Directions in Mobile Device Packaging

E. Jan Vardaman
President
TechSearch International, Inc.

www.techsearchinc.com

© 2014 TechSearch International, Inc.

Era of Mobile Devices

Computing Growth Drivers Over Time, 1960-2020E

- Top growth drivers are mobile devices
- Consumers want smaller and thinner products
- Driving growth of thin package solutions

Source: ITU, Mark Lipacis, Morgan Stanley Research
TSMC

© 2014 TechSearch International, Inc.
Mobile Devices

- Mobile Devices
  - Laptops
  - Smartphones
  - Tablets
  - Feature phones
  - Wearable electronics
- Attributes
  - Typically shorter lifetimes (2 years)
  - Performance varies
  - Require high reliability in focused on drop test for high-end smartphones and tablets, some manufacturers not as concerned with drop or reliability because customer does not expect it
- System packaging needs
  - Small form factor
  - High performance, high bandwidth
  - Lower power consumption (consumers want longer battery life)
  - Thermal issues (air flow difficult)
  - Lower cost
- Packaging options
  - BGA, FBGA, LGA (including MCM), PoP, stacked die CSP, QFN, SON, CLGA, WLP
- Cost/Performance Trade-off Determines Adoption, but Form Factor is Key

Packages for Mobile Devices

- Touch screen controllers: quad flat no-lead (QFN), fine pitch ball grid arrays (FBGA)
- Antenna: ceramic land grid array (CLGA), QFN
- Power amplifiers: LGA (with laminate substrate), typically wire bond moving to flip chip
- RFIC: FBGA, flip chip BGA (FC-BGA), wafer level package (WLP), Fan-out WLP (FO-WLP)
- Modem IC: FC-BGA, stacked die package (FC and WB), package-on-package (PoP)
- Application processor: FC-BGA, bottom package of PoP
- NAND flash: FBGA
- Power management IC (PMIC): FC-BGA, WLP
- WiFi/Bluetooth: CLGA, LGA (with laminate substrate), WLP
- Near Field Communications (NFC): FBGA
- Sensors: LGA
Thin is In! Enabled by WLP

Tablet PC

Thickness < 8.5mm

Hard Disk Drive

Source: ASE

Growth in WLP Shipments

- Major application for WLP driven by mobile product such as smartphones, tablets
- Provides smaller, thinner package (low profile)
- CAGR of ~11% in units (2012 to 2017)
WLP Trends

- Consumer products and other applications
  - Mobile phones (highest volume application)
  - Digital cameras and camcorders
  - MP3 players (such as iPods)
  - Watch modules
  - Laptop and tablet computers
  - Medical
  - Automotive
  - Wearable electronics
- Conventional WLPs for many device types
  - WLPs for analog functions, power management, RF, wireless LAN, IPD, LED driver, sound IC, etc.
  - Highest I/O count 309 (Fujitsu power management IC)
  - Largest body size Apple/Cirrus Logic Audio CODEC 5.72 x 6.03 x 0.59 mm, 121 solder balls, 0.5mm pitch
  - Increasing number of 0.4mm pitch parts, some 0.35mm pitch

Source: TPSS

HTC One X Main Board

Source: TPSS

© 2014 TechSearch International, Inc.
WLP Examples in Mobile Phones

<table>
<thead>
<tr>
<th>Mobile Phone (number of WLPs)</th>
<th>Supplier (function)</th>
<th>Ball Count</th>
<th>Size (mm)</th>
<th>Pitch (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple iPhone 5 (11+)</td>
<td>Unknown</td>
<td>9</td>
<td>1.49 x 1.49 x 0.57</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>AUI</td>
<td>9</td>
<td>1.58 x 1.58 x 0.45</td>
<td>0.5</td>
</tr>
<tr>
<td>Qualcomm (RF power reg.)</td>
<td>105</td>
<td>1.63 x 1.63 x 0.57</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>RFMD (antenna)</td>
<td>12</td>
<td>1.51 x 1.51 x 0.53</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Apple/Cirrus</td>
<td>42</td>
<td>2.79 x 2.79 x 0.45</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>8</td>
<td>1.96 x 1.96 x 0.47</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>NXP (LED driver)</td>
<td>36</td>
<td>2.11 x 2.11 x 0.45</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>Broadcom (controller)</td>
<td>72</td>
<td>3.31 x 3.31 x 0.54</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>AKM (electronic compass)</td>
<td>14</td>
<td>4.64 x 4.64 x 0.48</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>TI (touch screen controller)</td>
<td>99</td>
<td>4.64 x 4.64 x 0.64</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Shidof (kg sensor)</td>
<td>6</td>
<td>2.4 x 2.4 x 0.8</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Samsung Galaxy S3 GT-10000 (6)</td>
<td>Asahi-Kasei (w/p)</td>
<td>14</td>
<td>2 x 1.98 x 0.51</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Maxim (PMIC/C) (control)</td>
<td>100</td>
<td>4.52 x 4.52 x 0.69</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Maxim (PMIC)</td>
<td>144</td>
<td>5.14 x 5.14 x 0.94</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Broadcom (receiver)</td>
<td>42</td>
<td>3.04 x 2.87 x 0.57</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Wolfson (CODEC)</td>
<td>90</td>
<td>4.18 x 3.86 x 0.45</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Intel (RFIC) (w/l)</td>
<td>139</td>
<td>5.5 x 3.0 x 0.87</td>
<td>0.4</td>
</tr>
<tr>
<td>HTC One X (7)</td>
<td>Intel (WLC) w/L</td>
<td>148</td>
<td>3.59 x 3.59 x 0.67</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Asahi-Kasei (w/p)</td>
<td>14</td>
<td>1.08 x 1.08 x 0.48</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>TI (WiFi/Bluetooth/FM tran)</td>
<td>174</td>
<td>5.7 x 5.7 x 0.84</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>TI (PMIC)</td>
<td>81</td>
<td>4.8 x 4.8 x 0.55</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>36</td>
<td>3 x 3 x 0.7</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Tri (PMO for Tegra 3)</td>
<td>104</td>
<td>5.36 x 5.36 x 0.54</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>20</td>
<td>2.09 x 1.71 x 0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Source: TPSS

Fan-Out Wafer Level Package

- Reconstituted wafer and perimeter mold compound allows for redistribution of I/O beyond current chip footprint
  - Uses KGD
  - Number of interconnects, pitch of interconnect independent of chip size
  - Mold compound used to support the FO
  - Single, multi-die, or 3D solution
- Considered an embedded package because die is placed with interconnect on top
- Fan-out WLP (FO-WLP) from ADL Engineering, Amkor, ASE, Deca Technologies, Freescale Semiconductor, FCIFujikura, J-Devices, NANIUM, Nepes, SPIL, STATS ChipPAC, TSMC, YOUR NAME HERE
- Infineon eWLB (wireless operation acquired by Intel)
  - Technology licensed by ASE, STATS ChipPAC, NANIUM
  - Production lines at STATS ChipPAC and NANIUM today are wafers, panel in future
Fan-Out WLP Applications

- Applications
  - RF
  - Baseband processor
  - Potential for memory, PMIC, Application Processor, ASIC, controllers, media chips, medical devices, sensors
- FO-WLP shipments of hundreds of millions of units each year
  - Infineon (now Intel’s IMC division) wireless products
  - Others

Intel Wireless Division
LTE analog baseband
5.32 x 5.04 x 0.7mm eWLB
127 balls, 0.4mm pitch

Source: TPSS

FO-WLP: Drivers

- Smaller form factor, lower profile package: similar to conventional WLP in profile
- Increased I/O density
  - Originally marketed as an alternative to fine pitch fan-in WLP
- Thinner than flip chip package (no substrate)
  - Comparing to FC-CSP
- Excellent electrical and thermal performance
- Excellent high temperature warpage performance
- Fine L/S (10/10µm)
  - Can enable a low-profile PoP solution as large as 15 mm x 15 mm
- Multiple die in a low-profile package
  - Die fabricated from different technology nodes can be assembled in one a single package
- Multi layer RDL with FO-WLP
  - Higher routing level with more lines and traces
  - Shield and power dissipation needs
  - Enabler of further form factor reduction

Source: Casio Micronics

Source: IMC
Embedded Components

- **Formed**: Materials are added to the printed circuit structure to create the passive element.
- **Placed**: The component is placed on an internal layer then buried as additional layers are added.

**Resistors**

**Capacitors**

**Active**

**Passive**

**Why Embedded Components Today?**

- Small form factor (reduced Z-height), enables reduced board thickness
  - Provides low profile SiP for mobile applications
  - Embedded die in bottom of PoP substrate
  - Alternative until 3D IC with TSV ready for HVM
  - Includes fan-out WLP packages
- Improved performance
  - Shorter electrical path, EMI reduction,
  - Passive devices (capacitors today, high capacitance material in future)
- Shielding advantages for RF components

Source: JISSO International Council, May 2004

© 2014 TechSearch International, Inc.
Applications for Embedded Components

- PoP in smartphones
  - as embedded active die (application processor) in bottom laminate substrate
  - Fan-out WLP with application processor as bottom package
- RF modules for mobile and other applications
- Power management modules for mobile and other applications
- Battery management modules
- MEMs microphones
- Fingerprint sensors
- Memory products
- Automotive electronics (power devices)
- Medical
- Wearable electronics, including medical applications

Source: Infineon

Application Processors for Mobile Devices

- Increasing number of examples of application processors with embedded placed capacitors in package substrate
  - Example of Exynos processor in Samsung smartphones and tablets
  - Qualcomm modem plus application processor
- Smartphones driven by thinner package and smaller footprint
  - Today 1.0mm height requirement, future ≤0.8 mm
  - Improved performance

Source: TPSS
Application Processor Packaging Trends

- Thinner package and smaller footprint
  - Today 1.0mm height requirement
  - Future ≤0.8 mm
- 3D IC with TSV provides the ultimate in in package height reduction
  - Highest density, highest performance
  - Lowest profile, smallest form factor
- PoP in smartphones
  - Embedded capacitors for improved performance HVM today
  - as embedded active die (application processor) in bottom laminate substrate
  - Fan-out WLP with application processor as bottom package

Source: Intel  Source: H. Ueda, SemiConsult

What’s Next? Wearable Electronics

- Wearable electronics includes watches and bands, eye wear, hearing aids, fitness and health trackers, conformal electronic skin patches, sensing and touch-based e-textiles, personalized lighted clothing, gaming
- Strong growth market
  - $14B in 2014 to $70B market in 2024
  - 10X growth in unit volumes 2013-2018
- Variety of devices
  - Power management
  - Sensors
  - Microcontrollers
  - LEDs and RFIDs
  - Passives
- Variety of package types
  - BGAs and CSPs
  - Leadframe packages such as QFNs
  - WLPs
  - SiPs
  - Embedded devices and materials
- Challenges: Cost, miniaturization and thermal

© 2014 TechSearch International, Inc.
Conclusions

• Mobile world continues to drive...
  – Volumes
  – Package trends
  – Technology development
  – Some future wearable electronics
• Thin products are driving thin package solutions
  – Must meet steep ramp with high volume
• Trend in WLP for mobile devices
  – Conventional WLP
  – FO-WLP
• Old technology, new names
• Adoption of new technology
  – Cost/performance trade-off
  – Test considerations
  – Established infrastructure