Considerations for Embedding Passives and Actives in PCBs

PwrSoC 2014
What is embedding?

Styles

- Layer embedding
  - Capacitive and/or resistive layers

- Partial embedding
  - Cavities in substrates

- Full embedding
  - Components in substrates
  - Focus on ECP from AT&S
Why are we embedding?

Trends and challenges in electronics

- More functions
- Smaller devices
- Shorter development cycles
- Increased component density
- More-fragile components
- Miniaturisation

- Reliability
  - More-complex supply-chain
  - Increased cost of IC design
  - Higher power dissipation
  - Lower power
  - Increased clock frequency

- Ease-of-use
  - Performance
  - Embedding in PCB / PwrSoC 2014
Agenda

- Why embedding?
- Embedding flavours
- Embedding by AT&S
- Reliability comparison
- Supply chain
- Comparison with QFN
- Conclusion
Embedding flavours

Embedded layer

- **Pros**
  - High flexibility in number and position of passive functions
  - General compatibility with standard PCB processes

- **Cons**
  - Higher material cost than standard PCB
  - Limitation to low passive values
  - Limitation to passive functions
Embedding flavours

Partial embedding

- **Pros**
  - Similar price to standard PCB
  - Compatibility with standard components
  - Possibility to improve electrical/thermal performance

- **Cons**
  - Increased complexity of component placement
  - Loss of integration
  - Limitation to wirebonded actives for low-layer-count PCBs
Embedding flavours

Full embedding

- **Pros**
  - Miniaturisation through 3D integration
  - Increased performance through short connections
  - Increased performance through heat conduction

- **Cons**
  - Higher m2 price
  - Limitation to process-compatible components
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Embedding by AT&S

Component placement
Component placement

- 1 ASM X4 equivalent to 80 die placers
Embedding by AT&S

PCB and interconnect formation

IC
Embedding by AT&S

Interconnect formation

- 1 laser-drilling station equivalent to 100 wirebonders
Embedding by AT&S

Structuring and finish
Embedding by AT&S

Requirements

- Cu terminations (minimum 5 mm)
- Components in tape-&-reel
- Nothing else!
Embedding by AT&S

Benefits

- High integration
- High performance
- Very-high-scale production

Efficient and cost-effective technology
Agenda

Why embedding?

Embedding flavours

Embedding by AT&S

Reliability comparison

Supply chain

Comparison with QFN

Conclusion
Reliability comparison

Passives
Reliability comparison

Passives
Reliability comparison

Passives

- Drop test (JESD22-B111) @ 1500 g
  - SMT components (126 daisy chains)
    - First failure @ 304 drops
    - 100-% failure @ 974 drops
  - ECP components (126 daisy chains)
    - First and only failure @ 832 drops
    - Test end @ 1000 drops
Reliability comparison

Passives

- TCT (JESD22-A104C) @ [-40; +125] degC
  - SMT components (35 daisy chains)
    - Zero failure @ 1000 cycles
  - ECP components (35 daisy chains)
    - Zero failure @ 1000 cycles
Reliability comparison

Actives
Reliability comparison

Actives
Reliability comparison

Actives

- Drop test (JESD22-B111) @ 1500 g
  - SMT components (70 daisy chains)
    - First failure @ 792 drops
    - 4 failures @ 1000 drops
  - ECP components (70 daisy chains)
    - Zero failure @ 1000 drops
Reliability comparison

Actives

- TCT (JESD22-A104C) @ [-40; +125] degC
  - SMT components (70 daisy chains)
    - First failure @ 684 cycles
    - 100-% failure @ 999 cycles
  - ECP components (70 daisy chains)
    - Zero failure @ 1000 cycles
Reliability comparison

Actives

- Bend test (JEDEC-9702) @ 2 mm/min (28 mm maximum)
  - SMT components (63 daisy chains)
    - First and only failure @ 3.71 s
  - ECP components (63 daisy chains)
    - Zero failure @ 14 min
Supply chain

Suppliers

- Actives
  - Cu available from selected foundries
  - RDL available from OSATs

- Passives
  - Resistors available from AVX and Murata
  - Capacitors available from KOA and Panasonic

- IPDs
  - Available from IPDiA, Maxim and STMicroelectronics
Supply chain

Technology complexity (or lack thereof)

- Standard PCB processes
- Standard SMT processes
- Main production facilities in China

☞ Very quick capacity extension possible
Supply chain

Integration in packaging flow

- Very-high-yield process
  - 2L @ 99+% 

- Flexibility of delivery format
  - Any size up to 400*550 mm

- Intermediate-testing relevance
  - If QFN replacement
    - Only after singulation
  - If SiP
    - Do you test after every component placement/interconnection?

- Seamless integration in standard packaging flow
Supply chain

Partnership

- Agreement with TDK-EPCOS
  - TDK-EPCOS as second source for ECP
  - AT&S as second source for SESUB
  - Limiting customer concerns with regards to technology selection/dissemination
  - Co-development of next-generation embedding technology

- Need to encourage ecosystem
  - Risk of customer distrust (monopoly)
Agenda

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Comparison with QFN

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Comparison with QFN

Structure

ECP

2.5D

QFN
## Comparison with QFN

### Characteristics

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<th>ECP</th>
<th>2.5D</th>
<th>QFN</th>
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<tr>
<td>Die size (mm)</td>
<td>2*2</td>
<td></td>
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<tr>
<td>Package size (mm)</td>
<td>4*4</td>
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</tr>
<tr>
<td>Number of I/Os</td>
<td>12</td>
<td></td>
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<tr>
<td>Die thickness (µm)</td>
<td>150</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Package thickness</td>
<td>300</td>
<td>500</td>
<td>700</td>
</tr>
<tr>
<td>Interconnect</td>
<td>Via</td>
<td>WB</td>
<td>WB</td>
</tr>
<tr>
<td>Thermal resistance (K/W)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\theta_{j-top}$</td>
<td>30</td>
<td>94</td>
<td>120</td>
</tr>
<tr>
<td>$\theta_{j-bottom}$</td>
<td>0.7</td>
<td>0.6</td>
<td>0.7</td>
</tr>
<tr>
<td>$\theta_{j-ambient}$</td>
<td>0.7</td>
<td>0.6</td>
<td>0.7</td>
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<tr>
<td>Interconnect inductance (nH)</td>
<td>0.7</td>
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<tr>
<td>Cost</td>
<td>+</td>
<td>+</td>
<td>0</td>
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<tr>
<td>Testability</td>
<td>QFN footprint</td>
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Conclusion

Embedding

- Different variants depending on requirements
  - Embedded layer
  - Partial embedding
  - Full embedding

- Improved performance for limited to neutral cost increase
  - Size reduction
  - Improved thermal resistance
  - Improved electrical characteristics

- Maturing and reliable technology

- Full supply chain in place with second-source options

➡️ What will be the next big application?
Thank you for your attention!

Questions?