# Production Wafer Probe of 77-81 GHz Automotive Radar Applications

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TestConX™

Virtual Event ● May 11-13, 2020

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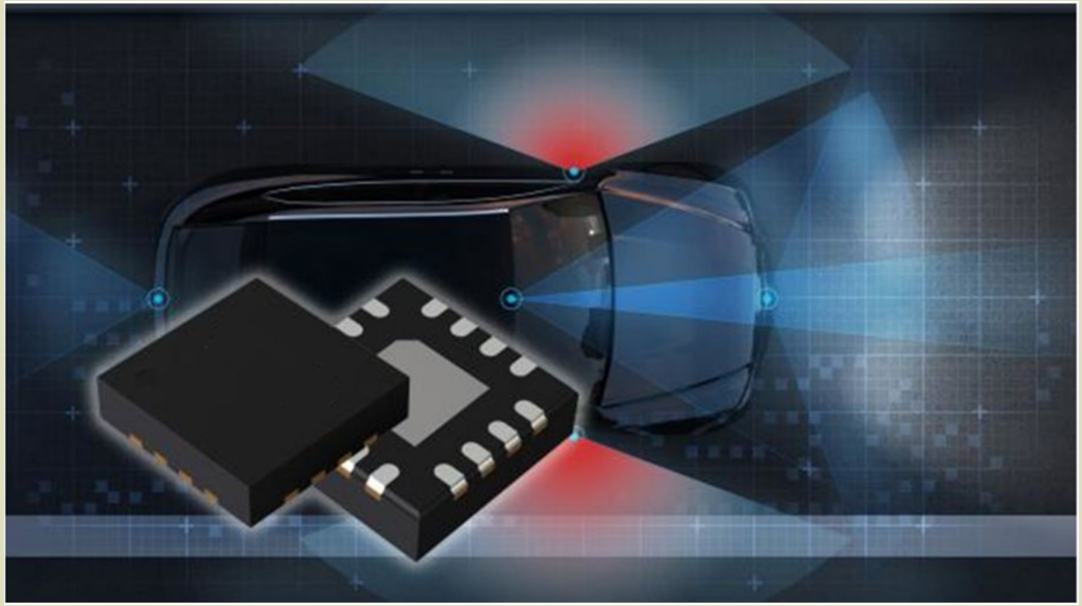
# Outline

- Introduction – Automotive Radar Devices and Testing
- Benefits and Challenges in testing the new generation
- Testing requirements and options
  - Pogo with PCB absorber
  - Membrane Solution
  - xWave with absorber
    - Advantages
    - Modification to the standard xWave
- Test Results
  - Initial and current
- Improvements along the way
- Next Steps
- Summary/Conclusion

# Introduction

- Automotive Radar has been used since 2007
  - First Generation (Approximately 2007 – 2013)
    - 28 Ghz
    - Short range
    - Limited functionality
  - Second Generation (Approximately 2014 – 2018)
    - 80 Ghz – improved resolution
    - Longer range
    - Increased functionality
- Now entering a third generation (2019 – TBD)
  - 80 Ghz
  - Longest range
  - Increased performance and functionality
  - Lower cost
  - New testing challenges

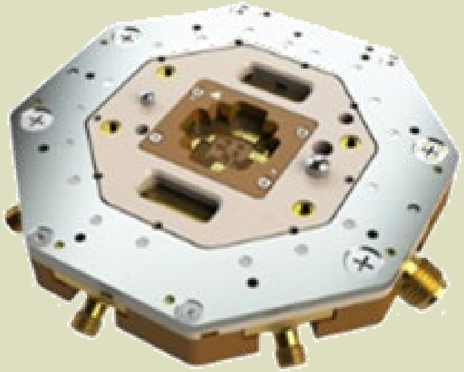


# Introduction – Cont.

- Second Generation
  - Devices packaged in traditional formats (i.e. BGA, QFN, etc.)
  - Multiple packages for receiver (RX), transmitter (TX) and voltage controller (VCO)
  - Packages combined into module
  - Testing required at multiple levels (wafer, film frame, package, transceiver module)
    - About 15 tests, many of them repetitive
  - mmWave Automated Test Equipment (ATE)
    - Expensive new
    - Difficult to get repeatable results due to sensitivity
    - Extensive set-up due to calibration
    - **Basically need an RF Lab on your test floor with RF engineers to keep it going!**

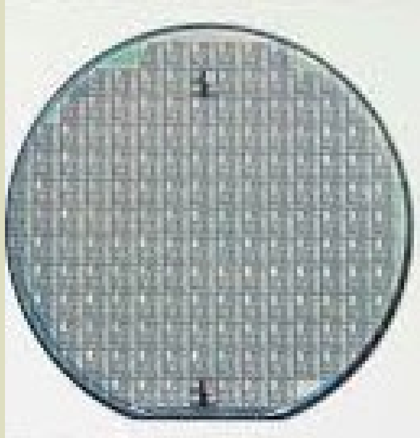
# Benefits in testing the new generation

- Third Generation
  - Die level integration of receiver (RX), transmitter (TX) and voltage controller (VCO)
  - Packages no longer required
  - Testing required at wafer and WLCSP
    - ambient, hot, cold, fewer total tests and less repetition (4 total)
  - Built-in Self Test (BIST)
    - BIST allows die to do internal testing.
    - Eliminates need for expensive mmWave test equipment
    - Better fit with standard wafer test environment
  - Multi Site Testing
    - Higher throughput



# Challenges in testing the new generation

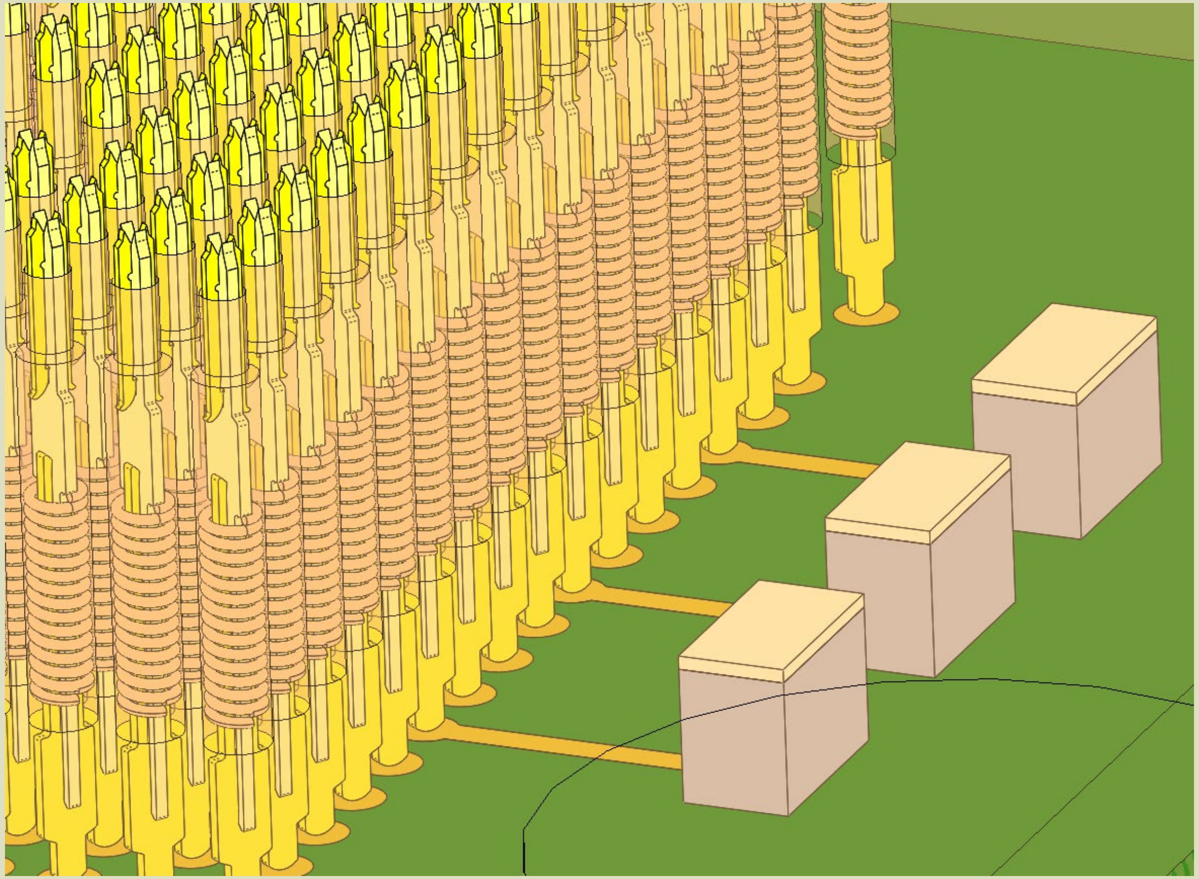
- Built-in Self Test (BIST)
  - Requires the I/O for the high frequency signals to be properly terminated while still providing a path for sourcing a DC voltage to the DUT.
  - New functionality in the test hardware/probehead
  - Dual frequency ranges to optimize with differing absorption requirements
- Wafer/WLCSP testing
  - Smaller target
  - More sensitive to coplanarity
  - Temperature sensitivity
- Integration of the three devices into one die
  - More complex test program



# Challenges in testing the new generation (cont.)

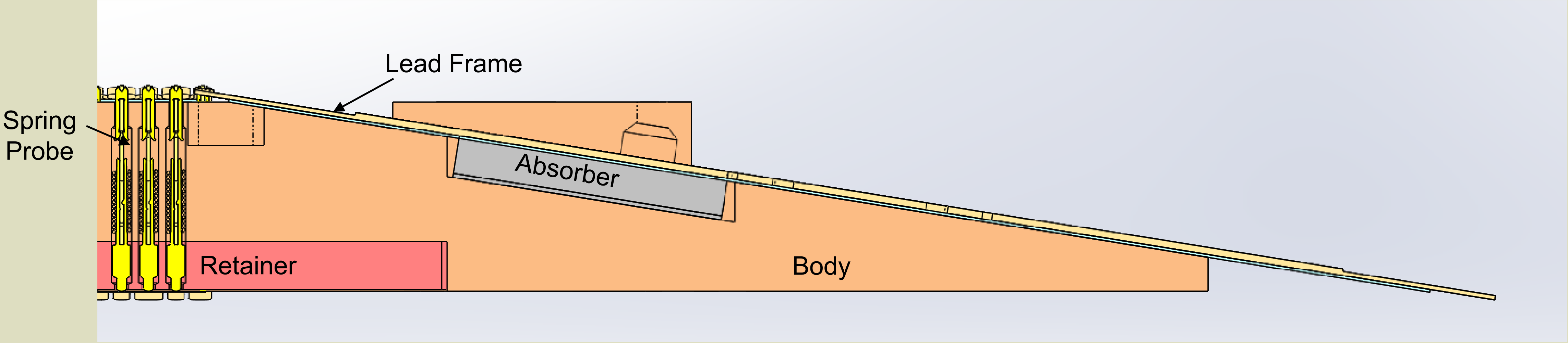
- Multi Site Testing
  - Coplanarity challenges
    - Reduction of forces
    - Adding support for PCB (Bridge Beam)
  - Site to site alignment
  - Site to site variation
  - CTE
- Contact Technology – Dual
  - Spring Probes for standard signals
  - Leadframe for RF frequency signals
- Production Worthy Solution

# Test Solutions – Absorber on PCB



- 90° transition at PCB creates significant signal reflection

# Test Solutions – Prototype Build
# Leadframe with PCB Connection



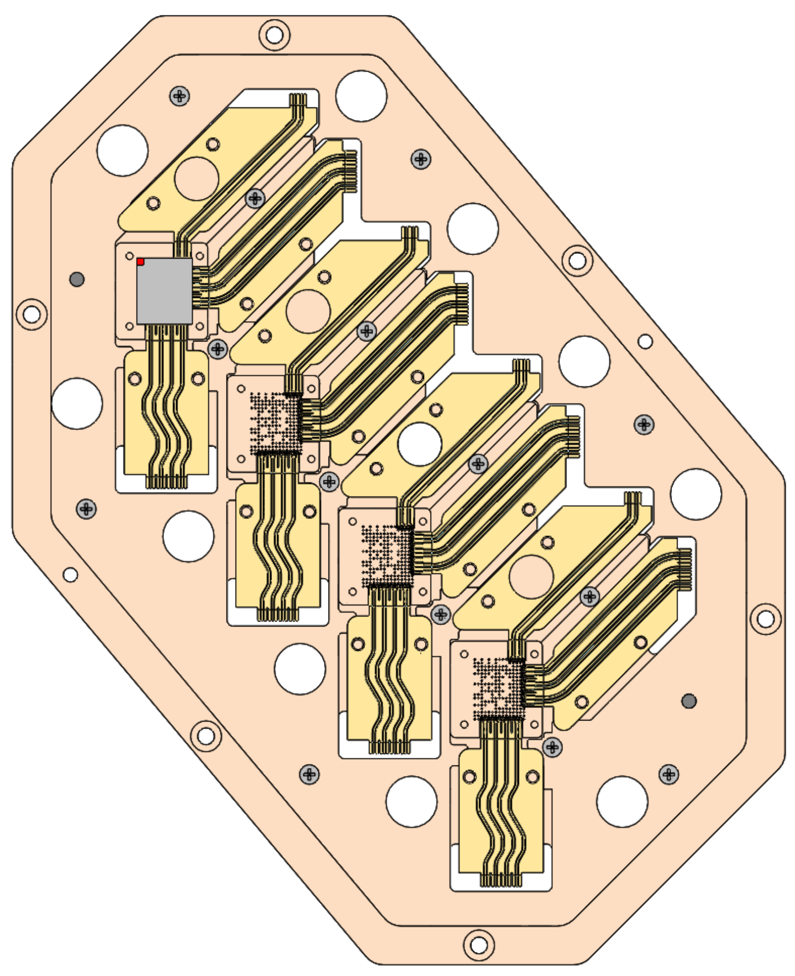
## Issues Solved

- Straight leadframe with shallow angle connection to PCB reduces reflections.
- Absorber attenuates signal.

## New Issues

- Tolerances of absorber create mechanical bowing issues
- Initial leadframe mechanics require larger than planned overdrive

# Test Solutions – Prototype Build
## Leadframe with PCB Connection - MultiSite

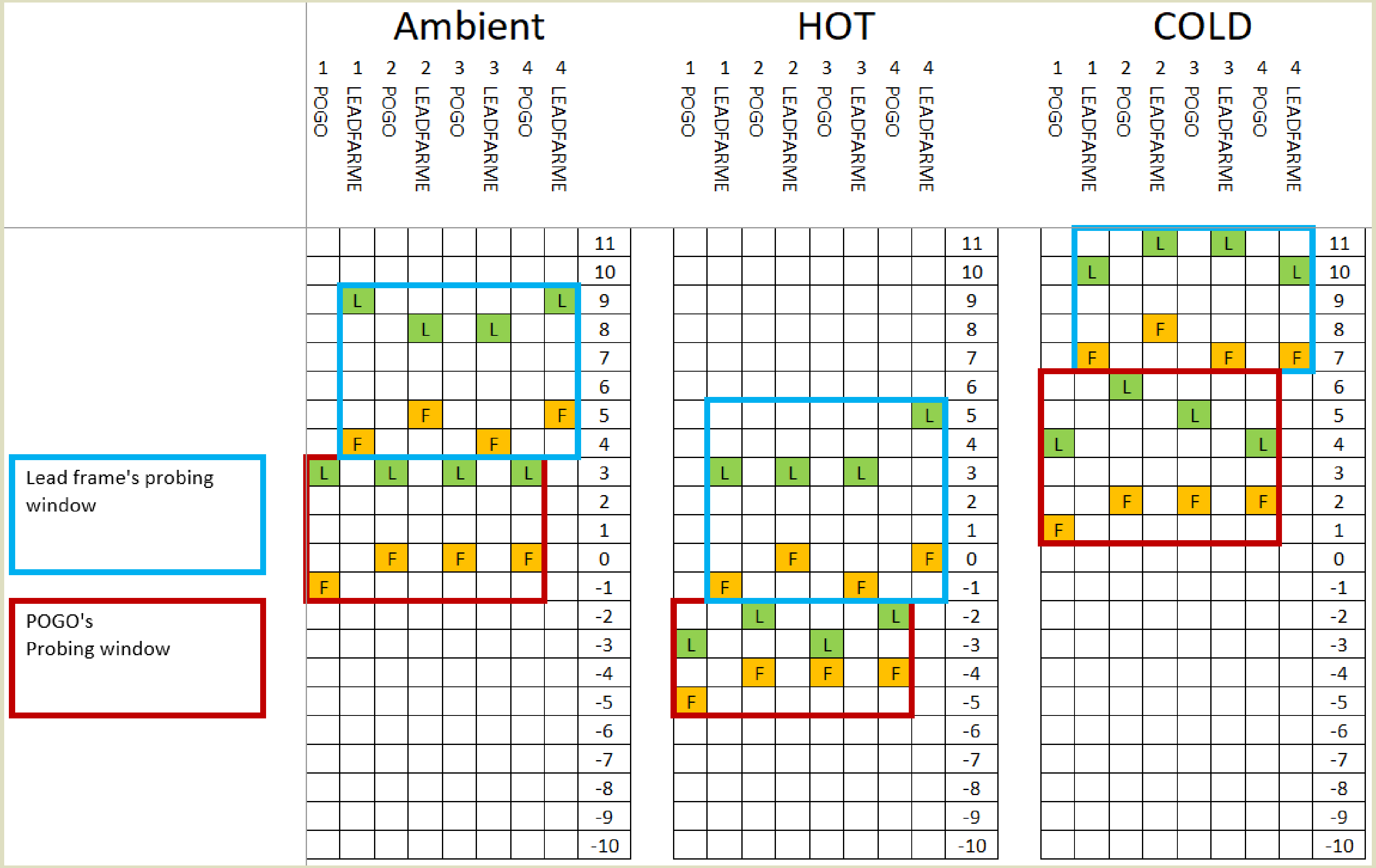


- Multi-site required some new thinking with leadframes fanning out at 45° from three sides

# Challenges in Prototype Build

- Bowing of Probehead
  - Additional mounting locations required
  - Reduction of force applied by absorbers – more compliant second layer
  - Redesign of components to add rigidity
- Coplanarity of PCB
  - Stiffener in original design
  - Added adjustable support beam to coplanarize
- Logistics Across Multiple Sites
  - Probe Card Stiffener compatibility

# Field Results – Initial Production with Prototype Build



Lead frame's probing window

POGO's Probing window

### Ambient

| | 1 POGO | 1 LEADFARME | 2 POGO | 2 LEADFARME | 3 POGO | 3 LEADFARME | 4 POGO | 4 LEADFARME |
|---|---|---|---|---|---|---|---|---|
| 11 | | | | | | | | |
| 10 | | | | | | | | |
| 9 | | L | | | | | | L |
| 8 | | | | L | | L | | |
| 7 | | | | | | | | |
| 6 | | | | | | | | |
| 5 | | | | F | | | | F |
| 4 | | F | | | | F | | |
| 3 | L | | L | | L | | L | |
| 2 | | | | | | | | |
| 1 | | | | | | | | |
| 0 | | | F | | F | | F | |
| -1 | F | | | | | | | |
| -2 | | | | | | | | |
| -3 | | | | | | | | |
| -4 | | | | | | | | |
| -5 | | | | | | | | |
| -6 | | | | | | | | |
| -7 | | | | | | | | |
| -8 | | | | | | | | |
| -9 | | | | | | | | |
| -10 | | | | | | | | |

### HOT

| | 1 POGO | 1 LEADFARME | 2 POGO | 2 LEADFARME | 3 POGO | 3 LEADFARME | 4 POGO | 4 LEADFARME |
|---|---|---|---|---|---|---|---|---|
| 11 | | | | | | | | |
| 10 | | | | | | | | |
| 9 | | | | | | | | |
| 8 | | | | | | | | |
| 7 | | | | | | | | |
| 6 | | | | | | | | |
| 5 | | | | | | | | L |
| 4 | | | | | | | | |
| 3 | | L | | L | | L | | |
| 2 | | | | | | | | |
| 1 | | | | | | | | |
| 0 | | | | F | | | | F |
| -1 | | F | | | | F | | |
| -2 | | | L | | | | L | |
| -3 | L | | | | L | | | |
| -4 | | | F | | F | | F | |
| -5 | F | | | | | | | |
| -6 | | | | | | | | |
| -7 | | | | | | | | |
| -8 | | | | | | | | |
| -9 | | | | | | | | |
| -10 | | | | | | | | |

### COLD

| | 1 POGO | 1 LEADFARME | 2 POGO | 2 LEADFARME | 3 POGO | 3 LEADFARME | 4 POGO | 4 LEADFARME |
|---|---|---|---|---|---|---|---|---|
| 11 | | | | L | | L | | |
| 10 | | L | | | | | | L |
| 9 | | | | | | | | |
| 8 | | | | F | | | | |
| 7 | | F | | | | F | | F |
| 6 | | | L | | | | | |
| 5 | | | | | L | | | |
| 4 | L | | | | | | L | |
| 3 | | | | | | | | |
| 2 | | | F | | F | | F | |
| 1 | F | | | | | | | |
| 0 | | | | | | | | |
| -1 | | | | | | | | |
| -2 | | | | | | | | |
| -3 | | | | | | | | |
| -4 | | | | | | | | |
| -5 | | | | | | | | |
| -6 | | | | | | | | |
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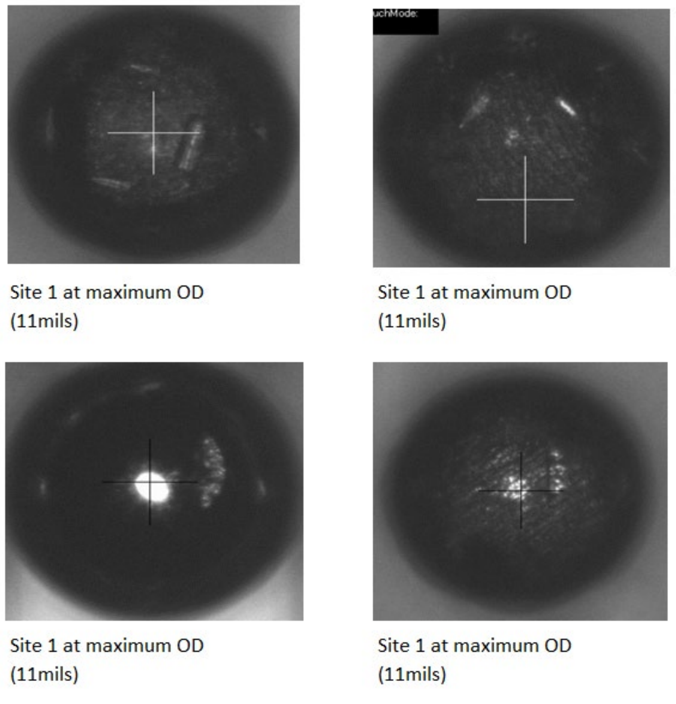


Site 1 at maximum OD (11mils)

Site 1 at maximum OD (11mils)

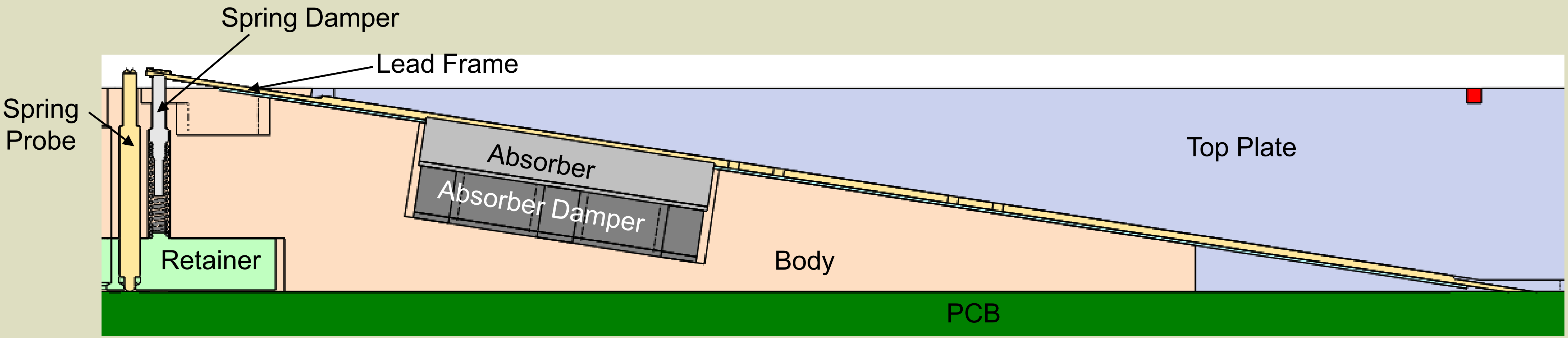
Site 1 at maximum OD (11mils)

Site 1 at maximum OD (11mils)

Total overdrive of about 11 mils to achieve continuity

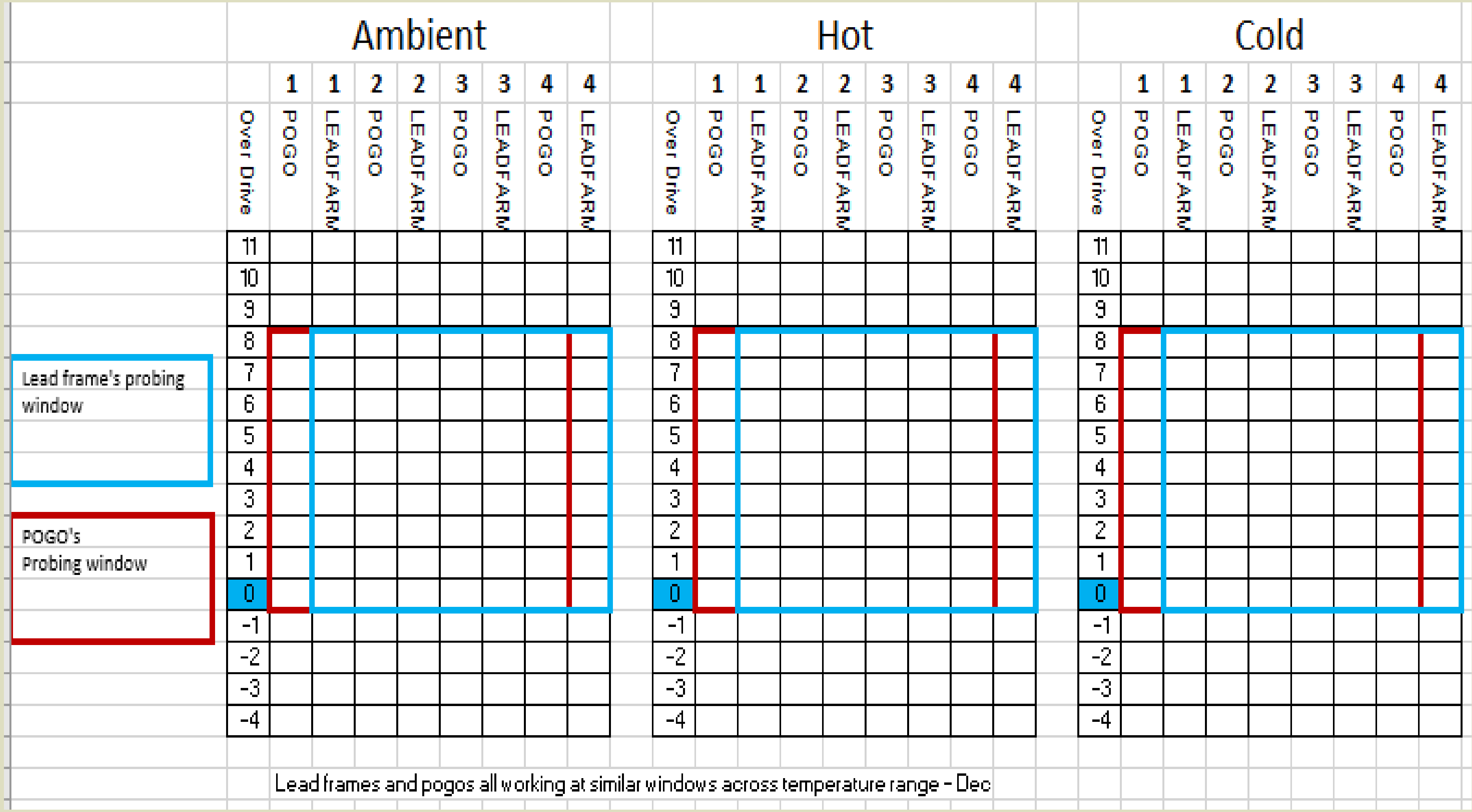
Successful but window was limited and production team wanted improvements

# Test Solutions – Production Build



- Spring damper to better support leadframes
- Absorber damper to add compliance/reduce bowing of top plate

# Field Results – Improved Production



| Ambient | | | | | | | | | Hot | | | | | | | | | Cold | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| Over Drive | POGO | LEADFARM | POGO | LEADFARM | POGO | LEADFARM | POGO | LEADFARM | Over Drive | POGO | LEADFARM | POGO | LEADFARM | POGO | LEADFARM | POGO | LEADFARM | Over Drive | POGO | LEADFARM | POGO | LEADFARM | POGO | LEADFARM | POGO | LEADFARM |
| 11 | | | | | | | | | 11 | | | | | | | | | 11 | | | | | | | | |
| 10 | | | | | | | | | 10 | | | | | | | | | 10 | | | | | | | | |
| 9 | | | | | | | | | 9 | | | | | | | | | 9 | | | | | | | | |
| 8 | | | | | | | | | 8 | | | | | | | | | 8 | | | | | | | | |
| 7 | | | | | | | | | 7 | | | | | | | | | 7 | | | | | | | | |
| 6 | | | | | | | | | 6 | | | | | | | | | 6 | | | | | | | | |
| 5 | | | | | | | | | 5 | | | | | | | | | 5 | | | | | | | | |
| 4 | | | | | | | | | 4 | | | | | | | | | 4 | | | | | | | | |
| 3 | | | | | | | | | 3 | | | | | | | | | 3 | | | | | | | | |
| 2 | | | | | | | | | 2 | | | | | | | | | 2 | | | | | | | | |
| 1 | | | | | | | | | 1 | | | | | | | | | 1 | | | | | | | | |
| 0 | | | | | | | | | 0 | | | | | | | | | 0 | | | | | | | | |
| -1 | | | | | | | | | -1 | | | | | | | | | -1 | | | | | | | | |
| -2 | | | | | | | | | -2 | | | | | | | | | -2 | | | | | | | | |
| -3 | | | | | | | | | -3 | | | | | | | | | -3 | | | | | | | | |
| -4 | | | | | | | | | -4 | | | | | | | | | -4 | | | | | | | | |

Lead frame's probing window

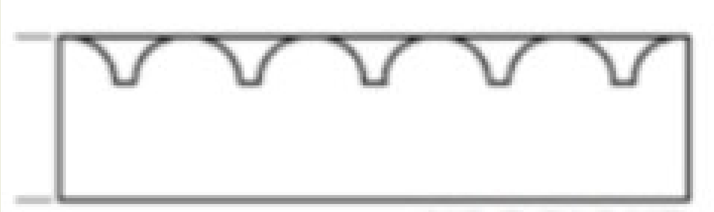
POGO's Probing window

Lead frames and pogos all working at similar windows across temperature range - Dec

- Full continuity at all temps at 8 mils of overdrive
- Max overdrive of 13 mils allowed
- 5 mil working window
- Production team approved for release

# Field Results – Ongoing concerns

- Over 250,000 insertions on the first probe head
- In-Situ cleaning as angled leadframes are more difficult to clean than pogo pins or flat leadframes – reviewing new cleaning media
- Absorber system may degrade over time and require repair/improvement



# Strengths

- Excellent RF performance over a broad range of frequencies
- Long life
- Multi-site capability
- Large compliance window

# Weakness

- Complex to balance multiple contact technologies on one DUT
- Some limits on the number and location of RF signals
- In-situ cleaning is difficult
- May need maintenance on absorpbtion system over time

# Next Steps

- Project has moved to production and additional test cells are being deployed to meet end user demand!
- Testing in-situ cleaning media and methods
- Testing life performance of absorption system
- Better control of force on leadframes with modifications to support system (future projects)
- Have improved tolerance capabilities and geometries on leadframes
- Have implemented pad compatible geometries

# Summary/Conclusion

- Advances in IC design architectures and contacting methods make high volume test of automotive radar RF devices production capable with test resources already available on production floors.

- Thank you to NXP for the opportunity and collaboration to make it happen!

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