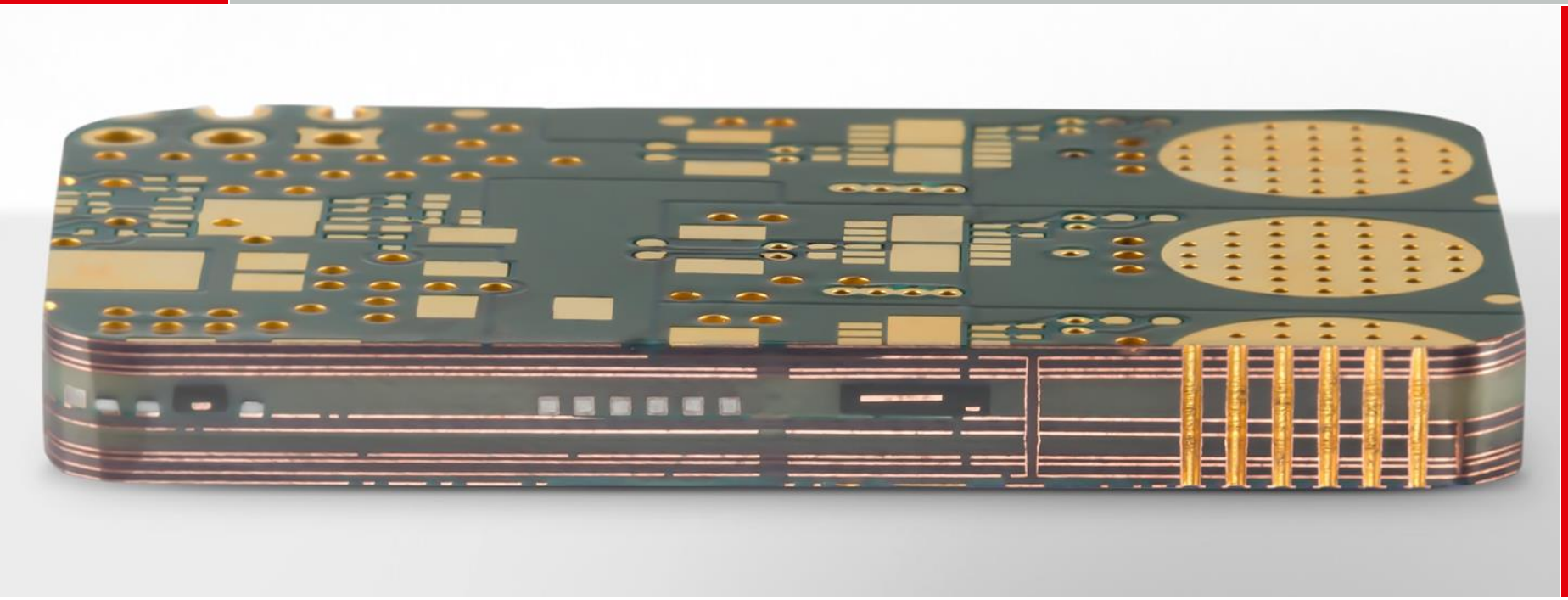
The World of Embedded Components in Printed Circuit Boards

Part 2 – Layout and Applications



Jürgen Wolf
Würth Elektronik GmbH & Co. KG
Circuit Board Technology
Advanced Solution Center

YOUR SPEAKER TODAY

- **Jürgen Wolf**
  Dipl.-Ing. Microsystems Technology

- **Head of Advanced Solution Center**
  - Responsible for the technology for embedding components/functions into printed circuit boards and for stretchable printed circuit boards (STRETCH.**flex**)
  - Support of sales for embedding technology and new technologies
  - Qualification, planning and further development of these technologies

- **With Würth Elektronik Circuit Board Technology since 2008**

Save my contact details directly in your address book!

AGENDA

1. Short Summary of Part 1
2. Overview of EDA tools and their capabilities
3. How to Design a PCB Layout with Embedded Components
4. Application Examples

AGENDA

1 **Short Summary of Part 1**

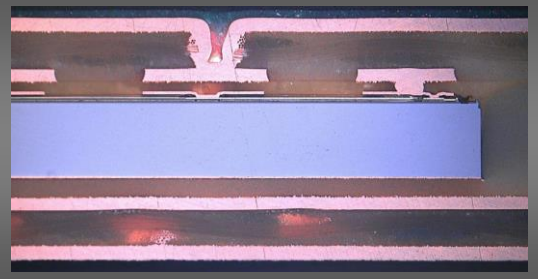
2 Overview of EDA tools and their capabilities

3 How to Design a PCB Layout with Embedded Components

4 Application Examples

EMBEDDING TECHNOLOGY – THE BASICS

From Part 1: Variants of the Embedding Technology



MICROVIA.**embedding**

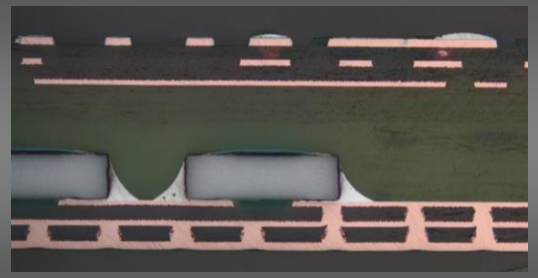
Bare Dies, dedicated R`s and C`s

mounted onto inner layer core or Cu-foil

electrical contact through Microvias

highest reliability

large volumes



SOLDER.**embedding**

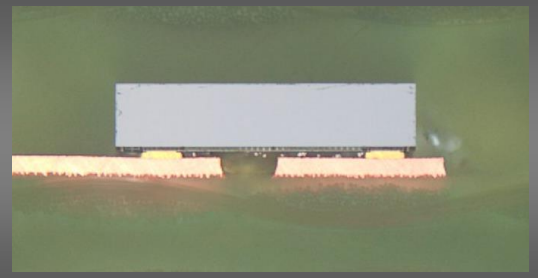
SMD components

soldered onto inner layer core

electrical contact by solder

high reliability

small, medium and large volumes



FLIP-CHIP.**embedding**

bumped Bare Dies

mounted onto inner layer core

electrical contact by ACA

high reliability

small, medium and large volumes

EMBEDDING TECHNOLOGY – THE BASICS

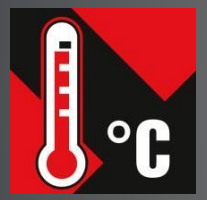
From Part 1: Advantages and Benefits of Embedded Components

Miniaturisation

- Package replacement
- Space savings of assembly area on the outer layers

Performance/ Function

- Integrated shielding
- Short signal paths
- Protection against plagiarism



Reliability

- Protection against environmental influences
- Secure and full-surface fixing
- Thermal management

AGENDA

1 Short Summary of Part 1

2 **Overview of EDA tools and their capabilities**

3 How to Design a PCB Layout with Embedded Components

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EMBEDDING TECHNOLOGY

Short Question

WÜRTH ELEKTRONIK

POLL

Which EDA software do you use?
(Multiple answers possible)

Please insert the answers in
the question-section of GoToWebinar!

Small list of tools to select from (sorted alphabetically - without rating and not complete!)

Allegro PCB Designer (cadence)
Altium 365
Altium Designer
Cadstar (Zuken)
CircuitMaker (Altium)
CircuitStudio (Altium)
CR-8000 (Zuken)
DesignSpark
Eagle
gEDA
KiCAD
NEXUS (Altium)
OrCAD PCB Editor (Cadence)
Pads (Siemens EDA/Mentor)
Pulsonix
Sprint Layout
Target 3001!
Ultiboard (NI)
Xpedition (Siemens EDA/Mentor)

EMBEDDING TECHNOLOGY – LAYOUT

Übersicht EDA-Tools

EDA Tools for Embedding Technology - The current versions of these software tools:

ALTIUM DESIGNER

cadence®
Allegro PCB Design Solution
Miniaturization Option

SIEMENS EDA
(Mentor Graphics®)
Xpedition Enterprise

ZUKEN
CR-8000™

PULSONIX

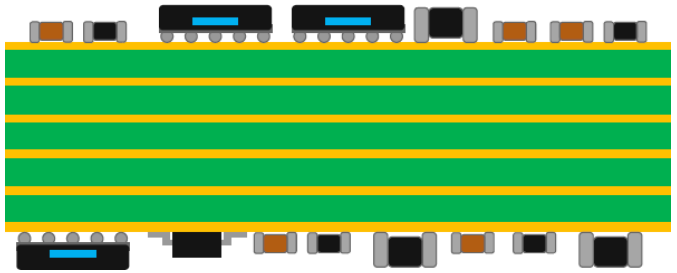
**Further tools possible,
but with strong limitations**

EMBEDDING TECHNOLOGY – LAYOUT

Capabilities of the EDA tools - using the example of cadence® Allegro

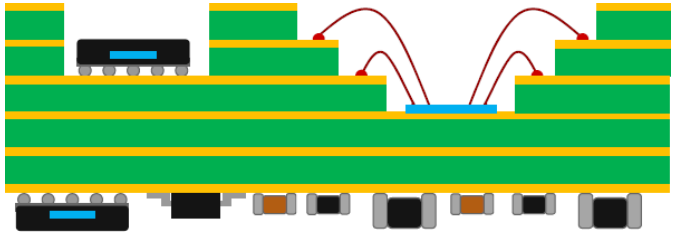
Normal Multilayer-PCB

Components on Top and Bottom



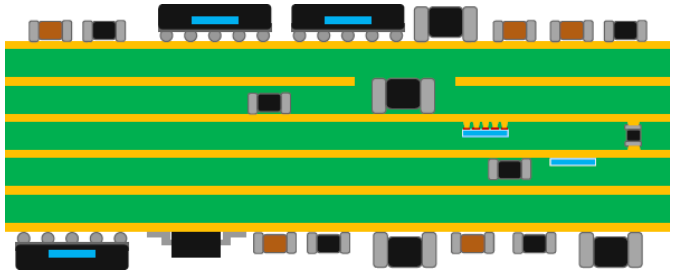
PCB with Cavities

Components in the defined cavities on defined layers and assembly from "outside".



PCB with Embedded Components

Components on the defined inner layers with layer connection and orientation (up/down)



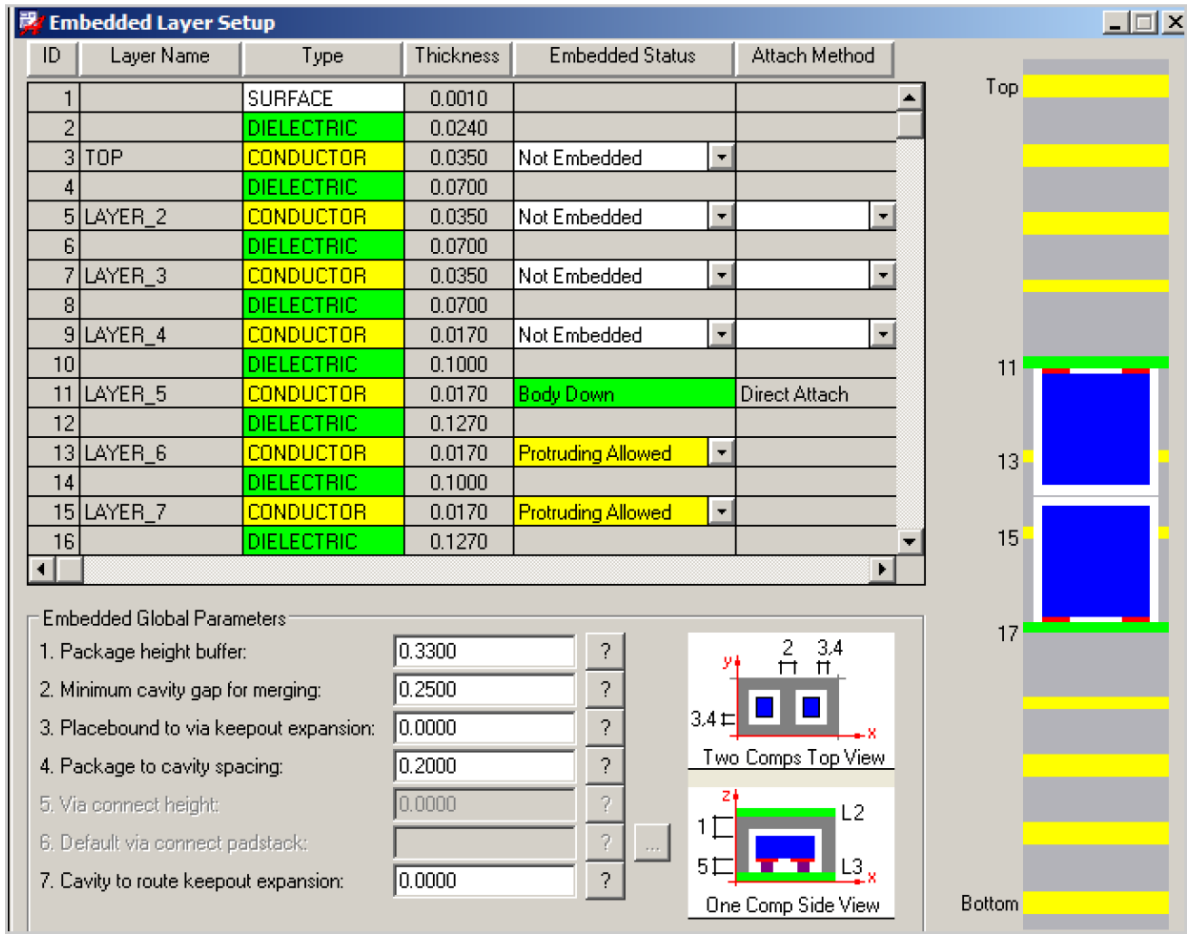
Source: Rolf Nick (Fa. FlowCAD) – „Mit Embedded Components Leiterplatten kostengünstig miniaturisieren“

EMBEDDING TECHNOLOGY – LAYOUT

Capabilities of the EDA tools – using the example of cadence® Allegro

Layer setup of PCBs with Embedded Components

- **Orientation of components**
- **Allow protruding of adjacent layer**
- **Contacting methods**
  “Direct Attach” corresponds to MICROVIA**.embedding**
  “Indirect Attach” corresponds to SOLDER**.embedding**



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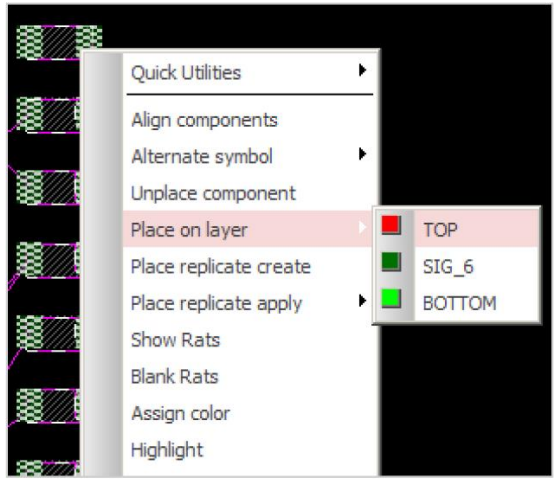
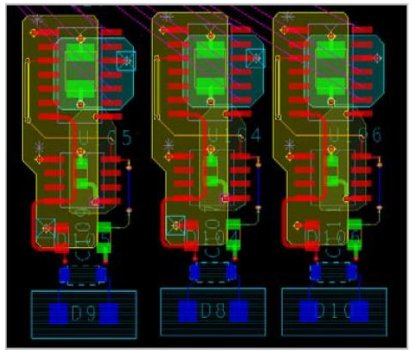
EMBEDDING TECHNOLOGY – LAYOUT

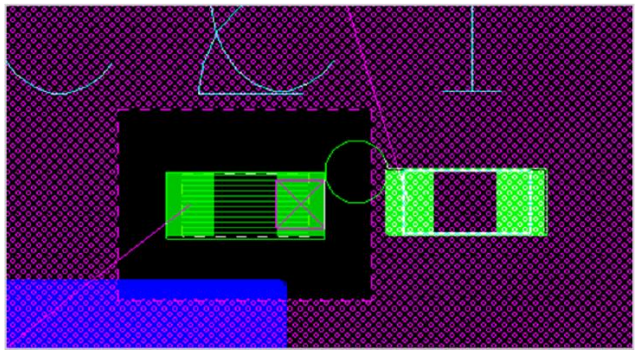
Capabilities of the EDA tools – using the example of cadence® Allegro

Placement of the components

- **Onto allowed layers**
- **DFA-Support with complex rules for distances**







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AGENDA

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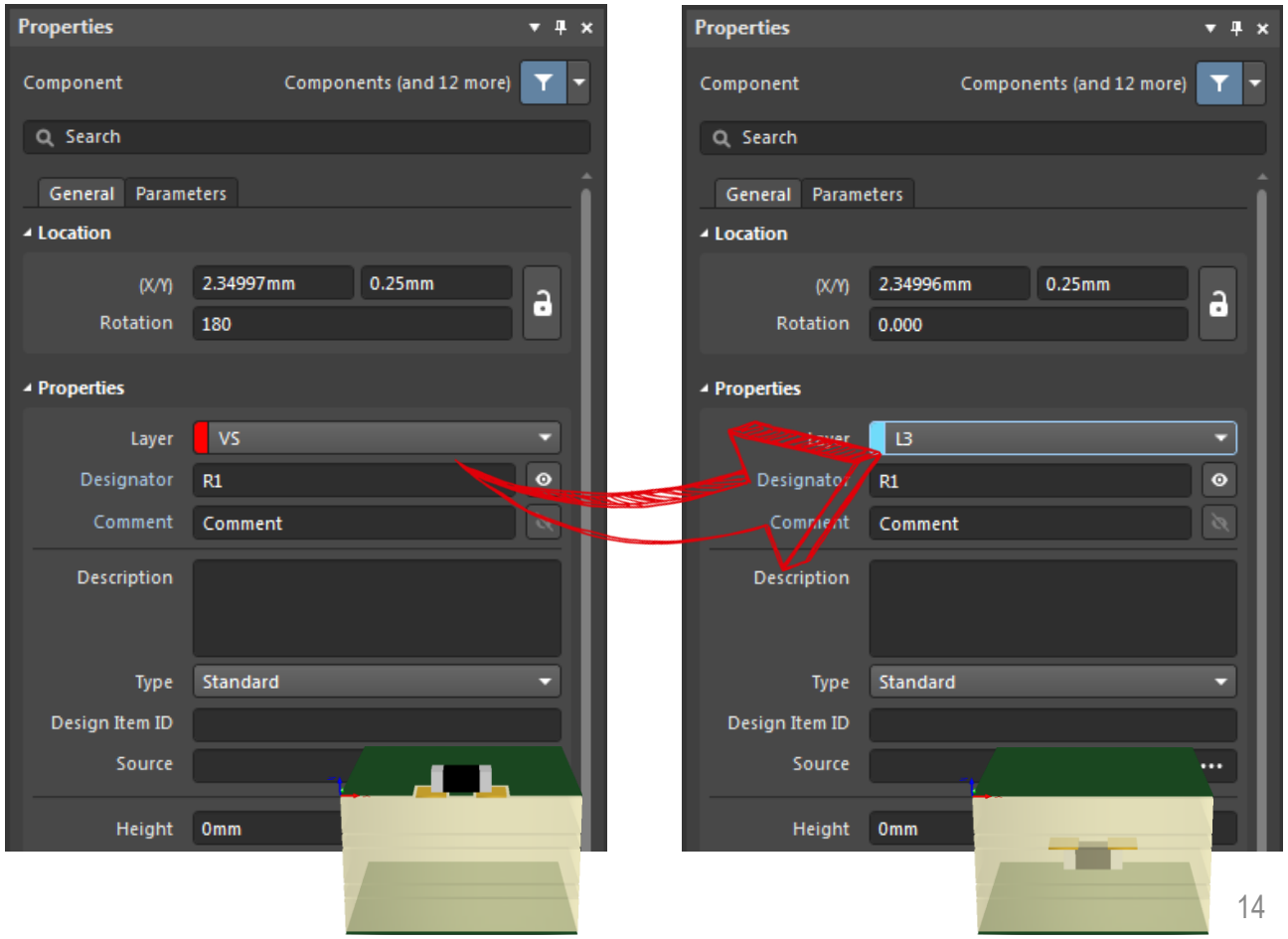
EMBEDDING TECHNOLOGY – LAYOUT

How to Design a PCB Layout with Embedded Components

Library of components

- **Components are created in the library like any other component**
- **Recommendation: Copy "normal" SMD component and use it only as embedded component afterwards**
- **Additional information may be required in the component library:**
  - Solder mask for inner layers
  - Solder paste for inner layers
  - specific component outline
  - Height of the component as separate parameter
- **It becomes an embedded component only when it is moved to an inner layer in the layout**



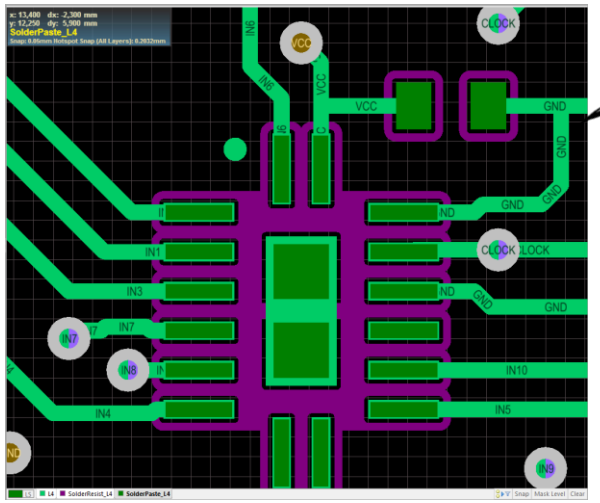
EMBEDDING TECHNOLOGY – LAYOUT

How to Design a PCB Layout with Embedded Components

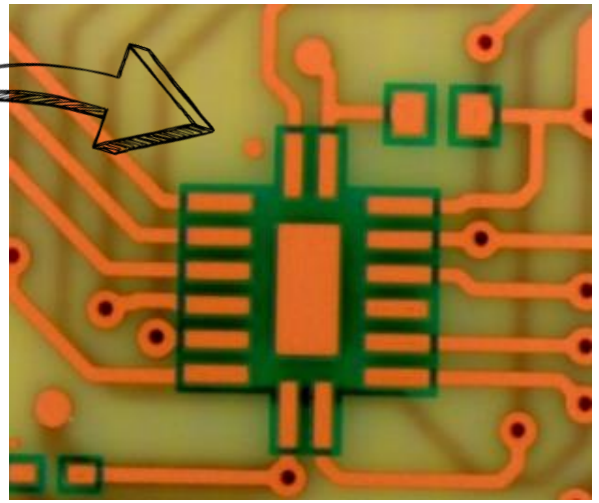
Library of components – additional information

- **Some tools are not capable of providing solder resist and paste data for inner layers.**

Workaround:
Create additional mechanical layers for solder mask and solder paste data on inner layers



QFN-Footprint in Layout



QFN-Footprint with solder resist before assembly

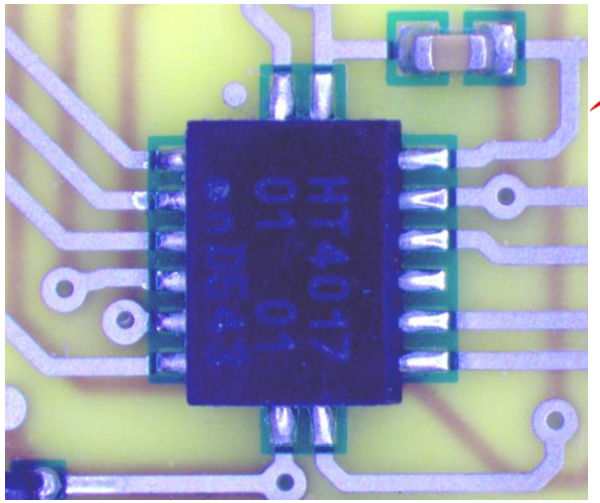
Side note and reminder of part 1:
Either the solder stop frames can be designed positively - or the clearances as a negative, which we will then convert into frames. Please document accordingly!

EMBEDDING TECHNOLOGY – LAYOUT

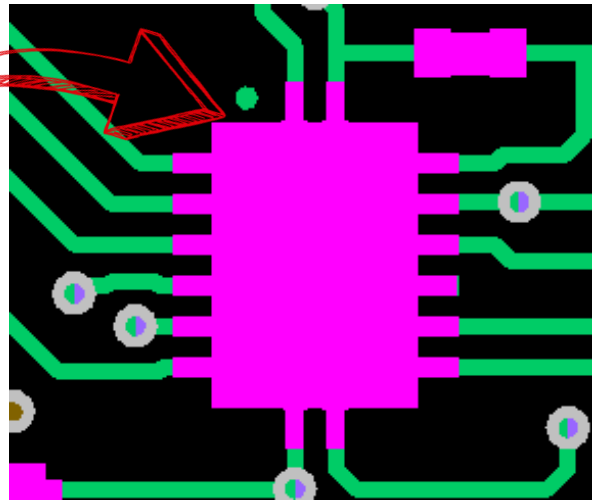
How to Design a PCB Layout with Embedded Components

Library of components – additional information

- **Component outline (X/Y) in the data**
  - Serve on the one hand the PCB manufacturer for the definition of the “pockets/internal cavities/cut-outs” for the components (see part 1).
  - But are also used for DRC, e.g. to avoid accidental vias through components.
    ⇨ Define outline not only as contour but as filled area



Assembled QFN for embedding



QFN-Footprint with filled areas for the component outline

EMBEDDING TECHNOLOGY – LAYOUT

How to Design a PCB Layout with Embedded Components

Library of components – additional information

- **„Pocket/cavity/cut-out“ for components**

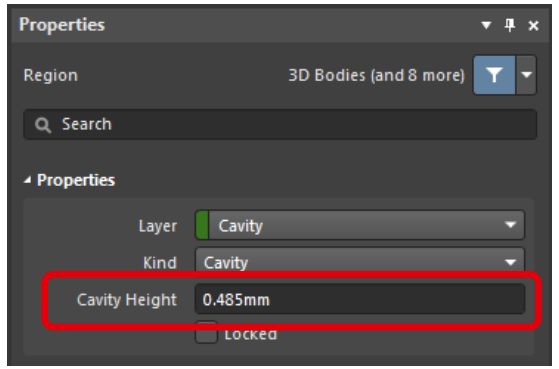
  Depending on the technology - e.g. with SOLDER**.embedding the height of the cut-out is composed as follows:**

  – Height
  max. tolerance – see data sheet

  – Solder stand-off
  approx. 25..50µm

  – Space above component
  typ. approx. min. 70..100µm

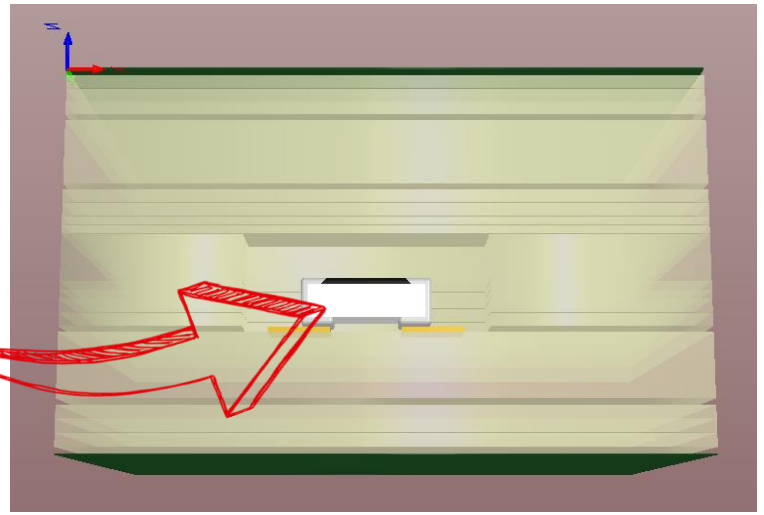
- **Can be used by the PCB manufacturer and the layouter to check whether the desired component fits the layer stack-up**



Definition of the internal cavity

Layer	Name	Material	Thickness	Constant	Board Layer Stack	Stack0
1	Top Overlay					
2	Top Solder	Solder Resist	0,015mm	3,5		
3	VS	Copper	0,040mm			
4	PP2116	FR4 TG150	0,102mm	4,2		
5	PP2116	FR4 TG150	0,102mm	4,2		
6	PP2116	FR4 TG150	0,102mm	4,2		
7	L2	Copper	0,035mm			
8	0.50mm-035+035	FR4 TG150	0,500mm	4,2		
9	L3	Copper	0,035mm			
10	PP2116	FR4 TG150	0,102mm	4,2		
11	PP2116	FR4 TG150	0,102mm	4,2		
12	PP1080	FR4 TG150	0,062mm	4,2		
13	PP1080	FR4 TG150	0,062mm	4,2		
14	0.36mm-018+018	FR4 TG150	0,360mm	4,2		
15	PP1080	FR4 TG150	0,062mm	4,2		
16	PP1080	FR4 TG150	0,062mm	4,2		
17	PP2116	FR4 TG150	0,102mm	4,2		
18	PP2116	FR4 TG150	0,102mm	4,2		
19	L4	Copper	0,035mm			
20	0.50mm-018+018	FR4 TG150	0,500mm	4,2		
21	L5	Copper	0,035mm			
22	PP2116	FR4 TG150	0,102mm	4,2		
23	PP2116	FR4 TG150	0,102mm	4,2		
24	PP2116	FR4 TG150	0,102mm	4,2		
25	RS	Copper	0,040mm			
26	Bottom Solder	Solder Resist	0,015mm	3,5		
27	Bottom Overlay					

Stack-up from Altium



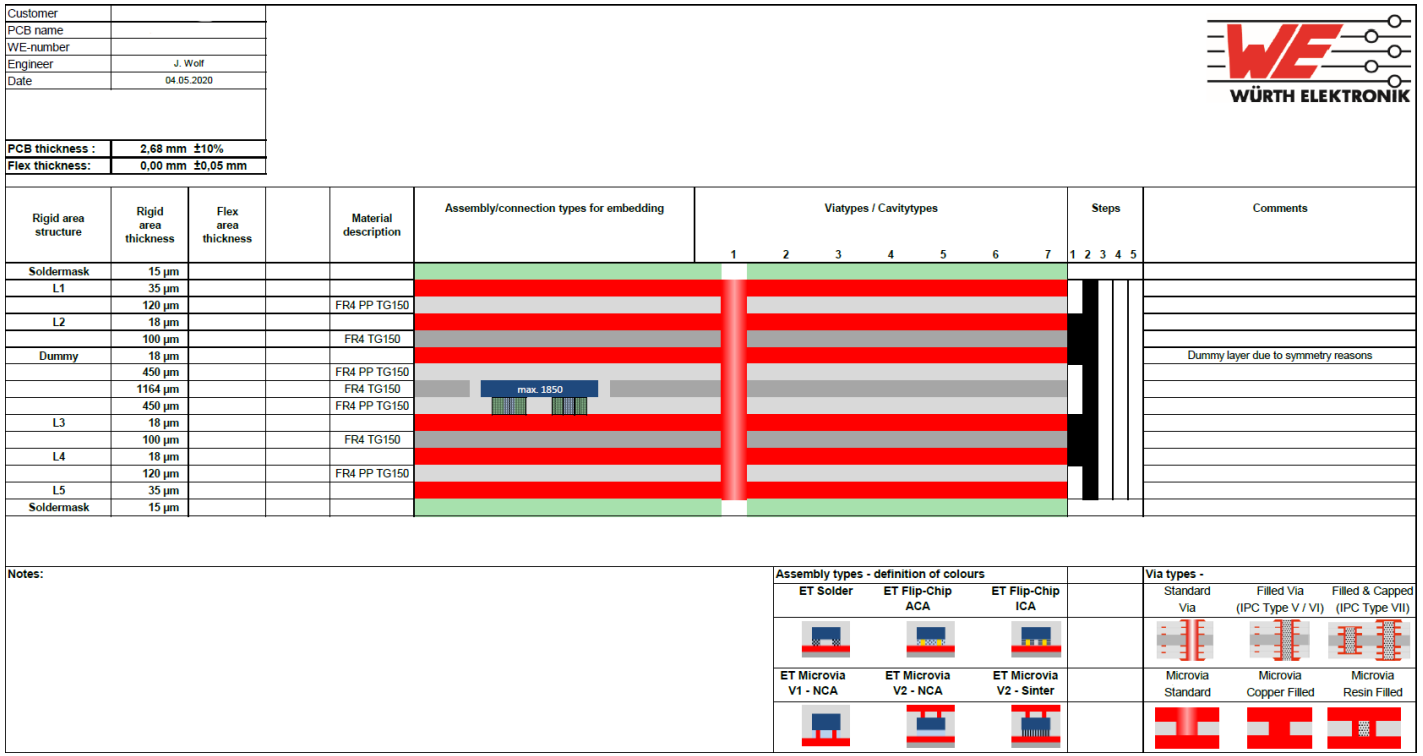
Altium 3D view

EMBEDDING TECHNOLOGY – LAYOUT

How to Design a PCB Layout with Embedded Components

Layer stack-up

- After analysing the BOM and defining the components to be embedded, a layer stack is provided by the LP manufacturer, which has to be implemented in the EDA tool
- In the layer stack-up, the component location/orientation, max. component heights and possible layer relationships (vias and impedances) are specified



Layer stack-up – created after BOM analysis

EMBEDDING TECHNOLOGY – LAYOUT

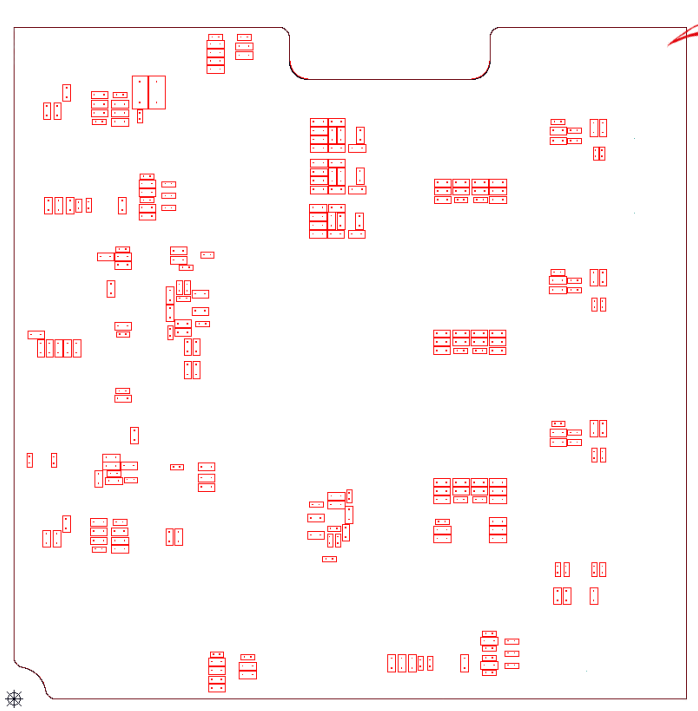
How to Design a PCB Layout with Embedded Components

Placement of components

- **Brief reminder of part 1: Components are embedded by the resin of the prepregs used in the stack-up**

  ⇨ Not the entire area on the inner layer can/may be equipped with components.

  ⇨ Components should be arranged in groups if possible



Placement of components

Program for the routing of used prepregs

AGENDA

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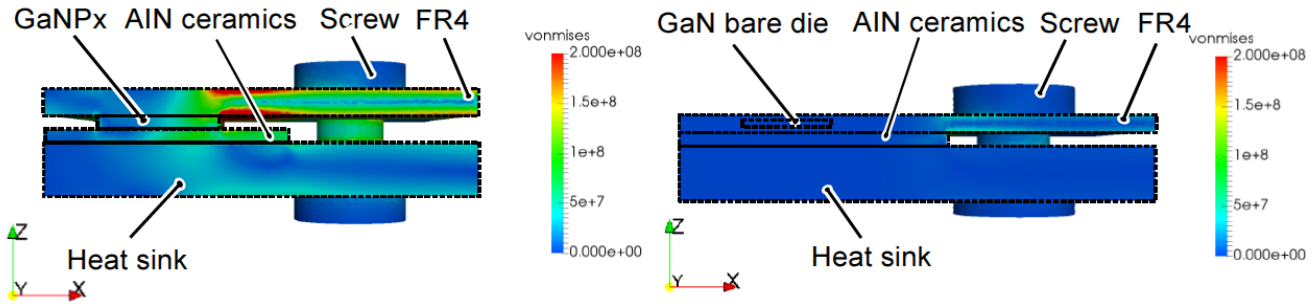
4 **Application Examples**

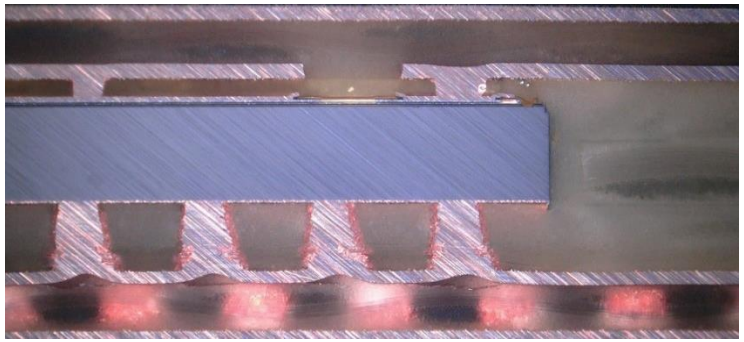
EMBEDDING TECHNOLOGY

Application Examples

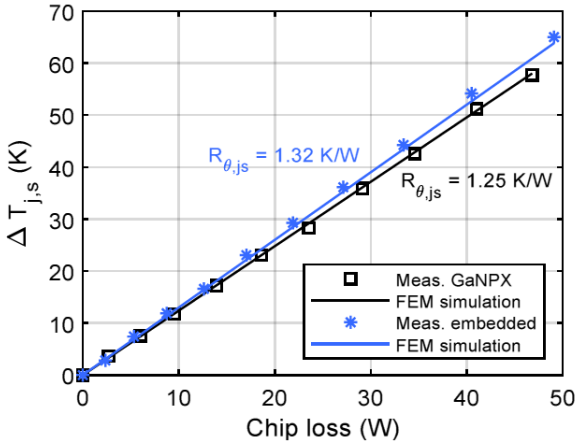
Automotive: Embedded GaN Half Bridge Switching Cell



Build-up and comparison of mechanical stress
Primary package vs. Embedding



Microsection of the printed circuit board



Simulated and measured Junction-Temperature

Source:
Dechant et. al., »Performance of an Ultra Low Inductance GaN Half Bridge Switching Cell with Substrate Integrated Bare Dies", PCIM 2019

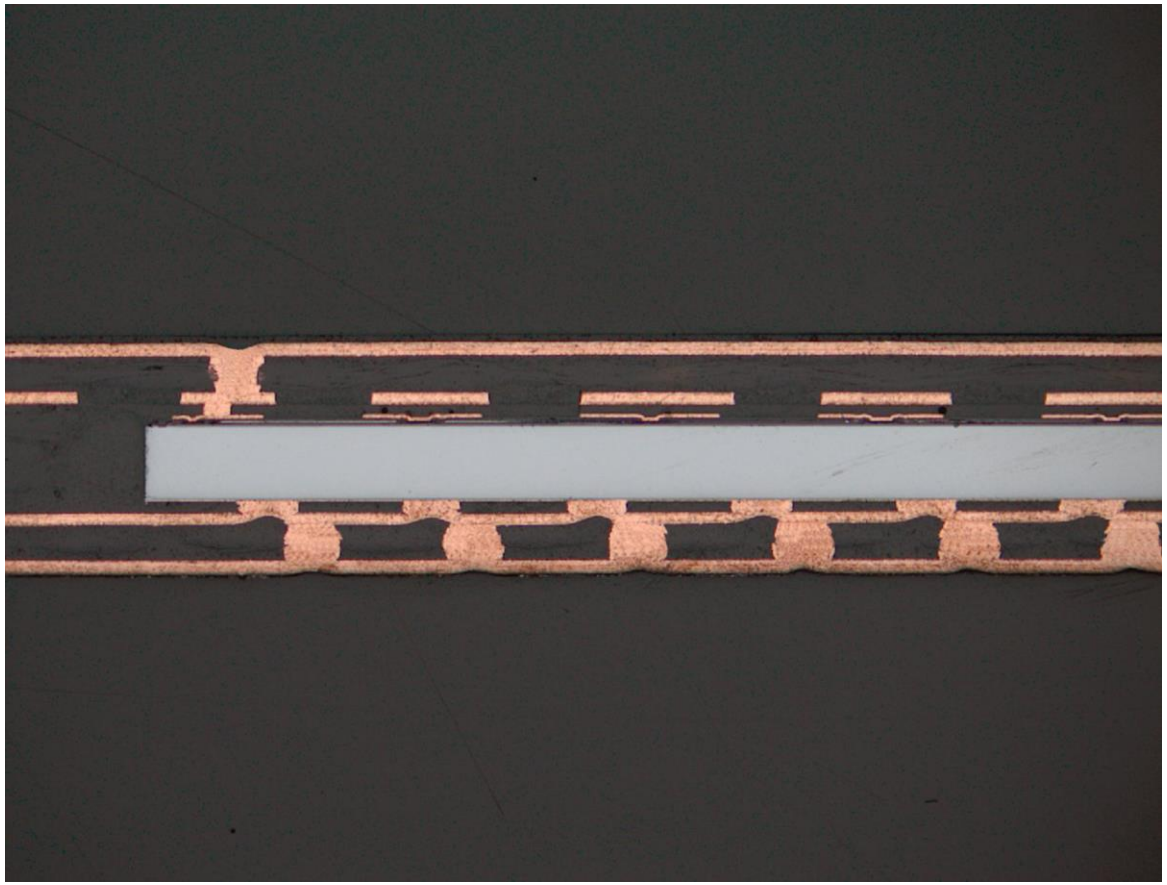
For even better performance, the number of µVias can be doubled.

EMBEDDING TECHNOLOGY

Application Examples

Automotive: Embedded GaN Half Bridge Switching Cell

- GaN IC embedded in 4-layer HDI multilayer
- Contacted by Microvias on all layers



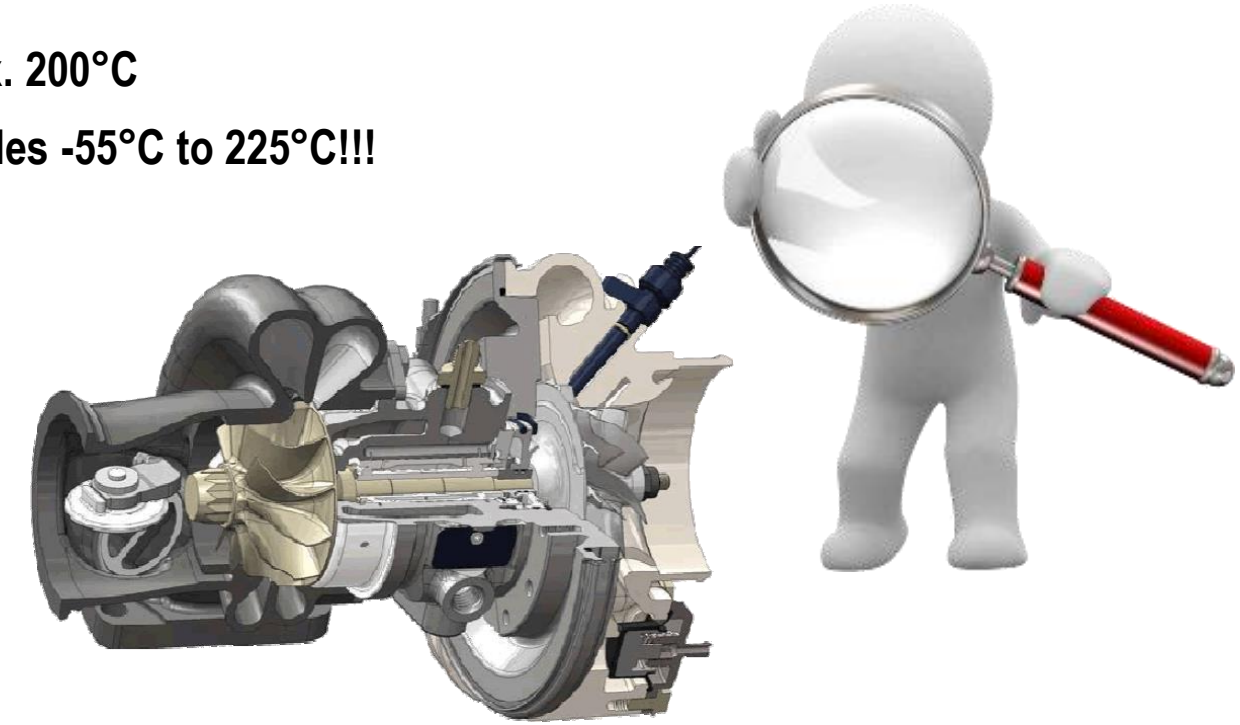
Microsection - optimised layer stacking for improved back side connection

EMBEDDING TECHNOLOGY

Application Examples: Highest Reliability Requirements

Automotive: embedded silicon components – sensor in the engine compartment

- **Operating temperature max. 200°C**
- **Cycle-proof: TCT 1.000 cycles -55°C to 225°C!!!**
- **As small as possible**
- **Injection moulding-proof**



EMBEDDING TECHNOLOGY

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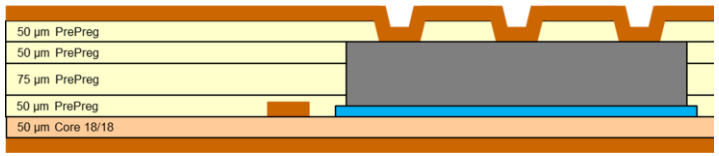
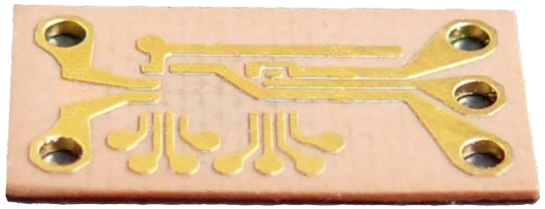
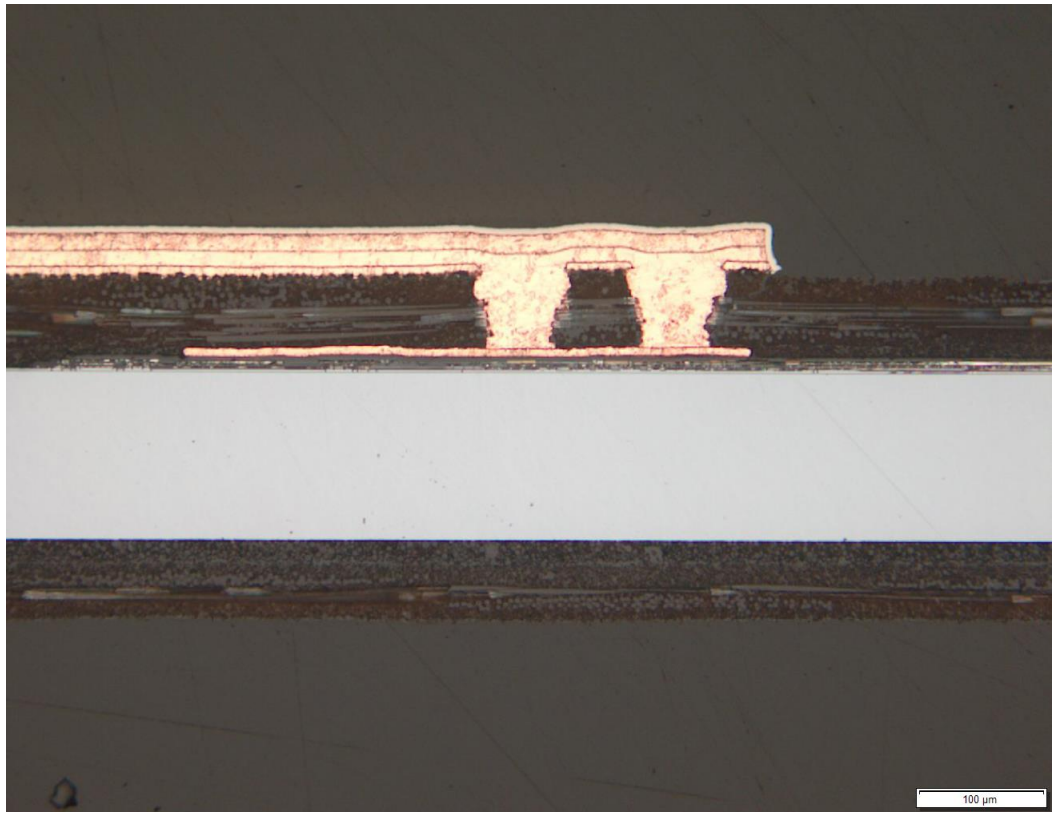


Stack-up: <= 300µm overall thickness



Module with embedded ASIC and 2x Si-C‘s



Microsection after 1000 cycles TCT -55°C to 225°C

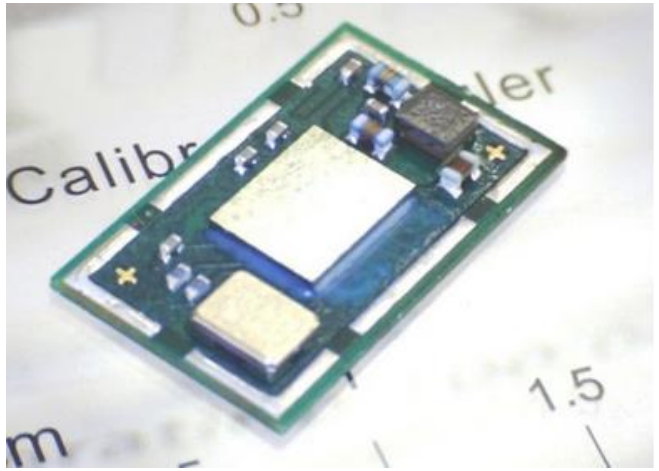
EMBEDDING TECHNOLOGY

Application Examples: Highest Reliability Requirements

Medical Technology: embedded ASIC – radio module for implants

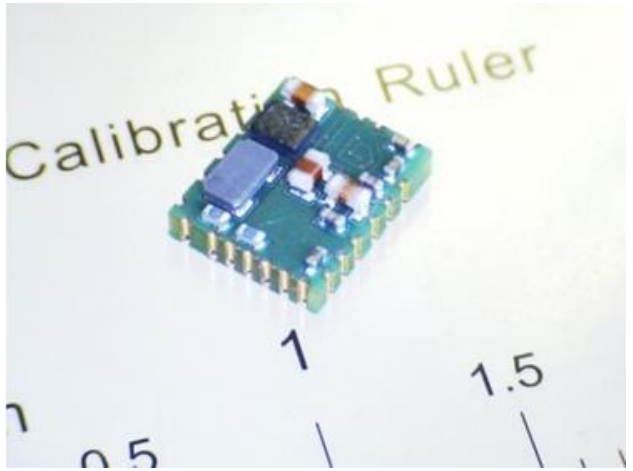
Microsemi ZL70323

„Miniaturized Standard Implant Module (MiniSIM)“
Complete radio solution for implant based on the MICS-Band (Medical Implant Communication Service)



Standard SIP – 12 x 7 mm² = 84 mm²

70%
space saving



Embedded Die – 5,5 x 4,5 mm² = 24,75 mm²

Source: Microsemi

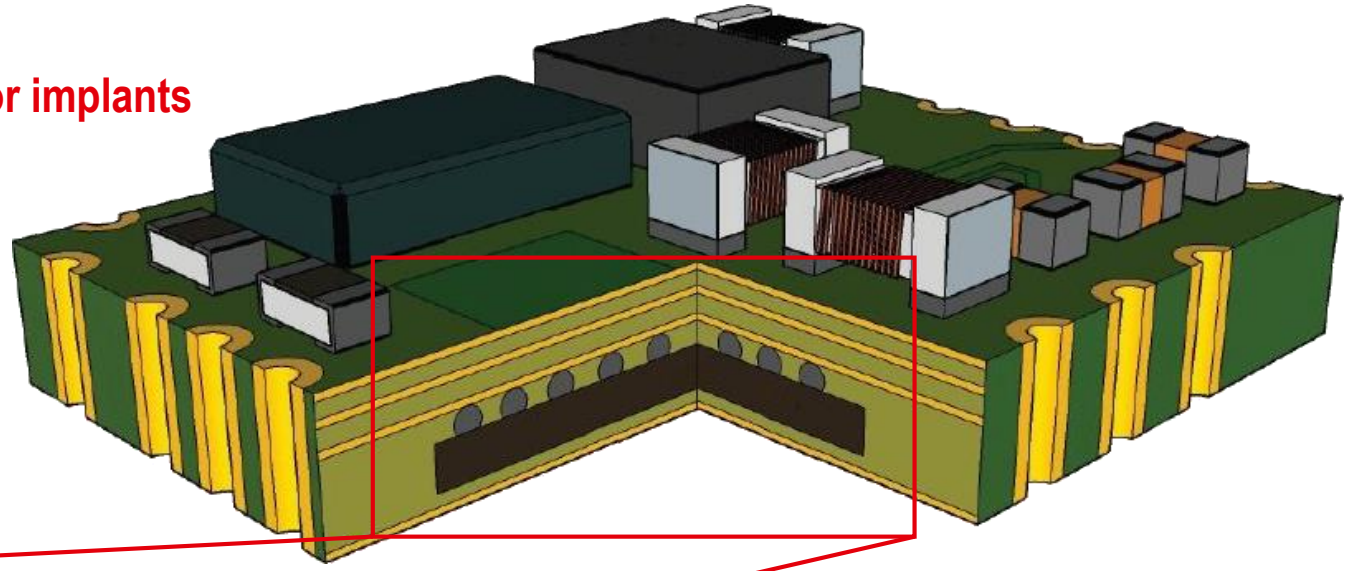
EMBEDDING TECHNOLOGY

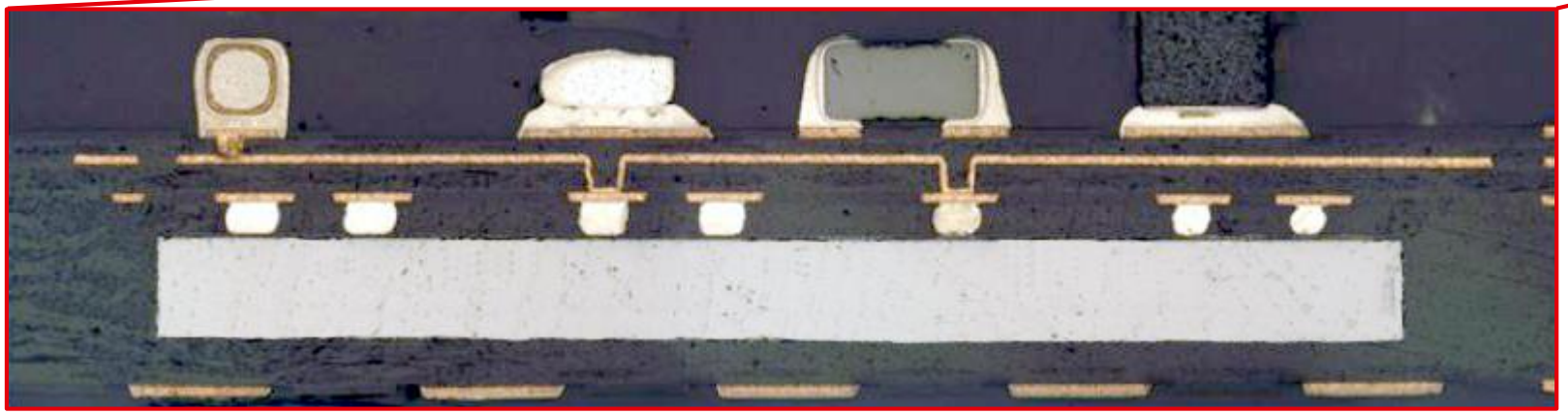
Application Examples: Highest Reliability Requirements

Medical Technology: embedded ASIC – radio module for implants

Microsemi ZL70323

„Miniaturized Standard Implant Module (MiniSIM)“





Source: Microsemi

EMBEDDING TECHNOLOGY

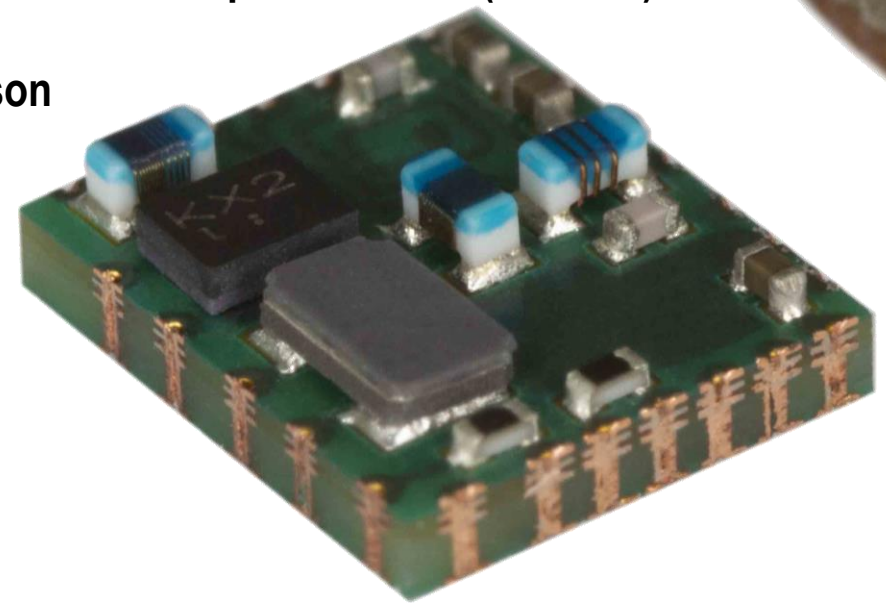
Application Examples: Highest Reliability Requirements

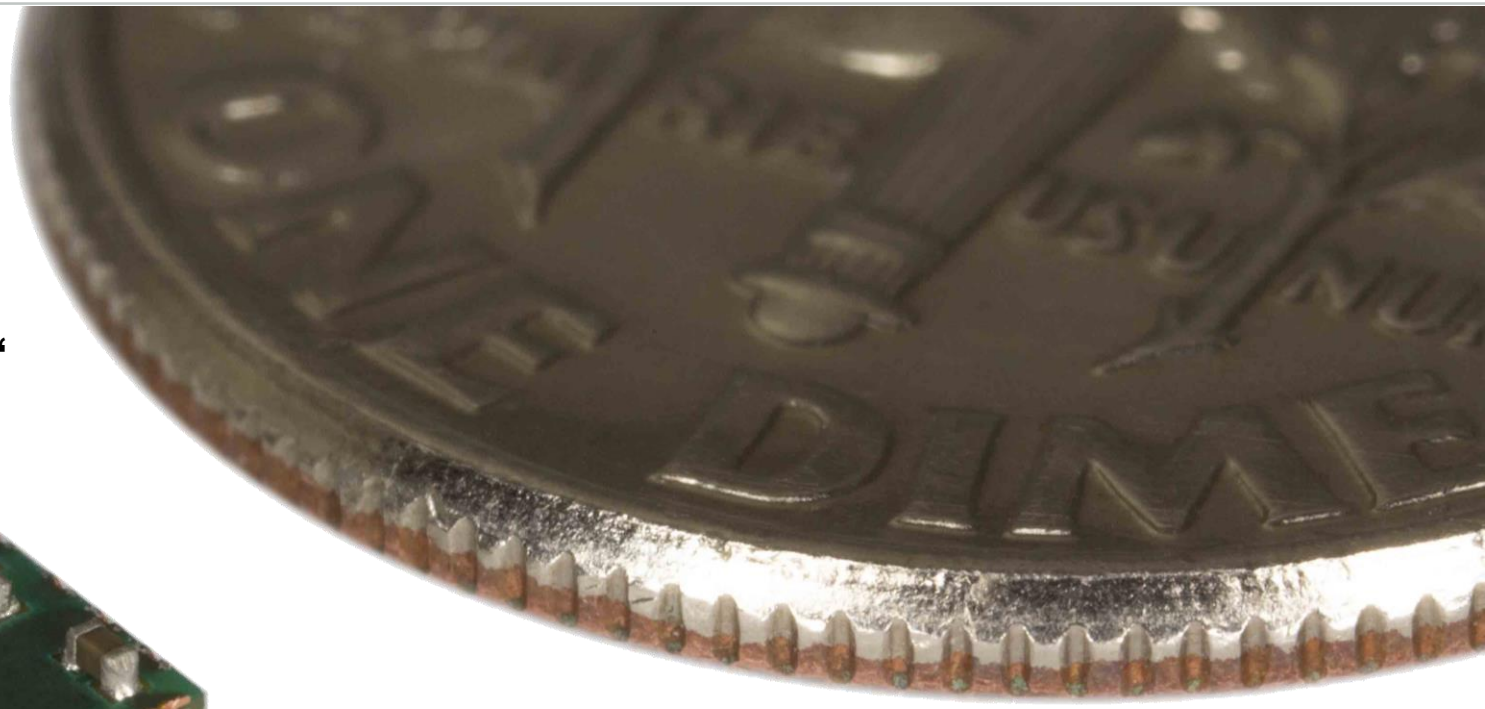
Medical Technology: embedded ASIC

Microsemi ZL70323

„Miniaturized Standard Implant Module (MiniSIM)“

Size comparison





Source: Microsemi

EMBEDDING TECHNOLOGY

Short Question

Poll

When you look back at the two parts, what do you think about our embedding technology?

Thank you for your attention!

JÜRGEN WOLF

Head of Advanced Solution Center

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