Non-Hermetic Packaging of RF Multi-Chip Modules

Matthew Gruber
Lockheed Martin – MST
Moorestown, NJ
A Comment about this Presentation

In accordance with ITAR restrictions, a few concessions had to be made to publicly release this information.

- **Representations of bare MMIC die and open modules are not the actual devices used**
- **Some performance data shown has been obscured (scales on charts were removed)**

“International Traffic in Arms Regulations (ITAR) dictate that information and material pertaining to defense and military related technologies may only be shared with US Persons unless approval from the Department of State is received or a special exemption is used. A "US Person" is a US citizen or permanent resident who does not work for a foreign company, a foreign government, or a foreign governmental agency/organization. It also means any corporation, business, organization or group that is incorporated to do business in the United States. United States companies can face heavy fines if the Department of State discovers they have exposed, without approval or the use of an exemption, non-US-Persons to ITAR-protected information, designs, test data, processes, software code, etc.”

[Link to Wikipedia](https://www.wikipedia.org)
Introduction

- **Chip and Wire (Traditional approach):**
  - Bare GaAs MMIC die mounted on a hermetic, ceramic substrate and interconnected by wirebonds
  - Size: 2.4” x 1.15” x .20”

- **Non-Hermetic Packaging:**
  - Plastic encapsulated GaAs MMICs mounted to a PC board using commercial surface mount assembly processes
  - Size: 1.5” x 1.1” x .25”

Electronics Packaging Inflection Points

- **Future of Electronics** – mmW, RF, Mixed Analog & Digital on a Single Chip

---

- **Increasing Performance**
- **Decreasing Cost, Size, Weight and Power (C-SWaP)**

**Inflection Point Requires Additional Investment to Maintain Industry Lead**

---

**Commercial Technology Is Driving Solutions That Benefit Defense Products**

---

Copyright © 2014  Lockheed Martin Corporation – All Rights Reserved
Advantages of Non-Hermetic Packaging

- Major reduction in packaging cost
  - Non-Hermetic packages $1-5
  - Ceramic package >$150

- Major reduction in assembly cost
  - Surface mount assembly costs ~10% of chip & wire assembly
  - Highly-integrated multi-channel PCB significantly reduces total system parts count

- Significantly improved yield
  - Components are easier to handle
  - Devices can be pre-tested prior to assembly

Non-Hermetic Packaging represents a major advancement in RF Multi-Chip Module design
A Range of Solutions are Available

A Family of Solutions Exist to Satisfy a Range of Cost and Performance Objectives
Encapsulated (QFN) Package

- JEDEC MO-220 (Standard for QFN Packages)

Copper Die Paddle
Direct Electrical &
Thermal Contact

5 x 5 mm 28 Lead
0.05 grams
QFN Cross Section – Encapsulated Package

QFN Package

GaAs Die

Plastic

Silicone

Thermal Epoxy

Bond Wire

Cu Leadframe

Stripline Interconnect

PbSn Solder

Copper Plating

Thermal Via

GaAs Die

Thermal Epoxy

Bond Wire

Cu Leadframe
Silicone Die Coating

- Die are coated with Dow Corning Silicone
  - low dielectric constant ($\varepsilon_r=2.2$)
  - Provides an additional moisture barrier
QFN Cross Section – Air Cavity Package

Air-Cavity QFN Cross-Section

- Dam & Fill Encapsulant
- QFN Package
- Lid
- Conformal Coating

Copyright © 2014 Lockheed Martin Corporation – All Rights Reserved
EM Modeling of Package to PCB Transition

- All RF transitions into and out of QFN must be EM modeled to ensure that the inductance of the leadframe and wirebonds do not de-tune the circuit.

- Accurate modeling is key to maximizing performance of the packaged MMIC.
## QFN Package Designs

<table>
<thead>
<tr>
<th>LNA QFN</th>
<th>MFC QFN</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Image" /></td>
<td><img src="image2" alt="Image" /></td>
</tr>
<tr>
<td>Package Size: 7.65mm x 5mm</td>
<td>Package Size: 7mm x 9mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Limiter QFN</th>
<th>Driver QFN</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3" alt="Image" /></td>
<td><img src="image4" alt="Image" /></td>
</tr>
<tr>
<td>Package Size: 8mm x 8mm</td>
<td>Package Size: 5mm x 5mm</td>
</tr>
</tbody>
</table>

---

*Copyright © 2014 Lockheed Martin Corporation – All Rights Reserved*
Environmental Testing

- An environmental test vehicle was fabricated with 3 variants:
  - Ceramic/Hermetic Package (Baseline)
  - Air Cavity QFN
  - Air Cavity QFN with ALD coating

- Three environmental tests were performed:
  - Temp Cycling: -40°C to +125°C – 1000 Cycles
  - THB: 85°C/85%RH, 2000 Hrs.
  - Unbiased HAST: 110°C/85%RH, 1000 Hrs.
  - HTOL: 150°C, 1000 Hrs.
Environmental Test Results

Environmental Testing Validates Reliability of Plastic Packaged MMICs
Summary

- Non-hermetic MMIC packaging significantly decreases RF Multi-Chip Module packaging cost
  - Increased yield
  - Decreased assembly complexity

- Encapsulated and Air-Cavity options provide end user with cost vs. performance options

- Use of Air Cavity QFNs enables RF performance closely matched to chip and wire baseline

- Environmental test results verify the robustness of the packaging approach against even extreme environmental conditions

Thank You!