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Driving Performance

"Design for performance and advanced characterization of new contactors"
Markus Wagner – Cohu & Milen Cheshmedjieiev – Melexis

"Investigation into Various Via Structures in High Speed Interconnect"
Carol McCuen - R&D Altanova

"Contactor and Package Design Effects on Crosstalk"
Noureen Sajid & Jeff Sherry - Johnstech International

"Contactor Based Final Test at 77 GHz on a Multi-Channel Radar Transceiver Chipset"
Brian Nakai & Jeffrey Finder - NXP Semiconductors
Contactor Based Final Test at 77 GHz on a Multi-Channel Radar Transceiver Chipset

Brian Nakai, Jeffrey Finder
NXP Semiconductors

BiTS Workshop
March 5 - 8, 2017
Agenda

- NXP Radar Device Overview
- Package
- Hardware Setup
- Mechanical Performance
- Current Challenges
- Future Improvements
NXP Radar Device Overview

Applications

- **Increasing applications for radar**
  - Value added Parking solutions
  - Pedestrian Detection
  - Cross Traffic Alert

- **Increasing performance with small size**
  - Transition 24 GHz → 77 GHz: improved resolution

- **Increasing attach rate per car**
  - Radar initially for safety emergency braking
  - Now moving to corner sensors, “cocoon radar”

Product Line

- **Long Range Radar**
  - **MR2001 Chip Set**
  - Scalable TX, RX Blocks
  - RaceRunner Processor

<table>
<thead>
<tr>
<th>Features</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scalable to Four Tx and 12 Rx Channels</td>
<td>Enables single radar platform with electronic beam steering over wide field of view, supporting LRR, MRR and SRR applications for budget to luxury vehicles</td>
</tr>
<tr>
<td>Integrated Rx BB Filter and VGA</td>
<td>Saves system BOM cost</td>
</tr>
<tr>
<td>Optimized for Radar Processor MPC57xK</td>
<td>Receiver path optimization with MPC57xK, including unique built-in system test features. Ensures the best receiver sensitivity required for excellent detection accuracy</td>
</tr>
<tr>
<td>Advanced Packaging Technology</td>
<td>Easiest to use, handle and manufacture for customers. Ensures highest performance and minimum signal interference on the customer PCB</td>
</tr>
<tr>
<td>Low Power Consumption of 2.5 W for the Total Transceiver: Best phase noise &lt; -85 dBc/Hz at 100 kHz offset</td>
<td>Low power consumption saves energy and heat. Best phase noise enables precise discrimination of objects for automatic cruise control, blind spot detection, lane departure warning and pedestrian detection</td>
</tr>
</tbody>
</table>
Radar Package Description

- 6 x 6 mm 0.5 mm Pitch RCP (Redistributed Chip Package)
- Similar to a thin BGA
- Three separate ball maps for the chipset products, VCO, Rx, Tx
Objective

- Develop a Final Test ATE solution for singulated 77 GHz testing.
- Needs to be standardized and robust for transfer into high volume manufacturing.
- Develop stable, high yielding process.
Initial Hardware Setup

- The 93K is a mature test platform retrofitted with a millimeter wave interface to extend RF frequencies to maximum frequency of 82 GHz
- Additional user power supplies inside: +/- 5V, +/- 12V and -3V
- 1 DPS128
- 6 digital channel cards

<table>
<thead>
<tr>
<th>Stimulus Power</th>
<th>Frequency</th>
<th>Level</th>
<th>Accuracy</th>
<th>Phase Noise (Typical)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Band</td>
<td>37.5 – 41GHz</td>
<td>-15 to +15dBm</td>
<td>± 1.0dB</td>
<td>-112dBc/Hz@1MHz</td>
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<tr>
<td></td>
<td>37.5 – 41GHz</td>
<td></td>
<td></td>
<td>-122dBc/Hz@10MHz</td>
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<tr>
<td>High Band</td>
<td>75 – 82GHz</td>
<td>-15 to +12dBm</td>
<td>± 1.0dB</td>
<td>-106dBc/Hz@1MHz</td>
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<tr>
<td></td>
<td>75 – 82GHz</td>
<td></td>
<td></td>
<td>-116dBc/Hz@10MHz</td>
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</table>

<table>
<thead>
<tr>
<th>Measure Power</th>
<th>Frequency</th>
<th>P1dB</th>
<th>Dynamic Range (100kHz BW)</th>
<th>Accuracy</th>
<th>Phase Noise (Typical)</th>
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<tbody>
<tr>
<td>Low Band</td>
<td>37.5 – 41GHz</td>
<td>+5dBm</td>
<td>55dB</td>
<td>± 1.0dB</td>
<td>-121dBc/Hz@1MHz</td>
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<tr>
<td></td>
<td>37.5 – 41GHz</td>
<td></td>
<td></td>
<td></td>
<td>-140dBc/Hz@10MHz</td>
</tr>
<tr>
<td>High Band</td>
<td>75 – 82GHz</td>
<td>+1dBm</td>
<td>50dB</td>
<td>± 1.0dB</td>
<td>-114dBc/Hz@1MHz</td>
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<tr>
<td></td>
<td>75 – 82GHz</td>
<td></td>
<td></td>
<td></td>
<td>-134dBc/Hz@10MHz</td>
</tr>
</tbody>
</table>
Initial Hardware Setup

- Delta Castle Pick and Place handler
  - Tri-Temp Capable
  - Tray to Tray handling
  - Vertical docking plane
  - Established handler within NXP
Initial Hardware Setup

- Waveguide Cage
  - Interface between Tester and DUT board/socket
  - NXP designed
  - Contains mmWave components
Initial Hardware Setup

• Xcerra mmWave Socket
  – Leadframe for mmWave signal connection
  – Spring pins for power, ground, and digital signals

Contactor Based Final Test at 77 GHz on a Multi-Channel Radar Transceiver Chipset
Initial Hardware Setup

- Socket/Board/Cage Connection

Contactor Based Final Test at 77 GHz on a Multi-Channel Radar Transceiver Chipset
Mechanical Performance (Gen1)

• Handler
  – Single Site Test
  – No issues handling RCP, no damage
  – Temperature stability needed to be characterized for each device

• Waveguide cage
  – Can bolt to the handler, tester docks to it
  – Each product requires a different cage
Mechanical Performance (Gen1)

- Castle Handler
- 93K Tester
- Waveguide Cage
- mmWave UDI

Contactor Based Final Test at 77 GHz on a Multi-Channel Radar Transceiver Chipset
Mechanical Performance (Gen1)

- **Socket**
  - Good electrical performance
  - Solder ball deformation observed
    - Ball extruding through leadframe holes
    - Passed automated outgoing inspection but were visual defects that should not be passed onto the customer
  - Elastomer cycle life was short causing yield issues
Solder Ball Deformation

Ball height spec is 0.25mm +/-0.07

Ball diameter spec is 0.3mm +/-0.05
Solder Ball Deformation Cause

• Socket leadframe design contacted all solder balls
  – Leadframe stiffness and elastomer caused high contact force on the solder balls

Contactor Based Final Test at 77 GHz on a Multi-Channel Radar Transceiver Chipset
Solder Ball Deformation Cause

Leadframe

Elastomer

Contactor Based Final Test at 77 GHz on a Multi-Channel Radar Transceiver Chipset
Socket Improvements

- New leadframe design implemented
  - Only contacts the RF Ground signals, ground island
  - Cantilevered design allows more flexibility
Socket Improvements

Leadframe

Elastomer

Contactor Based Final Test at 77 GHz on a Multi-Channel Radar Transceiver Chipset
Socket Improvements

- Elastomer design changes
  - Material was changed from Silicone to Viton
  - Design was changed to support the entire ground island, not just the RF signal trace
Mechanical Performance (Gen2)

• Socket
  – Good electrical performance
  – Solder ball deformation observed
    • Resolved the ball “extruding” but “flattening” of the solder balls still occurred
    • Worst case along the outer edge
  – Elastomer cycle life
    • Improved but still required frequent maintenance
    • Elastomer would shift from under the leadframe
Mechanical Performance (Gen2)

Contactor Based Final Test at 77 GHz on a Multi-Channel Radar Transceiver Chipset
Socket Improvements

• Elastomer design changes
  – Elastomer was changed to a “pocket” design.
  – Outer perimeter of elastomer removed to limit the elastomer to only the contact point regions of the leadframe.
  – Elastomer thickness increased to allow pockets to be machined into the socket floor to contain the elastomer islands.
Socket Improvements

Gen2.1 Socket with Pocket Elastomers

Contactor Based Final Test at 77 GHz on a Multi-Channel Radar Transceiver Chipset
Mechanical Performance (Gen2.1)

• Socket
  – Good electrical performance
  – Solder ball deformation minimized
    • Still see some flattening of the ball
  – Elastomer lifetime
    • Improved but still requires replacement
  – Leadframe Lifetime >1M cycles
Waveguide Cage Improvements

• Implementation of Universal Hard Dock (UHD)
  – Worked with inTEST to integrate components for all three products into one UHD cage.
  • Only the socket and DUT board are changed.
  • Allows easier and faster product changes in production.
  • Sockets can be maintained offline.
Current Challenges

• Some ball deformation still seen
  – Remove edge ball contacts

• Elastomer lifetime
  – Need to improve replacement frequency, currently 100-150K cycles.

• Handler variability
  – Chuck to Chuck yield variation
  – Handler jams causing socket damage
Future Improvements

- Elastomer alternative
  - Replace elastomer with non-conductive spring pins
- Socket Maintainability
  - Need improved socket assembly to allow replacement of leadframe and elastomer without removing the RF cables
- Reducing failure modes
  - Cable failures