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Minimizing Parametric Probe Card Stray Capacitance

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FormFactor Inc & GLOBALFOUNDRIES

Overview

- Definition Of Capacitance
- Importance of Minimizing Capacitance
- Background
- Capacitance of Probe Card Components
- Case Study Customer A
- GLOBALFOUNDRIES Case Study
- Summary

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- **Definition Of Capacitance**
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Stray Capacitance Definition

- **Stray capacitance is unintended and unwanted capacitance in a circuit.**
  - Capacitance doesn't exist only within capacitors. In fact, any two surfaces at different electric potential, and that are close enough together to generate an electric field have capacitance

(Wikipedia)

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Why is Stray Capacitance Important for Parametric Testing?

- **Capacitance is used for process monitoring in some tests**

Example :
Critical Capacitance measurement example , signature measurement of the technology

Classic measurement lpoly = length of poly = $\frac{\text{capacitance of poly finger}}{\text{capacitance of large area plate}}$

- **Aggressive test structure designs (space limited test structure-pad sharing) becoming less tolerant to probe card stray capacitance**
- **Measuring lower capacitance values in new advanced nodes**
  - Need the measurement to be more accurate
    - Some critical measurements are in the 100's of fF
  - Need tighter distribution as well

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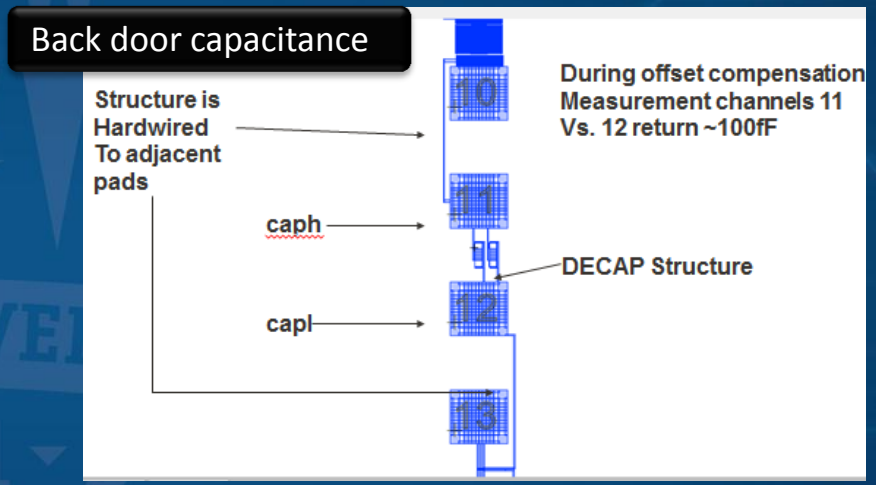
Background

- Why lower capacitance became more important?
  - For Case Study Customer A
    some pads are tied together in
    the wafer



  - In the case of GLOBALFOUNDRIES it was a desire to more closely match or improve on the existing technology

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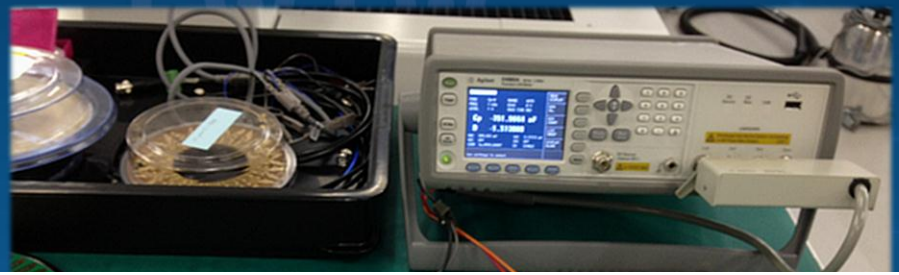
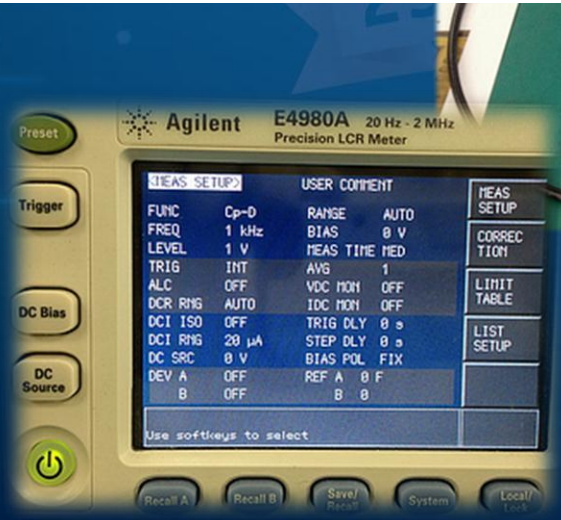
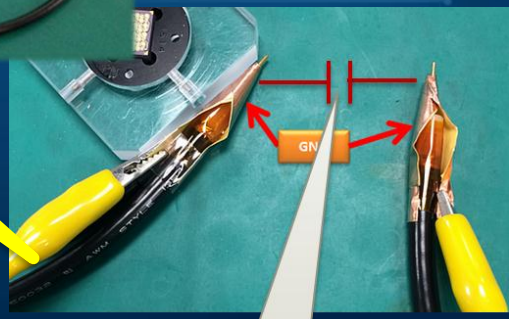
Engineering Stray Capacitance Measurement Method

- **Agilent E4980A**



Very important to have an engineering capability that correlates to testers in the field

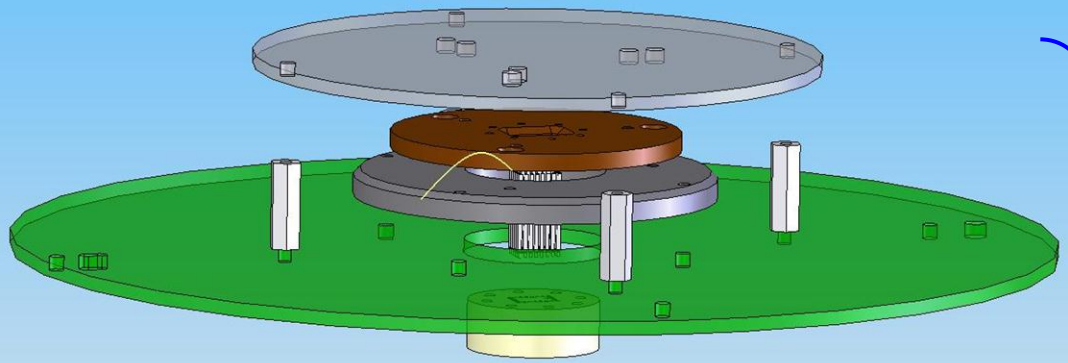




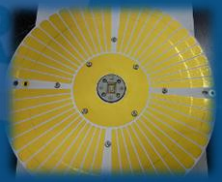
Calibration off set
Probe to probe

Capacitance of Probe Card Components

Interchangeable Platform Adds Complexity

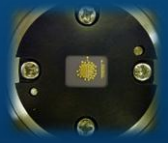


Mother Board



Probe Card

Interchangeable Insert Unit



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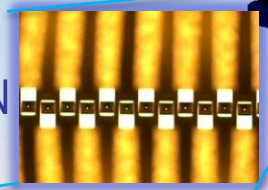
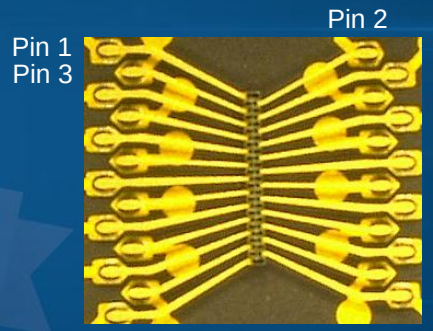


Common inserts for Multiple Tester Platforms

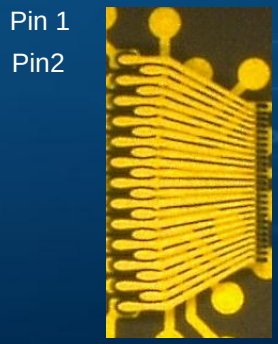
US Patent Nos. 7,498,825 and 7,898,242

Probe Card Stray Capacitance

- **Traditionally stray capacitance is measured from pin to pin in air and on the wafer**
  - Customarily pins have been designed to come from opposite sides for course pitch/larger pads

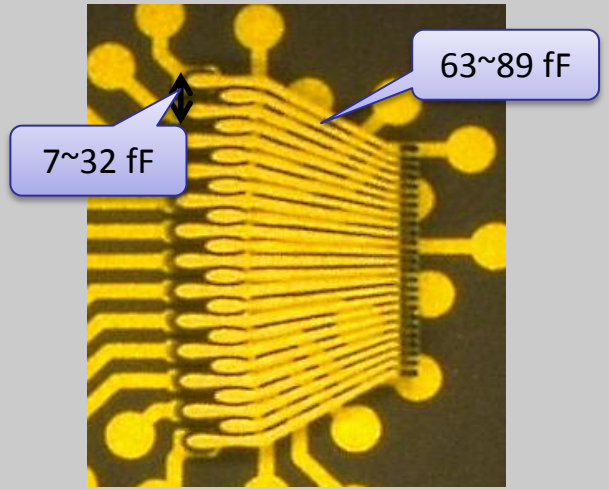
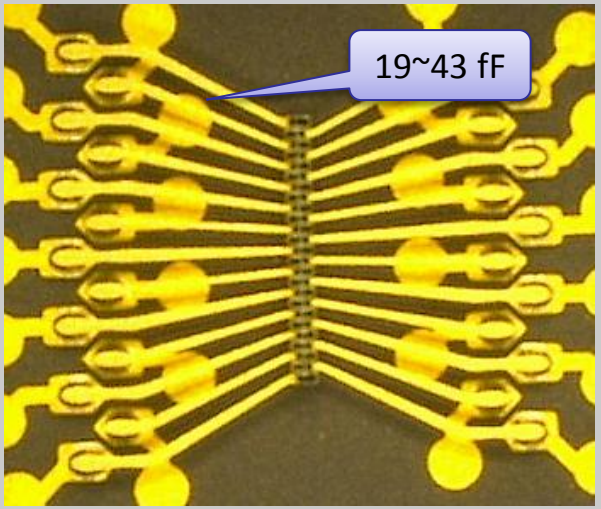
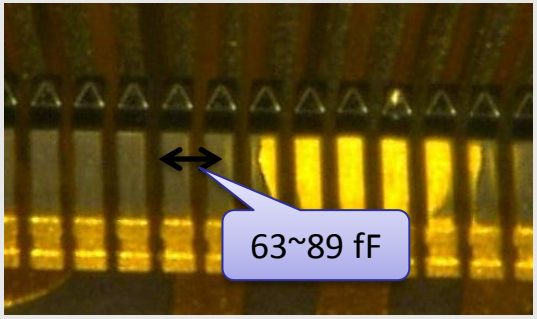
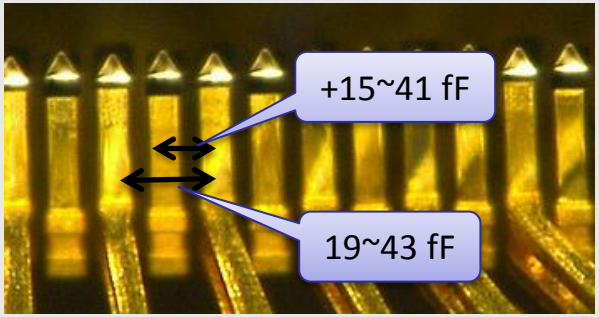


  - For tight pitch and small pads it is becoming more common for springs to come from one side to optimize probe mark alignment over time



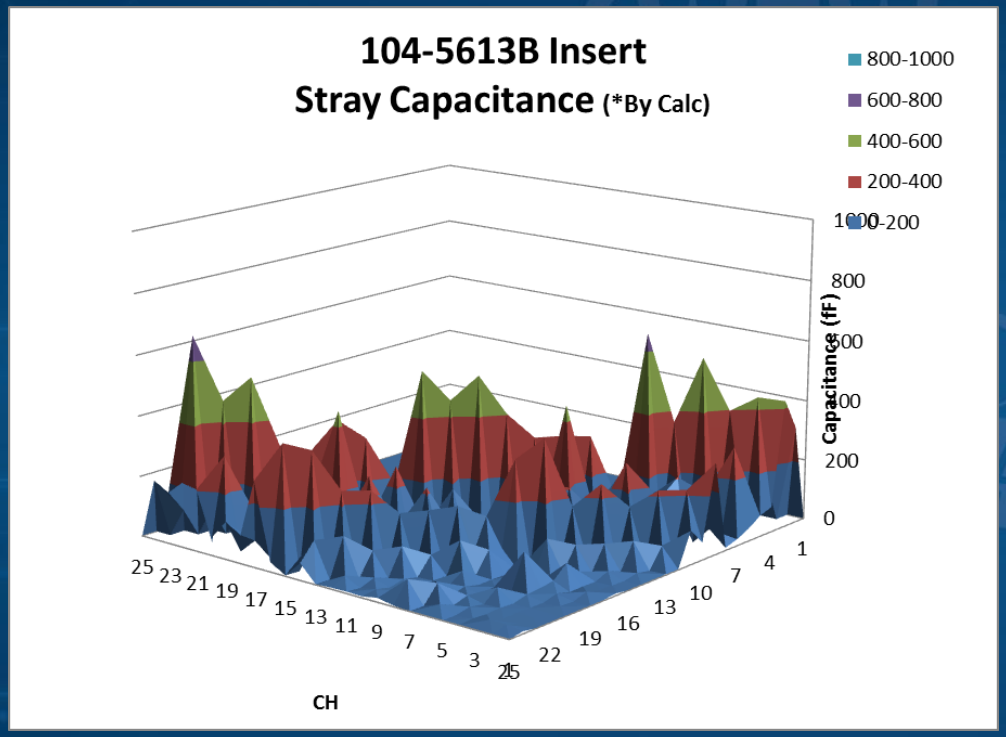
Prober Card Break Down
Probes

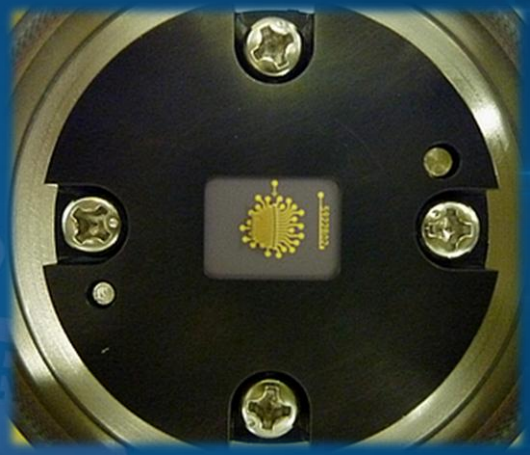
- 25 pin 80um pitch design

Single (Beam pitch Narrow)	Dual (Beam pitch Wide)
	
	

Beam to Beam clearance has the largest impact

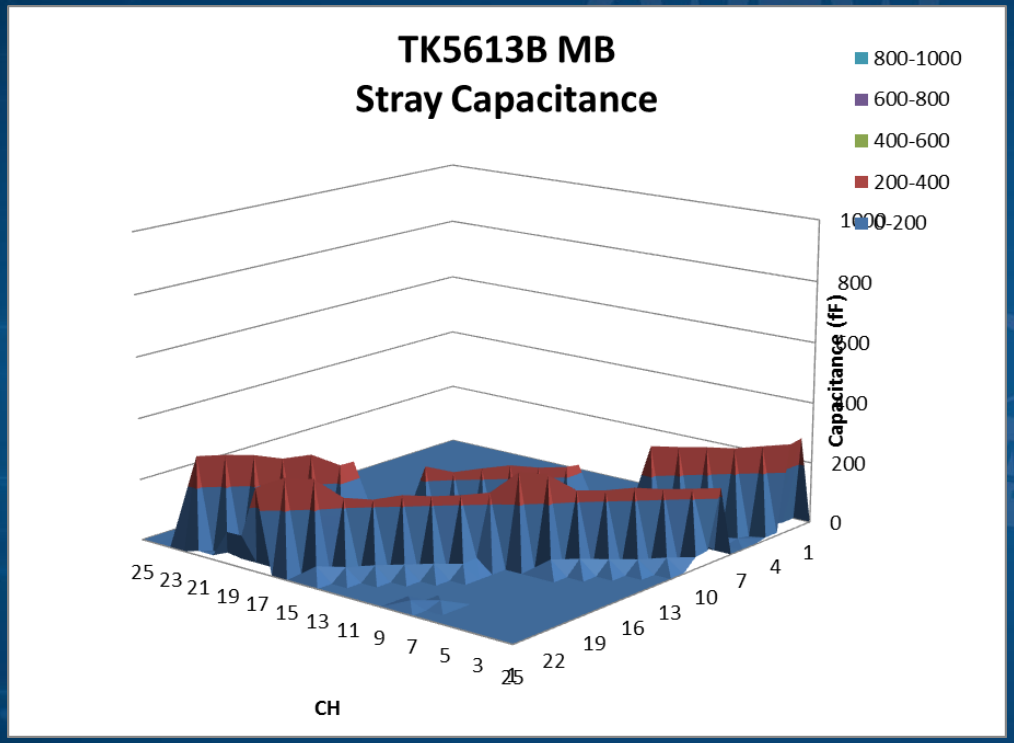
Probe Card Break Down
Interchangeable Insert Unit

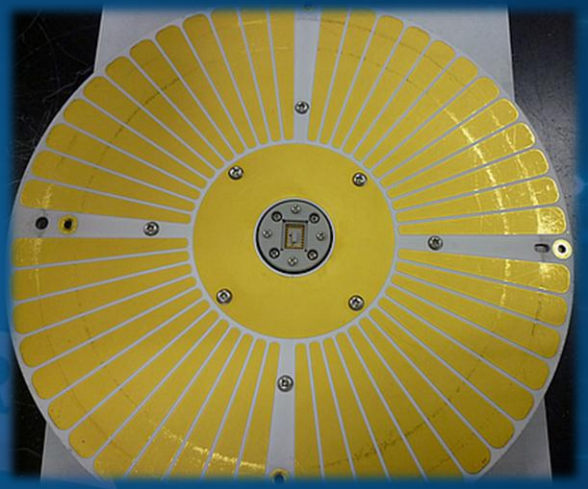




Max 682 fF
Average 87.9 fF

Probe Card Break Down
Mother Board

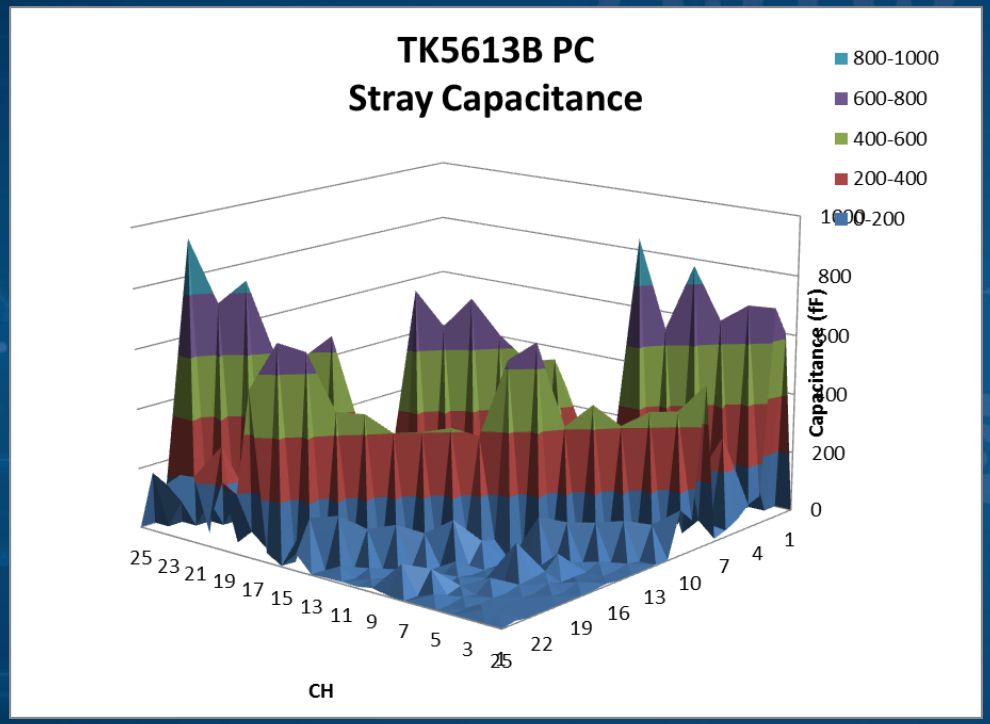


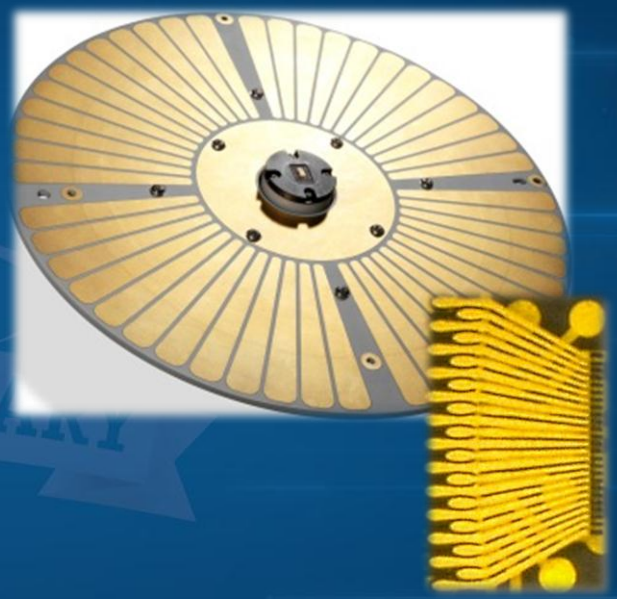


Max 300 fF
Average 37.9 fF

Full Probe Card of Stray Capacitance

25pin, 80um pitch,Single Direction
Using Standard Design Rules





Max 980 fF

Average 126 fF

Stray Capacitance Probe Card Component Summary

- **Components**
  - Probes have minor contribution
  - Focus on MB
  - Focus on Insert
- **Experimental Inserts were designed with both dual and single direction as well as a new MB**
  - Redesigned to minimize capacitance and tighten distribution
    - Keeping the goal of maintaining current cost/price

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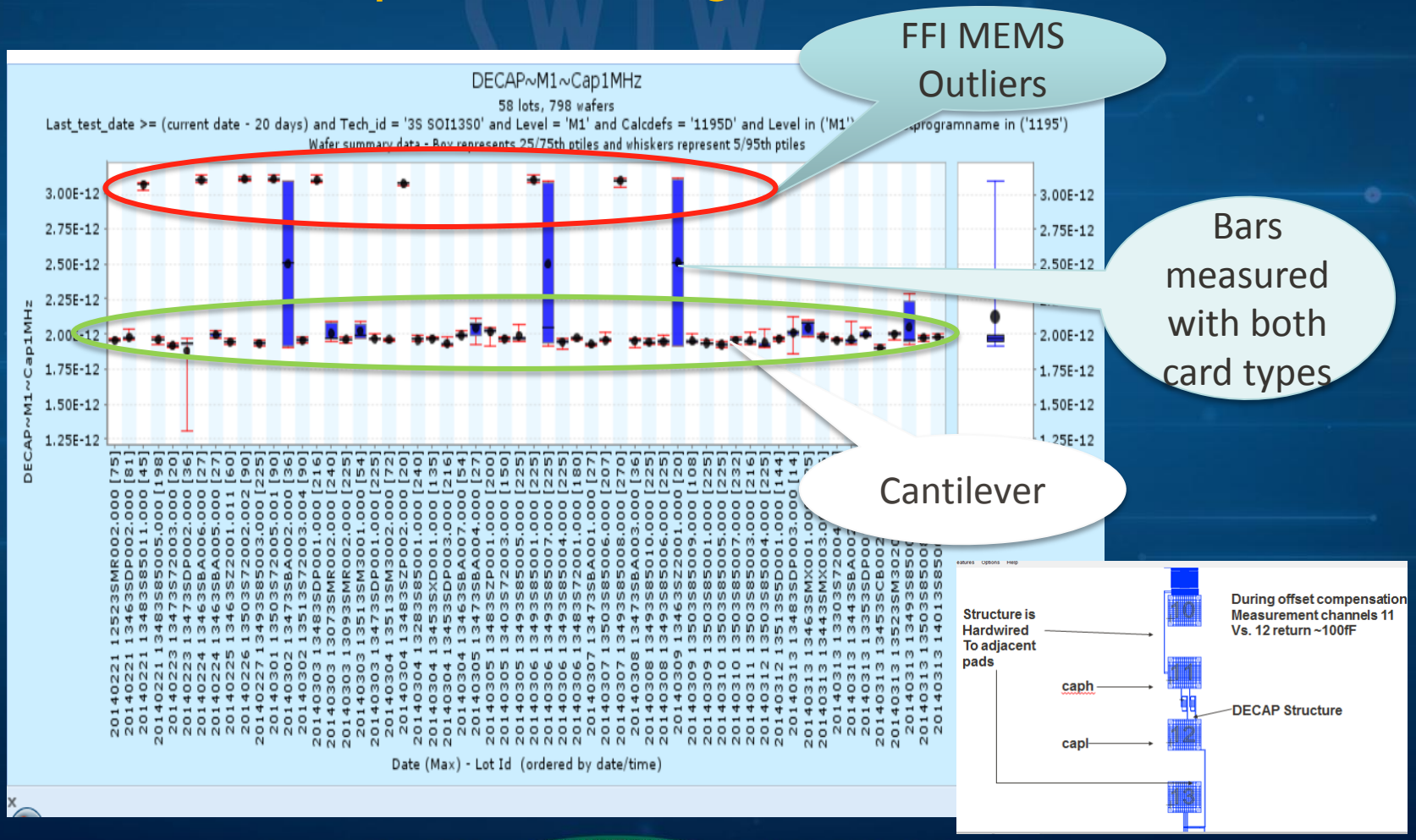
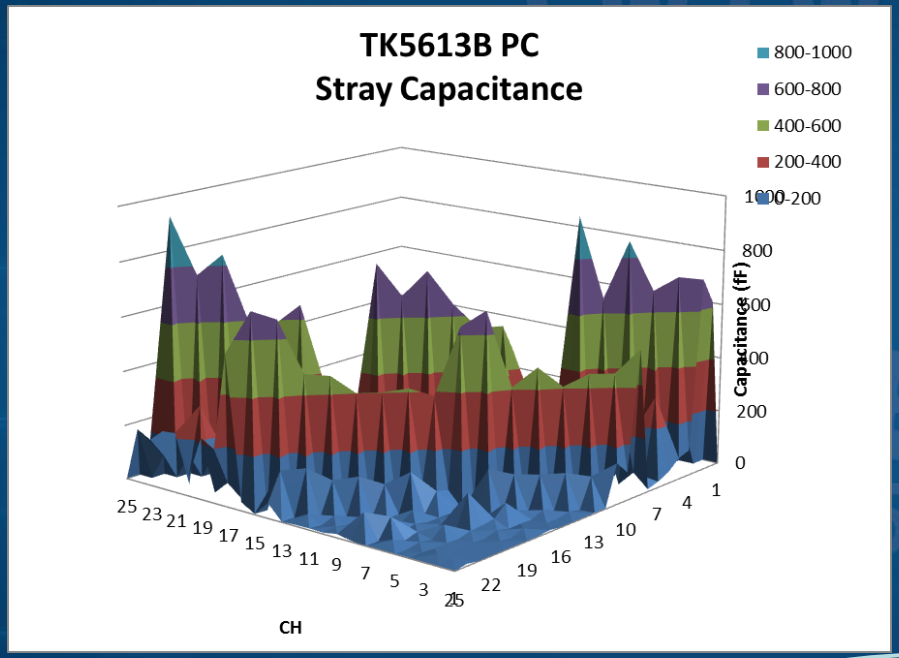
Case Study Customer A
Problem Statement

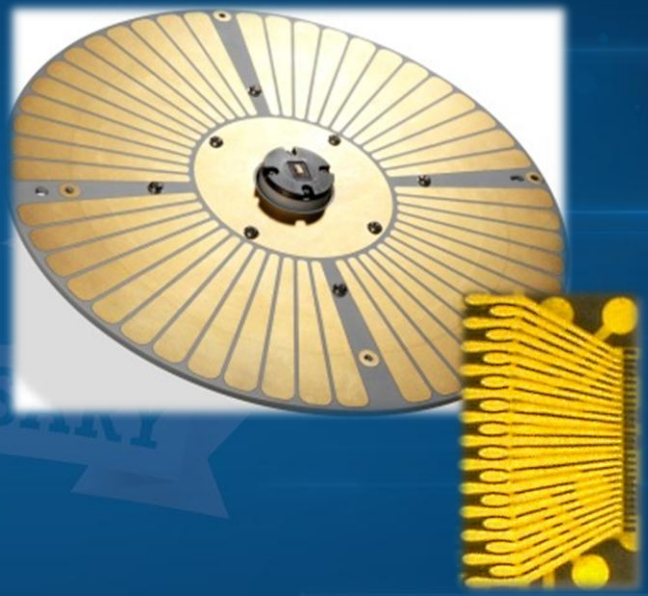
Outliers are pads tied together in the wafer



Original Full Probe Card of Stray Capacitance

Using Standard Design Rules (25pin, Single Direction)

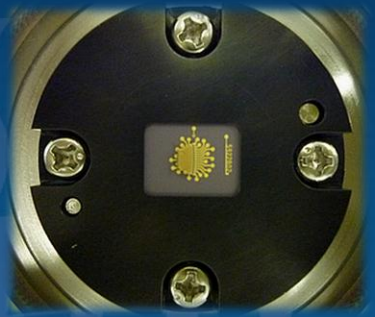




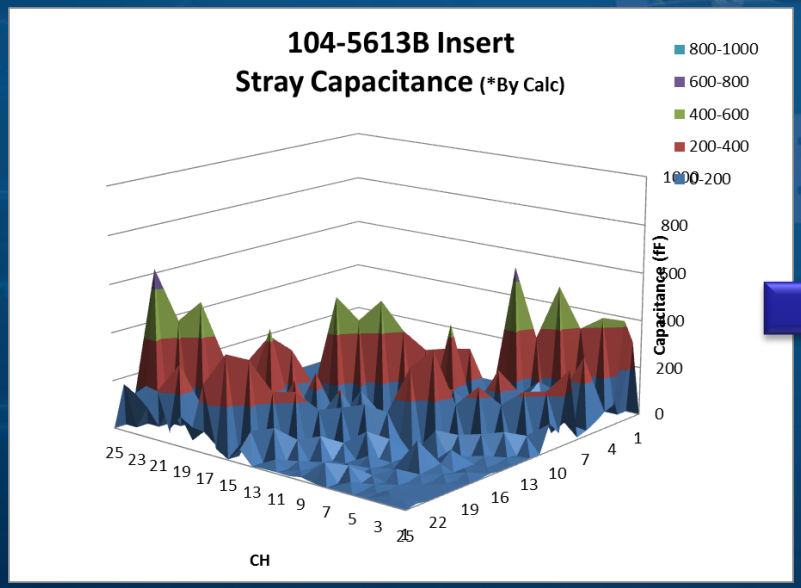
Max	980 fF
Average	126 fF

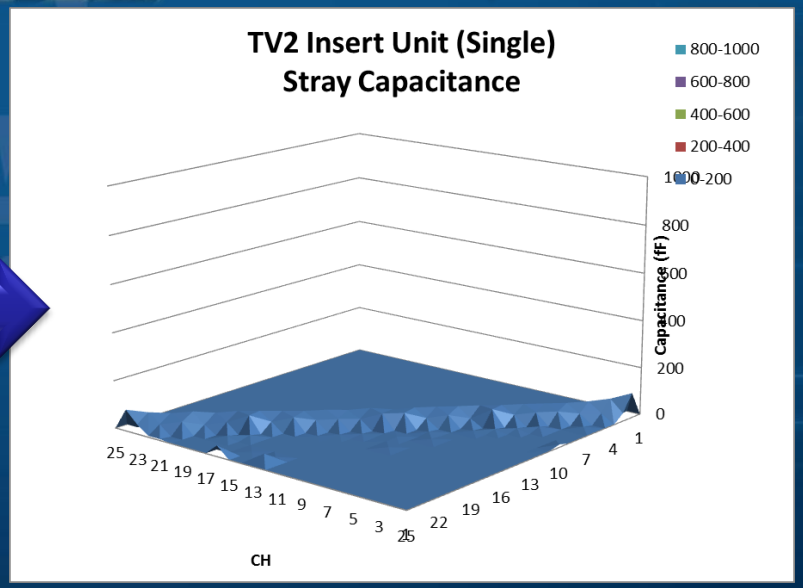
11 vs 12	85 fF
10+11 vs 12+13	1288 fF
10+11 vs 12+13+14	1351 fF

Probe Card Break Down
Interchangeable Insert Unit



Max 85% reduced
Average 89% reduced





Max	682 fF
Average	87.9 fF

11 vs 12	85 fF
10+11 vs 12+13	812 fF
10+11 vs 12+13+14	875 fF

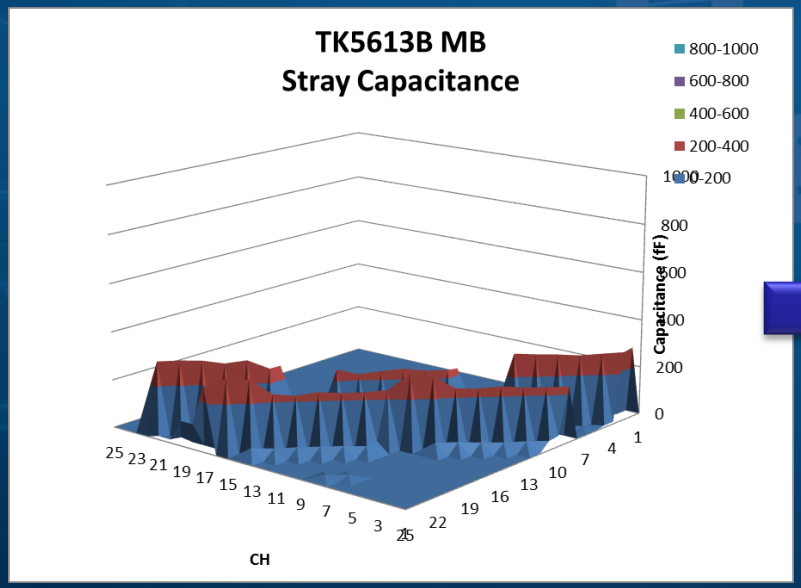
Max	105 fF
Average	10 fF

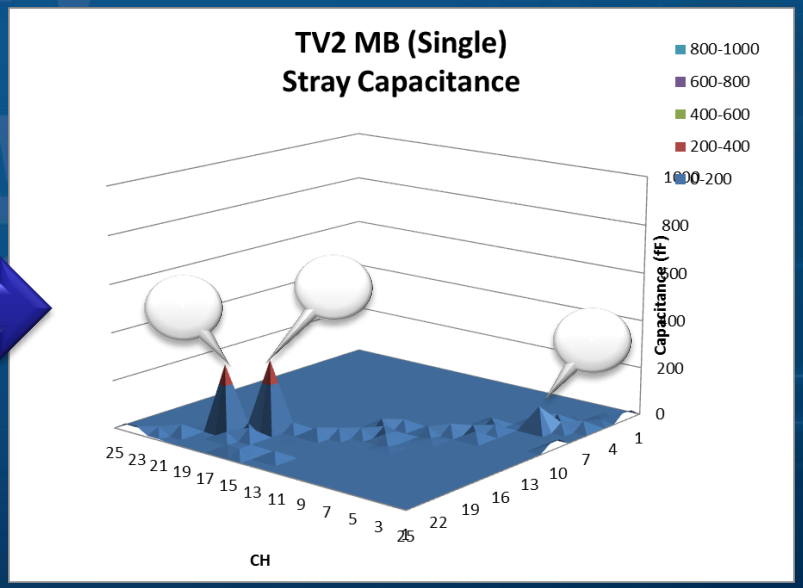
11 vs 12	68 fF
10+11 vs 12+13	164 fF
10+11 vs 12+13+14	164 fF

Probe Card Break Down
Mother Board

Average 84% reduced

*Max was not improved much due to cost restrictions (3 higher capacitance)





Max	300 fF
Average	37.9 fF

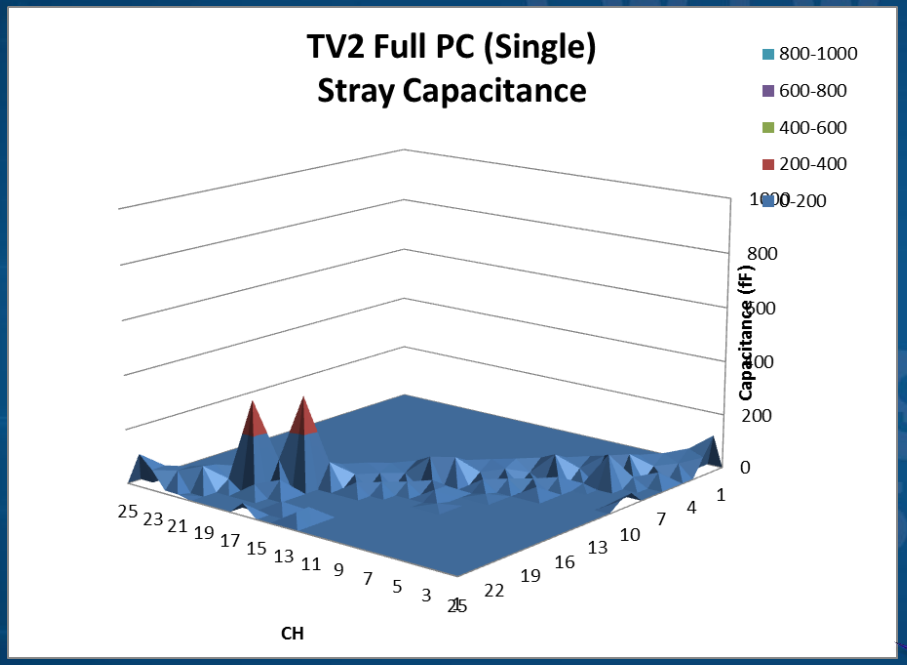
11 vs 12	0 fF
10+11 vs 12+13	476 fF
10+11 vs 12+13+14	476 fF

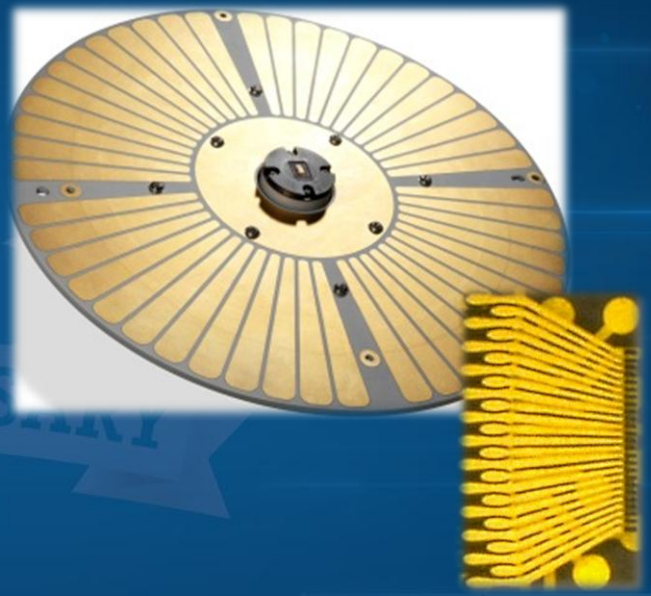
Max	297 fF
Average	6.18 fF

11 vs 12	0 fF
10+11 vs 12+13	34 fF
10+11 vs 12+13+14	34 fF

Full Probe Card of Stray Capacitance

Improved Design Rule(25pin, Single Direction)





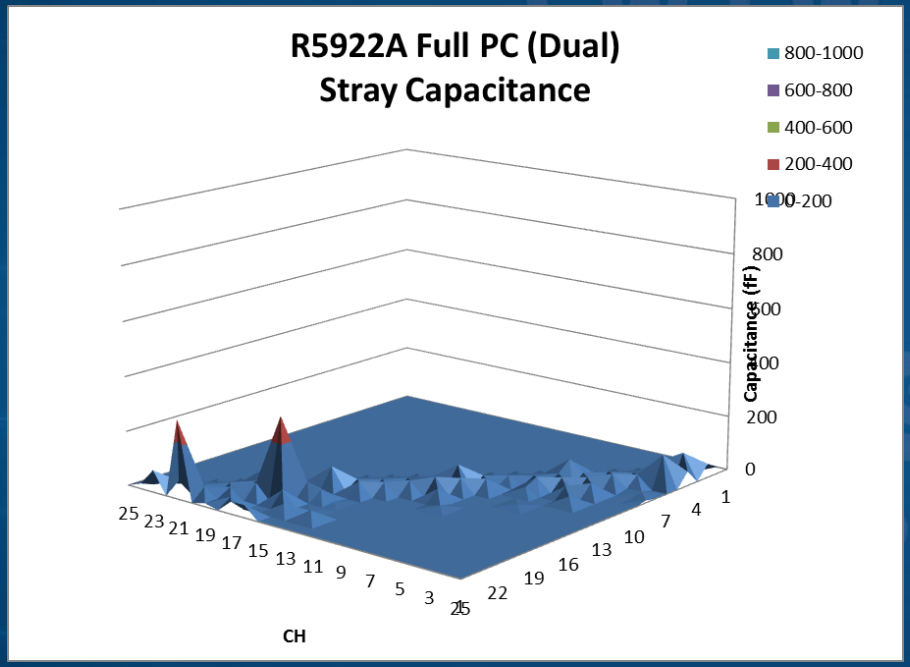
Max	335 fF
Average	16 fF

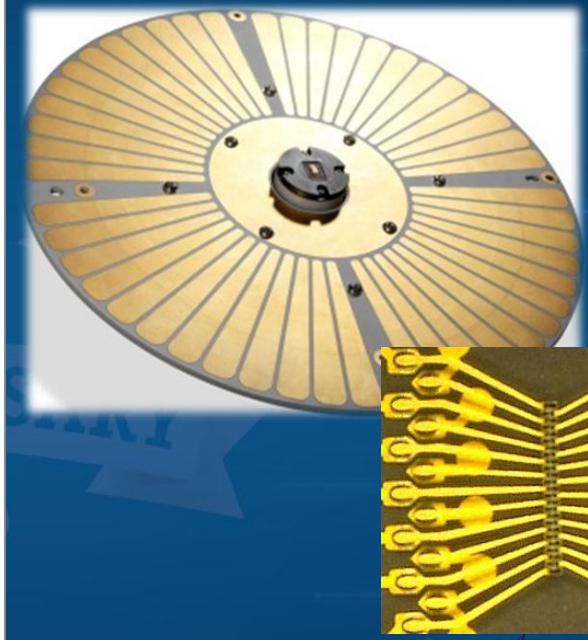
11 vs 12	68 fF
10+11 vs 12+13	198 fF
10+11 vs 12+13+14	198 fF

Max 66% reduced
Average 87% reduced

Full Probe Card of Stray Capacitance

Improved Design Rule(25pin, Dual Direction)





Max	295 fF
Average	11.8 fF

11 vs 12	18 fF
10+11 vs 12+13	121 fF
10+11 vs 12+13+14	172 fF

Max 70% reduced
Average 91% reduced

Case Study Customer A Summary

- **We were able to drastically reduce full card stray capacitance**
  - **Although the bridged probes still demonstrated higher capacitance, they were now within acceptable limits**

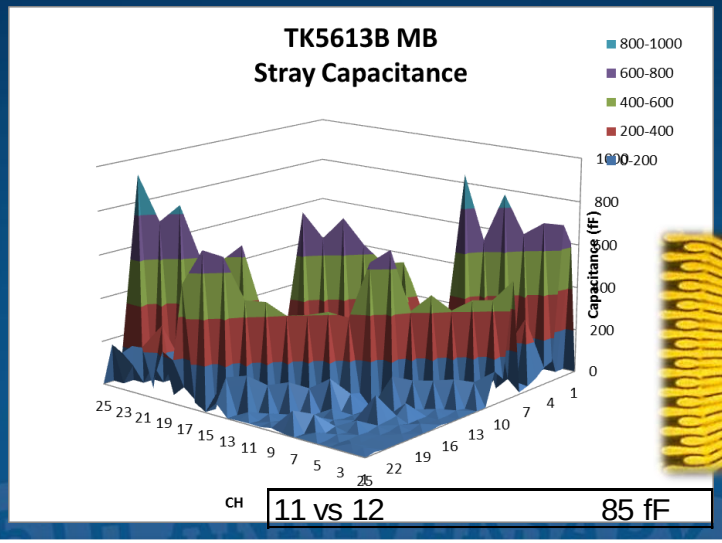
Stray Capacitance (unit:fF)
Measurement: Open circuit

Dual

Single

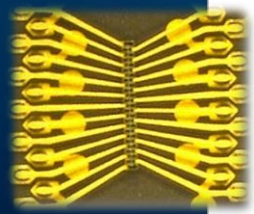
Sample		Cantilever	TK5613B		TV1		TV2	
Measurement By		Customer A		FFI				
Evaluation CH	Full CH Max			980	295	70%	335	66%
	Full CH Average			126	11.8	91%	16	87%
	11 vs 12	22	107	85	18	79%	68	20%
	10 + 11 vs 12 + 13	44	1274	1288	121	91%	198	85%
	10 + 11 vs 12 + 13 +14	35	1313	1351	172	87%	198	85%

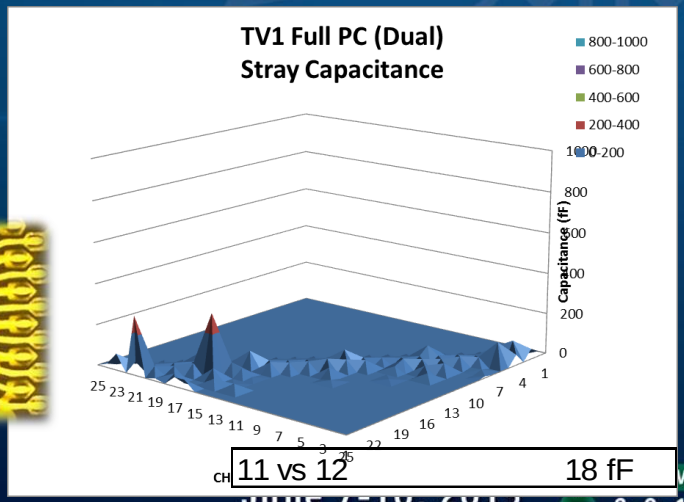
Case Study Customer A Final Results

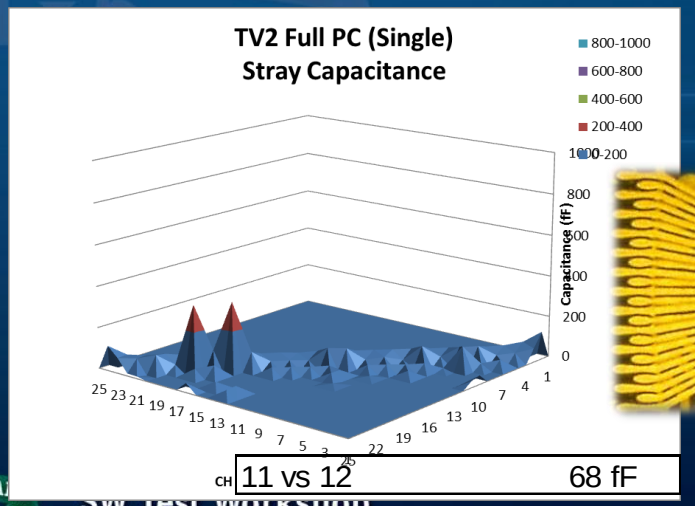


Standard Design

Improved Design







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GLOBALFOUNDRIES Quality Policy

Quality is a way of life

GLOBALFOUNDRIES will exceed our customers' expectations through the dedication and continuous improvement efforts of our employees. To do so, our employees embrace and adhere to the following principles:

- **Customer First**

We are committed to best-in-class service to our customers. "Customer First. Quality Always."

- **Committed People**

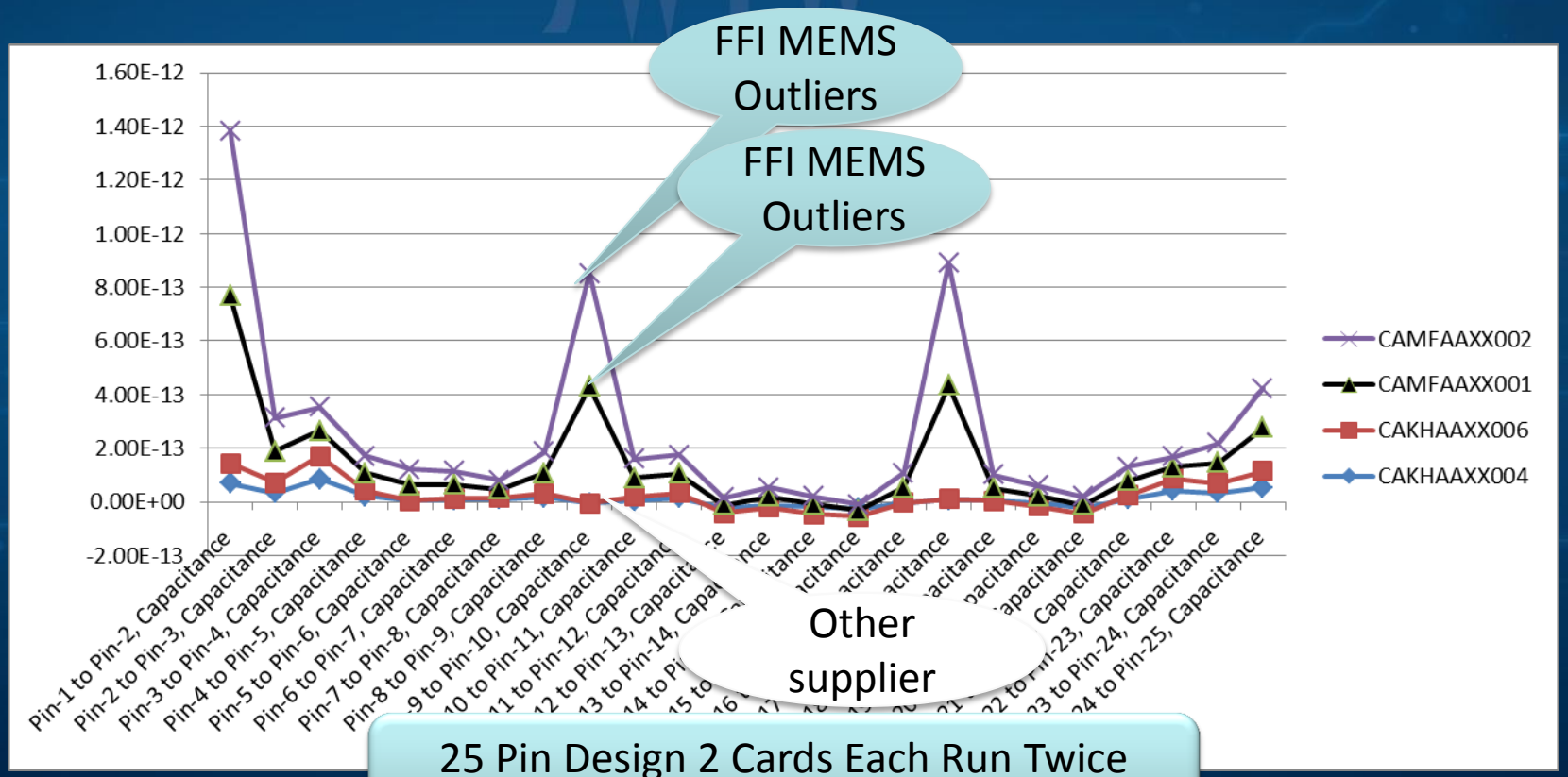
We take ownership in creating a quality culture where our people strive to do "First Time Right."

- **Continuous Improvement**

We strive for zero defects through continuous improvement in our processes, products and services

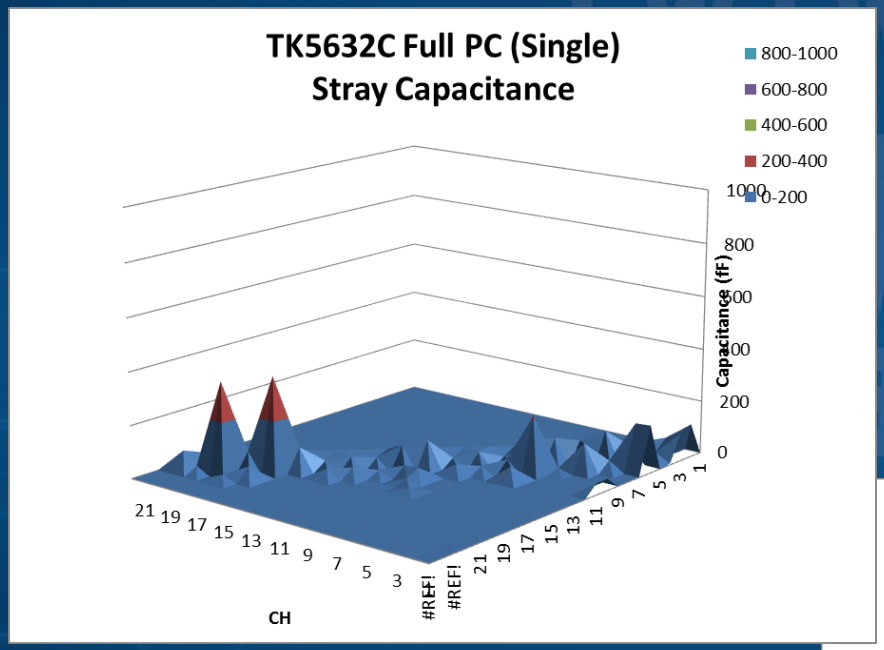
GLOBALFOUNDRIES Problem Statement

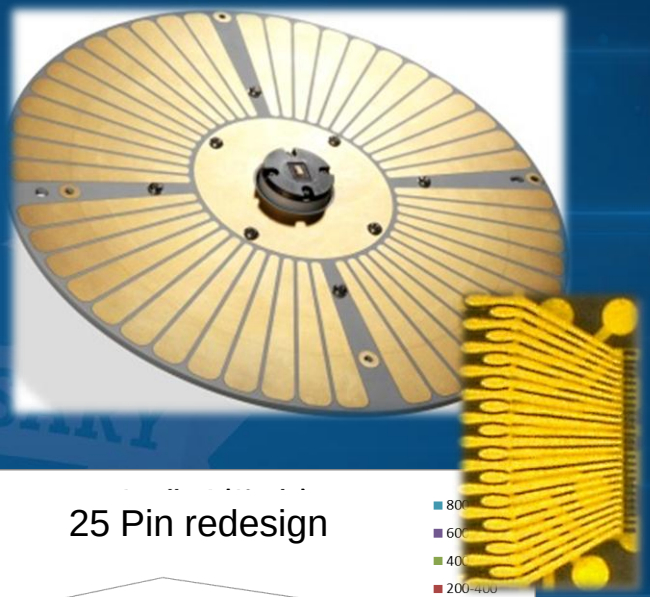
- **Standard FFI MEMS card has higher capacitance**

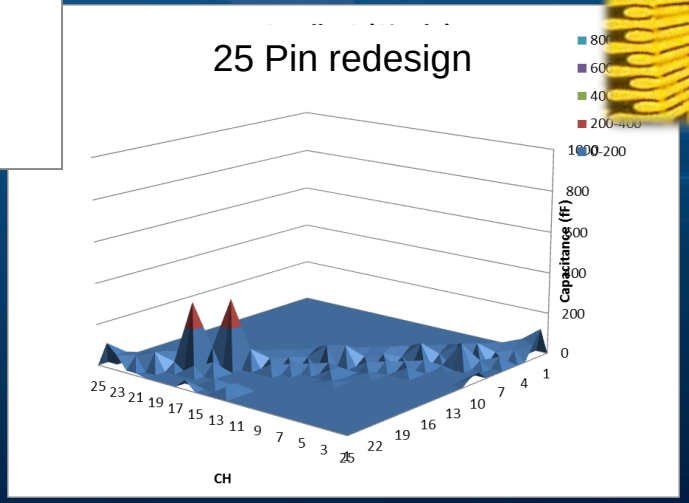


25 Pin Design 2 Cards Each Run Twice
No Pads Bridged together

22 Pin Single Direction Redesigned Measured at FormFactor







Redesigned 22 and 25 pin results very similar

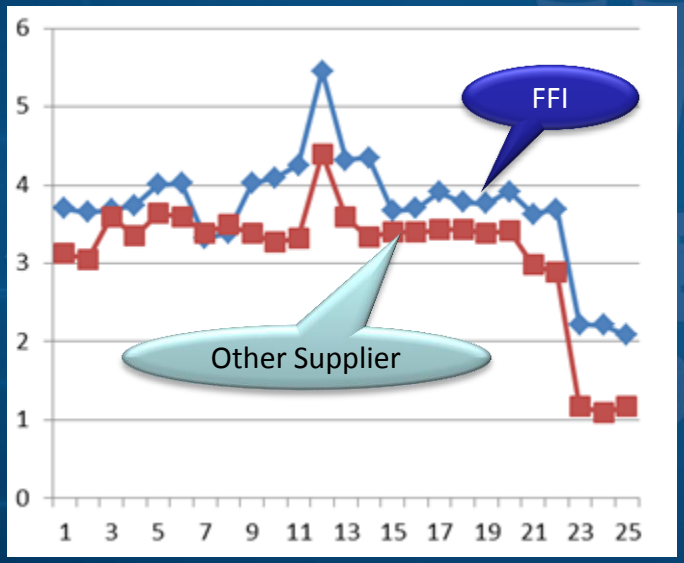
GLOBALFOUNDRIES Evaluation

- **GF does testing/qualifications at different frequencies during probe card validation**
  - Different devices have different capacitance/conductance ranges
- **Industry standard Capacitance and Conductance are (Test Freq):**

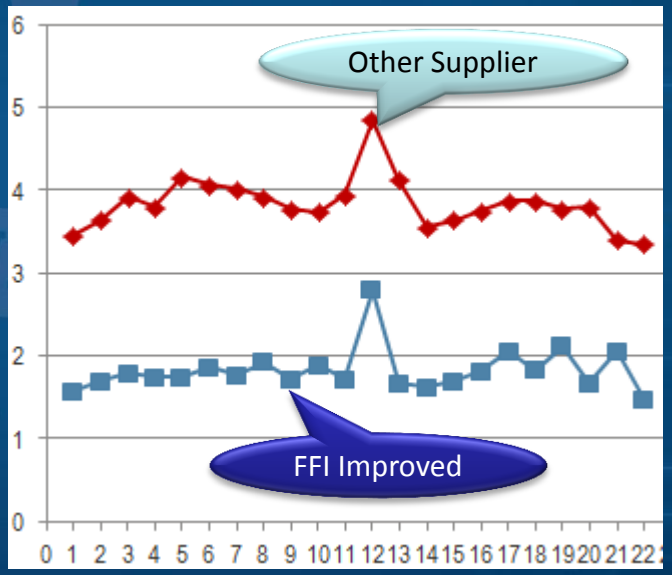
1 fF to 1.2 nF and 10 nS to 7.5 mS (1 MHz)
1 fF to 10 nF and 1 nS to 6.3 mS (100 KHz)
1 fF to 100 nF and 0.1 nS to 6.3 mS (10 KHz)
10 fF to 100 nF and 0.1 nS to 0.63 mS (1 KHz)

Capacitance Comparison-Frequency 1 KHz

22 pin Card
(Standard Design vs Other Supplier)



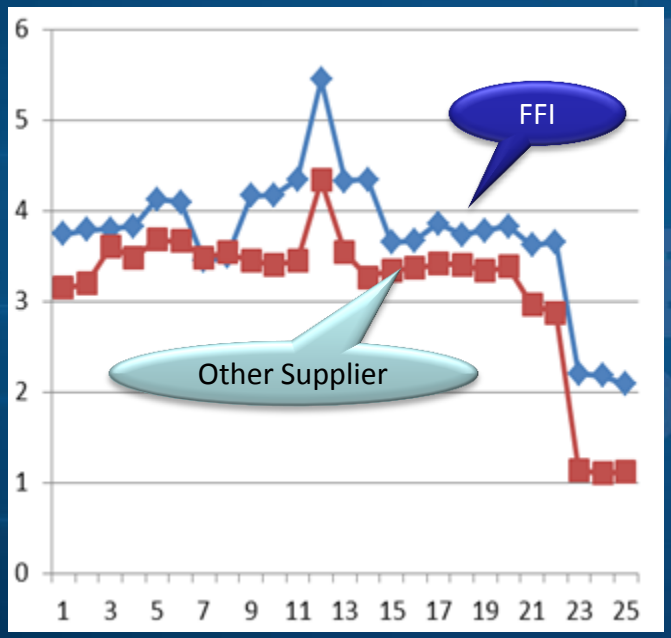
22 pin Card
(Standard Design vs Improved Design)



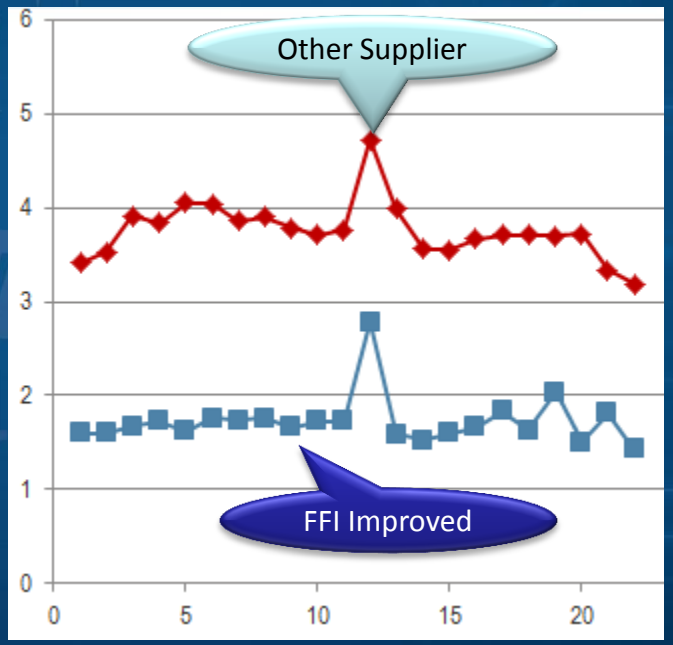
Measured with 25 channel tester

Capacitance Comparison-Frequency 10 KHz

22 pin Card
(Standard Design vs Other Supplier)



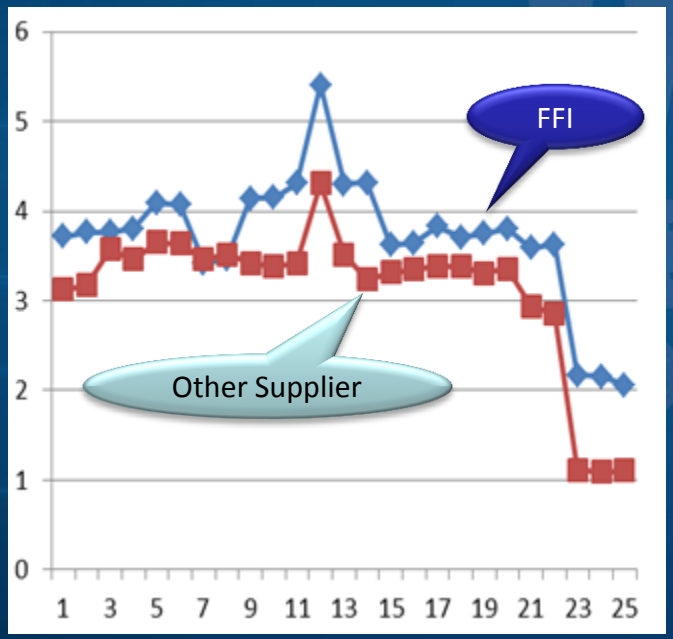
22 pin Card
(Standard Design vs Improved Design)



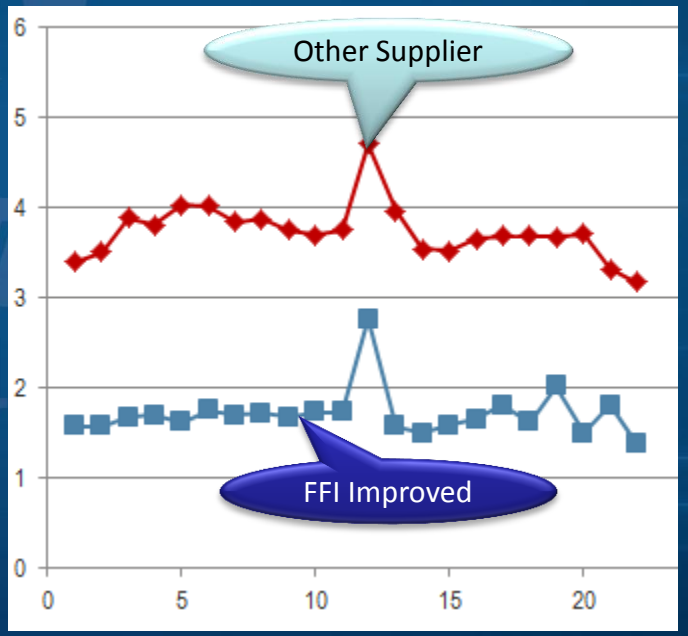
Measured with 25 channel tester

Capacitance Comparison-Frequency 100 KHz

22 pin Card
(Standard Design vs Other Supplier)



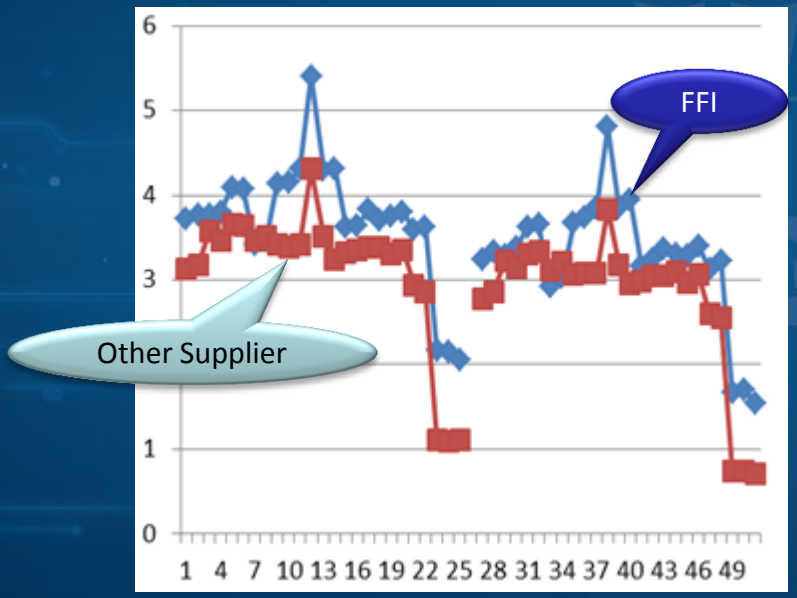
22 pin Card
(Standard Design vs Improved Design)



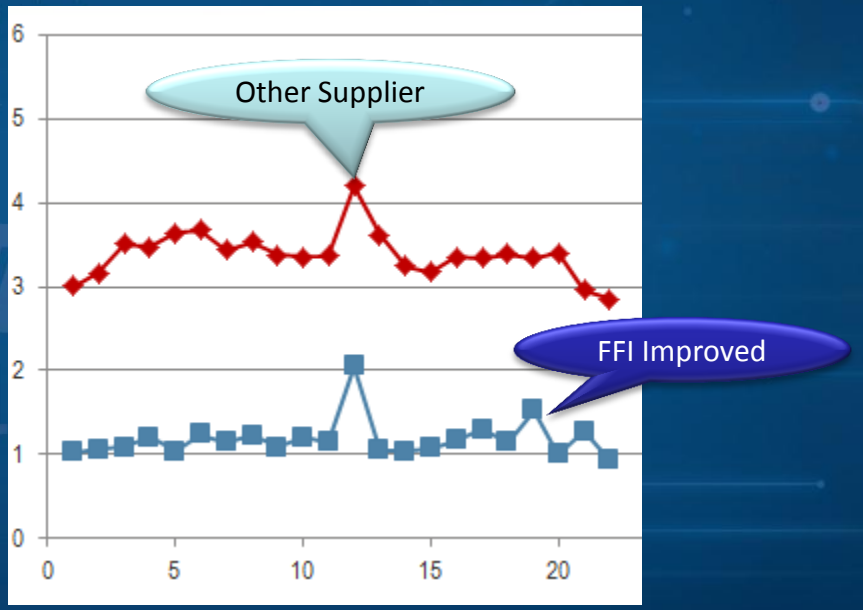
Measured with 25 channel tester

Capacitance Comparison-Frequency 1 MHz

22 pin Card
(Standard Design vs Other Supplier)



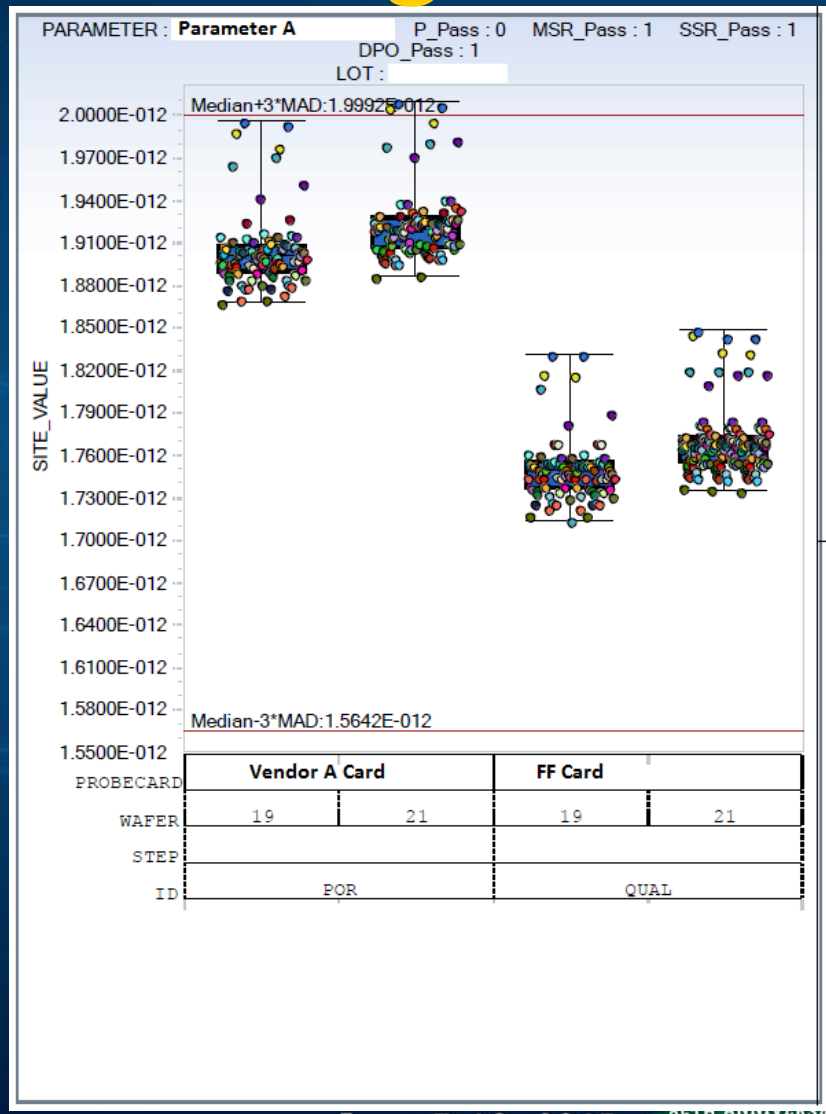
22 pin Card
(Standard Design vs Improved Design)

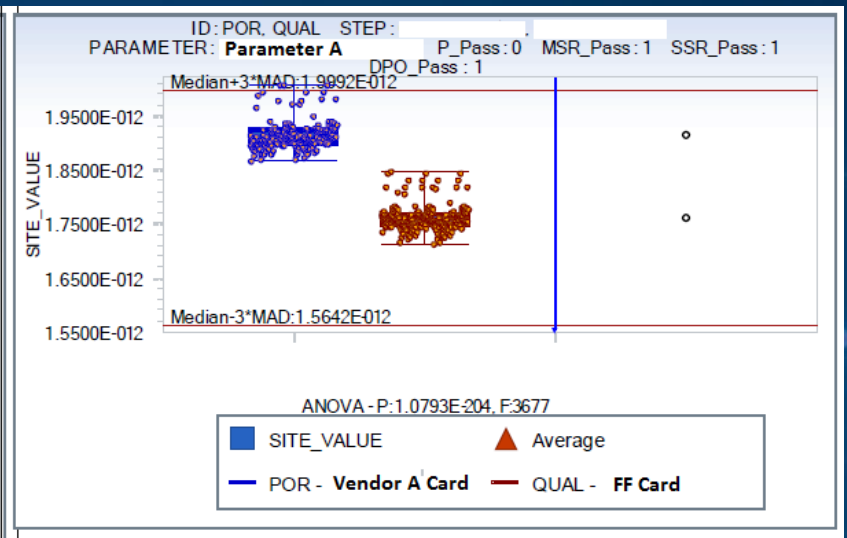


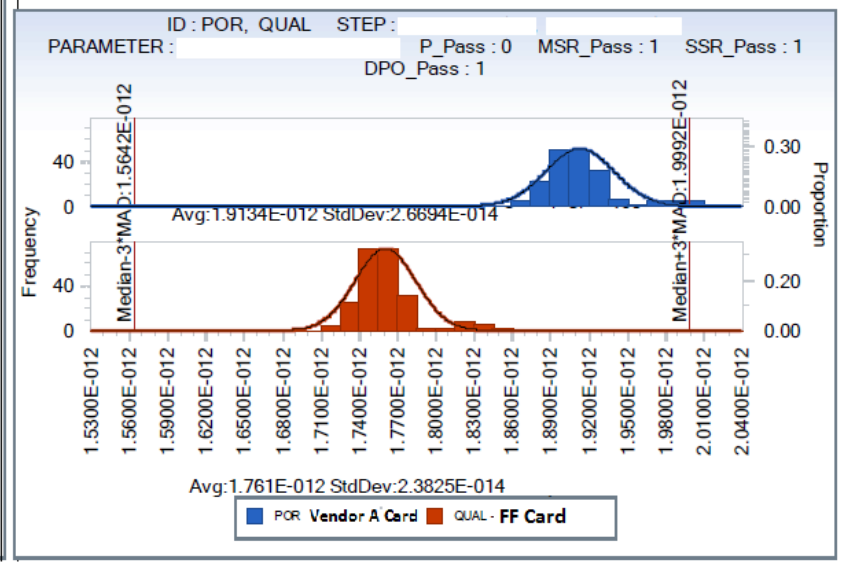
Measured with 25 channel tester

2x card shows same chart

1 MHz Plot Shows Improvement in Range and Distribution







Overview

- Definition Of Capacitance
- Importance of Minimizing Capacitance
- Background
- Capacitance of Probe Card Components
- Case Study Customer A
- GLOBALFOUNDRIES Case Study
- Summary

Stray Capacitance Summary

- **Prior to doing parametric test a procedure is usually performed to null out the capacitance produced by the tester and probe card.**
  Despite this effort, uncompensated probe card and tester stray capacitance can still be a problem
- **The uncompensated stray capacitance can/did become a significant percentage of the final measurement, particularly with regard to leading edge technology test requirements**

- **By localizing the values of stray capacitance produced by the main components of the probe card we were able to reengineer the card, greatly reducing the stray capacitance and tightening the distribution while addressing the impact of potential structures in the wafer.**

- **Less capacitance is always better**
  - Further improvement is possible if cost is not an issue

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  - Goto-san
- **FFI Japan**
  - Yoshida-san, Kawamata –san

Thank You