Solidus Technologies, Inc.

MEMS Test Equipment & Semiconductor Engineering

Salland Engineering

Your challenge, our strength.

Solidus Technologies, Inc.
Dynamic Testing Overview

Agenda

- ❑ Company Discussion and Value Proposition
- ❑ Product Solution Overview
  - ❑ Experience
  - ❑ Tester Capabilities
  - ❑ Software
  - ❑ Defect Detection
  - ❑ Enabling KGD (Known Good Die)
  - ❑ Easy to Use
  - ❑ GUI Interface
  - ❑ Training & Demo

Solidus Technologies, Inc.

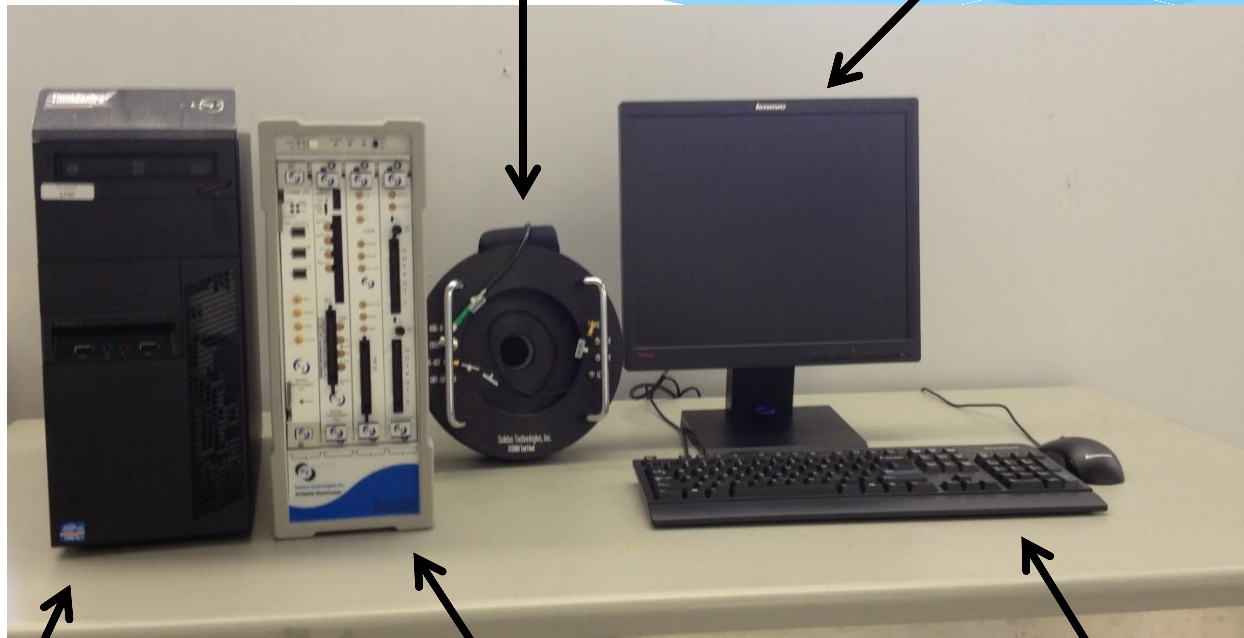
www.solidustech.com

STI3000 Production Test Systems

STI3000 Test System (Type 1 Test Head)

STI3000 Test Head Type 1

STI9000 Monitor



STI9000 Computer

STI9000 Mainframe (Test Rack)

STI9000 Keyboard & Mouse

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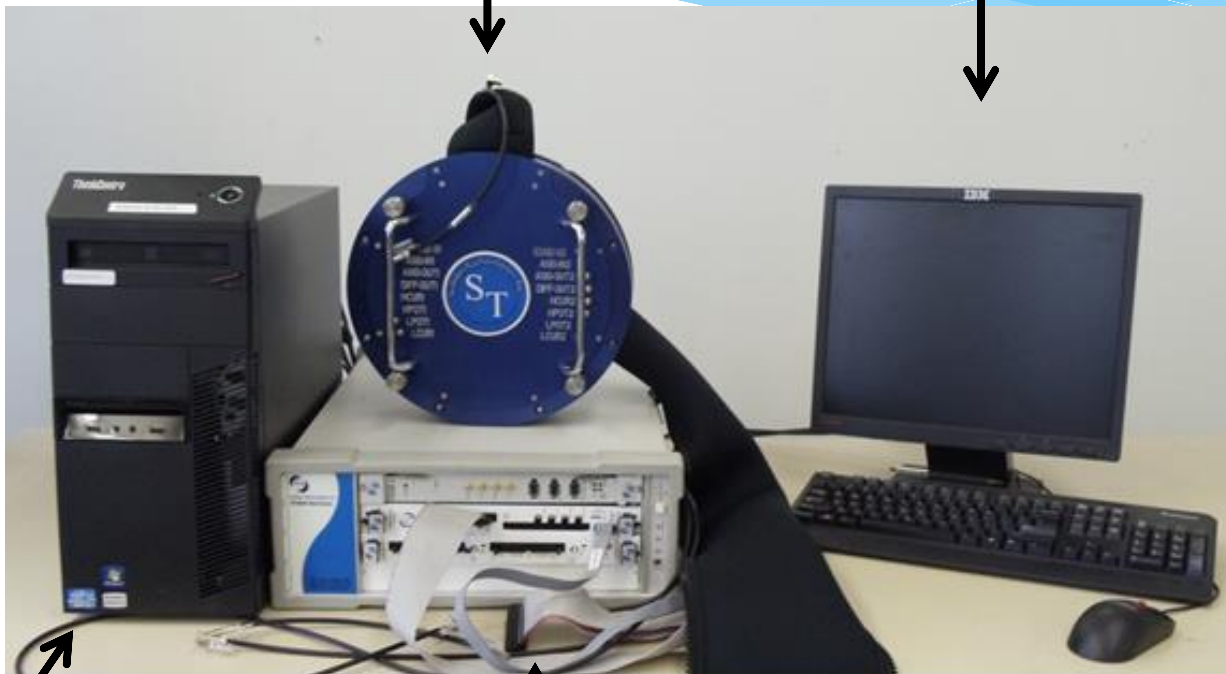
STI3000 Test System (Type 2 Test Head)

STI3000 Test Head Type 2

STI9000 Monitor



STI9000 Computer

STI9000 Mainframe (Test Rack)

STI9000 Keyboard & Mouse

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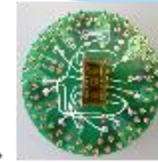
Type 1 Test Head Details

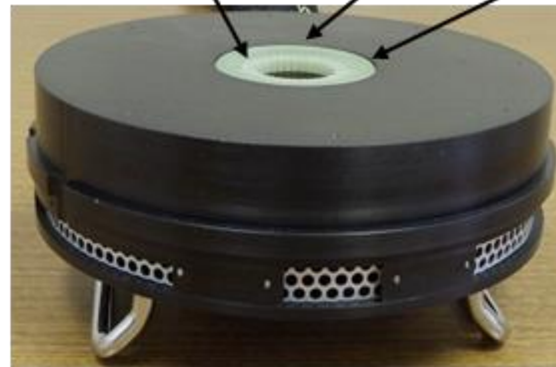
Needle Probe

Package Probe



Contact Block

Placement



STI3000 Main Frame (Test Rack)

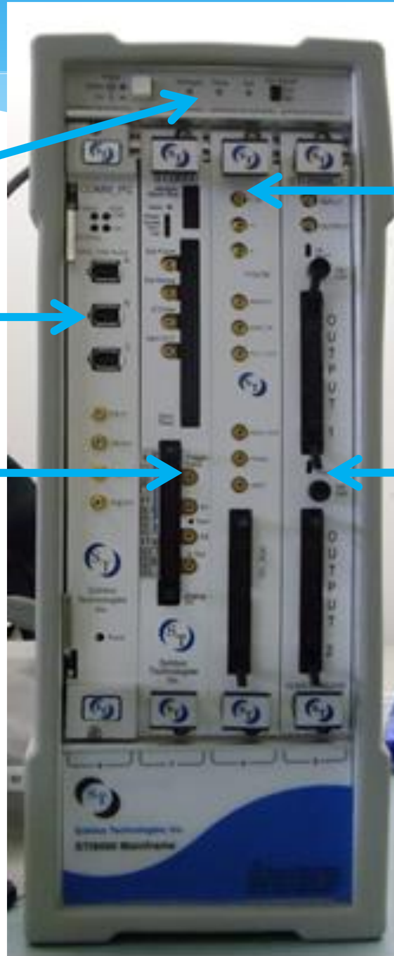
Mainframe: ST105092

PC_COM: ST105094

STI9000: ST107055

FGCM: ST107228

PSM: ST107179



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Wafer Testing STI3000 System

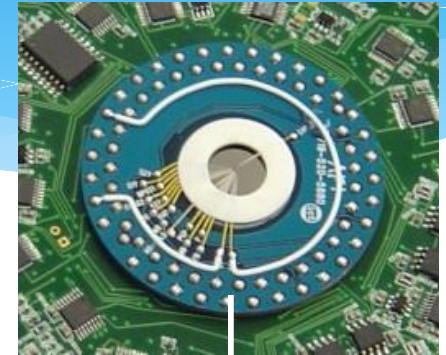
Basic STI9000
Mixed Signal Test System

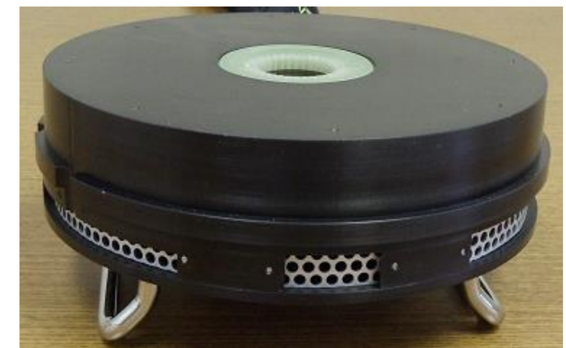
- High volume manufacturing test
- High speed parallel processing
- Robust
- Handler Interface
- Database Interface
- Pressure & Inertial Sensors
- Accelerometers & Angular Rate

STI3000
Test Head
Standard

STI3000 Type I
Test Head Module

STI Probe Needle Card



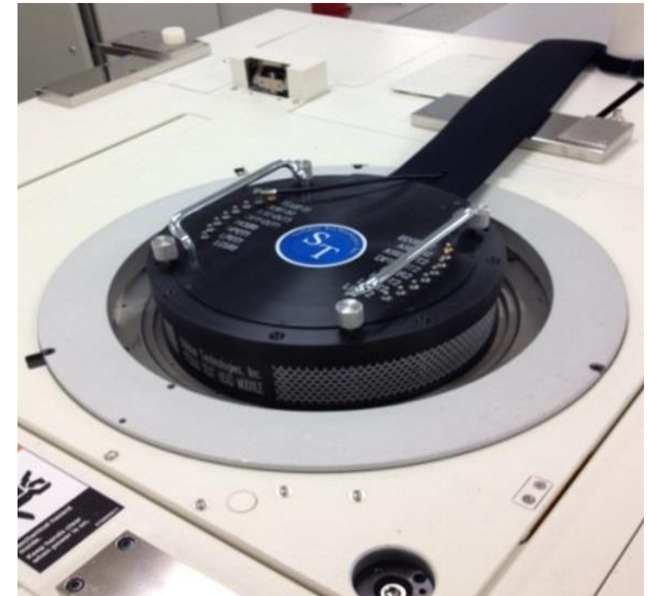


STI3000 Type II
Test Head Module

Value Proposition

Product differentiators provide an umbrella of security that:

1) Increase your product quality and performance.
2) Eliminate the product related failures experienced by customers
3) Provide the vital data needed for continuous product performance improvement.



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Value Proposition (Continued)

There are <u>three</u> distinct ways the Solidus MEMS expertise and MEMS tester system will enhance your profitability over any home grown test solution or alternative test product found on the market today:

1. **Wafer fabrication monitoring:** Traditional "CMOS" processing methods (i.e., process control monitors and parametric testing) does not insure MEMS sensor element function and quality. The Solidus tester is far better at evaluating the extent to which the fab process is under control. Thus, it allows you to determine whether fab processes require adjustment.
2. **Known good die to final testing:** Final package test is one of the most costly steps in the MEMs manufacturing process. As proven by Solidus customers, the Solidus wafer test ensures that only known good die reach final package test, maximizing the efficiency of resources, which significantly reduces the overall cost of test.
3. **Increasing transducer test coverage:** The Solidus tester screens fabrication defects not screened with either traditional wafer sort or package testing. This approach eliminates the possibility that serious fabrication defects such as Stiction, mechanical obstruction, or fractured elements will escape the fab to enter the product line, only to be discovered later by unhappy customers.

These are the key components to the sustained product quality, performance and growth needed to maximum your return on investment and profitability for IoT modules. The Solidus test solution will work extremely well on both monolithic or 2 chip products.

Cost Savings From Wafer-Level Performance Testing

Using the Wafer Test Cell Solution with **Dynamic**, wafer-level testing, monitors the element fabrication process and the generation of **Known Good Die (KGD).**

Typical Wafer Process Flow		Wafer Sort Testing Parameters
Wafer Bonding Etching Release Annealing Lid Sealing Backside Grinding	**Processes Affecting Die Performance**	Leakage Capacitance Natural Frequency Damping Quadrature Error Resistance, PCM **Known Good Die**

Case Study:

1. Dynamic measurements determined correlation of wafer process to die performance. Example: Lid Sealing vs Damping and Grinding vs Frequency
2. KGD performance increase by 25% by using sort through use of performance measurements.
3. Use of performance parameter measurement stabilized foundry elements quality.

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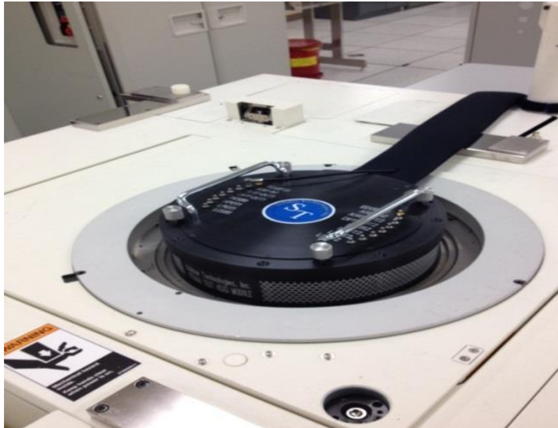
Production Solution

- ❑ Multi-Site Testing (Standard System 8 microphones in parallel)
- ❑ STDF (Standard Test Data Format) and CSV
- ❑ Programmable GUI environment
- ❑ Fast Test Times
- ❑ Very Small Footprint
- ❑ Sort for performance



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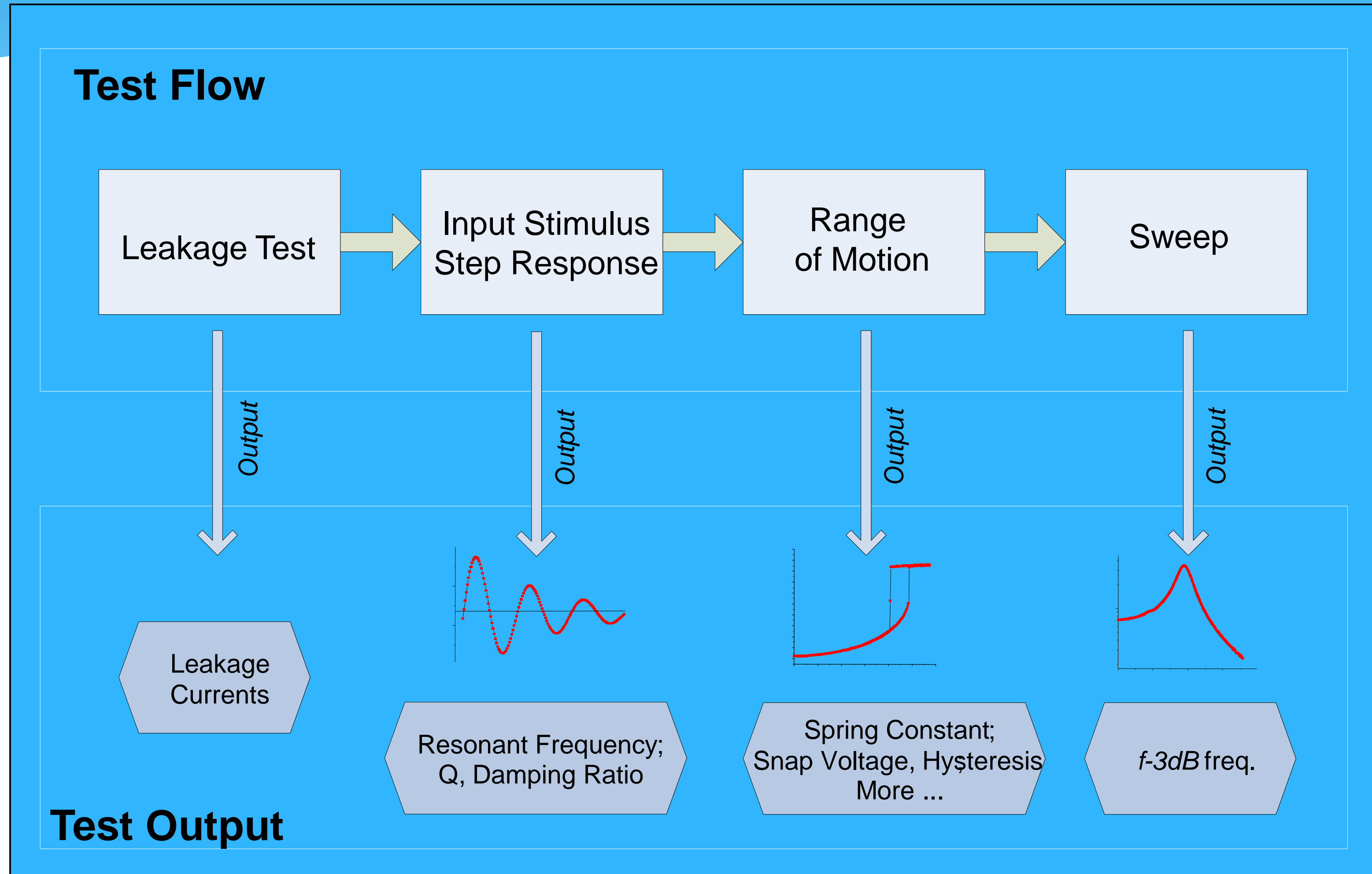
Production Solution Testing



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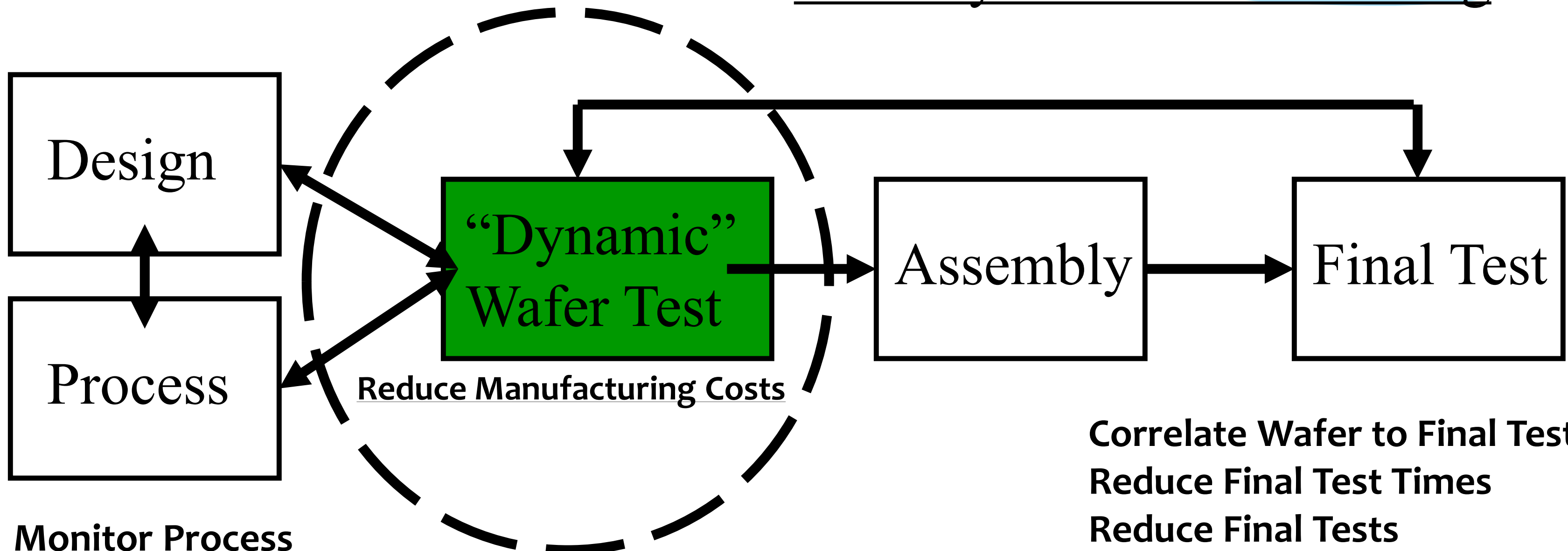
Production Solution

Design Feedback
Improve Design
Match Design with Process
Match Design with Test Performance

<u>Gain MEMS Manufacturing Value</u>
<u>With Dynamic Wafer Testing</u>



Monitor Process
Correlation Wafer Test to Process
Reduce Process Variation
Validate Process with Wafer Test Distributions
Sort for Performance

Correlate Wafer to Final Test
Reduce Final Test Times
Reduce Final Tests
Improve Final Test Yields
Increase UPH

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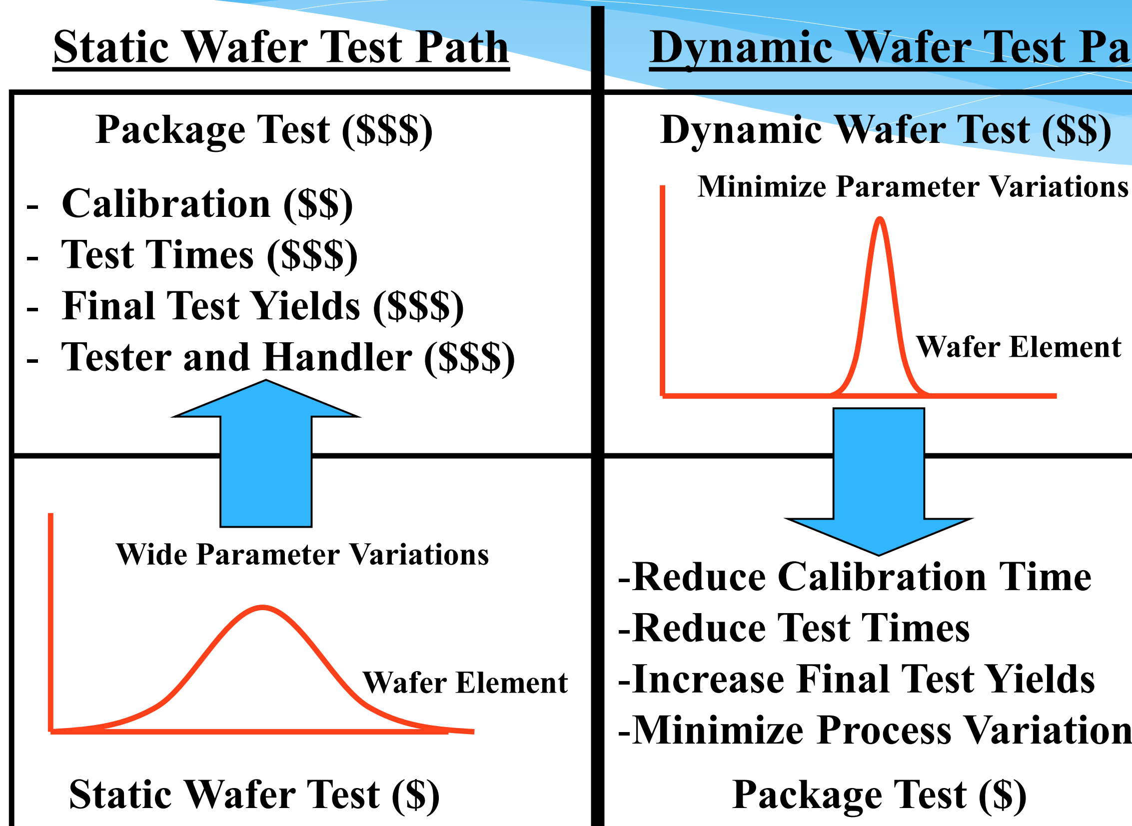
Production Solution

*Goal: Reduce Cost of Final Test and Overall Product Cost



- Sort for Performance at Wafer Test
- Reduces Wafer test time by (3-4X)
- Increase Test Coverage and Quality

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STI3000 Dynamic Test Data and Production Solution

- Test data is used for feedback to MEMS design to improve MEMS design models
- Provide feedback to MEMS fabrication process to reduce process variation
- Test data is used as a process control monitor to validate fabrication process
- STI3000 test system is single system for product development through Production
- Sort for product performance
- STI3000 test data is used to improve final test yields and to reduce or eliminate tests/conditions at final test
- Electrostatic or Acoustic Stimulation
- Low cost probe card solution

MEMS Wafer Testing STI3000 System

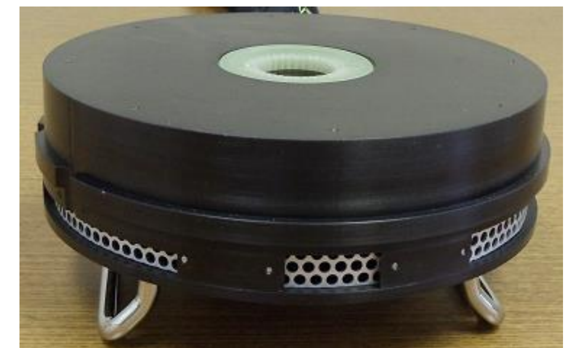
STI9000
Mixed Signal Test System

- High volume manufacturing test
- High speed parallel processing
- Robust
- Handler Interface
- Database Interface
- Pressure & Inertial Sensors
- Accelerometers & Angular Rate

STI3000
Test Head
Type I

STI3000
Test Head

STI Probe Needle Card



STI3000
Type II

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Experience

* Privately held corporation (Colorado), established June 1999.
* Established by former Ford Microelectronic Inc. Automotive MEMS Sensor personnel.
* Solidus Technologies has 19+ years of continuous operation in supporting the MEMS industry.
* Technical leader in providing MEMS wafer level test equipment, advanced signal processing software, and test methodologies for MEMS Testing. Over 40 accelerometers, 16 Gyros and multi axis, 5 optical mirrors, 6 microphones, 30+ pressure sensors and other.
* Engineering Services provider for new MEMS product designs (Angular Rate, Accelerometer, Pressure and Optical MEMS elements).
* Turn-key system solutions provider (tester, handler and software). Both wafer testing and package testing.
* Service and support provider (maintenance and applications)

STI3000 Tester Capabilities

Unique Dynamic Testing

Solidus Technologies has developed an innovative and unique wafer-level dynamic test equipment technology called Drive Sense Technology (DST).

This technology can quickly test the dynamic Electro/Mechanical AC performance of the MEMS device at wafer testing before the expensive package level calibration and final test stage.

The STI3000 can measure AC performance parameters at wafer level including resonant frequency, quality factor (Q), mechanical f3dB, quadrature error, frequency response, as well as hysteresis and Stiction.

These AC parameters better represent and predict the true mechanical behavior of the MEMS device. This dynamic performance data can be used to correlate to etching processes, reduce fabrication process variation and increase package-level calibration final test throughput.

Tester Capabilities

❑STI3000 Resources

- ❑ Phase and Magnitude Calibrated
- ❑ STIM: AWG to FGCM to Analog Signal, AC +/- 100Vac & +100 Vdc.
- ❑ Resources: 8 paPMU (leakage), 16 PDAC & 8 DST DAC, 8 ANSIG DAC .
- ❑ 4 Static Capacitance Resources (22pF to 4 aF).
- ❑ External Instruments Supported, LCR, Audio Wave Generator…etc.
- ❑ Range of Motion (ROM), streaming capacitance for deflection.
- ❑ 1: 4 quadrant PMU with 8000u. 800u, 80u amp sources
- ❑ Native CSV files with STDF
- ❑ Easy to use and extremely accurate and repeatable
- ❑ On site AC and DC calibration
- ❑ 70 Pin Resources

2 70
10S 1 09S
10F -5VA 09F
ASDA3 10G 09G 08S
11F ASCL3 GND 08F
11G 08G
10
+5V
11S +15V 07S
10 9
11 8
60
12F 12G 07G 07F
12
GND 12S 7 ASDA2 ASCL2
13G 06S
13F 13 6 06F
13S 06G
+3.3V ES -15V
14G 05S
20
14F 14 5 05F
14S 05G
50
GND ASCL4 15 4 ES_1 ES_2
ASDA4 15G 04G 04S
16 3
15S 1 2 GND 04F
15F 16G 03G
-12V 03S
30
16F 16S 01G 01S 02G 02S ASDA1 03F
36 40
GND 01F +12V 02F ASCL1

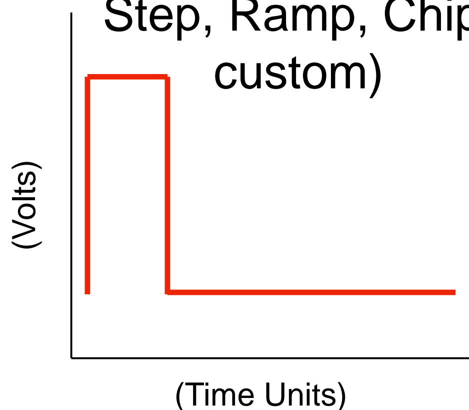
Tester Capabilities

What is Dynamic Level Testing?

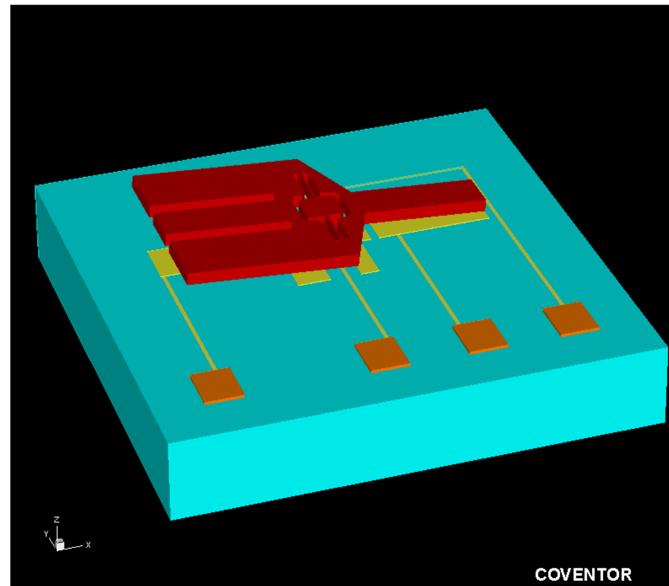
- The ability to move a MEMS element at wafer level with a Drive Voltage and then Sense or Measure the element's movement or behavior (Drive Sense Technology).
- Measurements: Leakage, Capacitance, Natural Frequency, Frequency Response, Damping Ratio, Q, Spring Rate, f3dB, Stiction, Hysteresis, Streaming Capacitance, Range of Motion, quadrature Error, phase, coefficient of determination, acoustic response and much more.

Drive or Force

(Signal Pattern Input: Step, Ramp, Chip, custom)



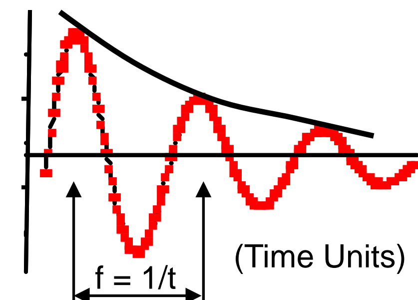
1 Axis Accelerometer



Sense or Measure

(Device Response Output)

Slope = Damping Ratio, Zeta and Q



(Continuous Data Stream)

Digitized Waveform Output

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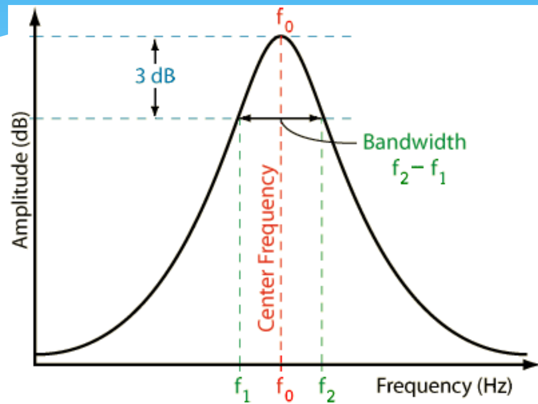
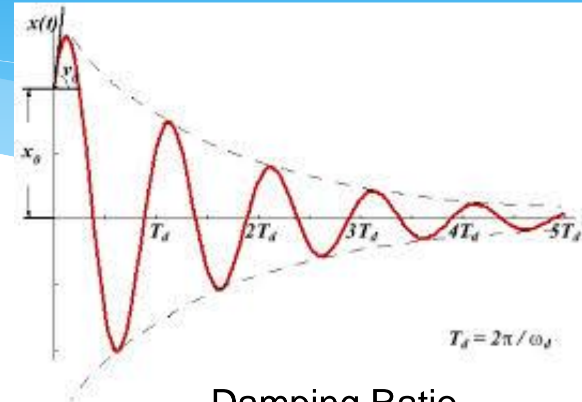
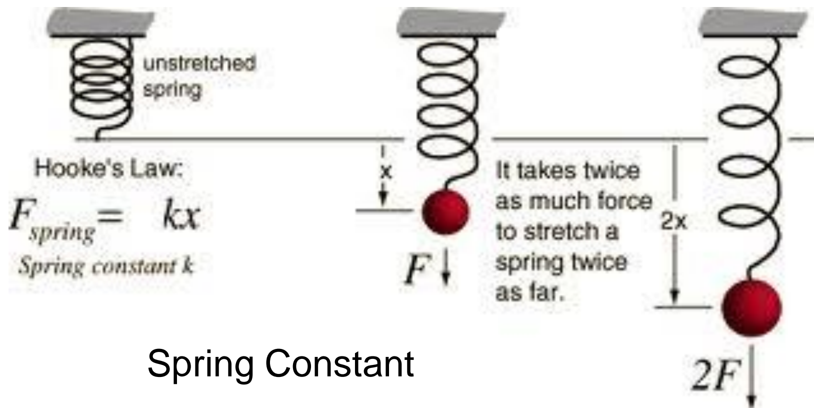
Test Definitions - Examples



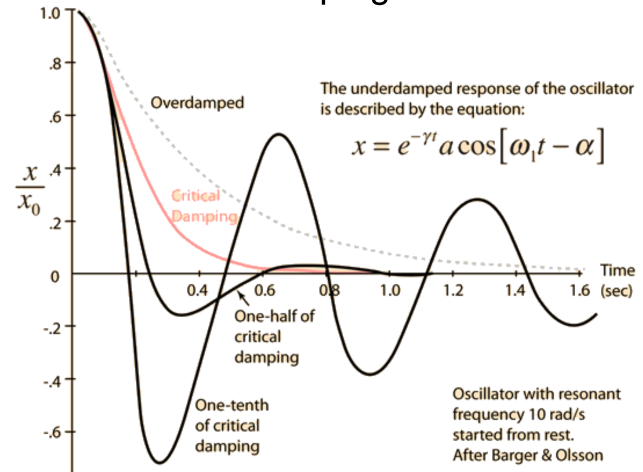
3 db. frequency



Damping Ratio



Spring Constant



Mechanical Resonance

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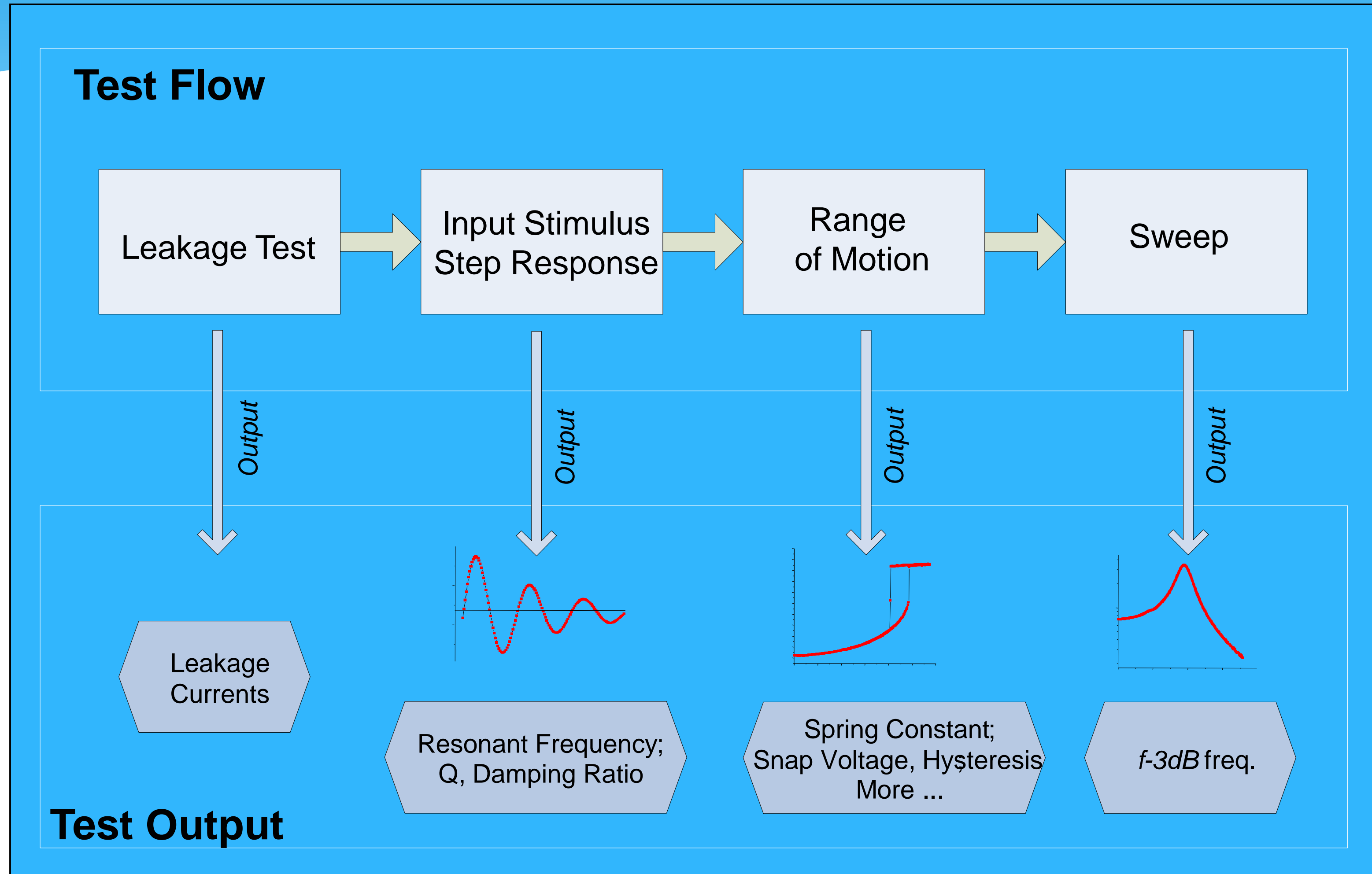
Production Solution Testing



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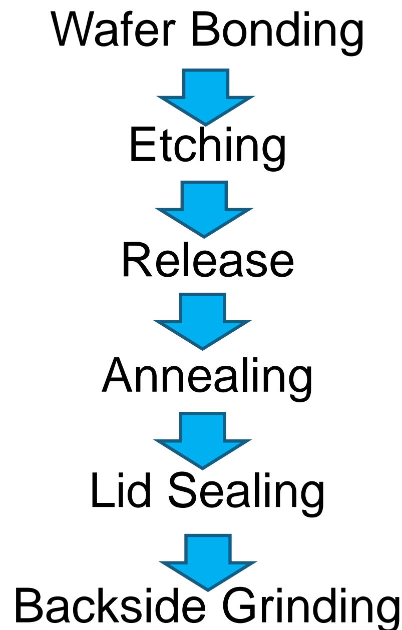
Cost Savings Derived From Wafer-Level Performance Testing

Using the Wafer Test Cell Solution with **dynamic**, wafer-level testing, monitors the element fabrication process and the generation of **Known Good Die (KGD).**

Typical Fabrication Process Flow

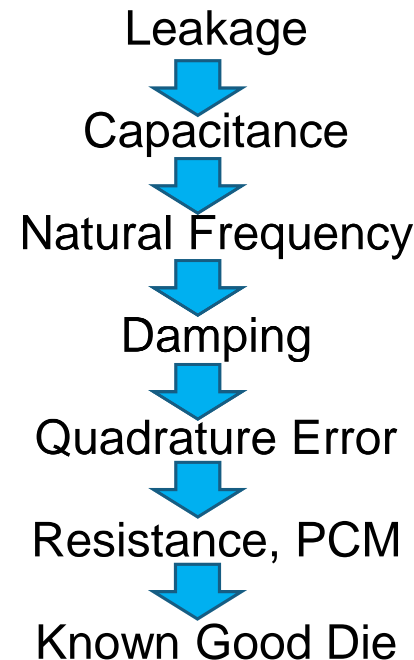
Typical Test Flow



Processes Affecting Die Performance

Typical Wafer Sort Test Flow

Wafer Sort Testing Parameters



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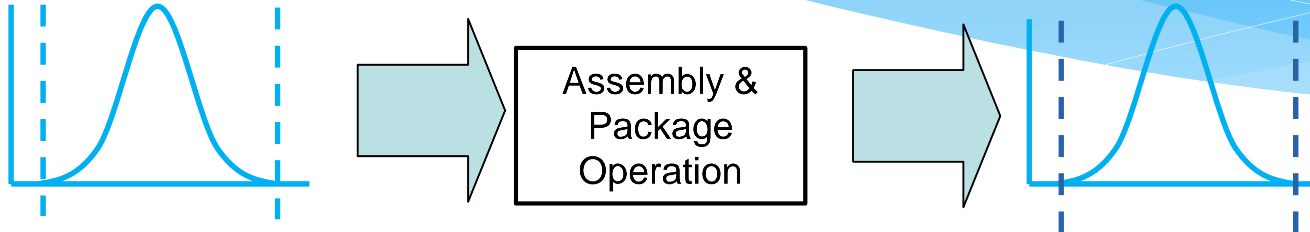
More Cost Savings: With Solidus

Wafer Sort Today with Parametric Tester Today
- Limited Value to Fab
- Sort for Gross Failures Only
- Limited Continuous Improvement
- Parameters can not sort for KGD

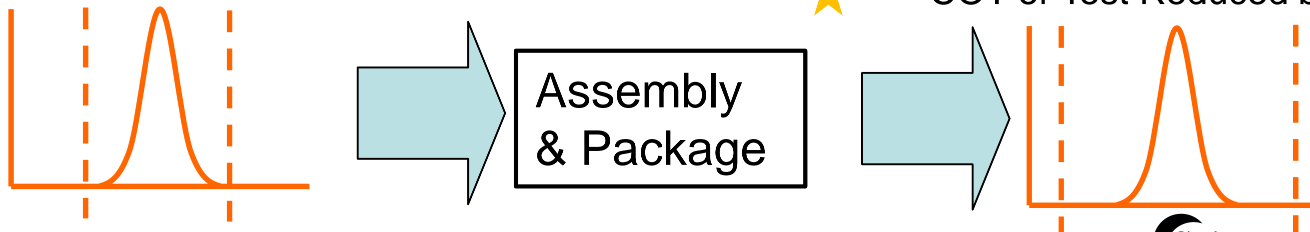
Package Test Today
- Must flip to +G, -G position each axis for Cal
- Must flip to G position each axis for Verify
- Limited Continuous Improvement
- Difficult in Separating Die, Package, ASIC root causes



Xcerra Solidus Test Solution – The Revolutionary Approach to MEMS Testing

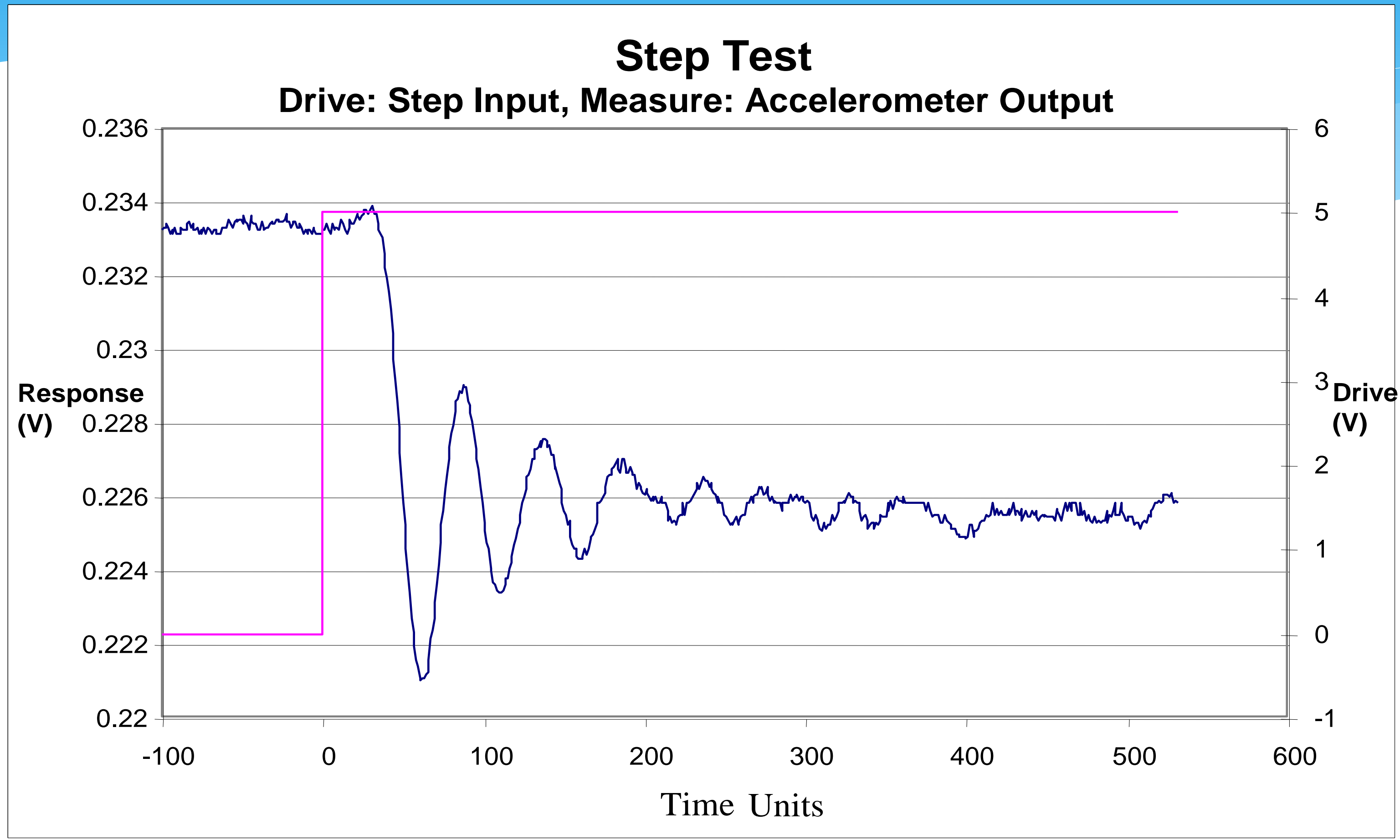
Wafer Sort with STI Dynamic Tester
- Enhance Feedback Value to Fab
- Sort for Performance and Cal Factors
- Monitoring of Fab Performance
- Parameters Sort for KGD

Package Test with Xcerra Cell
- Fixed Calibration Constants or Factors
- Elimination of Cal Stimulus (20-30% test reduction)
- Verify Stimulus to each G axis Only
- Ability to Sort for PKG and ASIC Failures
- COT or Test Reduced by 20% to 30%



Increased Throughput by 20%to 30%
(Customer Validated)

Dynamic Measurement Test Methods STEP Test



Note: Test Data from STI3000 Test System

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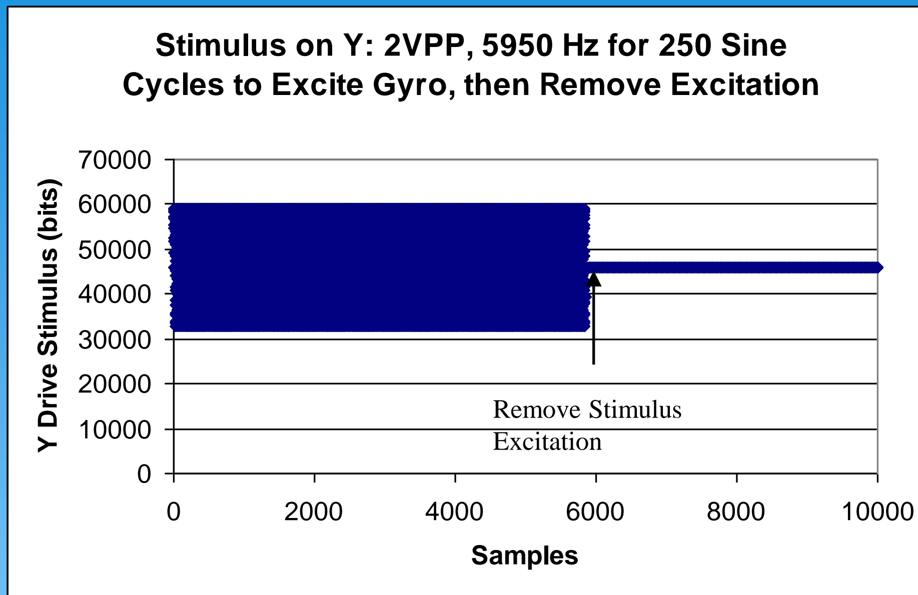
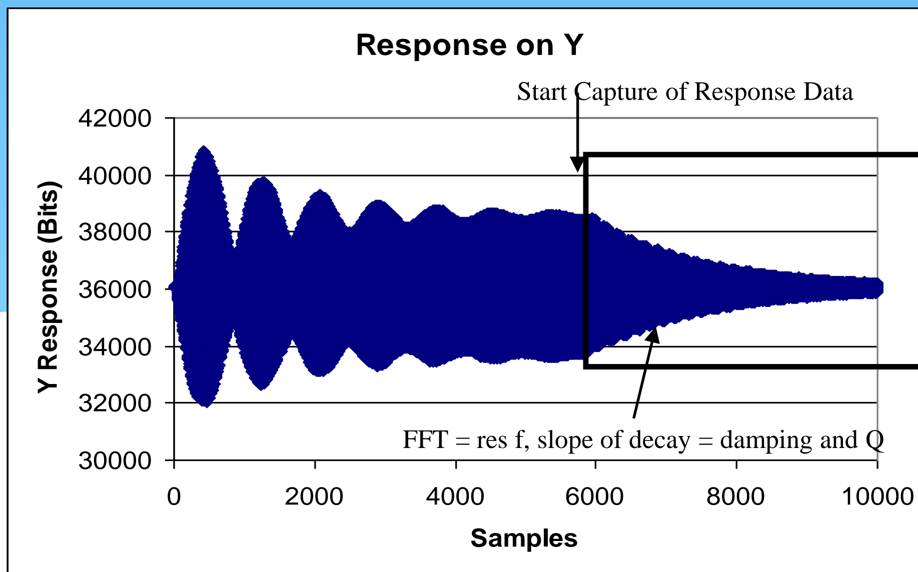
3-Axis Gyroscope Test Data Example

STI3000 Drive and Sense Data Example

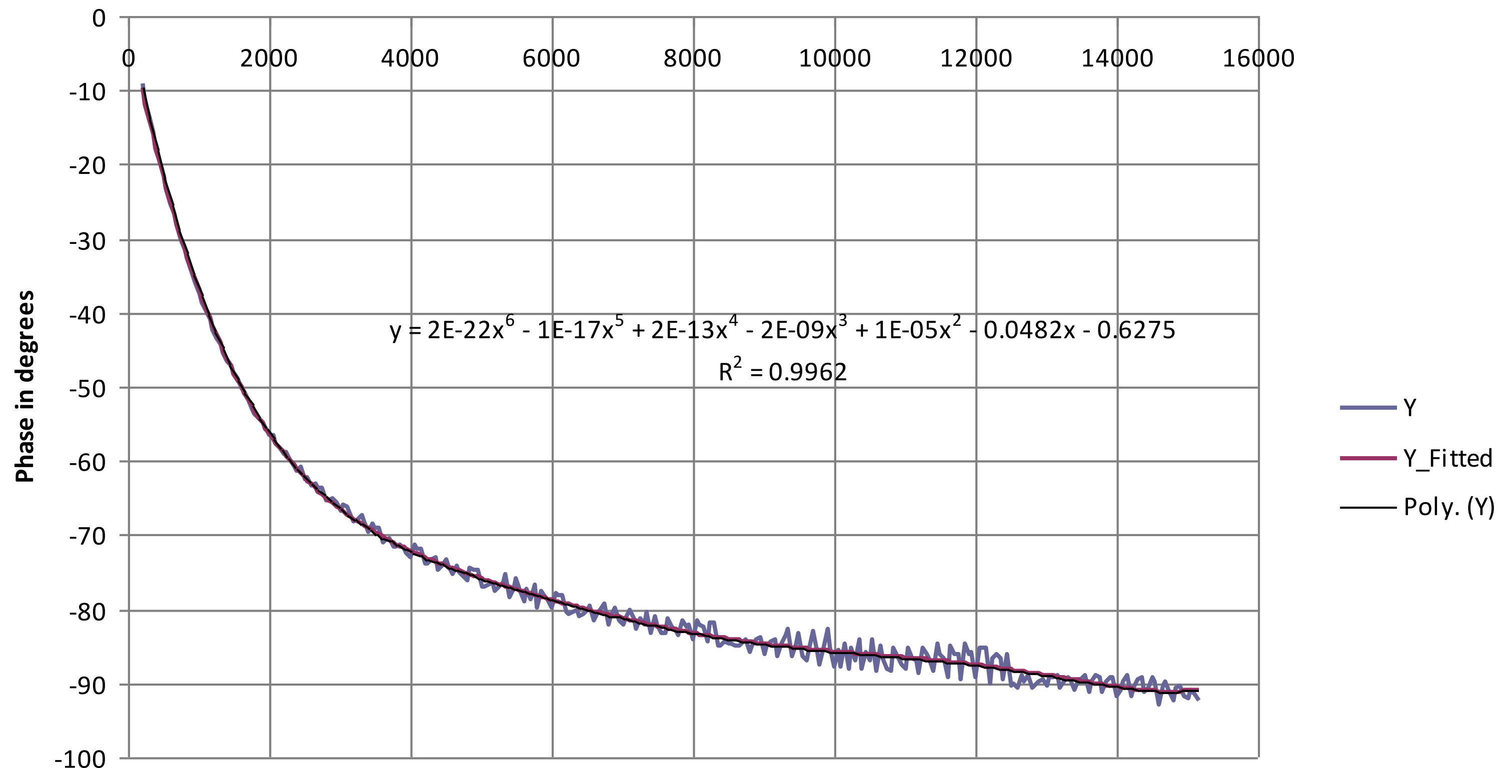


STI3000 Drive Signal



Gyro Response Signal

Natural Freq. Using Phase Analysis



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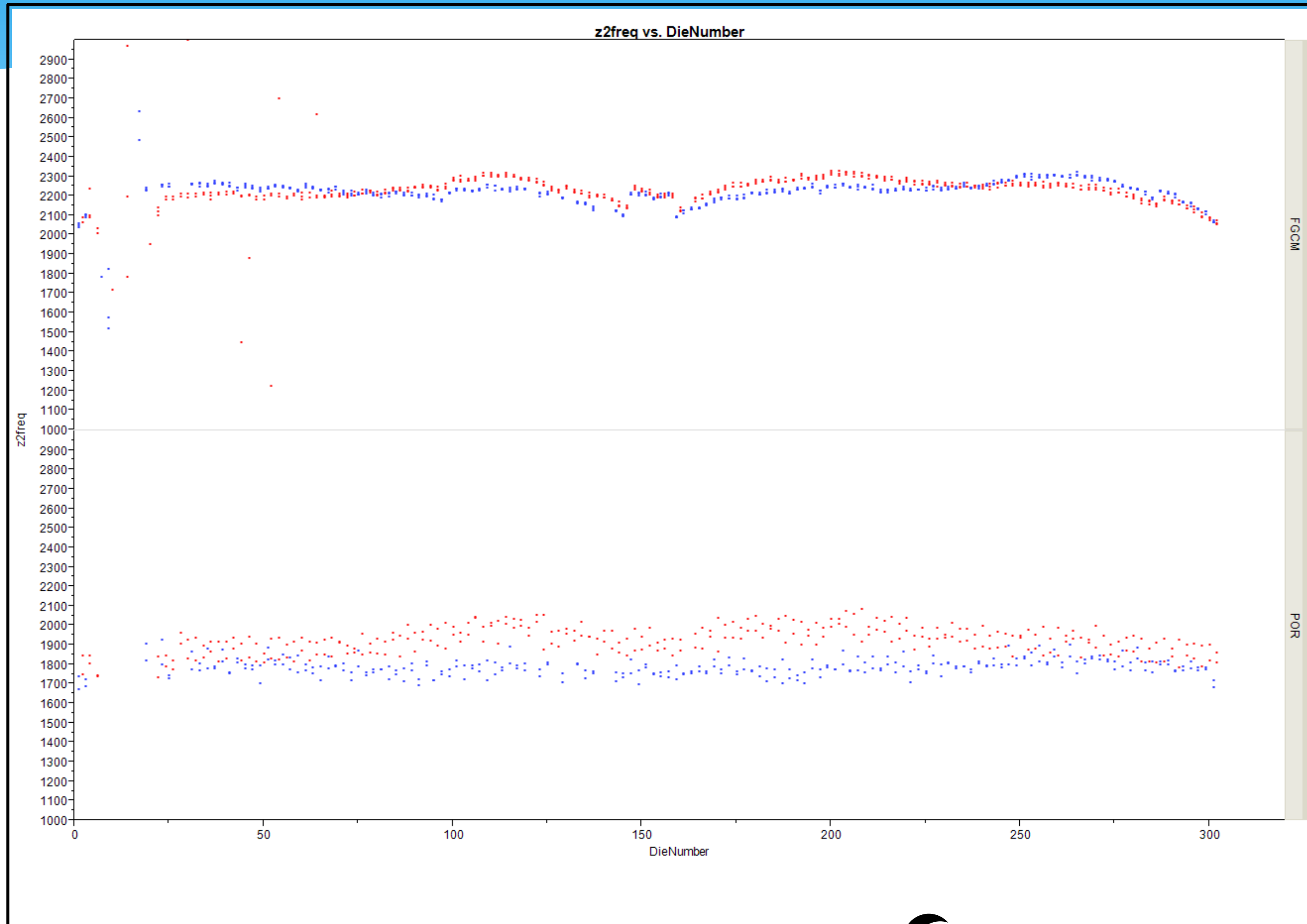
Z Natural Frequency Data



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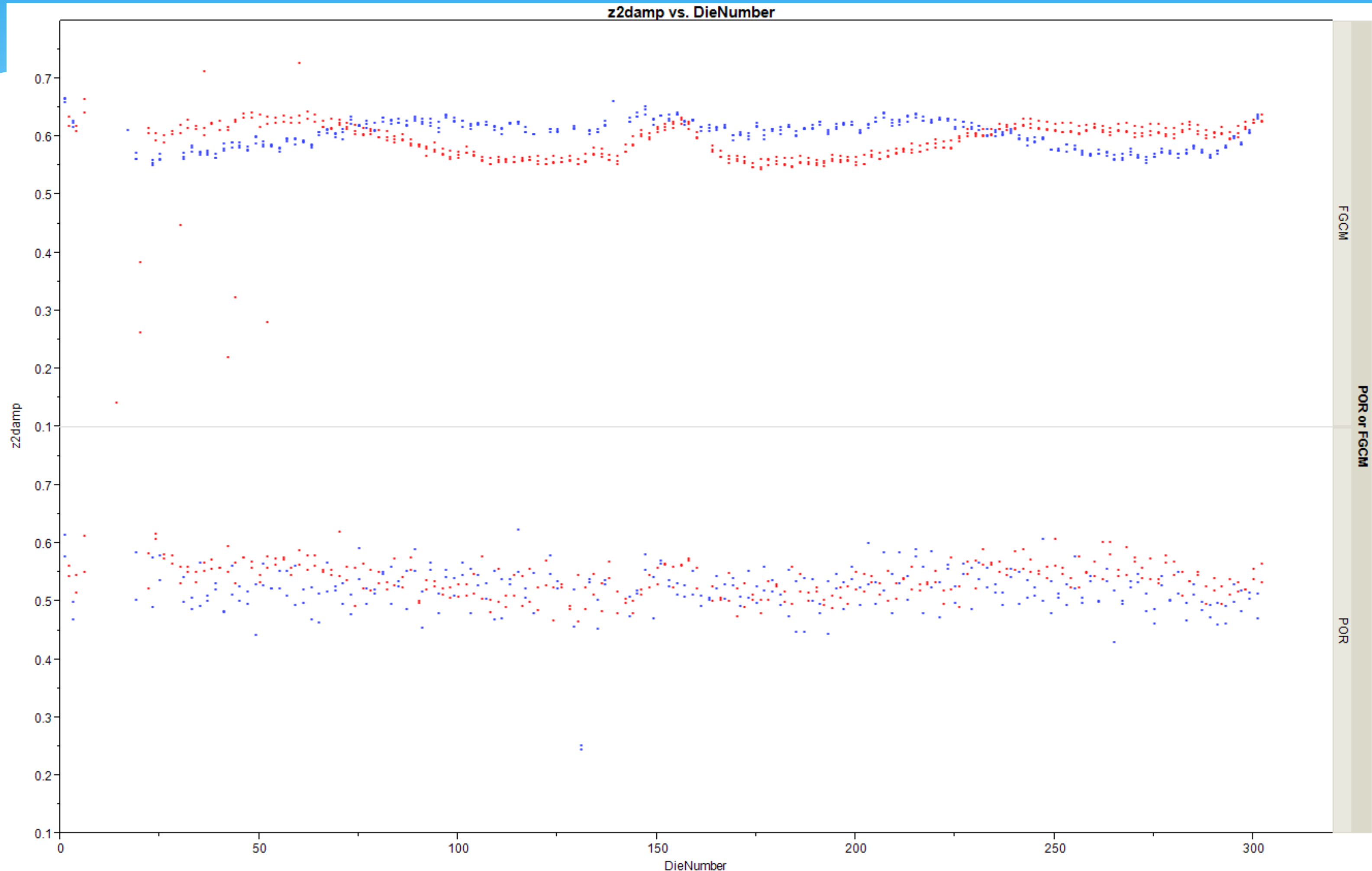
Z Damping Data



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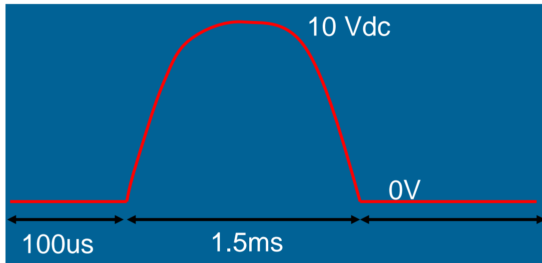
Full Range of Motion Testing (Stiction)

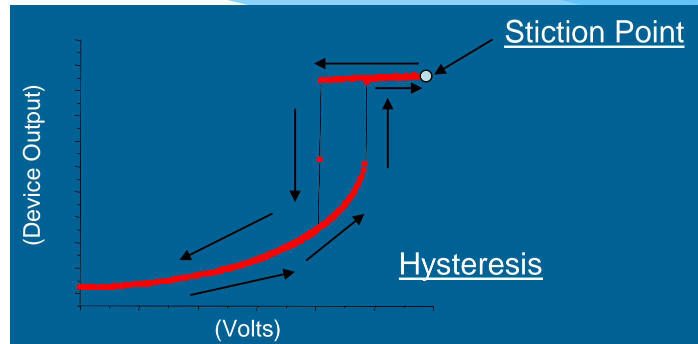
Drive or Force

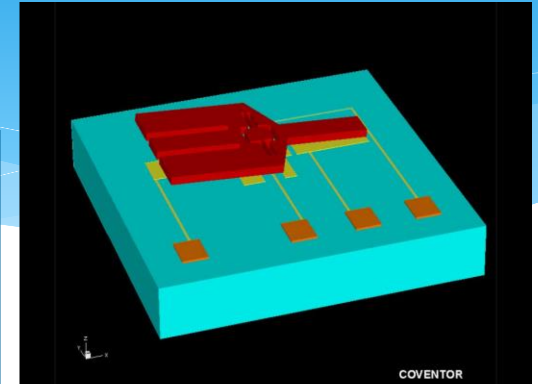
(Device Input)

Sense or Measure

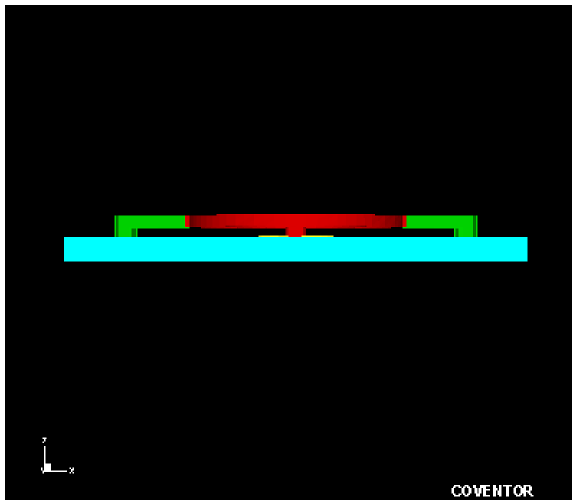
(Device Output)



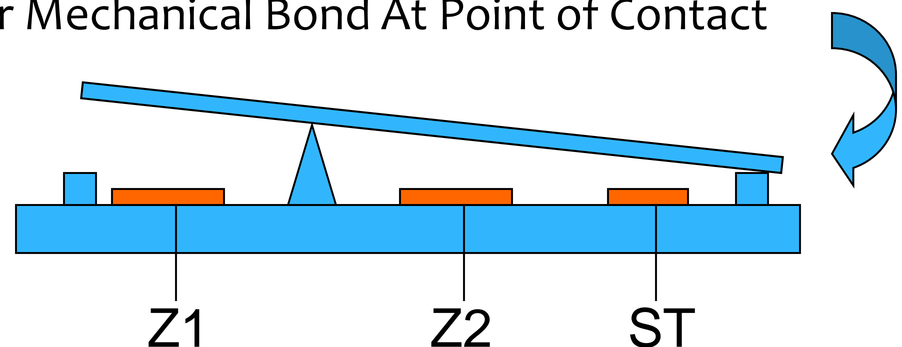




Teeter Totter Type Element



Element Travels Full Range and STICKS Making a Fusion or Mechanical Bond At Point of Contact



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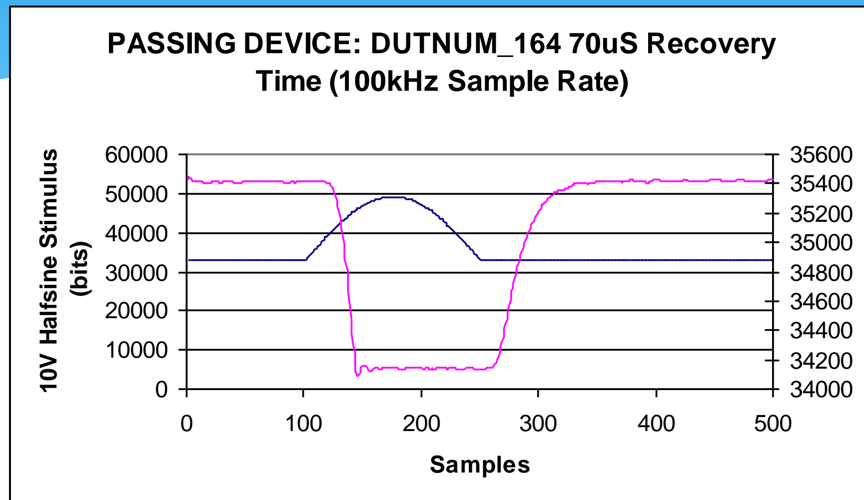
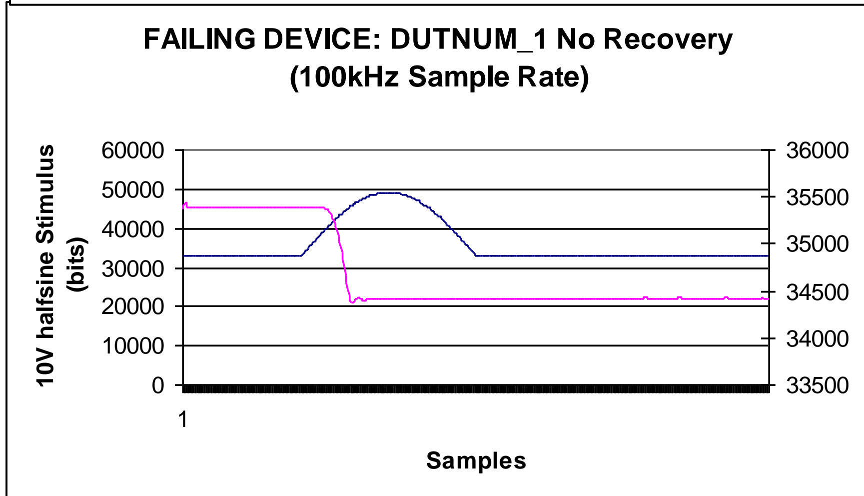
Full Range Motion Test Examples (Stiction)



Passing Part

Hard Stiction Failure



Failing Part

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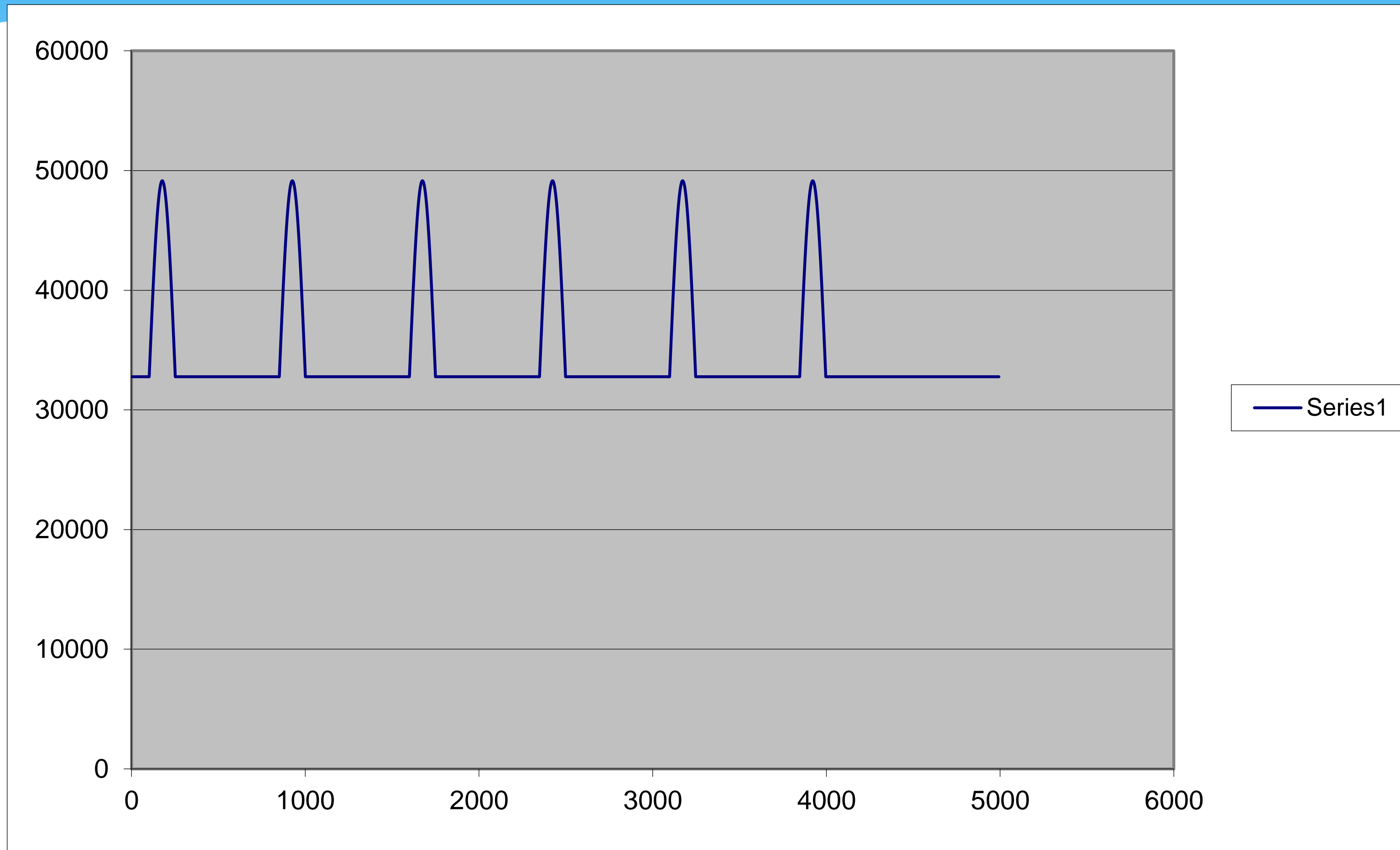
ROM Multiple Pulses Stimulus



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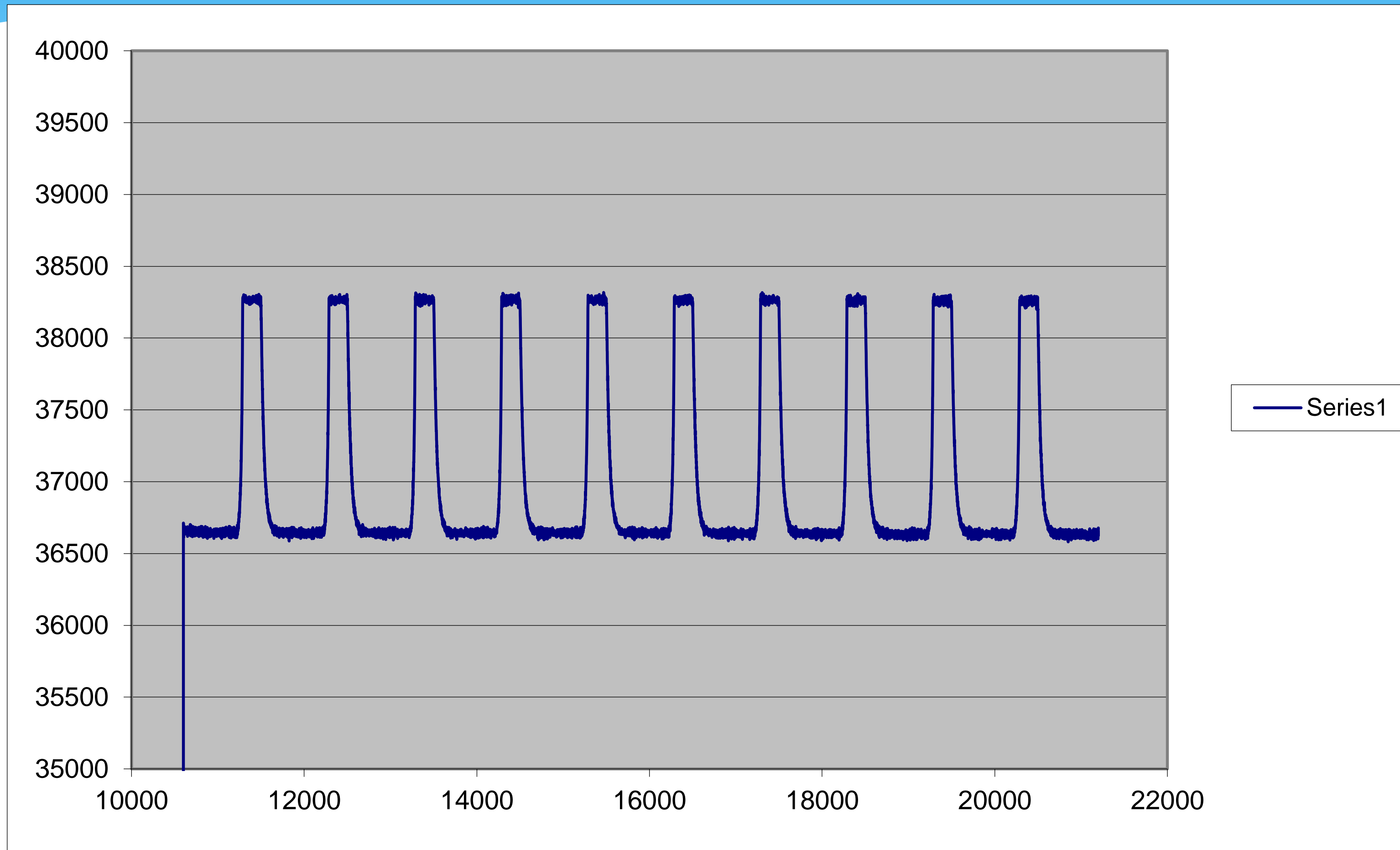
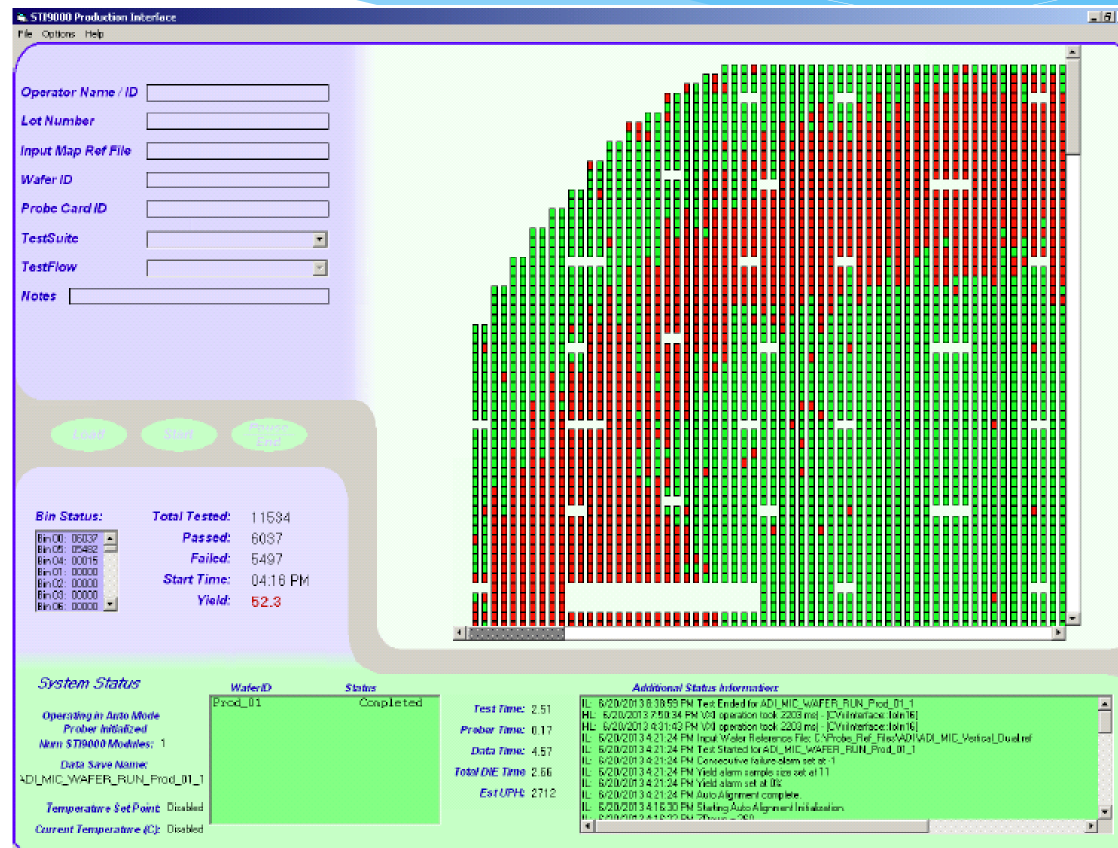
ROM Multiple Pulse Response Pass



Tester Program Environment

- ❑ **Software: C++., Visual Basic and Visual studio**
- ❑ **Programmable GUI**



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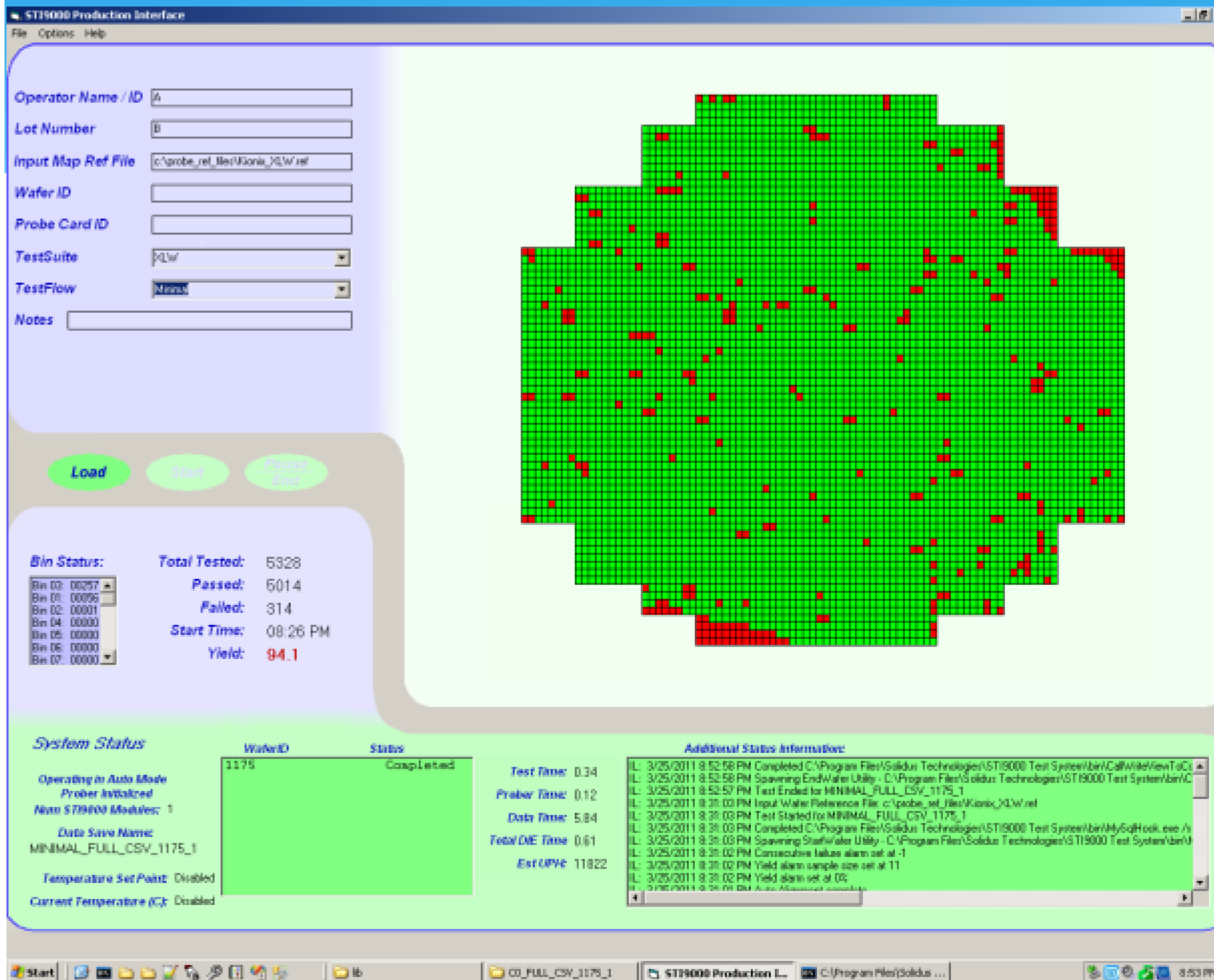
Graphical user interface (GUI)



The STI9000 ATE software incorporates a production graphical user interface (GUI) providing convenient test execution, test status and pass/fail results.

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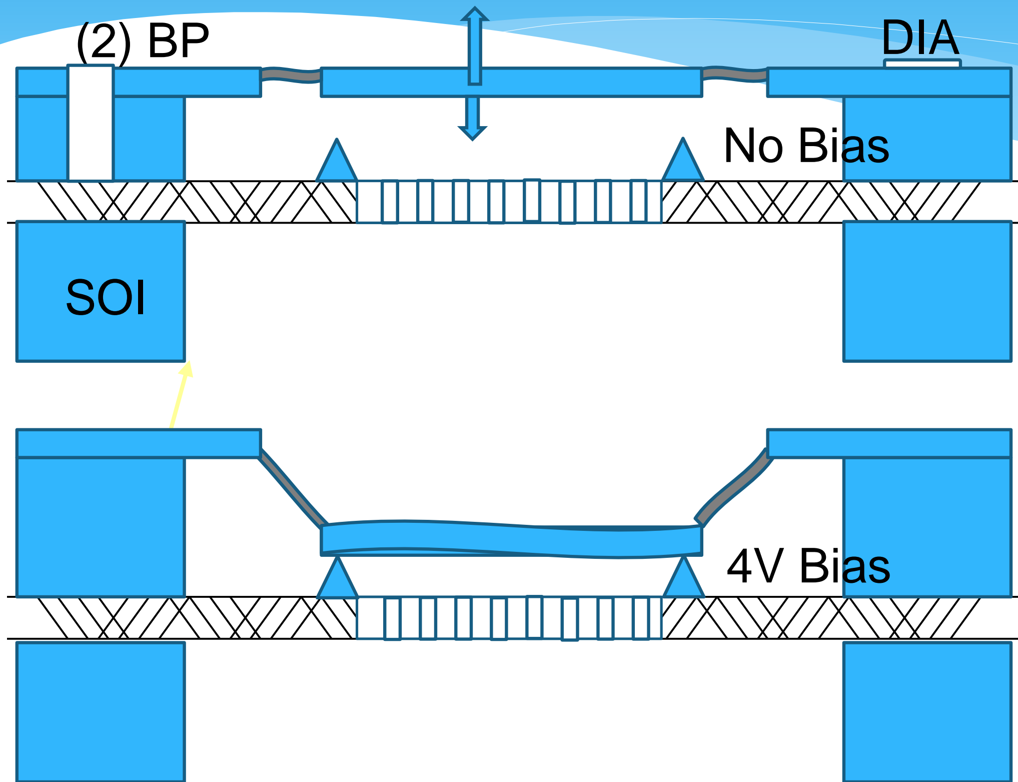
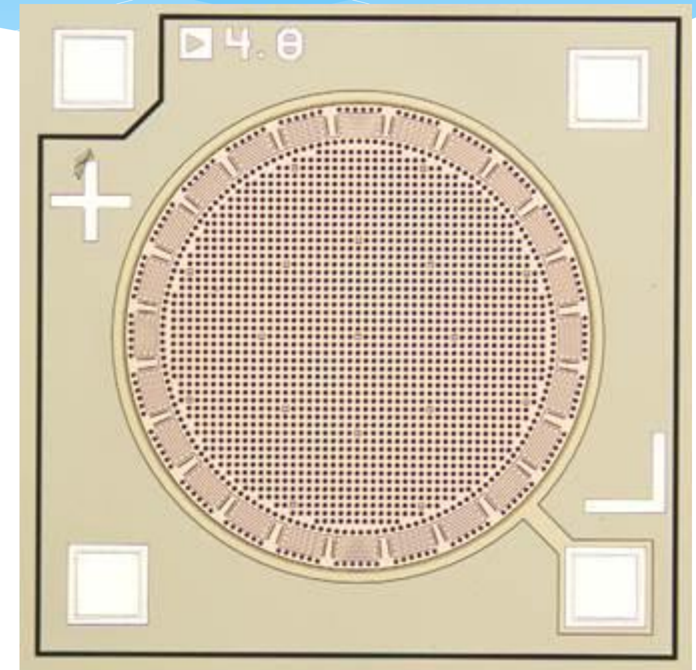
Microphone Testing Cross Section





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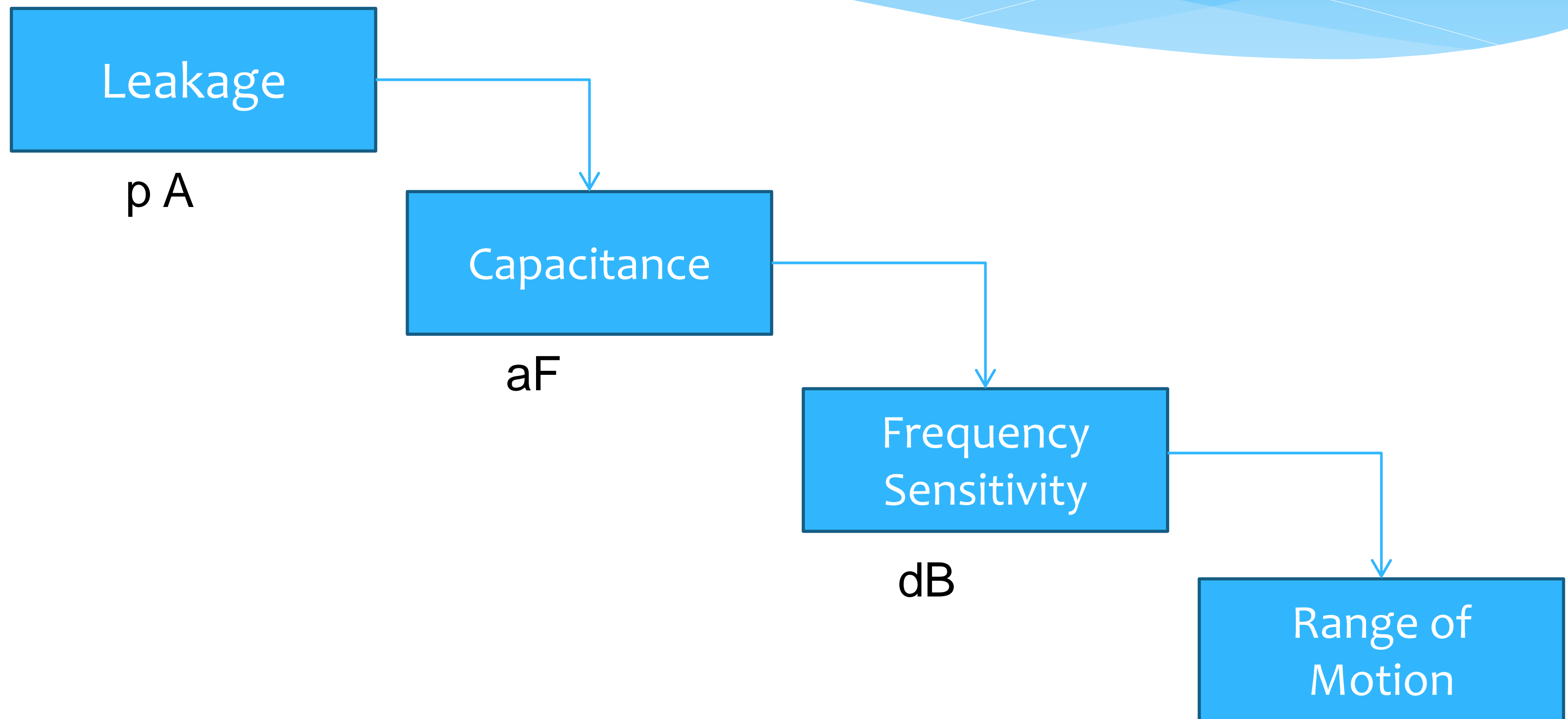
Defect Detection

Test Flow



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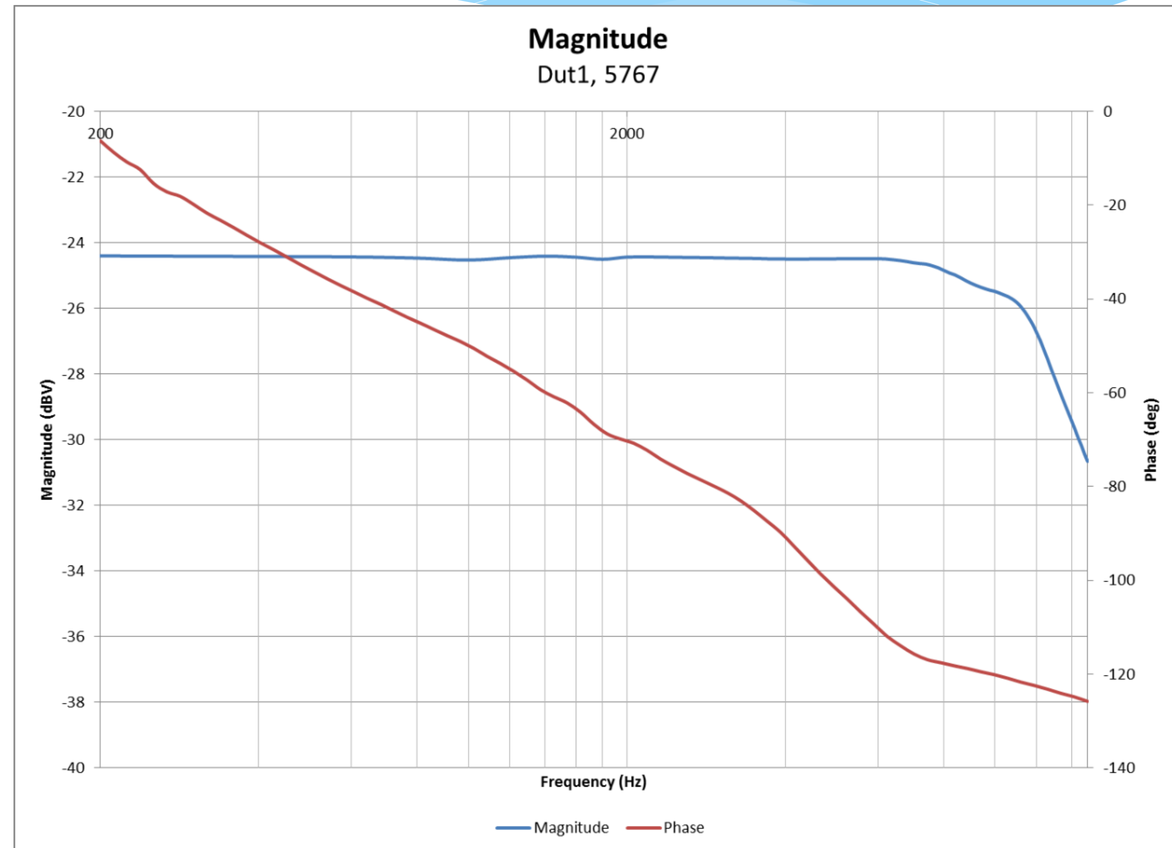
Microphone Test Instruments

Standard Test Instruments available to test Microphones

1. **<u>Drive Sense Technology (DST).</u>** Drive with analog sweep, measure: <u>Frequency</u>, <u>Phase</u>, <u>Magnitude and Damping</u>.

* Test
  * Newer experiment wafer
  * Sweep
    * 20
    * 0 to 15,000Hz, 200 Hz steps
    * 4.0Vdc, 3.0Vpp
    * 10x gain
  * Full wafer map
* Results
  * Full wafer
  * Expected roll-off plot on magnitude plot



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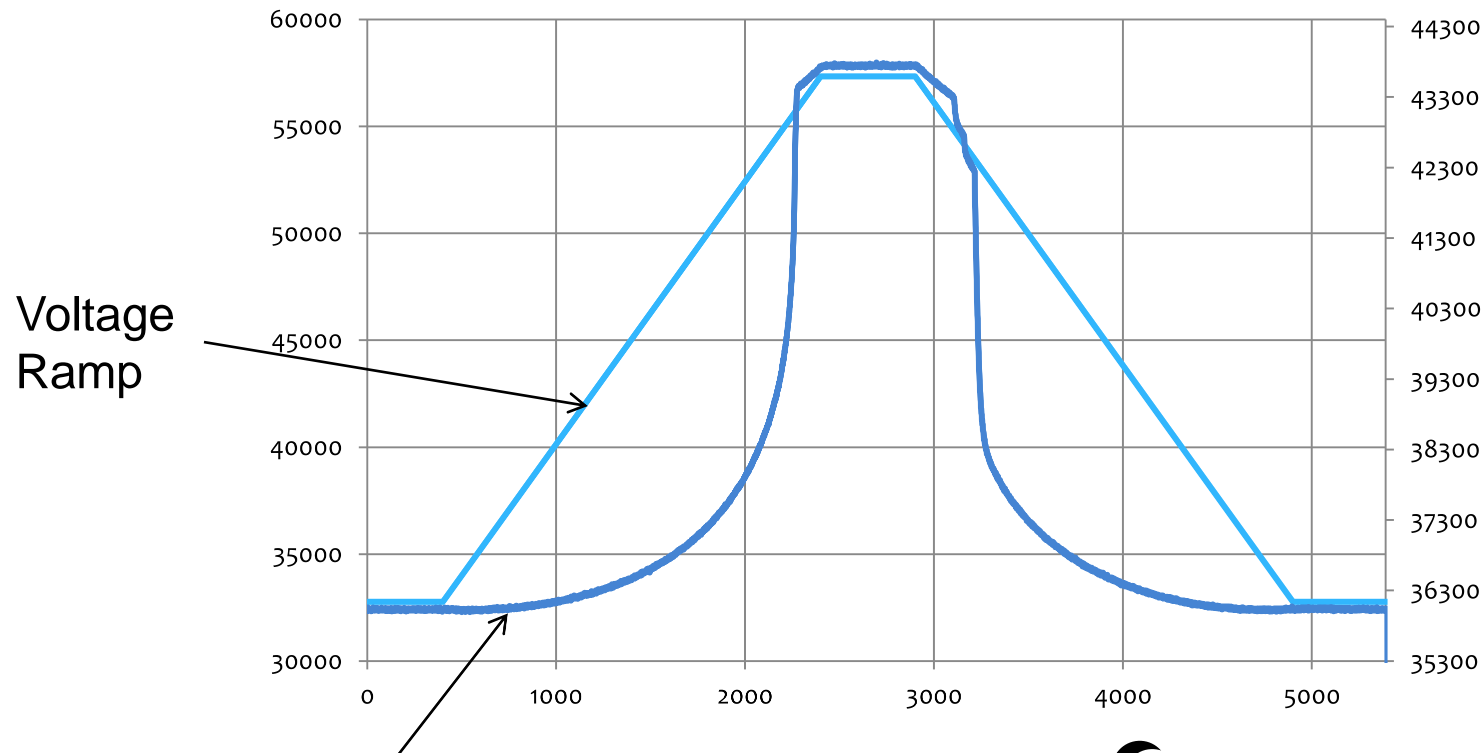
Microphone Test Instruments

Standard Test Instruments available to test Microphones

1. **<u>Range of Motion (ROM):</u>** Measures the voltage output based on change in capacitance, real time.



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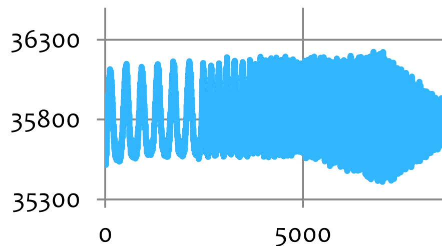
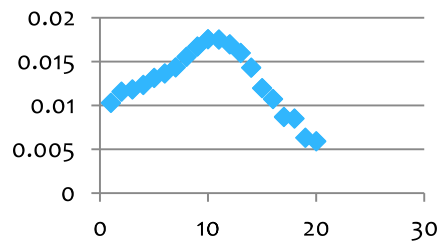
Technical Challenge

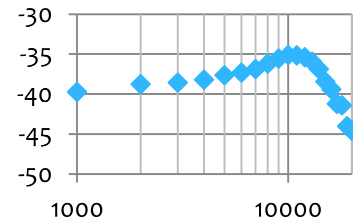
Raw data sweep



DFT to get amplitude



Converted to dB



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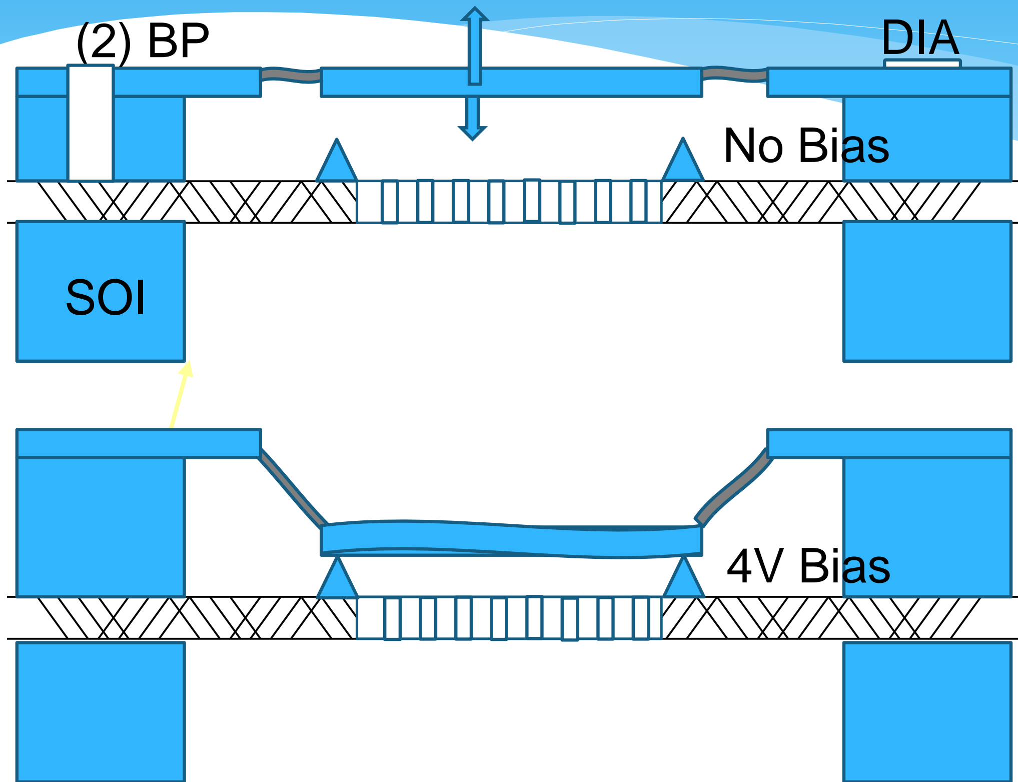
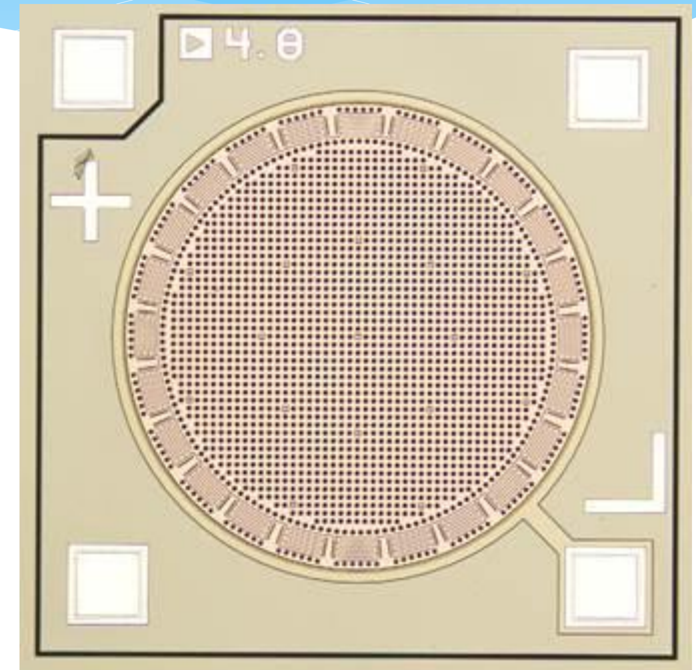
Microphone Testing Cross Section





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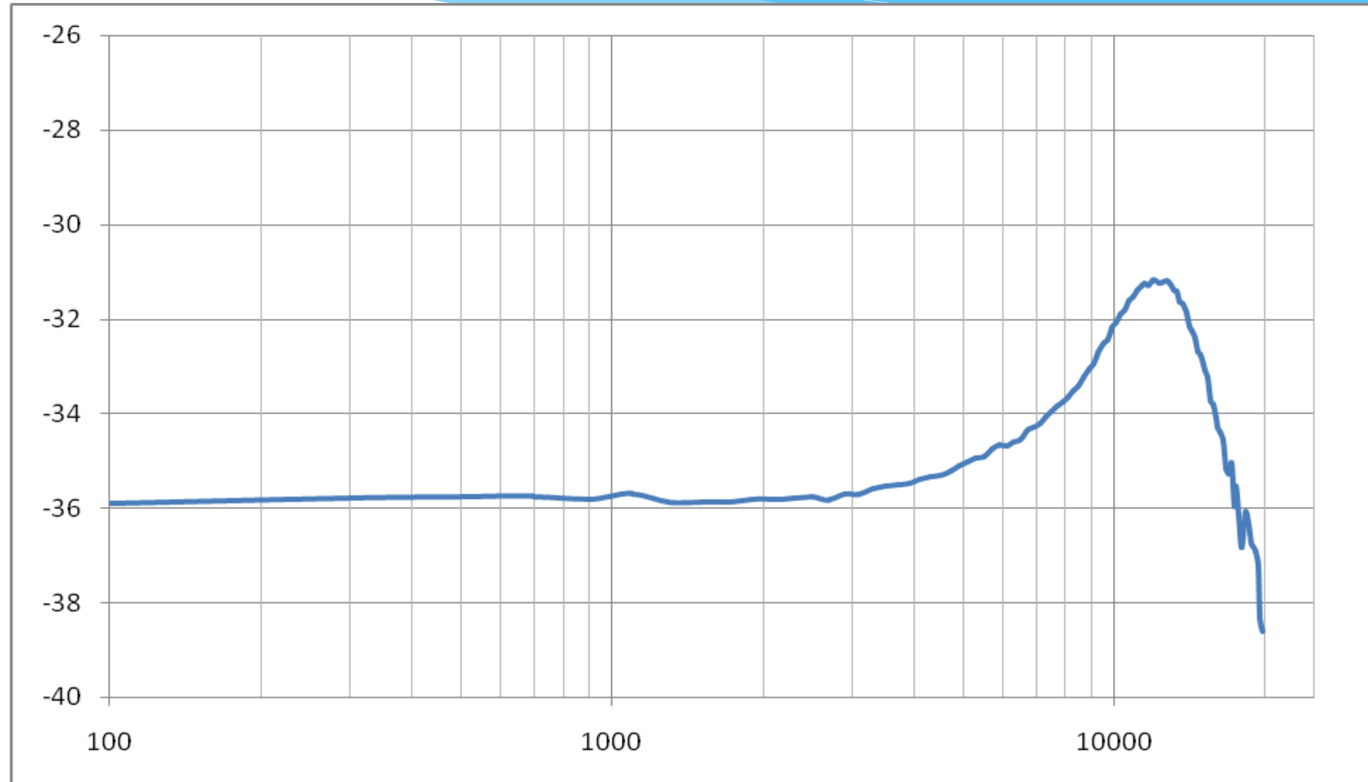
Continuous Single Electrostatic Element Sweep

Solidus provide microphone performance screening at wafer level.



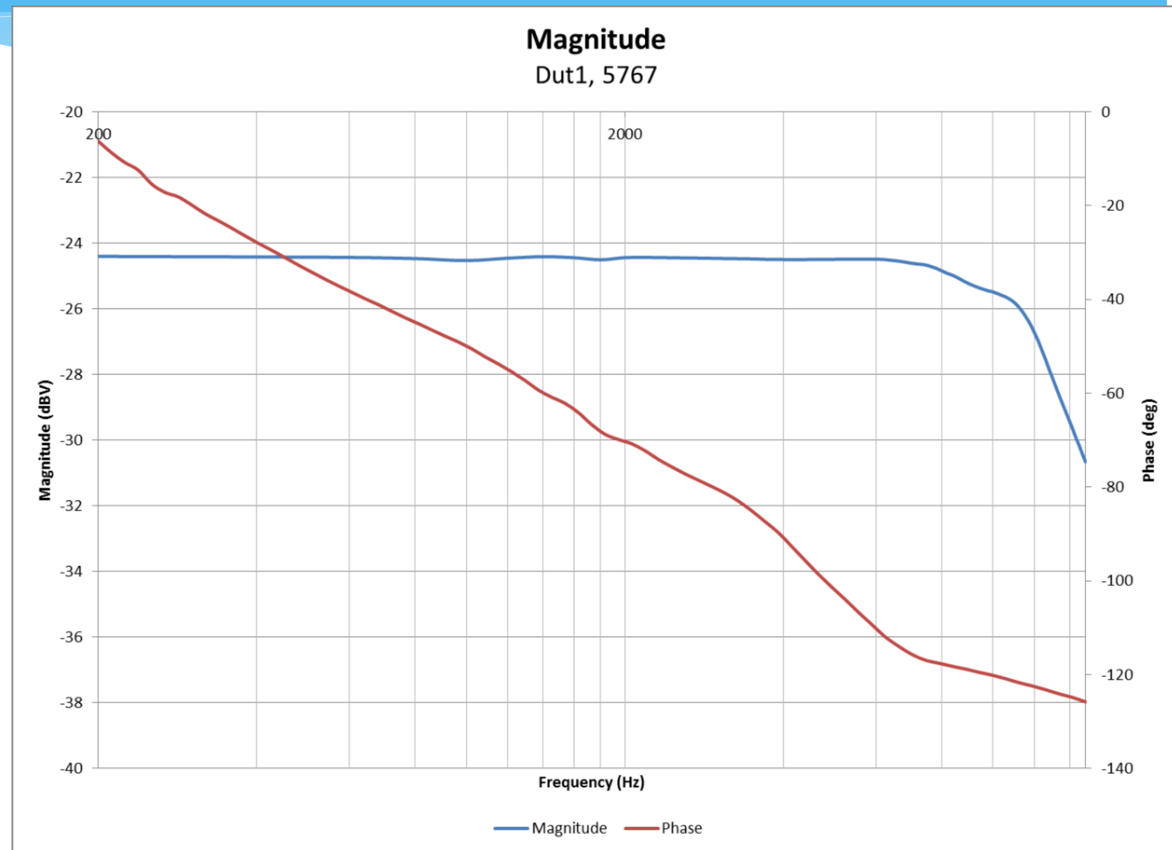
Single-Die frequency sweep

A frequency sweep of multiple working die resulted in response curves as shown above. The frequency was swept in 200 Hz increments from 100 Hz to 19.9 kHz.

Wafer Testing Results

Typical Magnitude Results

* Test
  * Sweep
    * 20
    * 0 to 15,000Hz, 200 Hz steps
    * Bias Vdc, AC Vpp
    * 10x gain
  * Full wafer map
  * STI wafer fixture
* Results
  * Full wafer
  * Expected roll-off plot on magnitude plot



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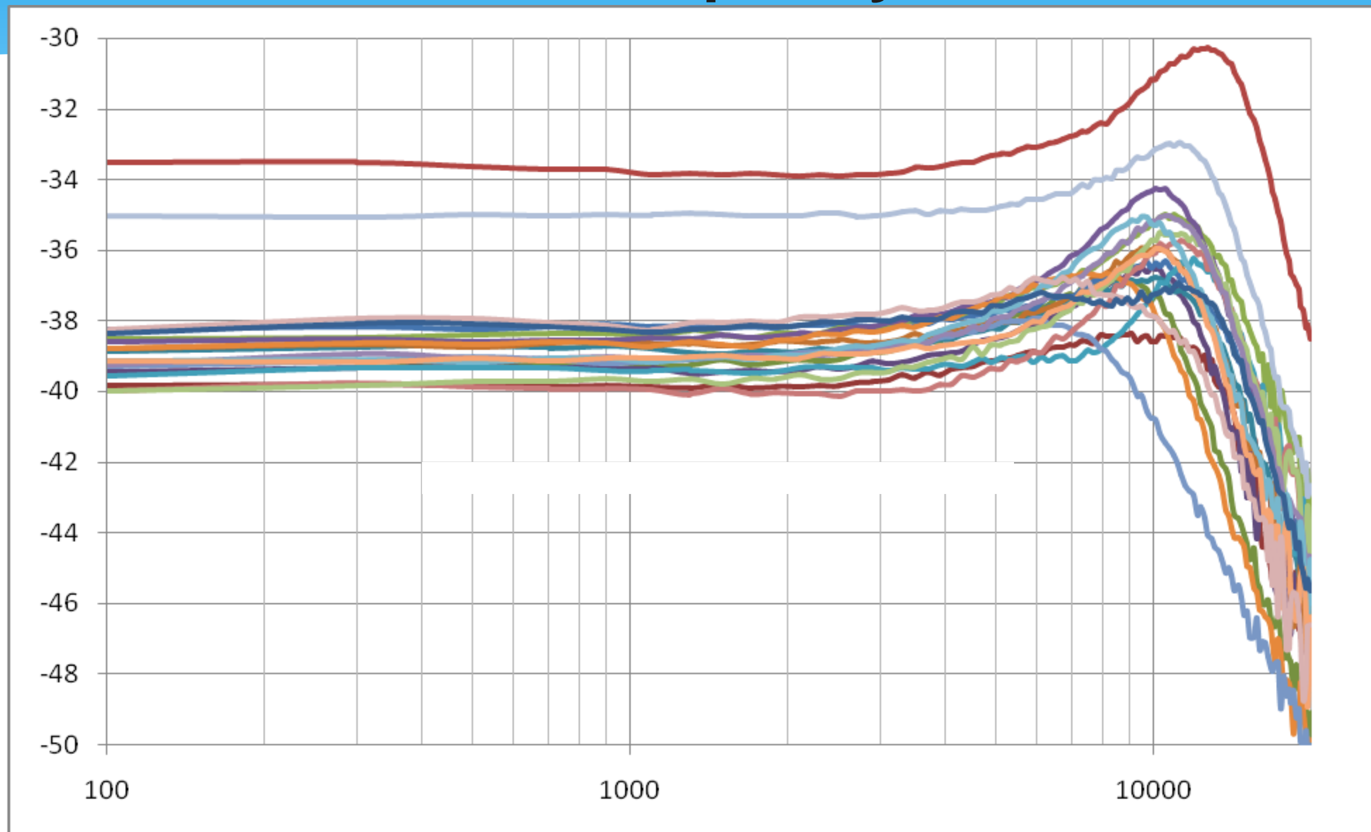
Multi-Element Sweeps
dB vs Frequency



Multi-Die frequency sweeps
A frequency sweep of 20 working die resulted in response curves as shown above.
The frequency was swept in 200 Hz increments from 100 Hz to 19.9 kHz.

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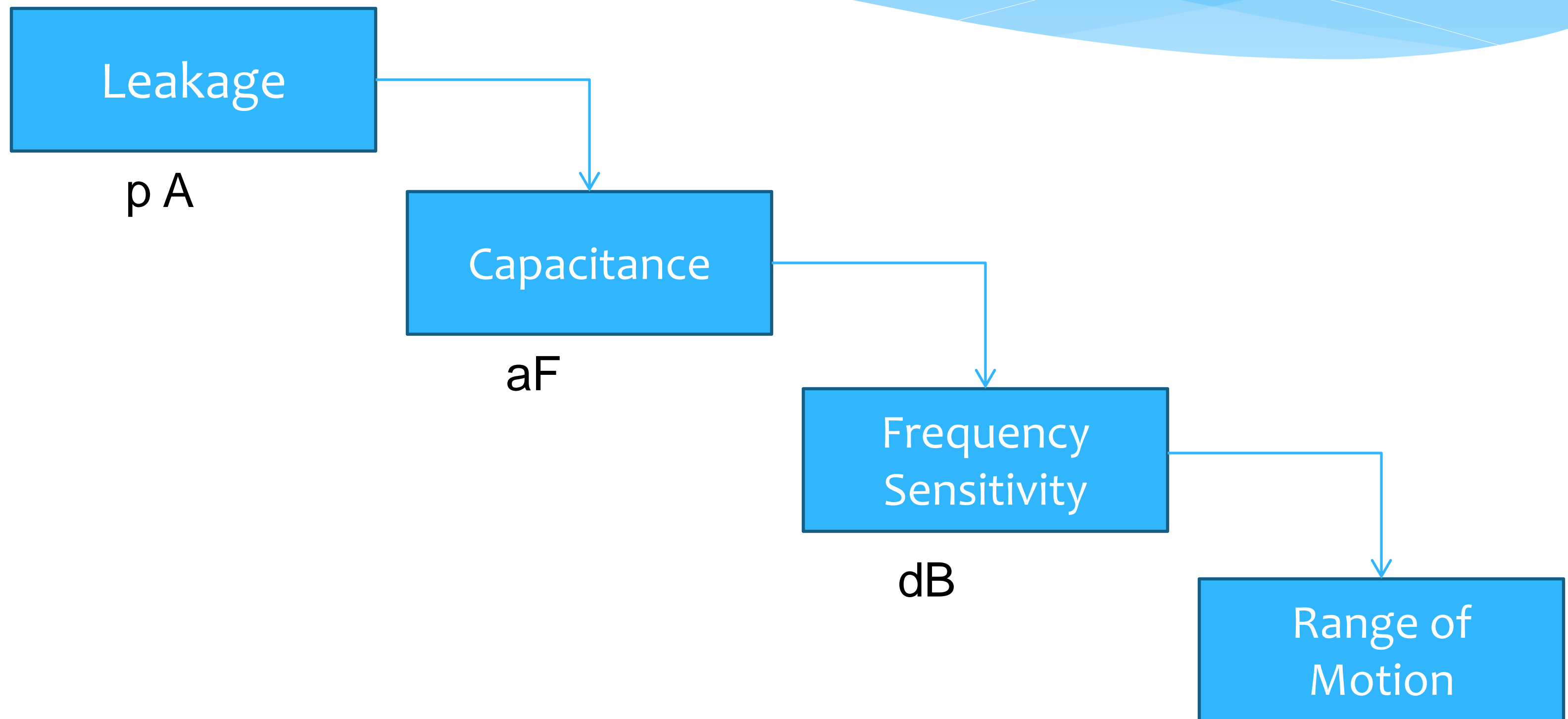
Test Flow

Test Flow



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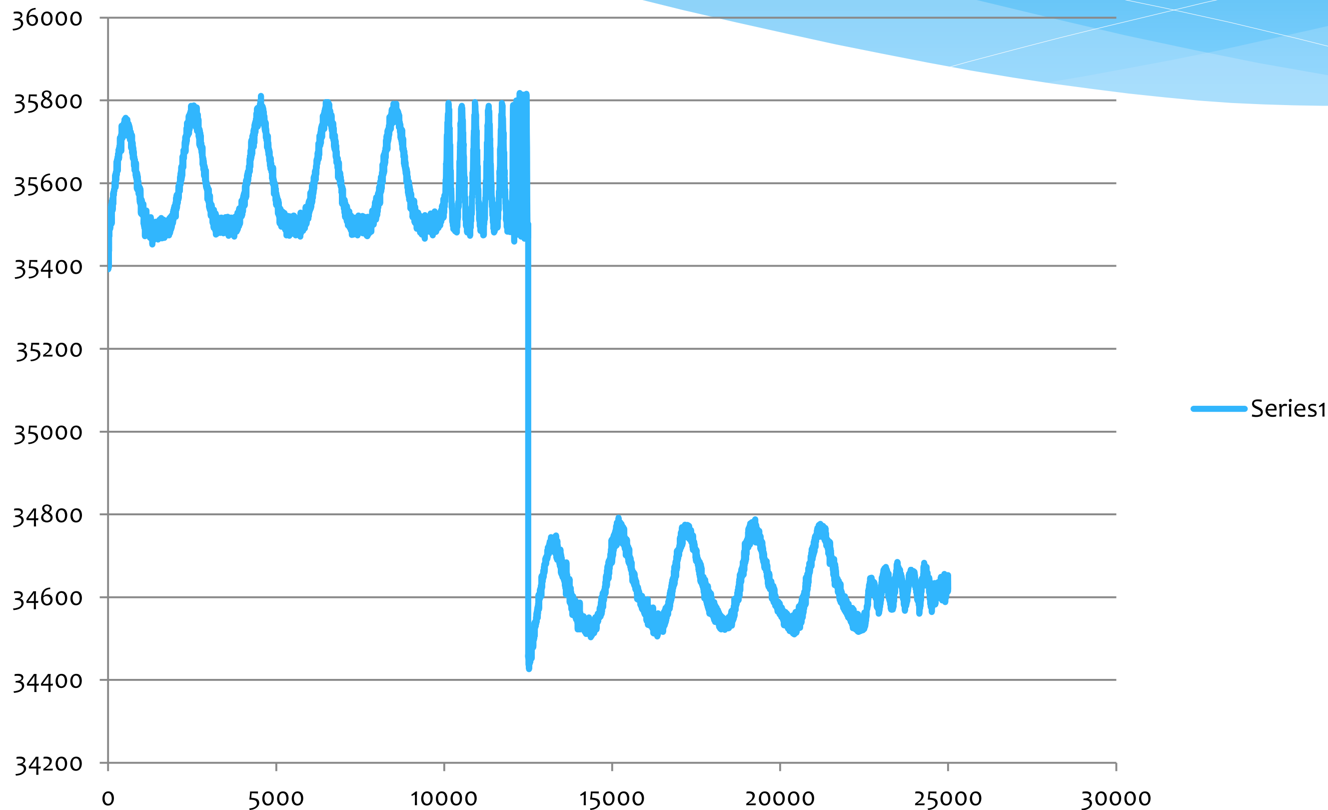
Segmented Sweep Output Wave Patterns

Frequency sweep at 200, 1000 an 4000 Hz – one good and one bad



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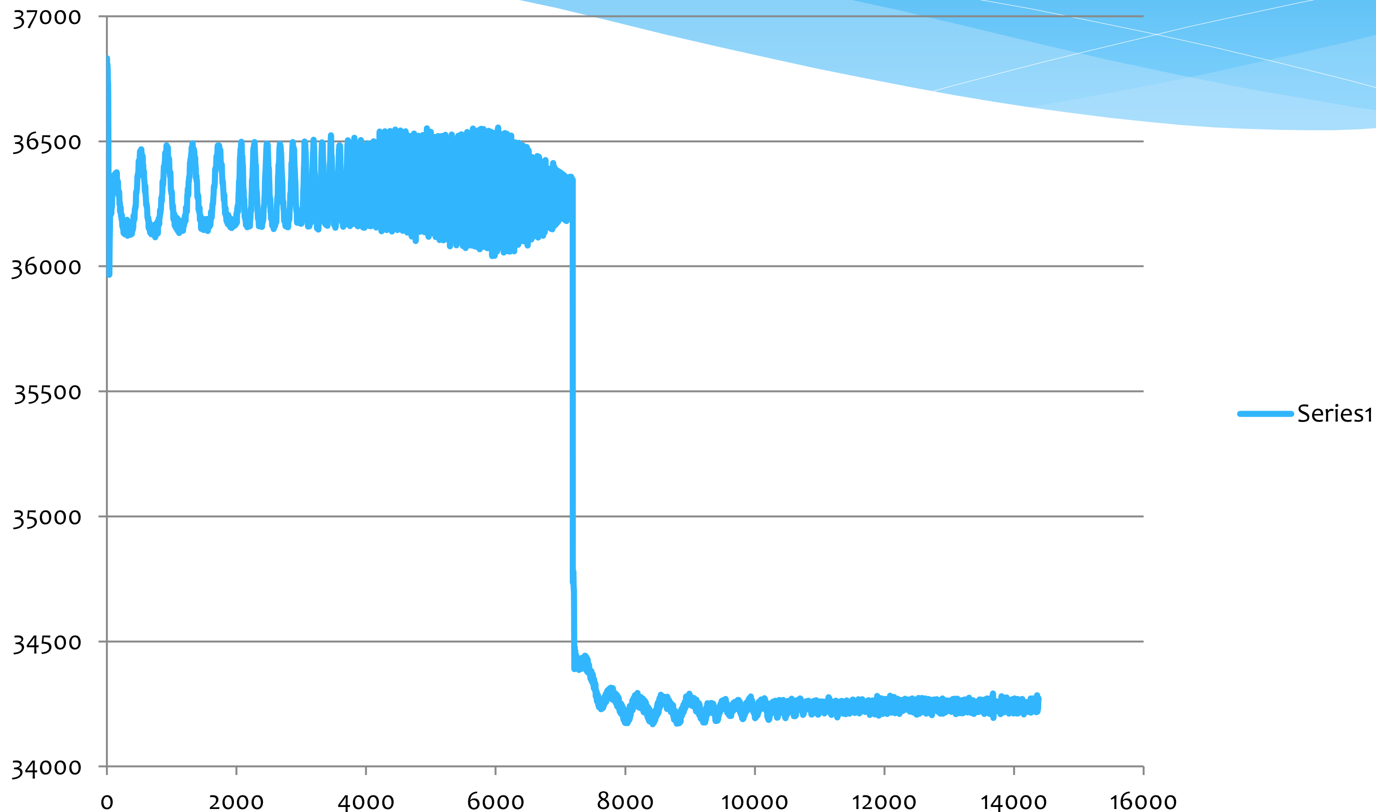
Output Wave Pattern Native to STI

Element frequency sweep – one good and one bad die



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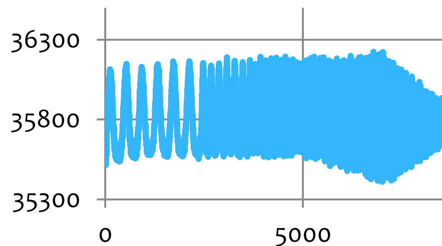
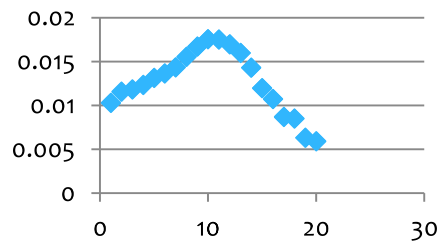
Conversion to dB

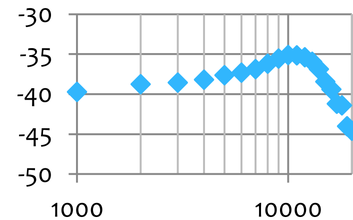
Raw data sweep



DFT to get amplitude



Converted to dB



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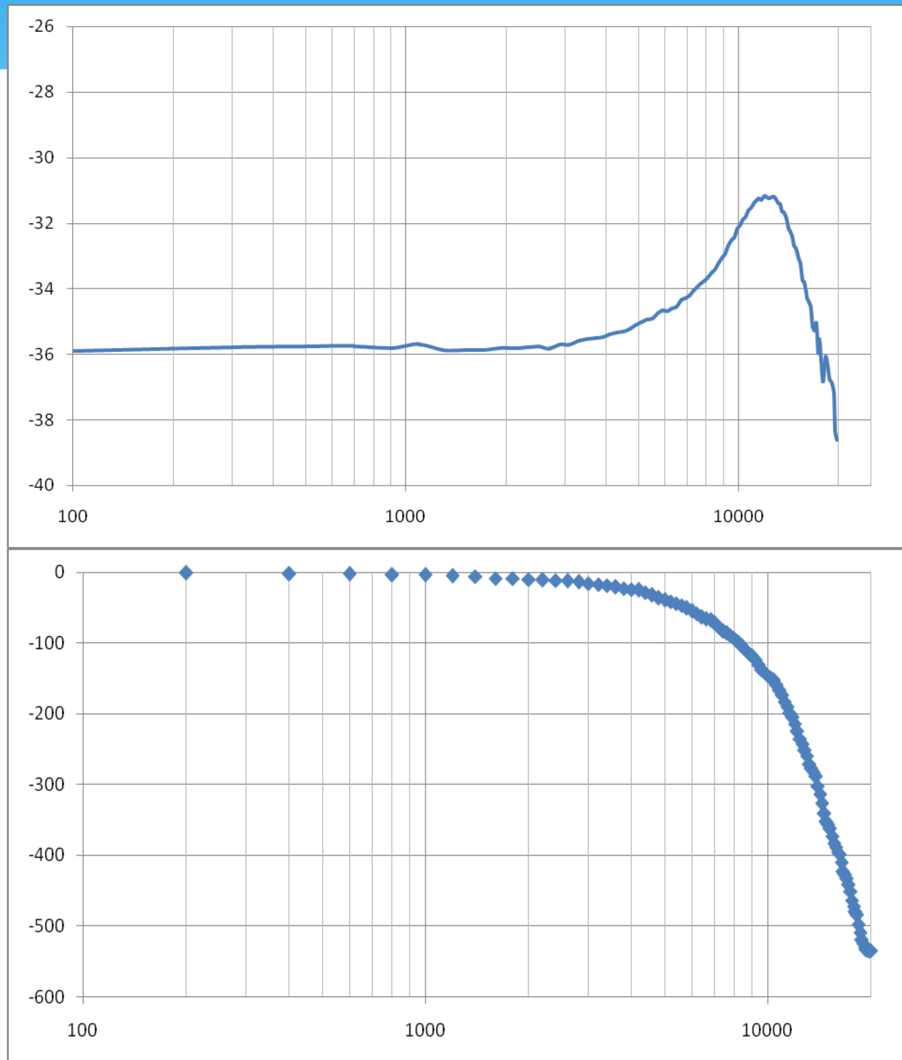
STI Frequency and Phase Output



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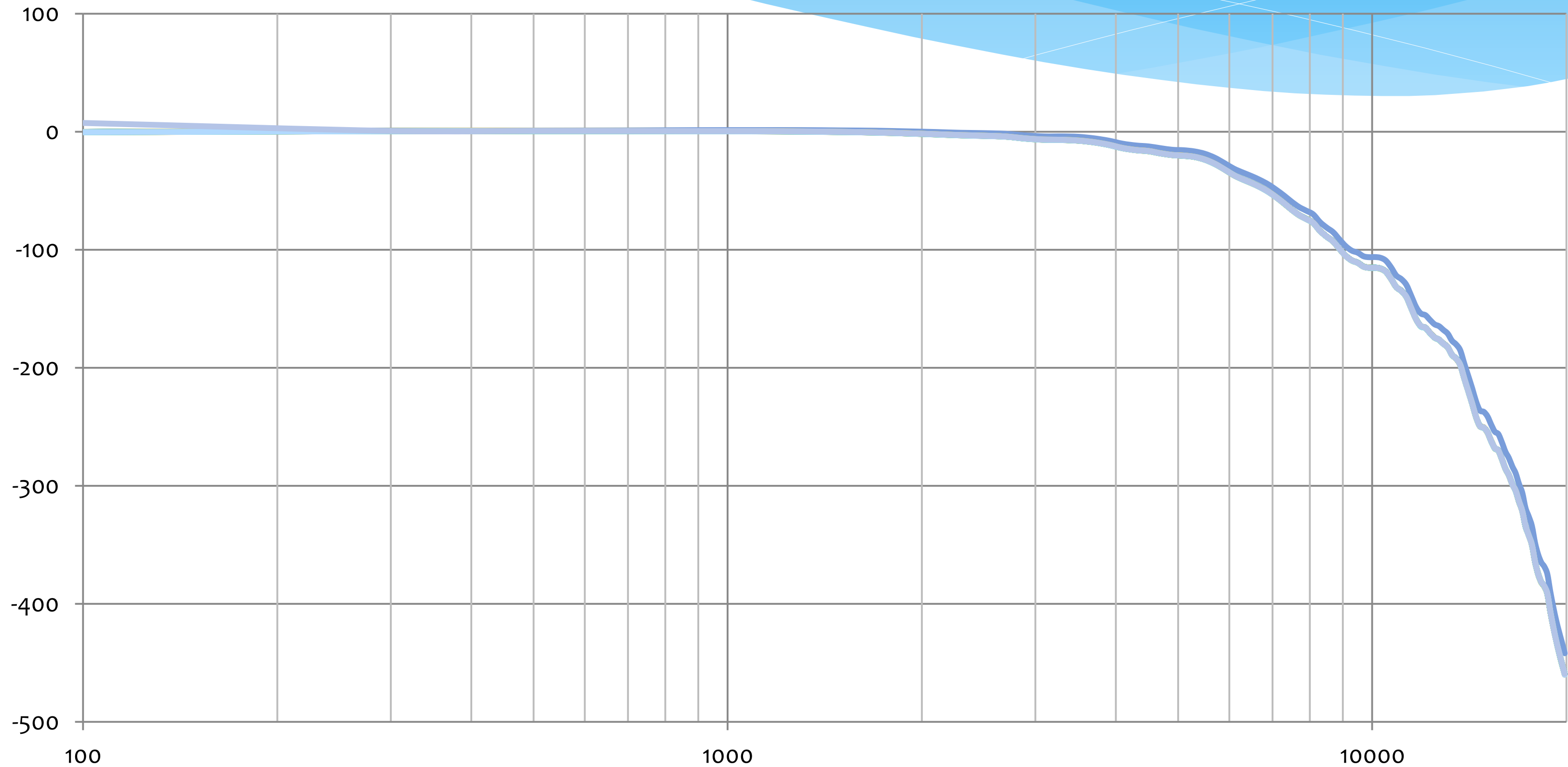
Diced Wafer Phase 20 Die, Frequency Sweep

Plot of Phase vs. Frequency



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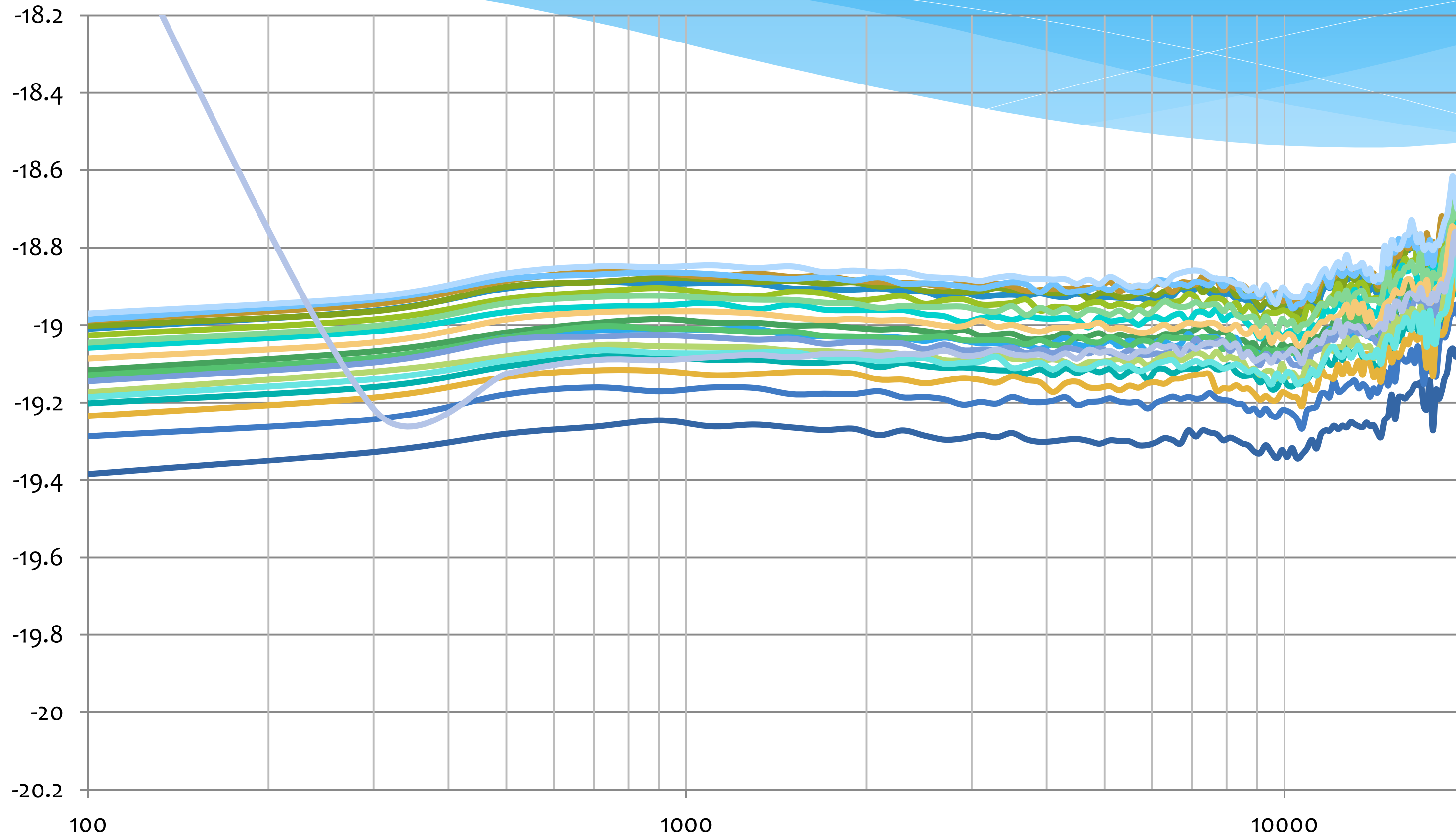
Diced Wafer Frequency 20 Die
Plot of dB vs Frequency



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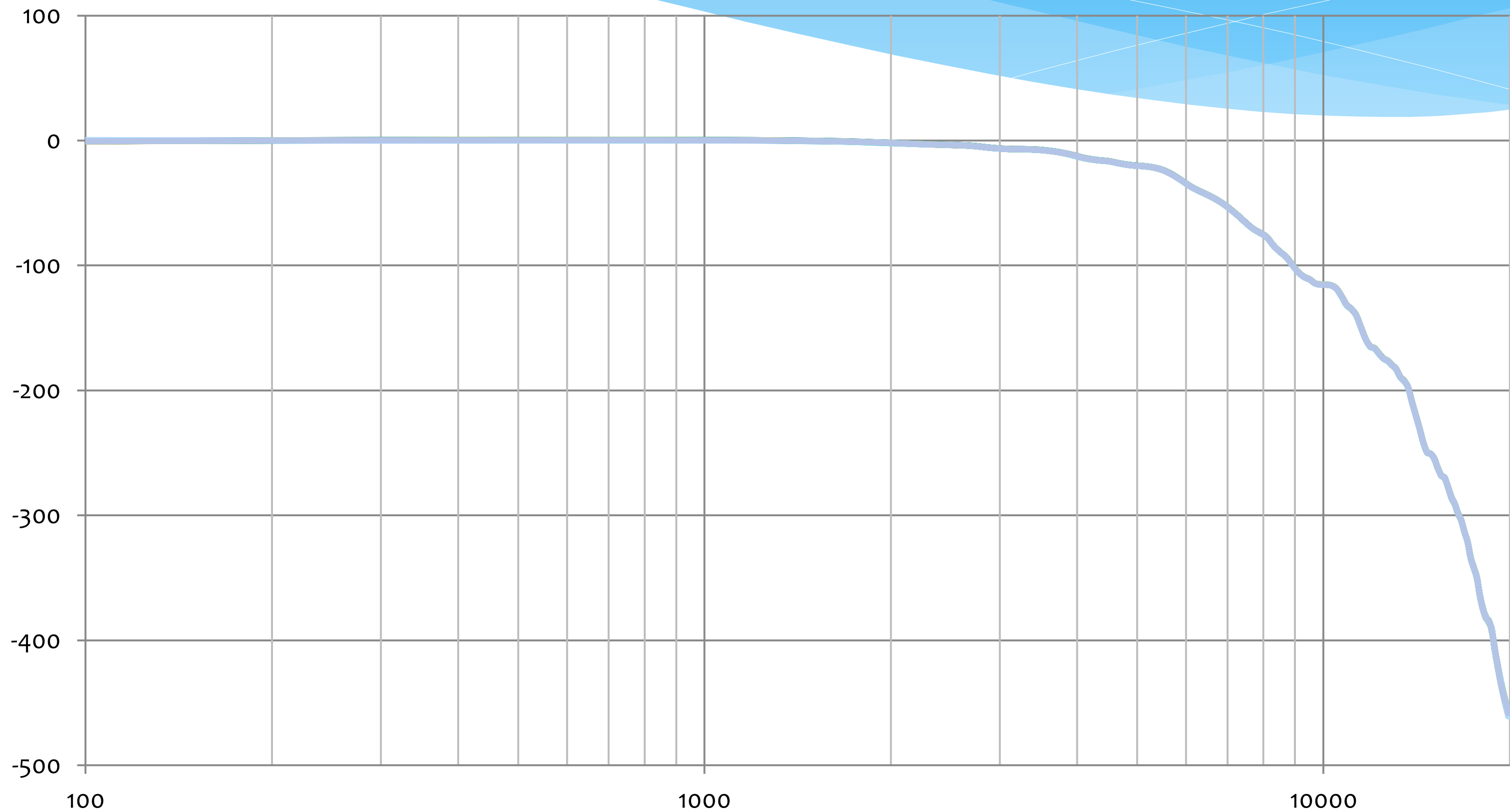
Un-Diced Wafer Phase 20 Die

Plot of Phase vs Frequency



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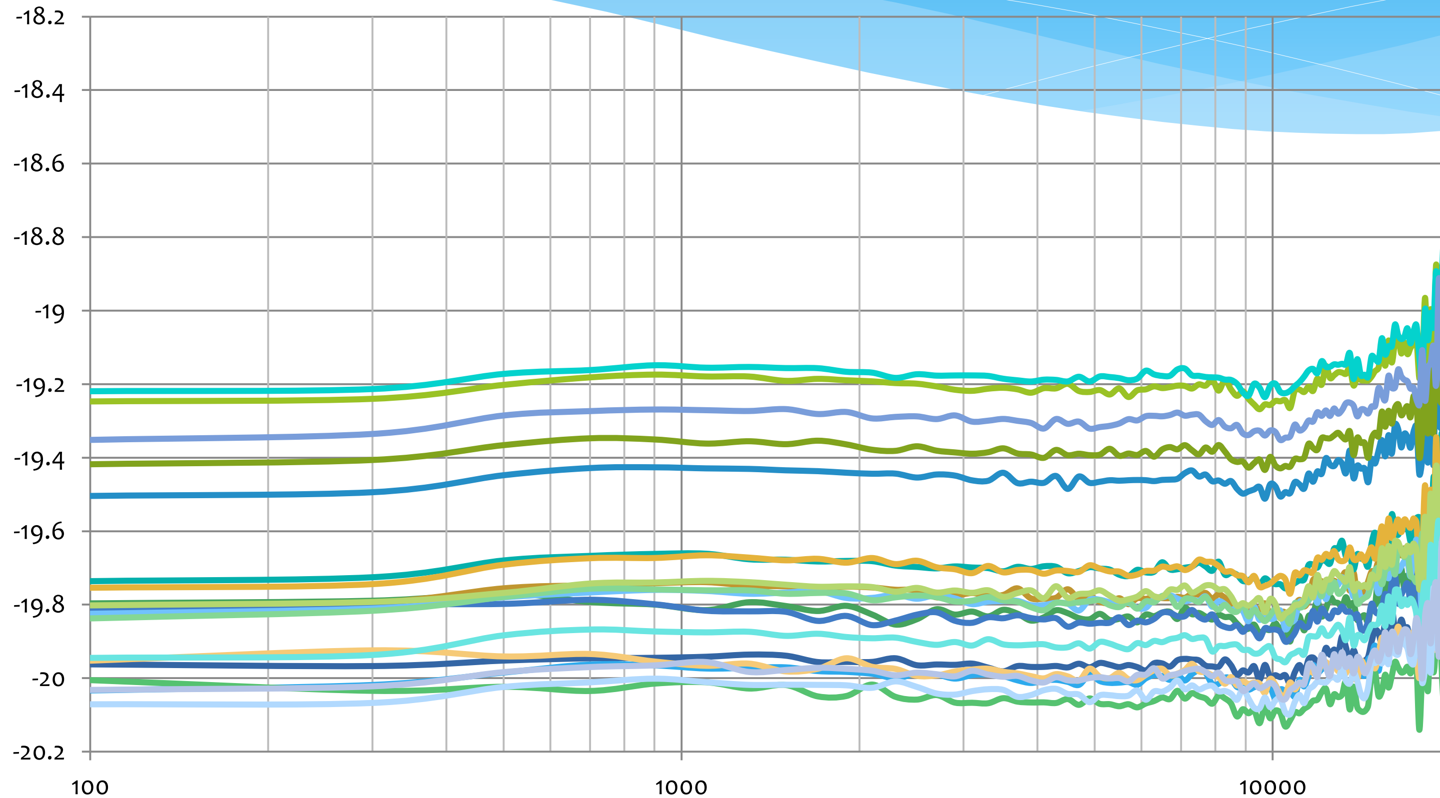
Un-Diced Wafer Frequency 20 Die

Plot of dB vs Frequency



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Testimonials

- Solidus dynamic testing virtually eliminated our customer returns
- Using Solidus, customer returns went from greater than 10% to less than 0.1%
- Director of Quality requires all our MEMS sensors to go through Solidus
- Package test yields have gone from 85% to 99.x%.
- Wafer Fab Manager insisted on Solidus system in the FAB as a quality gate.
- Our final package yield are so good now that we were able to find a .5% ASIC issue.
- Design Engineer: The data from the Solidus test system is the only data I have ever seen match my gyro simulations.
- After using the Solidus testers for more than a year we have decided to send all our MEMS product through the test systems. The systems improve our quality and we find more product defects and it helps keeping our processes in control.
- The wafer level testing with the solidus systems was key in fixing our gyro designs before product launch.
- Wafer sorting our MEMS devices was key to achieving our goal no physical stimulus at final package test.

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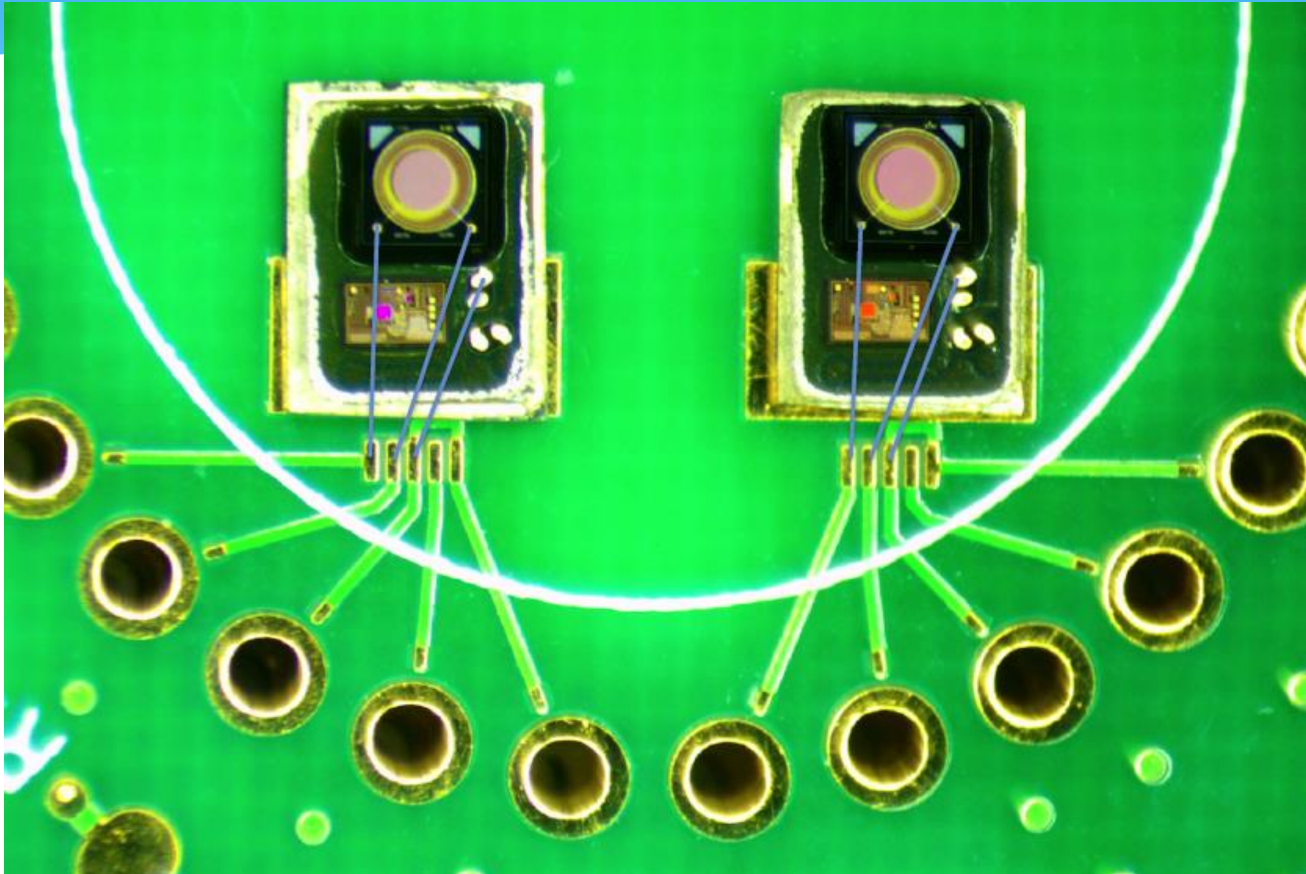

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STI3000 Production Test Systems

Thank You