Power Module Packaging Technology

Steven Kummerl, Chuck Devries, Usman Chaudhry, Jim Moss

June 10, 2016
Power Module Package Technology

• IC Packaging and Inductor Technology Trends

• Power Module Technologies
  – TI modules
    • Molded Leadframe Based
    • MicroSIP embedded die modules
  – Inductor Based modules
  – Industry Modules

• Future Module Direction
IC Packaging Trends Enabling Disruptive Technologies

Miniaturization of Packages

Tube
Can
PDIP
SOIC
TSSOP
SOT
BGA
TQFN
UTQFN
WCSP
PicoStar
Can
Tube
Multi-Chip-Packages
SiP- System In Package
TSV- Stacking / Interposer
Wireless Interconnects
Revolution towards Integration
Miniaturization
Miniaturization
Miniaturization

TI Information – NDA Restrictions
# Inductor Technology Matrix

<table>
<thead>
<tr>
<th></th>
<th>Chip (MultiLayer)</th>
<th>Chip (Molded)</th>
<th>Molded</th>
<th>Assembled</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Image</strong></td>
<td>![Chip MultiLayer Image]</td>
<td>![Chip Molded Image]</td>
<td>![Molded Image]</td>
<td>![Assembled Image]</td>
</tr>
<tr>
<td><strong>Use</strong></td>
<td>Low I, &lt;50V Low Cost</td>
<td>Low-Mid I, &lt;20V</td>
<td>5-50A</td>
<td>Low Cost</td>
</tr>
<tr>
<td><strong>Features</strong></td>
<td>Sintered Ceramic with silver electrode windings</td>
<td>Flat Wire Winding, pressed magnetic powders with organic binders, chip format</td>
<td>Flat Wire Winding w/pressed magnetic powders &amp; organic binders</td>
<td>Sintered or pressed metal cores with wound wire coils.</td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>Low DCR, Soft Saturation</td>
<td>Low DCR, Soft Saturation</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Density</strong></td>
<td>Compressed</td>
<td>Compressed</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>EMI</strong></td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Fair/Poor</td>
</tr>
<tr>
<td><strong>Cost/other</strong></td>
<td></td>
<td></td>
<td></td>
<td>Lowest Cost</td>
</tr>
</tbody>
</table>
Defining Power Modules

Combine Silicon...

...Plus Components...

...On a Carrier...

...to Create a POWER MODULE
Vin to Vout Complete System in Package

Focus on POL
DC / DC
Non-Isolated
PE, Comms, Industrial, Enterprise

Leadframe Laminate
Leadframe Based Passive Integration

15-mm x 9-mm x 2.8-mm QFN

- Resistors
- Capacitors
- Integrated Controller + FETs in a QFN pkg
- Sub Assembly
- TI Leadframe

**Leadframe Based Passive Integration**

15-mm x 9-mm x 2.8-mm QFN

- Resistors
- Capacitors
- Integrated Controller + FETs in a QFN pkg
- Sub Assembly
- TI Leadframe

Leadframe Based Passive Integration

15-mm x 9-mm x 2.8-mm QFN

Resistors

Capacitors

Integrated Controller + FETs in a QFN pkg

Sub Assembly

TI Leadframe

System-In-Package

Inductor

Integrated Power Module Integration Trend

2D Side by Side

<table>
<thead>
<tr>
<th>Pkg X &amp; Y</th>
<th>11x9mm, 15x9mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pkg Height</td>
<td>2.8mmt</td>
</tr>
<tr>
<td>Current</td>
<td>2A-6A</td>
</tr>
<tr>
<td>Availability</td>
<td>Released</td>
</tr>
</tbody>
</table>

2.5D Stacked Inductor

<table>
<thead>
<tr>
<th>Pkg X &amp; Y</th>
<th>10x10mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pkg Height</td>
<td>4.3mmt</td>
</tr>
<tr>
<td>Current</td>
<td>10A, 6A, 4A</td>
</tr>
<tr>
<td>Availability</td>
<td>Released</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pkg X &amp; Y</th>
<th>16x15mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pkg Height</td>
<td>5.8mmt</td>
</tr>
<tr>
<td>Current</td>
<td>30A, 20A, 15A</td>
</tr>
<tr>
<td>Availability</td>
<td>Released</td>
</tr>
</tbody>
</table>

TI Information – NDA Restrictions
Package Thickness Progression enabling embedded solutions

- SOIC 1.75 mm
- TSSOP 1.2 mm
- QFN 1 mm
- MicroStar 1 mm
- Thin QFN 0.8 mm
- WCSP (NanoStar) 0.6/0.5 mm
- X-QFN 0.4 mm
- U*CSP 0.4 mm
- TWCSNP 0.4/0.3 mm
- PicoStar 0.15/0.1 mm
- PicoStar-2G 0.075 mm
- Invisible to naked eye ~0.04 mm
MicroSiP™ DC/DC Converter

- PCB (substrate)
- Embedded PicoStar™ DC/DC converter
- Integrated passives (L, C_{IN}, C_{OUT})
- Released to market


0402 Caps, 2012 Inductor
Inductor based modules

National Semiconductor Nano-module 2011

Ag inductor embedded in ferrite substrate.

Ferrite housing with Integrated inductor
# Industry Landscape & Construction Examples

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>LMZ31530</th>
<th>LTM4620</th>
<th>ISL8240M</th>
<th>MPM3686</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power Module</strong></td>
<td>SIMPLE SWITCHER®</td>
<td>DC/DC pModule Regulator</td>
<td>Step-Down Power Module</td>
<td>DC/DC Step-Down Power Module</td>
</tr>
<tr>
<td><strong>Linear Technology</strong></td>
<td>TI</td>
<td>Linear Technology</td>
<td>Intersil</td>
<td>MPS</td>
</tr>
<tr>
<td><strong>Vin (V)</strong></td>
<td>3 ~ 14.5</td>
<td>4.5 ~ 16</td>
<td>4.5 ~ 20</td>
<td>2.5 ~ 18</td>
</tr>
<tr>
<td><strong>Vout (V)</strong></td>
<td>0.6 ~ 3.6</td>
<td>0.6 ~ 2.5</td>
<td>0.6 ~ 2.5</td>
<td>0.65 ~ 5</td>
</tr>
<tr>
<td><strong>Sizes (mm)</strong></td>
<td>15 x 16 x 5.8</td>
<td>15 x 15 x 4.4</td>
<td>17 x 17 x 7.5</td>
<td>12 x 15 x 4</td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>&gt;95%</td>
<td>83%</td>
<td>94%</td>
<td>&gt;92%</td>
</tr>
<tr>
<td><strong>Frequency (max)</strong></td>
<td>850kHz</td>
<td>750kHz</td>
<td>700kHz</td>
<td>600kHz</td>
</tr>
<tr>
<td><strong>Substrate</strong></td>
<td>Leadframe</td>
<td>Multilayer laminate</td>
<td>Multilayer laminate /leadframe hybrid</td>
<td>Leadframe</td>
</tr>
<tr>
<td><strong>Exposed heatsink</strong></td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Inductor</strong></td>
<td>1 Cylindrical ferrite core</td>
<td>2 Cylindrical ferrite cores</td>
<td>1 Flat ferrite core</td>
<td>1 Cylindrical ferrite core</td>
</tr>
</tbody>
</table>

## Pros
- Ease of use
- Performance
- Reliability
- Reduced footprint

## Cons
- Complex Development
  - Power dissipation
  - Routable substrate
LTM 4620 Components layout and topology

- Cu clip heat sink
- Heat sink attached to 2 inductors and 2 MOSFET die stacks
- MOSFETs are stacked together with offset
- Switch node is embedded the PCB
ISL8272M Key packaging features

- External
  - 7.5 mm thick sawn-type QFN package
  - Over mold without exposed top heatsink

- Internal
  - Package in package
  - Power MOSFETs have Cu clips and their own controllers
  - Two dies are found in the high performance digital PWM controller

- Substrate
  - Leadframe
  - Routing using top half etch
  - Solder resist for insulation

- Inductors
  - Two clips passing through flat rectangular-shaped ferrite
  - Inductor feet has 90 degree bend
**POL Module—Continued Integration Over Time**

<table>
<thead>
<tr>
<th>Device</th>
<th>Inductor Volume</th>
<th>Inductance</th>
<th>Resistance</th>
<th>Frequency</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT6725</td>
<td>11%</td>
<td>11%</td>
<td>1.1mΩ</td>
<td>1MHz</td>
<td>Powder Iron, Edge Wound Flat Wire Plated Termination</td>
</tr>
<tr>
<td>PTH12050</td>
<td>11%</td>
<td>11%</td>
<td>1.5mΩ</td>
<td>1MHz</td>
<td>Powder Iron EI, Edge Wound Wire Self Term</td>
</tr>
<tr>
<td>LMZ31506</td>
<td>25%</td>
<td>11%</td>
<td>1.1mΩ</td>
<td>1MHz</td>
<td>Powder Iron Molded, Round Wire Weld on LF</td>
</tr>
<tr>
<td>TPS82130</td>
<td>45%</td>
<td>11%</td>
<td>0.6mΩ</td>
<td>1MHz</td>
<td>Powder Iron, Edge Wound Flat Wire Plated Termination</td>
</tr>
</tbody>
</table>

**Module Volume Density**

- **Reduction**: 250x Module, 70x Inductor

**Integration**
- Frequency
- Magnetics
- Packaging
THANK YOU