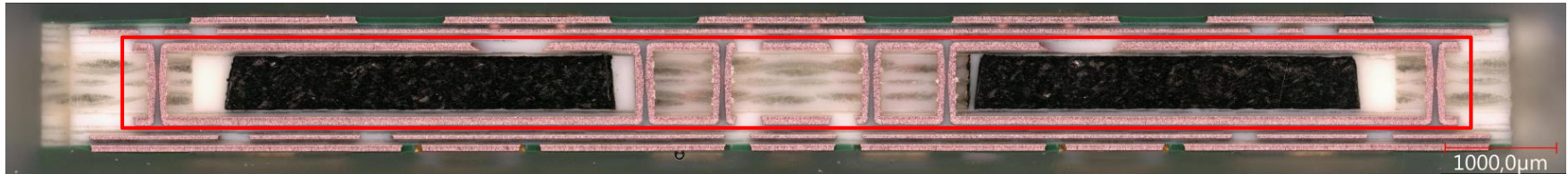
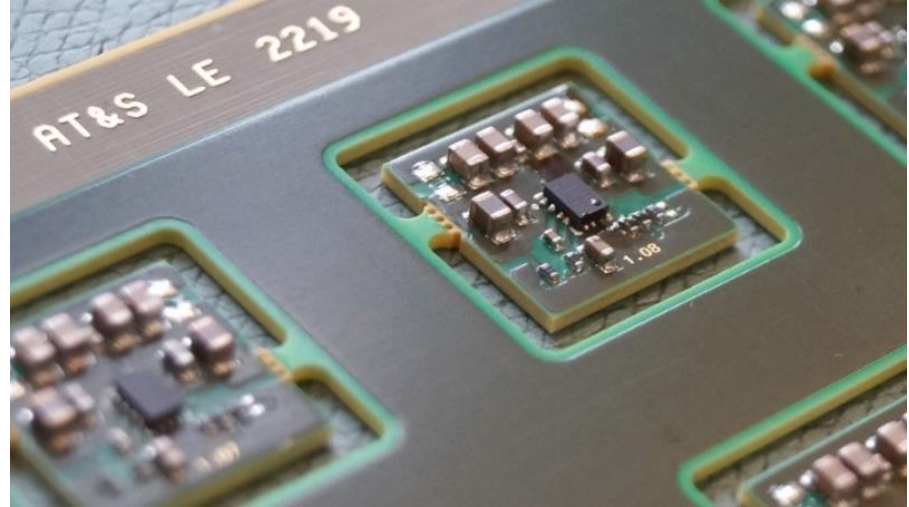
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Application Example: DC/DC converter module (I)

- Conversion from 12V to 3.3V with buried inductor
- Target: 2 μ H inductance at a current of 3 A
- Module size: 13.3 x 14 mm
- Based on 6 layers
- Overall board thickness is 1.4 mm
- Single IC solution (LMR33630)
- No components embedded
- Functional Demonstrator
- No material issues (e.g. delamination)



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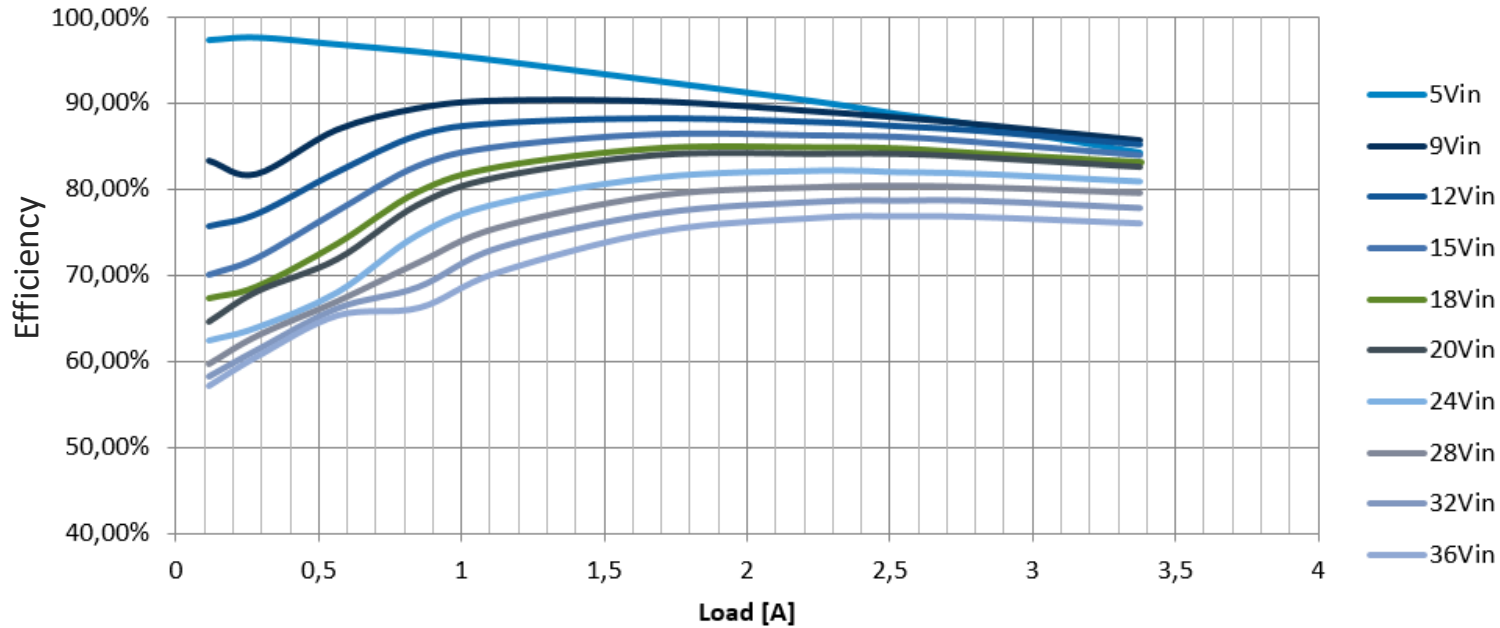
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Application Example: DC/DC converter module (II)

Converter efficiency at 5V output, 2.1MHz



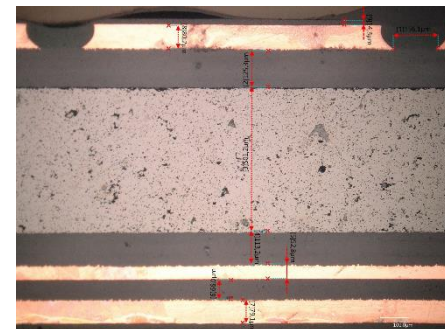
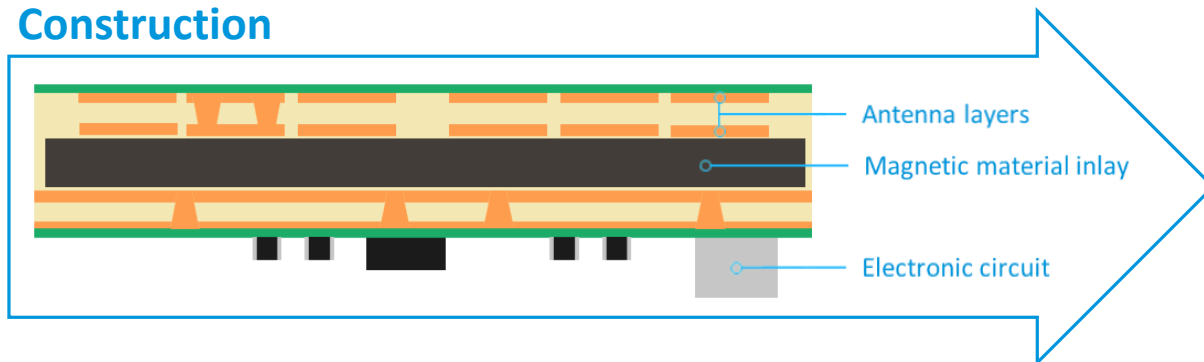
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Facts

- Handles up to 10W wireless charging power
- Proof of concept for large inlay size (50 mm x 50 mm x 500 μm)
- Optimized temperature distribution
- Coil DC-Resistance: 200 m Ω
- Overall construction height: 1 mm



Construction



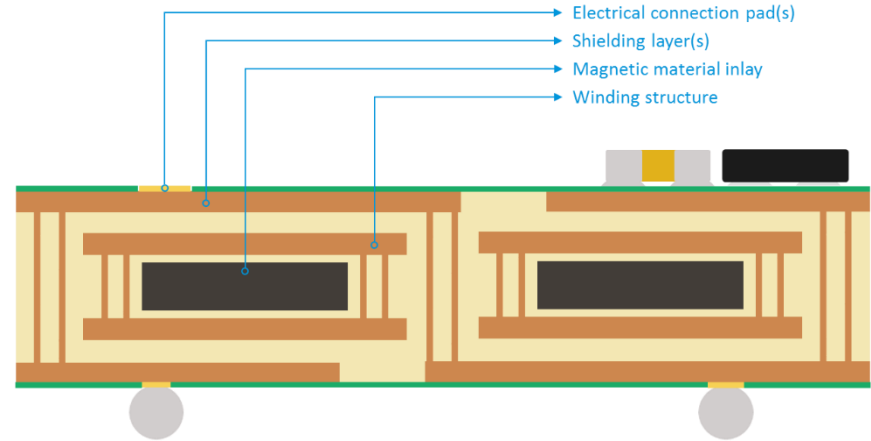
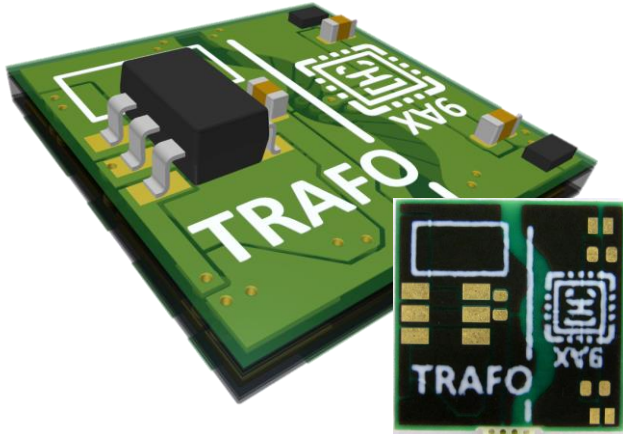
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Application Example: Transformer (I)



Transformer Demonstrator

- Overall size: 10 mm x 10 mm x 920 μm
- Embedded magnetic ring
- Ideal for miniaturized isolated power supplies and high side gate drive applications
- Application dependent/optimized footprint possible

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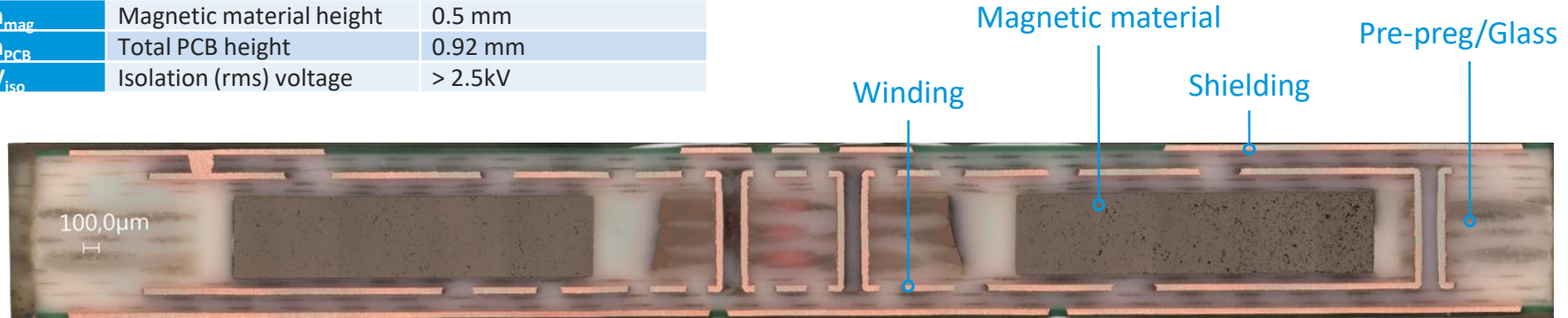
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Application Example: Transformer (II)

Symbol	Parameter	Value
a	Turns ratio	10:11
V_{in}	Input voltage	24 V
f_{sw}	Switching frequency	1.6 MHz
L_m	Magnetizing inductance	3.5 μ H
L_{leak}	Leakage inductance	0.5 μ H
I_{prim}	Primary (rms) current	0.5 A
I_{sec}	Secondary (rms) current	0.5 A
$R_{DC,1}$	DR resistance	$\sim$ 60mOhm
C_s	Stray capacitance	6 pF
h_{mag}	Magnetic material height	0.5 mm
h_{PCB}	Total PCB height	0.92 mm
V_{iso}	Isolation (rms) voltage	$>$ 2.5kV

- Based on push-pull converter concept
- Design adaptations according to other applications easy
- Inlay thickness variation possible
- Module/PCB embedding possible



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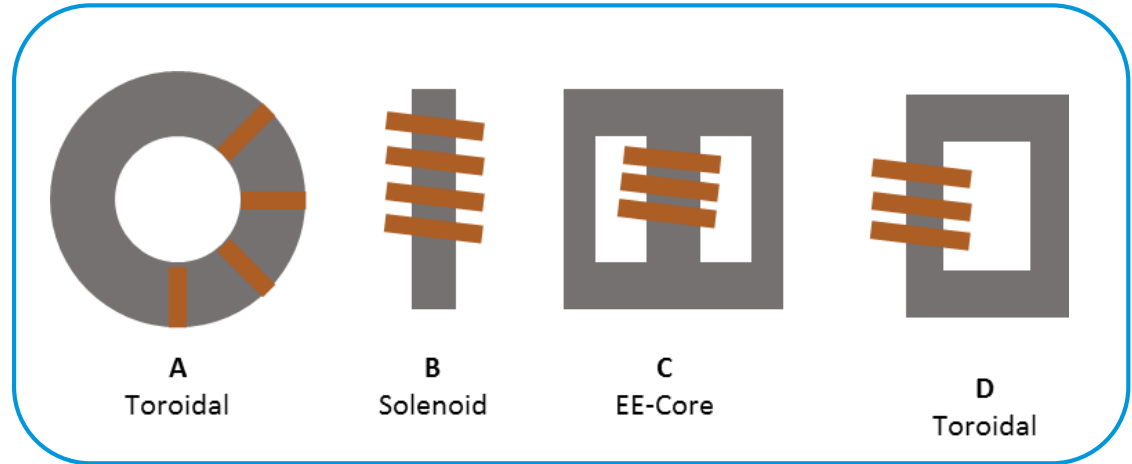
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Magnetic Material Inlay - Possible Shape

- Nearly every core shape can be processed
- Actual limitations:
 - VIA per area
 - L/S requirements @ demanded copper height
 - Current carrying capability

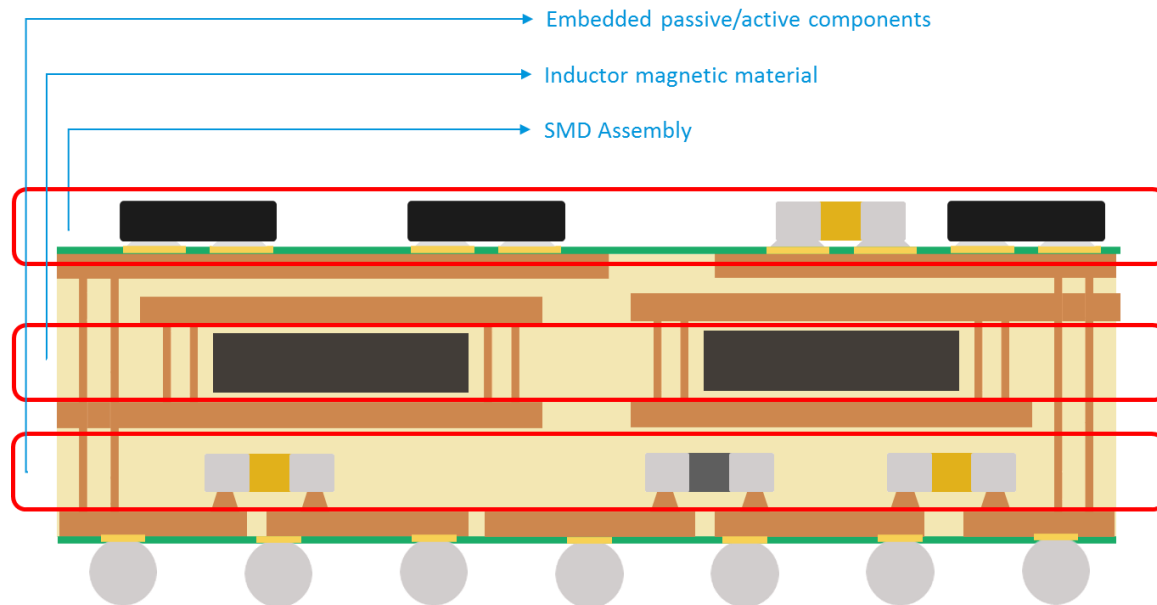


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Application Example: DC/DC converter module, Future Work

- Heterogeneous integration
- Two embedded areas stacked - similar to PoP
- Reduced form factor
- Better electrical performance
- Functions can be easily combined
- Low cost impact



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Conclusion

- Flexible solution
- Further miniaturization of power electronics
- Ultra thin concepts possible
- Different materials (and behavior) available
- Can be used for transformers, inductors, shielding and charging applications
- Technology can be combined with PCB processes
- *Future:* Integrated in package interposers/substrates
- *Ongoing now:* Reliability

Contact

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