Embedded Component Technology
Pioneering solutions
Your speakers today ...

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With around 1800 employees worldwide and sales of € 241 million in 2012/13, WITTENSTEIN AG enjoys an impeccable reputation for innovation, precision and excellence in the field of mechatronic drive technology – not just in Germany but internationally.

The group comprises eight pacesetting Business Units with separate subsidiaries for servo gearheads, servo actuator systems, medical technology, miniature servo units, innovative gearing technology, rotary and linear actuator systems, nano-technology and electronic and software components for drive technologies.

Through its 60 or so subsidiaries and agents in approximately 40 countries, WITTENSTEIN (www.wittenstein.de) is additionally represented in all the world's major technology and sales markets.
Embedded Component Technology: Pioneering Solutions

Embedded Component Technology – ECT

- Motivation
- ECT-µVia
- ECT-Flip Chip
- Components and Assembly

Active Implant with ECT

- Design Requirements
- Collaboration
- Realization - EDA-Tools
- Realization - PCB

ECT Reliability
Embedded Component Technology: Pioneering Solutions

 Embedded Component Technology – ECT

**Motivation**

ECT–µVia

ECT–Flip Chip

Components and Assembly

Active Implant with ECT

**Design Requirements**

**Collaboration**

Realization - EDA-Tools

Realization - PCB

ECT Reliability
Embedded Component Technology – ECT

Advantages of „buried“ components?

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

- **Performance/Function**
  - Integrated shielding
  - Short signal paths
  - Protection against plagiarism

- **Reliability**
  - Protected against influences
  - Secure Fixing
  - Thermal management
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ECT Reliability
Embedded Component Technology – ECT
ECT-µVia: Embedded active and passive devices

ECT-µVia Manufacturing

Assembly (Gluing/Sintering/Soldering)
Embedded Component Technology – ECT
ECT–µVia: Embedded active and passive devices

Assembly (NCA) onto Cu-Foil

Sample:
Top view of assembled foil

- Capacitors with Cu-Termination
- Resistors with Cu-Termination
- ASIC as bare die with NiPd-Metallisation
Embedded Component Technology – ECT
ECT-µVia: Embedded active and passive devices

ECT-µVia Manufacturing

Assembly
(Gluing/Sintering/Soldering)

Multilayer pressing

Drilling of vias and microvias
Non-plated microvia on embedded Capacitor with Cu-termination

Length: 58.97 µm
Length: 21.96 µm
Embedded Component Technology – ECT
ECT–µVia: Embedded active and passive devices

Top view: embedded IC

Microvia connection on top of IC pad

Cross section: embedded IC with microvia connections prior to Cu-structuring
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ECT Reliability
Embedded Component Technology – ECT
ECT–Flip Chip: Embedded active devices

ECT-Flip Chip Manufacturing

- Core with Footprint for Flip Chip
- Assembly (Flip Chip – ACA)
- Multilayer pressing
- Remaining PCB processes
Embedded Component Technology – ECT
ECT–Flip Chip: Embedded active devices

ECT-Flip Chip
„chip first / face down“
Embedded bare die ASIC
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ECT Reliability
### Embedded Component Technology – ECT
### Availability of components

#### Passive Components with Cu-Termination

<table>
<thead>
<tr>
<th>Component</th>
<th>Mounting Form</th>
<th>Thicknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>0402</td>
<td>150 µm, 330 µm</td>
</tr>
<tr>
<td>Capacitors</td>
<td></td>
<td>150 µm, 330 µm</td>
</tr>
</tbody>
</table>

#### Bare Die Silicon ICs with process compatible pads

<table>
<thead>
<tr>
<th>Pads Type</th>
<th>Cu</th>
<th>NiPd</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECT–µVia Pads</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECT–Flip Chip Pads</td>
<td>Wirebond Au Stud-Bumps</td>
<td>Wafer-level Au-Bumps</td>
</tr>
</tbody>
</table>

Generally a customer provision
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PCB manufacturer and the assembly of components?

Paradigm shift

PCB manufacturer assembles components to be embedded

ESD

Storage, stock and logistics of components
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Embedded Component Technology – ECT

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Design Requirements
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ECT Reliability
Active Implant with ECT

Design requirements

- Development of a robust, reliable and highly available prototype
- Active medical implant
  ⇒ limited physical dimensions with complex structures
- Connectors need to be eliminated due to space requirements
- Critical EMC, due to RF-sources (wireless energy and data transfer) onboard
- Direct connection to different actuators and sensors
- Development of a suitable test structure
Active Implant with ECT
Preliminary studies

Functional sample based on Multilayer Standard PCB

Packaged versions of ASIC and µController

SMT Assembly
Functional sample based on Multilayer PCB with Cavity onto first innerlayer

Assembly of Flip Chip-Components onto first innerlayer
Advantages of Embedded Components

- Reduction in volume
- Increase of robustness
- Improvement in thermal performance due to optimized heat conduction
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ECT Reliability
Very close collaboration is needed at a very early stage in concept and design phase for the success.
Embedding of active and passive components:

Initial meeting – what are the options?
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Embedded Component Technology – ECT

**Motivation**

**ECT–µVia**

**ECT–Flip Chip**

**Components and Assembly**

Active Implant with ECT

**Design Requirements**

**Collaboration**

**Realization - EDA-Tools**

**Realization - PCB**

ECT Reliability
Active Implant with ECT
Realization in EDA-Tools exemplified by Cadence Allegro

Realization based on the example of „Cadence Allegro“

With old EDA-Tools it was only possible to place components on top or bottom.

In the meantime, components may be placed on any layer.

Special DRCs monitor and control the required manufacturing rules.
Layer definition

- Layer defined as „embedded“
- Assembly direction
  - Body Down
  - Body Up

- Cut outs of next layers
  - “Protruding”
  - In adjacent layers

- Contact type
  - Direct
  - Indirect
Placing of components

- **Quickplace**
  - Components are placed coarsely onto predefined layers
  - Manual fine adjustment
  - Filter Embedded Components
    - Board Layer may be selected if layer is marked as „embedded“
Placing of components

- **DFA Support**
  - Spacing rules and online DRC

- Spacing between single components
  - x-, y-direction
  - z-direction

- **S:E S:S E:E E:S**
  - side-end
  - side-side
  - end-end
  - end-side
Placing of components

- Placement Replication
  - Supports groups (functional modules) of embedded and regular components

Embedded Components
Substrate Cavities

- **Closed Cavity**
  - Filled with resin
  - Possible heights
    - Between 2 Layers
    - Across multiple layers

- **Open Cavity**
  - Open space in which components will be placed
  - Possible depths
    - Multiple layers
    - Stair design at the edge
Active Implant with ECT
Realization in EDA-Tools exemplified by Cadence Allegro

Manufacturing Output

- Cross Section Chart
  - Manufacturing
    ⇒ Cross Section Chart

- Drill Legend
  - Support of Cavities
  - Start:Stop Layer
  - Number of components

- Artwork Film Records

- ODB++ Version 9.1

- In the future: IPC 2581
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ECT Reliability
Active Implant with ECT
Implementation of the design requirements

Build-up of PCB

- Buried Vias
- ECT-µVia: embedded resistors in two cores
- 40 µm isolation distance on inner layers
- ECT-Flip Chip
- Microvias on top and bottom (HDI-build-up 1-2b-2b-1)
- Rigid-Flex 1F-5Ri
- Castellation holes
Active Implant with ECT
Implementation of the design requirements

Development of a robust and reliable prototype design
- Realisation by the use of embedded components (Bare die ASIC and resistors)
Active medical implant with very limited available space

- Implementation: Realization only possible through complex outlines
  ⇒ Virtual, three-dimensional design of the board
Active Implant with ECT
Implementation of the design requirements

- Realization of rigid areas adapted to the contours
- Realization of flexible areas suitable for the construction and for the flattening into a 2D-board for the assembly
Active Implant with ECT
Implementation of the design requirements

3D designed board flattened for 2D assembly by the use of an assembly frame.
Active Implant with ECT
Implementation of the design requirements

Used components

- Bare Die ASIC with Au Stud-Bumps
- Passive components

Embedded ASIC

Embedded resistors
Separable structures for programming, test and setting-up operation

- Contact structures will be cut of after successful initial operation.
- Cut-off surfaces are secured through potting in the product.
Active Implant with ECT
Implementation of the design requirements

Simulated board in comparison with assembled board
Direct connection of different actuators and sensors

- Realization: No further connectors by the use of castellation holes
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Embedded Component Technology – ECT

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ECT Reliability
5x solder process lead-free
+
1000 cycles - 40 °C / + 125 °C
+
lamination process
+
5x solder process lead-free

⇒ no resistance change in daisy chain!

40 °C at 90 % rel. humidity  climate exposure 200 / 500 / 1000h
125 °C heat treatment 200 / 500 / 1000h
ECT-µVia temperature cycling

Cycles – End-Of-Life

Testpoints

Z6
Z5
Z4
Y6
Y5
Y4
X6
X5
X4

500 1000 1500 2000 2500 3000

0 2 4 6 8 10 12 14 16 18 20
Summary / Conclusion

- Technologies available to embed
  - active and
  - passive components

- Collaboration
  - High importance for success and
  - Already starting in planning phase

- Pre-serial samples finished

- Series production in planning
Thank you for your attention!

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