BiTS 2007 Session 1

ARCHIVE 2007

DESIGNING FOR SOCKET ELECTRICAL INTEGRITY

"Determining Inductance In Contactors"

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Everett Charles Technologies STG

"Evaluation of a New Low Inductance Socket Technology - For High Speed Memory Device Testing"

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"Socket Life Cycle RF Testing"

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Determining Inductance in Contactors

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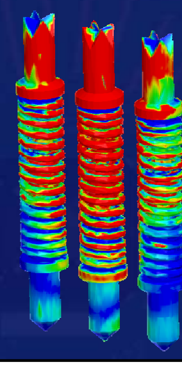
2007 BiTS Workshop

Introduction

- Inductance
  - Critical to contactor performance
  - Often interpreted incorrectly.
- Industry specs
  - Good for relative comparisons between probes
  - Not helpful when modeling and determining inductance through contactor
- Must increase our understanding to improve our models and better predict performance

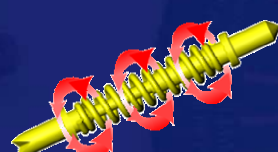
The Problem

- Two different definitions throughout industry
- Defined different for signal integrity vs. power delivery
- Often-used Definitions:
  - Signal Integrity (Controlled Impedance):
    - Function of pitch, ground location(s) w.r.t. signal
  - Power Delivery (Low Inductance):
    - Function of number of ground probes regardless of location



The Problem

- Loop inductance does not change depending on the type of signal passing through the network
- Therefore, these two inductance definitions cannot both be completely accurate.
- Must develop an understanding that doesn't break down, regardless of application
- Must be consistent with electromagnetic theory



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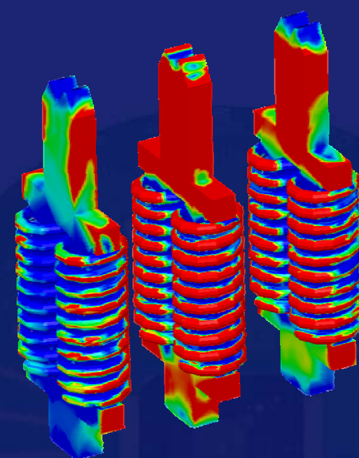
Agenda

- Basic principles of inductance
- Comparison between an inductor and a probe
- An accurate understanding of inductance
- Examples using EM simulation



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Principles of Inductance

- Inductance is the quantity of magnetic field lines per amp of current
- Magnetic field lines encircle all current-carrying conductors
- Current only flows in a loop. Likewise, inductance can only be measured in a loop
- Self-inductance and mutual-inductance are strictly mathematical concepts that cannot be explicitly measured.

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Principles of Inductance

- Equation for loop inductance:

  $$L_{LOOP} = L_{SIG} + L_{RTN} - 2 \times L_{MUTUAL}$$

- L_{SIG}, L_{RTN} : Self-Inductance of signal path, return path
- L_{MUTUAL}: Mutual Inductance between signal path and return path
- Loop inductance, L_{LOOP} is the only value that can actually be measured
- Self-inductance or mutual-inductance alone provides little or no value
- Loop inductance is primary concern

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Inductance in Contactors

- Inductance in contactors is:
  - Defined in a loop
    - Signal-Ground loop for Signals
    - Power-Ground loop for Power Delivery
      - Power pins are the signal path for power delivery nets
  - A function of pitch
  - A function of ground proximity and number of adjacent ground pins
    - The quantity and positioning of ground probes is best evaluated through 3D simulation
    - Loop inductance can be optimized for the application and cost trade-offs

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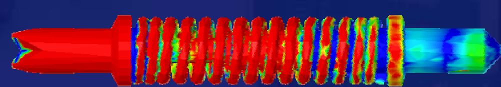
Inductance in Contactors

- Lower Inductance ≠ Higher Bandwidth
  - Lower inductance does not necessarily yield higher bandwidth
  - Increased bandwidth calls for controlled impedance
    - Not as concerned with inductance value
    - Concern is ratio of inductance to capacitance
- Power delivery focuses on minimizing inductance



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Probe-Inductor Comparison

- Reason for Comparison
  - For Power Delivery, many engineers assume that a probe acts as an inductor
  - Using this assumption, circuit theory is applied to derive the contactor inductance as being equal to the inductance spec divided by the number of ground probes
  - Probes cannot be accurately modeled as inductors
  - To determine inductance through contactor, must consider all source probes and ground probes

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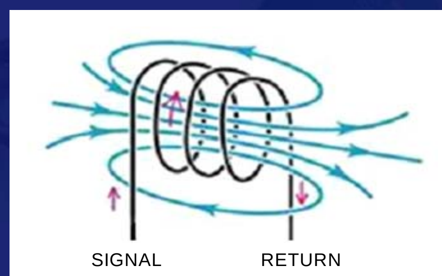
Wire-Wound Inductors

- Majority of magnetic fields are contained inside windings
- Inductance is a function of number of turns, size of loop, and thickness of conductor
- Inductance value is determined by loop inductance from input lead (signal) to output lead (return)



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Inductance in Contactors

- Current does not flow in helical direction
- Size of loop is defined by both signal and return paths
  - Individual probe does not create loop
- Increasing number of parallel probes in path will decrease inductance
- However, must understand how currents travel to understand which probes will impact inductance
  - All signals and currents will travel in the path of least impedance

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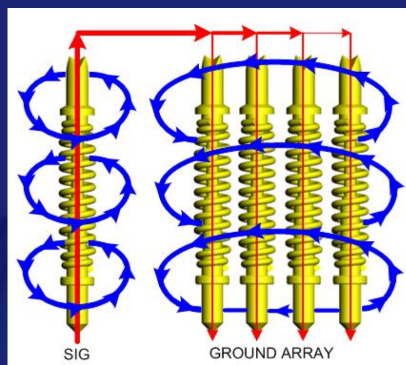
DC Currents

- At DC, impedance is dominated by resistance
- Resistance of each probe approximately equal, so current will travel equally through each probe



DC Current Flow

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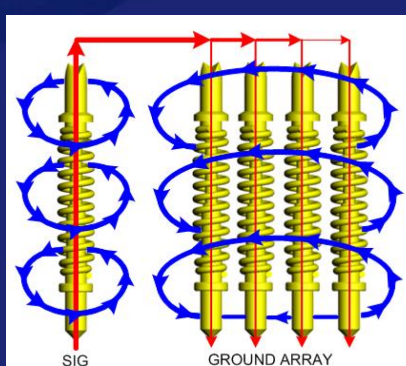
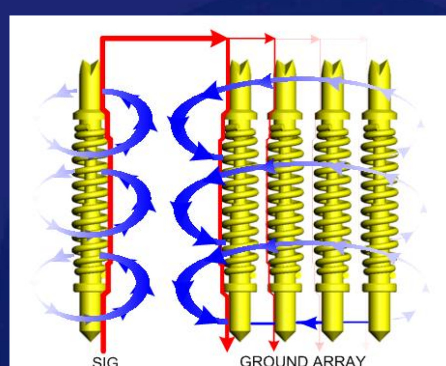
RF Currents

- At RF, impedance is dominated by inductance
- Same-direction currents will repel to decrease self-inductance



DC Current Flow



RF Current Flow

Note: For a more thorough explanation, see "Signal Integrity - Simplified", Eric Bogatin, 2004

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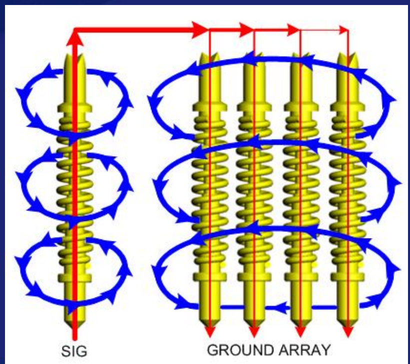
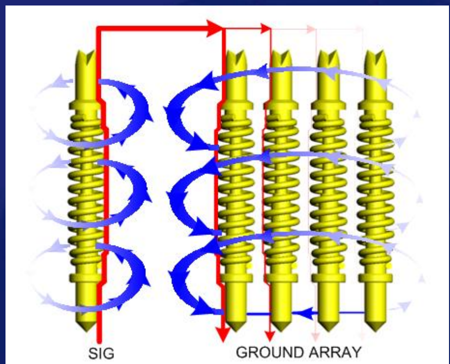
RF Currents

- Opposite-direction (source and return) currents will attract to each other to decrease mutual-inductance



DC Current Flow



RF Current Flow

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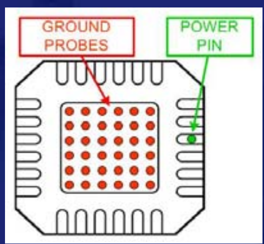
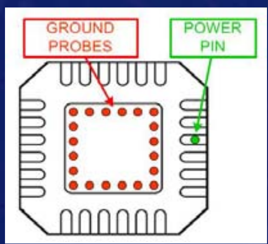
RF Current - MLF/QFN

- Return path will be dictated by path of least impedance
- Ground probe(s) physical spacing with respect to source will have a large effect on inductance
- Excessive ground probes will provide little or no benefit to lower loop inductance while adding cost
  - They may benefit for other reasons such as thermal or contact resistance





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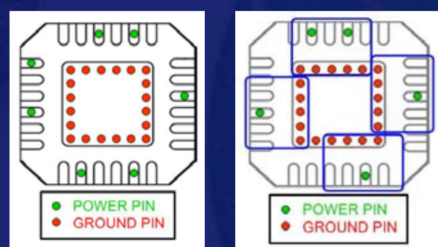
Modeling Inductance

- Full device too large for 3D Solver
- Must partition into manageable parts
- Make sure to include all probes that will effect results
- Simulate inductance of each part individually
- Equivalent inductance of contactor is determined by parallel combination of each power/ground loop inductance



Note: See also "Contactor Characterization of RF Test/Burn In", Ling Li Ong and Tim Swettlen, BiTS 2006

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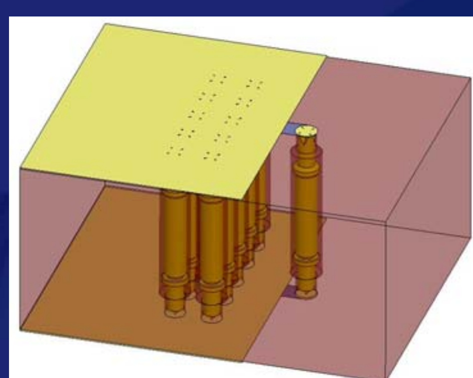
Modeling Example

- Simulate Partition of MLF/QFN device contactor
- One power pin (signal path)
- Probes in center array provide only ground reference



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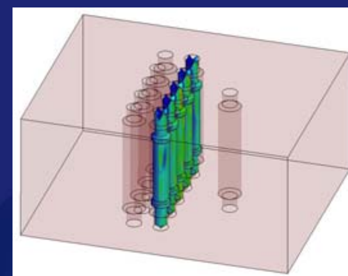
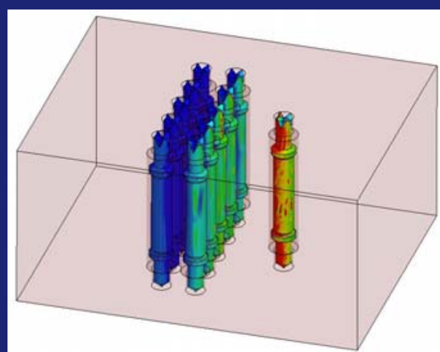
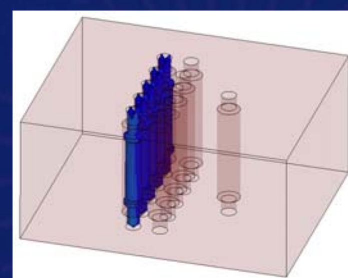
Plotting the RF Currents

- Same-direction currents repel Opposite-direction currents attract
- Most of the current travels on probes closest to signal path







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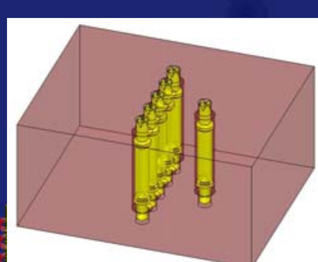
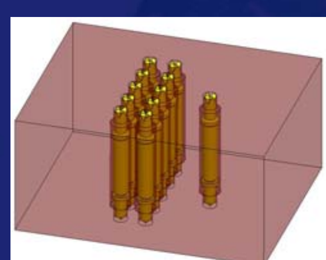
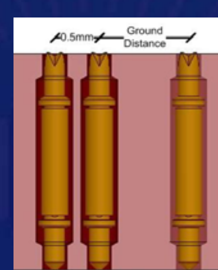
Modeling Results

- Inductance increases as pitch increases
- Probes closest to signal path have the greatest effect on inductance

Ground Distance	Inductance (nH)	
	1 Row Gnd Probes	2 Rows Gnd Probes
0.5mm	1.02	1.05
1mm	1.55	1.55
1.5mm	1.92	1.90
2mm	2.16	2.15
2.5mm	2.41	2.41







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Conclusion

- Inductance is a critical parameter that is often interpreted incorrectly.
- Loop inductance is best determined and optimized through 3D simulation.
  - For Signal Integrity, path impedance can be optimized for the application through modifying loop inductance to match impedance
- It is important to increase our understanding in order to improve our models and better predict performance
- Inductance must be defined in a way that is consistent for all applications

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Thanks!

Feedback is greatly appreciated

Feel free to contact me at Ryan.Satrom@ectinfo.com

Evaluation of a new low inductance socket technology

– for high speed memory device testing

2007 Burn-in and Test Socket Workshop
March 11 - 14, 2007

Joachim Moerbt
Advantest (Europe) GmbH

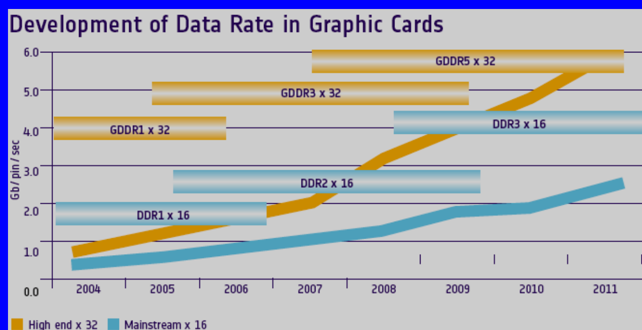
Outline

- Target of the new socket
- A new socket type
- Evaluation phases of the new socket
  - Electrical parameters
  - Mechanical reliability
  - Device under test
  - Yield evaluation
  - Handling method
- Conclusion

Target

Data Rate trends for memory devices

- DDR-II/III
- Graphic DRAM
- Data rates > 2Gbit/sec



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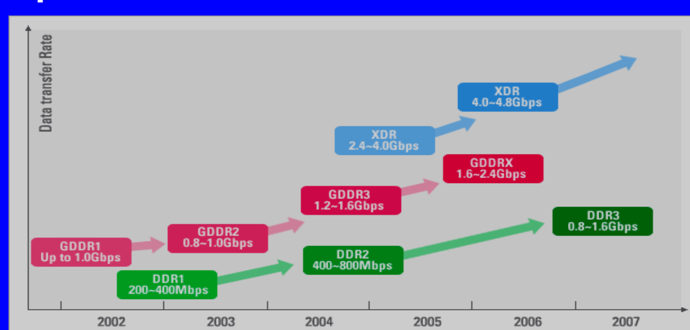
Target

- High speed memory devices
- GDRAM, DDR-III, X-DRAM
- 1GHz and beyond
- Pin pitch 0.75mm



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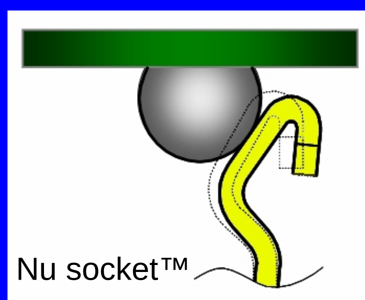
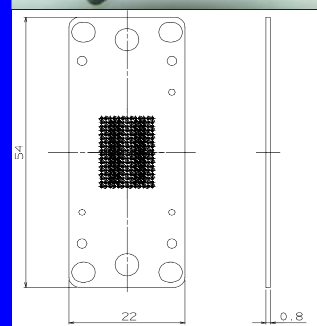
New socket type

- New concept
- No spring probe
- Ultra low profile
- Low inductance





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Evaluation Phases

I. Electrical parameters
   - Self inductance
   - Bandwidth
   - Contact resistance, force - travel
II. Mechanical reliability
   - Contact resistance versus contact cycles
   - Scratch mark
III. Device under test on new socket
IV. Yield evaluation under full production
V. Handling Method

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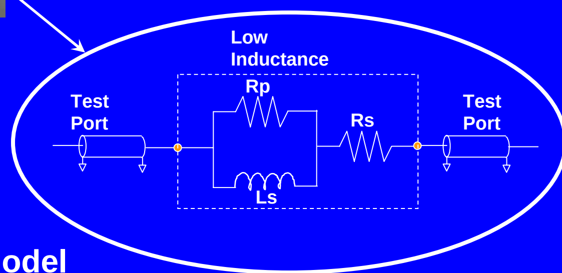
I. Electrical Parameters

- Self inductance

- RF Impedance/Material Analyzer: HP4291A（1MHz ~ 1.8GHz)
- Test Fixture: HP16301
- Single probe measured



Equivalent Circuit Model

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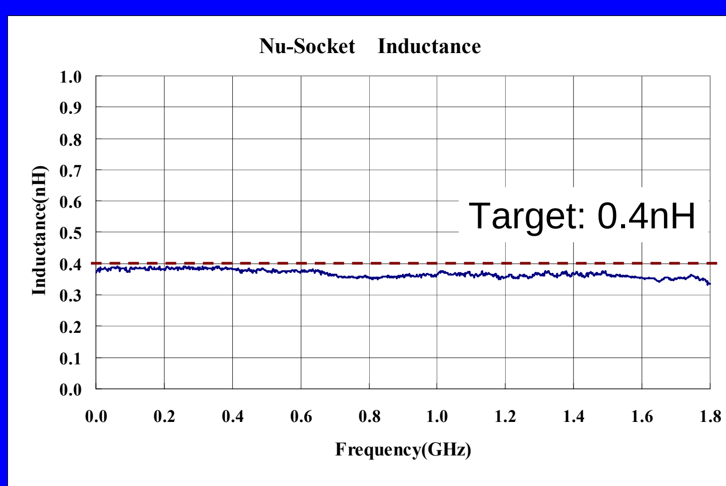
I. Electrical Parameters



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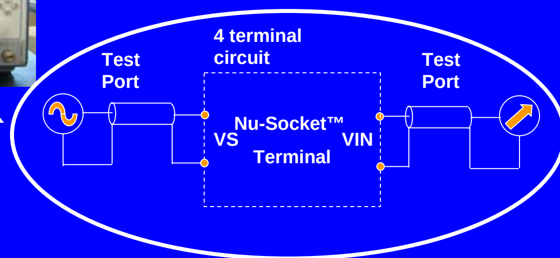
I. Electrical Parameters

- Bandwidth

- Vector Network Analyzer: Rohde & Schwarz ZVM (10MHz – 20GHz)
- Single probe measured



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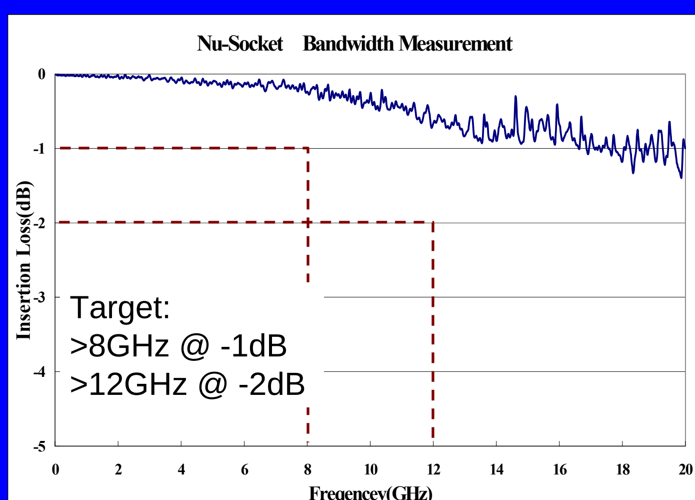
I. Electrical Parameters



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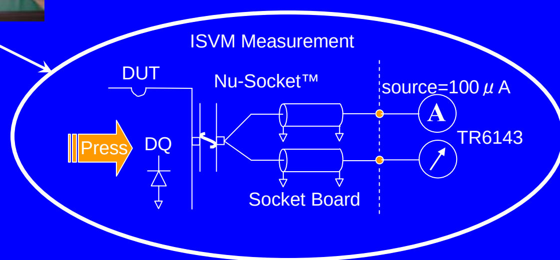
I. Electrical Parameters

- Contact resistance, force - travel
  - Force Analyzer: AIKOH
  - DC Voltage Current Source/ Monitor: TR6143
  - Single probe measured



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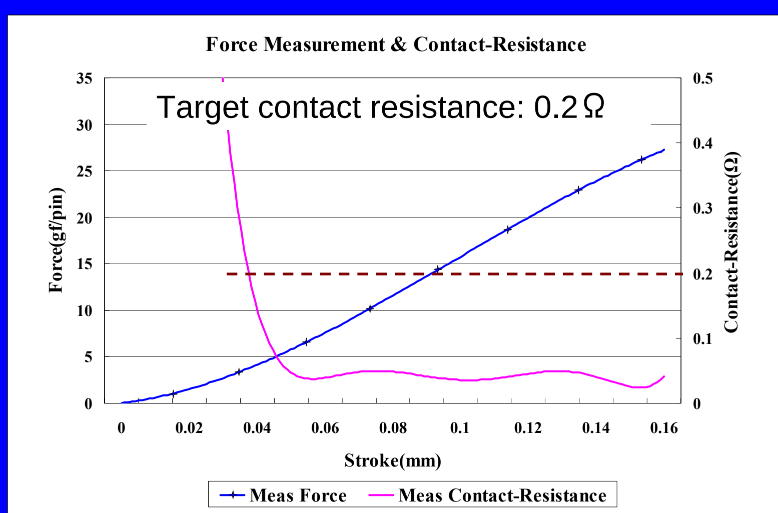
I. Electrical Parameters



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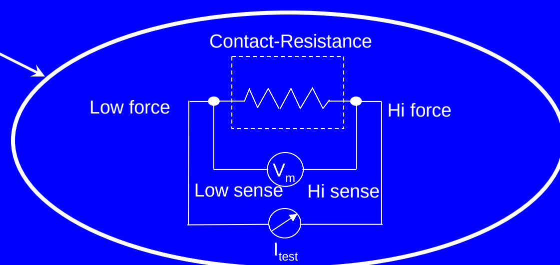
II. Mechanical Reliability

- Mechanical reliability

- Data Acquisition/Switch Unit: HP34970A
- Dynamic Test Handler: M6542AD
- Dummy Device : Au ball
- Measured 60 probes



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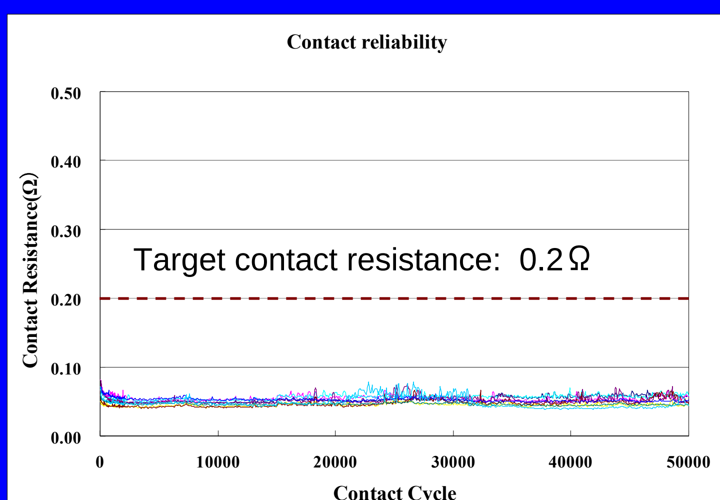
II. Mechanical Reliability



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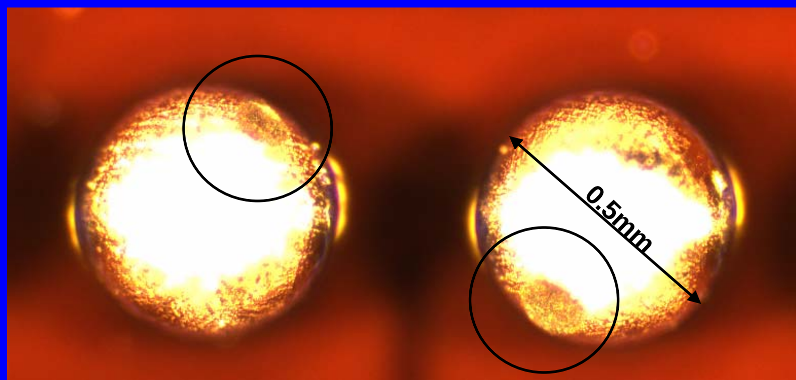
II. Mechanical Reliability

- Scratch Mark of the Nu-Socket™

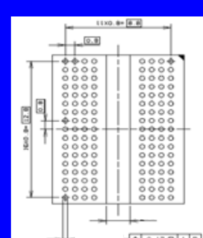


Lead-free solder alloy, single contact

III. Device under test

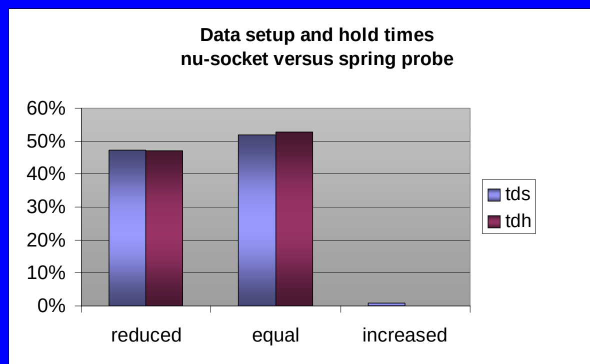
- Device under test on new socket

- Test System: T5501
- 4 Device GDDR3, 136 pins
- Manual operation
- Comparable measurement with 1.5nH spring probe socket



III. Device under test

- Measurement result
  - 32 data signals, cycled over the DUT position
  - New socket: reduced setup and hold times



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IV. Yield evaluation

- Yield benefits under full production

- Test System: T5501
- More than 3000 devices productive GDDR3
- Parallelism: 8 DUT
- Handler operation: M6771

- Comparable measurement with 1.5nH spring probe socket
- Verification of speed sorting

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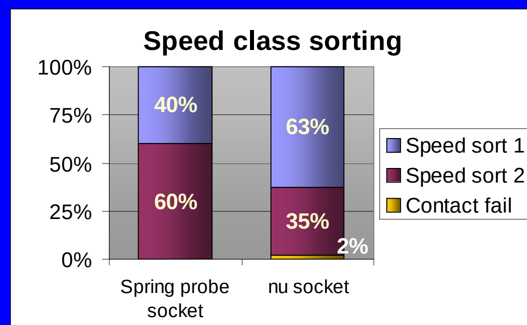
IV. Yield evaluation

- Results of comparable measurement
  - Higher speed class sorting increased
  - Max. frequency for test increased
  - Setup and hold times comparable
  - Scratch marks acceptable
  - Contact reliability to be improved



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V. Handling method

- Changing the concept for handling
  - Ultra low profile:
    Contact height reduced
  - Reliable seating required for carrying:
    New carrier shape
  - Compatibility for spring probe socket required

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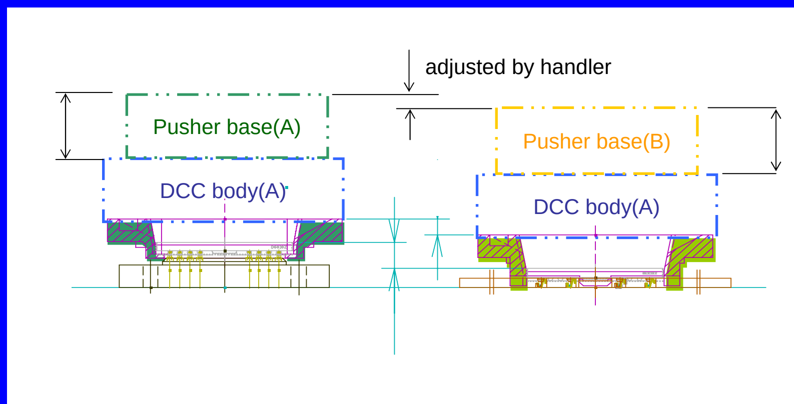
V. Handling method

- **Contact of the Nu socket™ versus spring probe socket**



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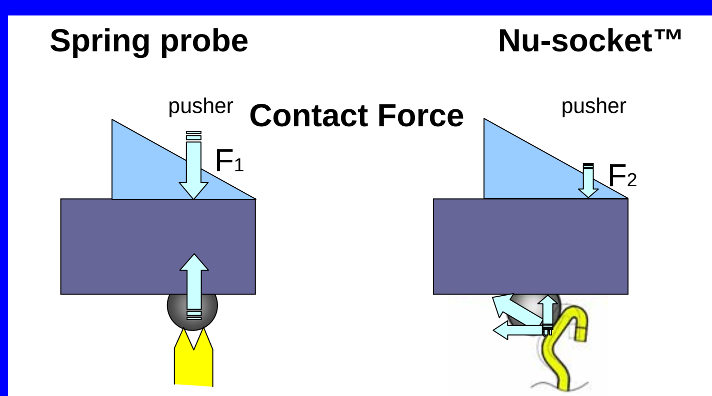
V. Handling method

- **Force distribution**



F1 [spring probe] > F2 [Nu-socket™]

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Conclusion

- Very good electrical parameters
- Long term reliability acceptable for production – to be improved after field experiences
- Long term production evaluation ongoing
- Contact reliability improved
- Reliable handling solution available
- Yield increase and improved speed sorting can be expected

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Socket Life Cycle RF Testing

2007 Burn-in and Test Socket Workshop

March 12 - 15, 2006

Gert Hohenwarter
GateWave Northern, Inc.
www.gatewave.com

A challenging test project was initiated by Analog Devices…..

- Determine variations in RF performance throughout a test regimen of 1 million cycles
- Test a significant number of sockets
- Sockets provided by manufacturers
- Data provided to manufacturers, then to AD

1/2007 BiTS 2007 Socket Life Cycling Test 2

Test Protocol

- *Perform initial characterization*
- *Perform 4 successive measurements* (DUT probe engages/disengages)
- *Run prescribed cycle number* (exchange of surrogates as needed)
- *Perform next set of 4 measurements*
- *Continue sequences until 1M cycles is reached*

Test #	Cycle #
1	0
2	0
3	0
4	0
5	8192
6	8192
7	8192
8	8192
9	65536
10	65536
11	65536
12	65536
13	262144
14	262144
15	262144
16	262144
17	1048576
18	1048576
19	1048576
20	1048576

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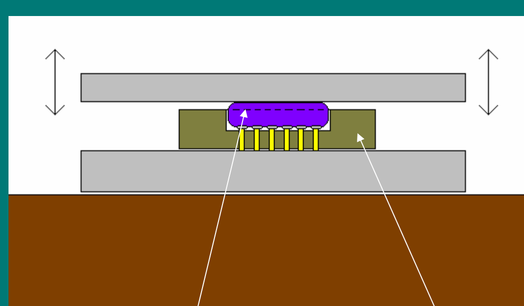
Device Actuation



Surrogate DUT is inserted into socket and actuated by the parallel moving top plate

1/2007 BiTS 2007 Socket Life Cycling Test 4

Parallel Plate Cyclers

The moving plate is inside the frame

1/2007 BiTS 2007 Socket Life Cycling Test 5

Test Setup Requirements

- Total number of RF tests expected >500
- Different types of sockets
- Robust
- Fast
- Repeatable
- Low cost / applicable to more than 1 DUT

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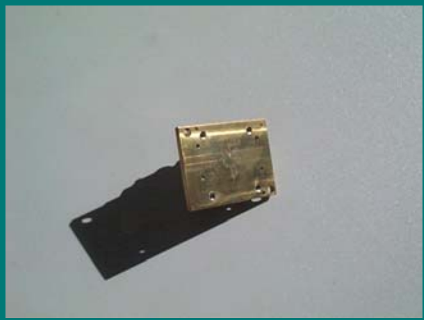
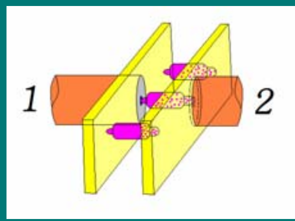
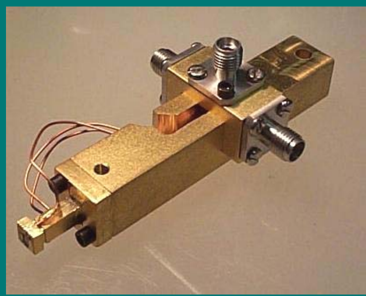
Test Setup for RF Measurements



Base plate





DUT plate with RF connections

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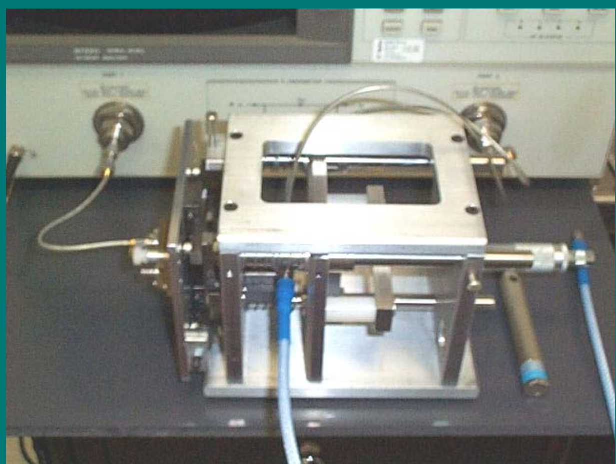
Test Setup for RF Measurements



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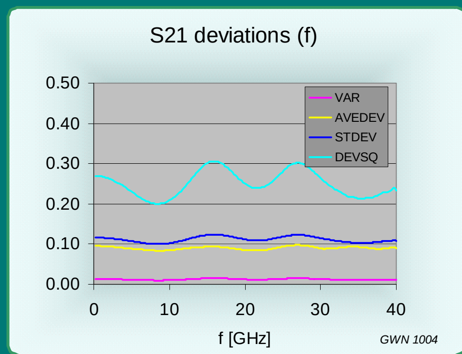
Repeatability



Data for 20 successive setup engagements/disengagements with a very thin conductive elastomer inserted

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Evaluation

- S-parameters
  - S11, S21, S31/41
- Capacitance
- Inductance
- Transmission line parameters
- Crosstalk

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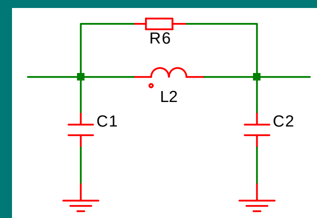
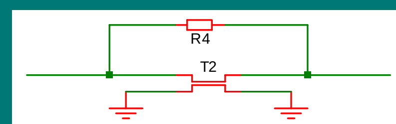
Models

- Lumped element model:
  {valid to ~f = 1/[7*√(L*C)]}



- Transmission line model:
  {no frequency limits}



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Test Result Presentation

Color sequence

It was not known a priori what types of variations were to be expected.

Evaluation therefore was set up to include several different statistical functions and data presentations.

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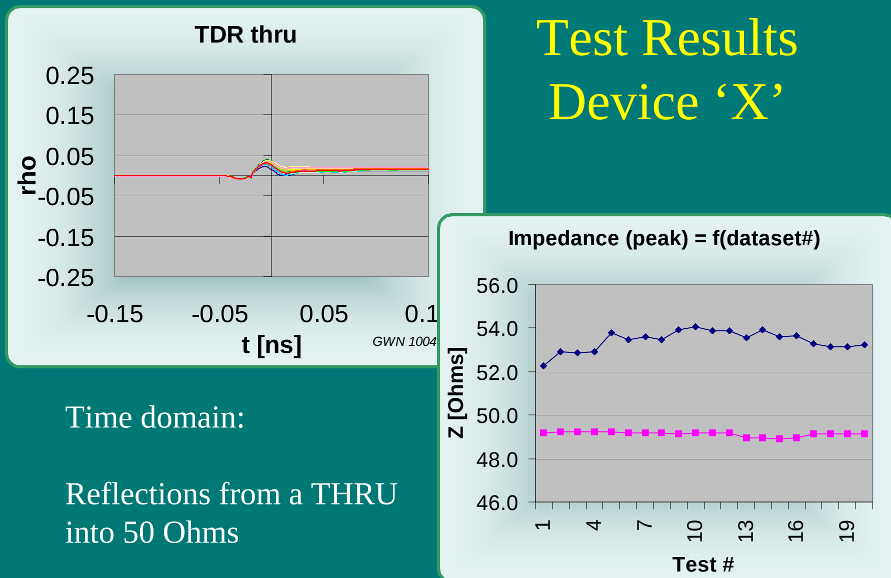
Test Results Device 'X'



Time domain:

Reflections from a THRU into 50 Ohms

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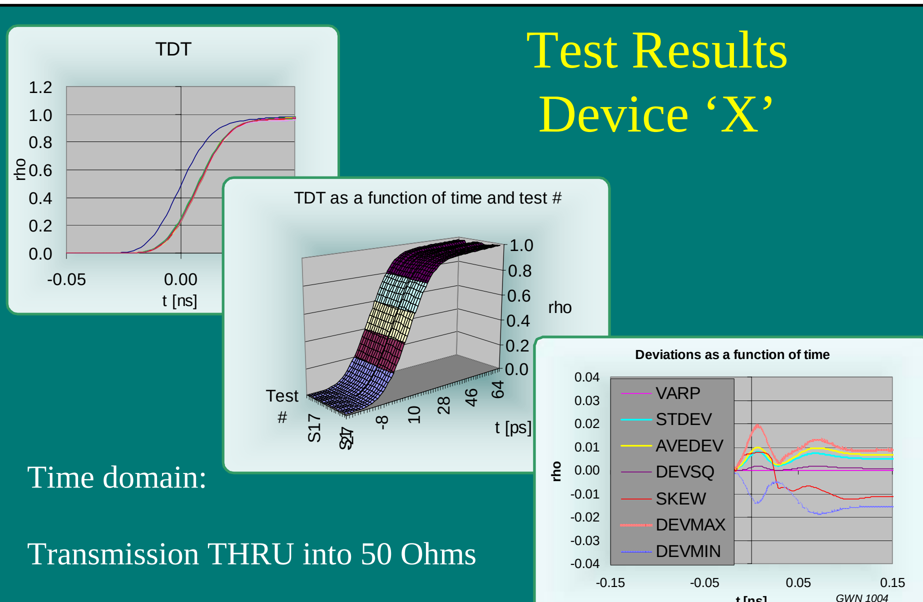
Test Results Device 'X'



Time domain:

Transmission THRU into 50 Ohms

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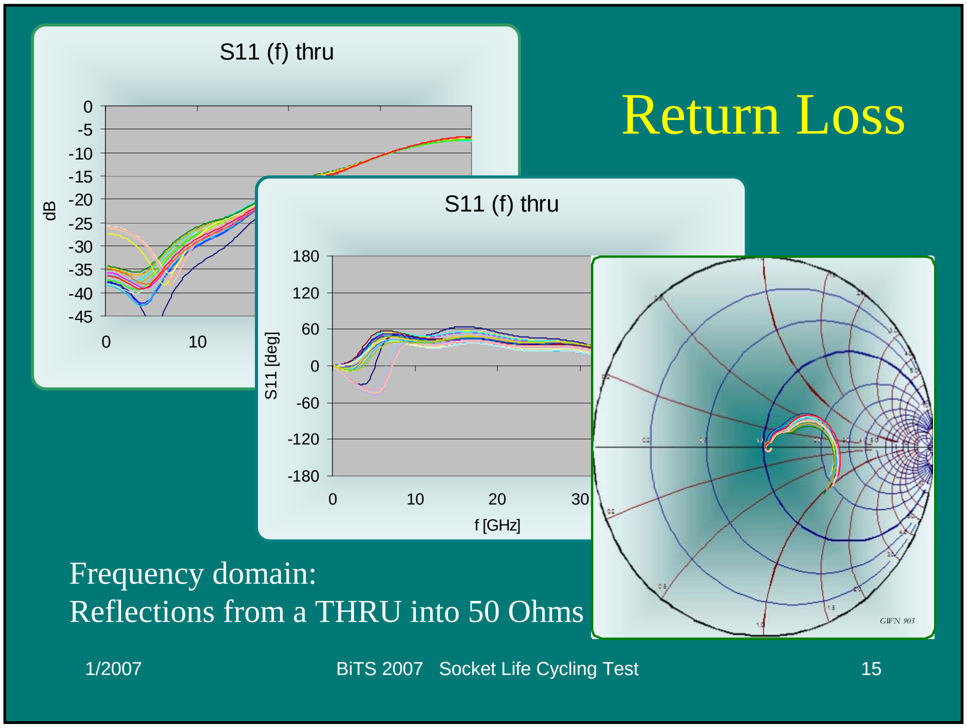
Return Loss
S11 (f) thru
dB
S11 (f) thru
S11 [deg]
f [GHz]
Frequency domain:
Reflections from a THRU into 50 Ohms
GWN 903
1/2007
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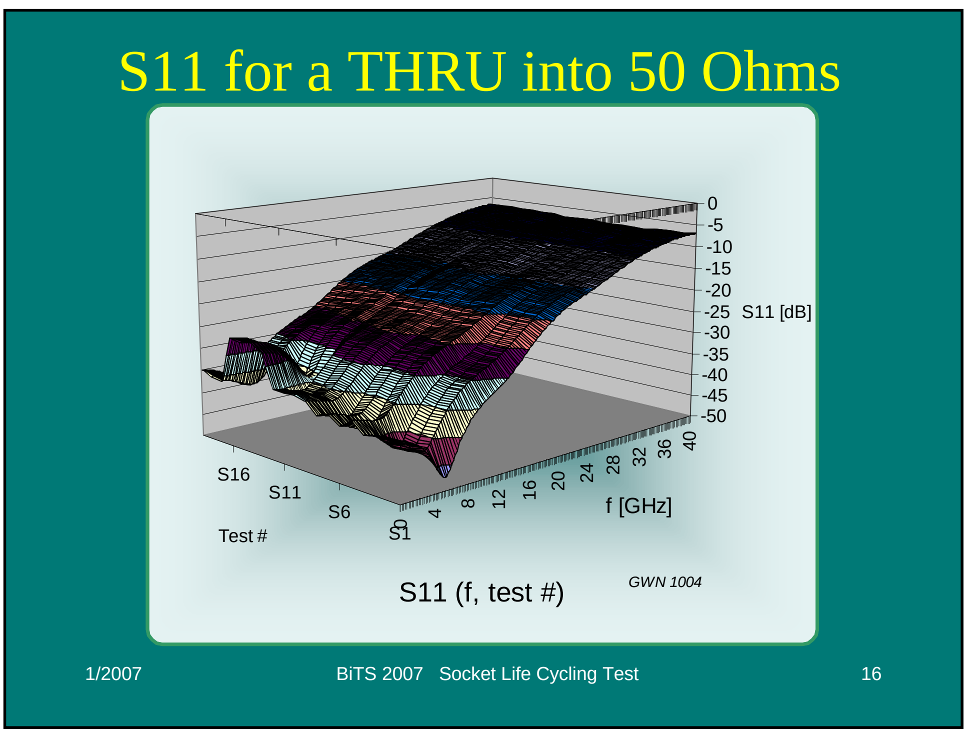
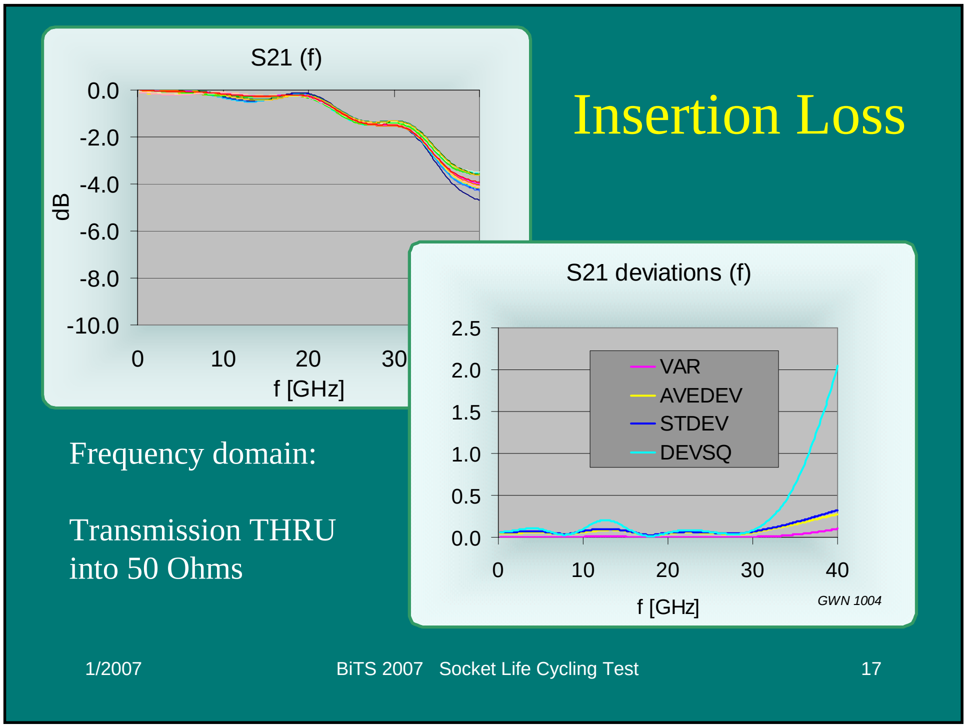

S11 for a THRU into 50 Ohms
S11 [dB]
f [GHz]
Test #
S16
S11
S6
S1
S11 (f, test #)
GWN 1004
1/2007
BiTS 2007 Socket Life Cycling Test
16


Insertion Loss
S21 (f)
dB
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
0
10
20
30
f [GHz]
S21 deviations (f)
2.5
2.0
1.5
1.0
0.5
0.0
VAR
AVEDEV
STDEV
DEVSQ
0
10
20
30
40
f [GHz]
GWN 1004
Frequency domain:
Transmission THRU into 50 Ohms
1/2007
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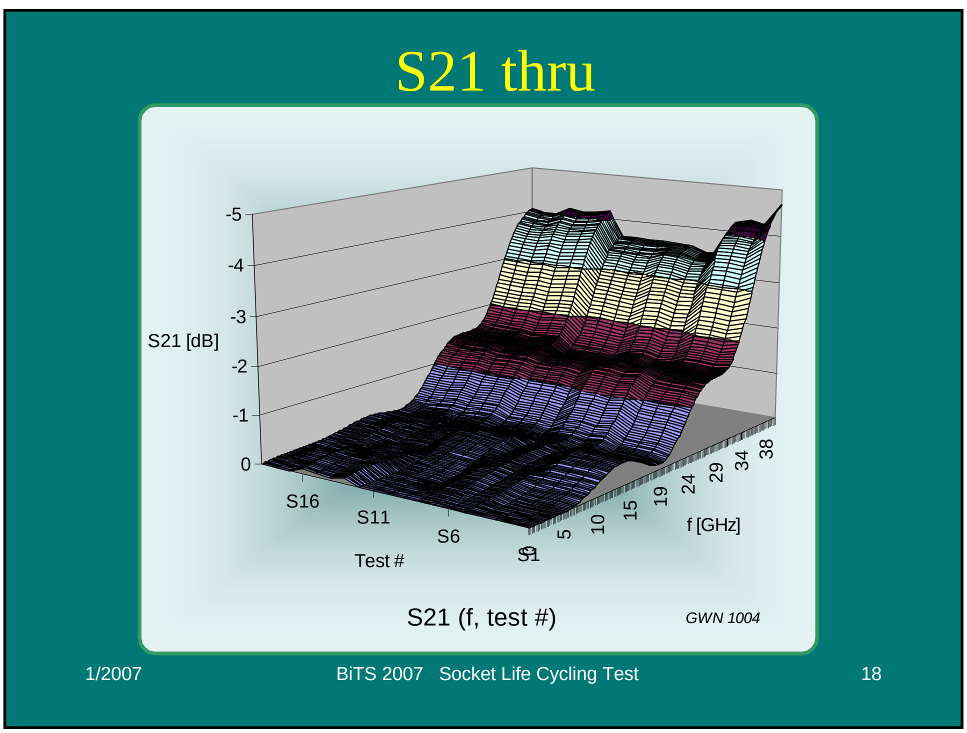
S21 thru
S21 [dB]
-5
-4
-3
-2
-1
0
S16
S11
S6
S1
Test #
5
10
15
19
24
29
34
38
f [GHz]
S21 (f, test #)
GWN 1004
1/2007
BiTS 2007 Socket Life Cycling Test
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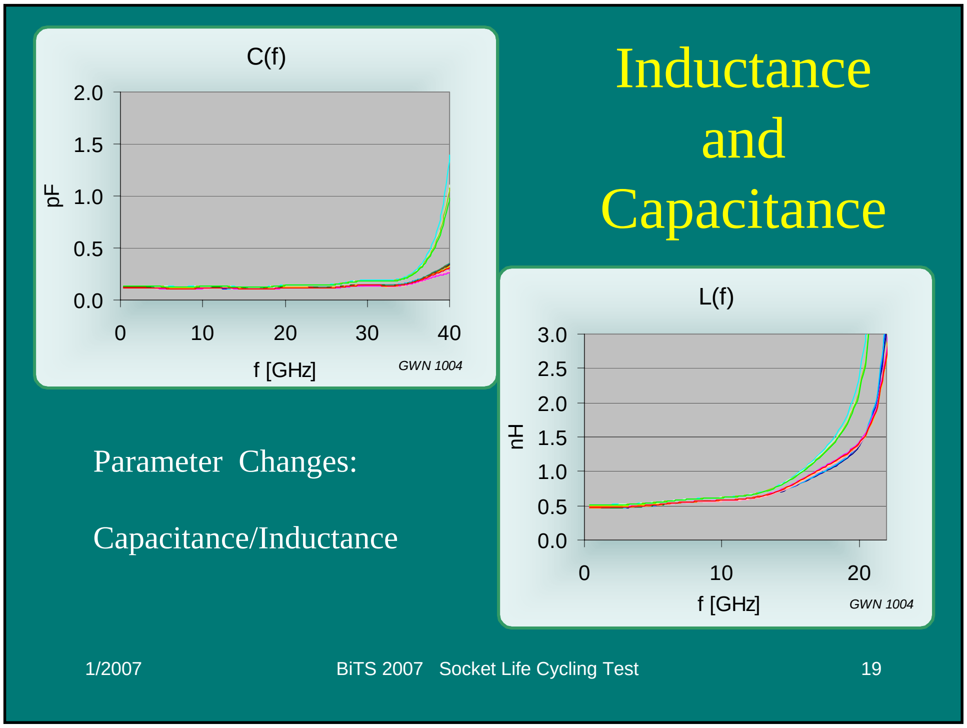
Inductance and Capacitance
C(f)
pF
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
f [GHz]
GWN 1004
L(f)
nH
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
f [GHz]
GWN 1004
Parameter Changes:
Capacitance/Inductance
1/2007
BiTS 2007 Socket Life Cycling Test
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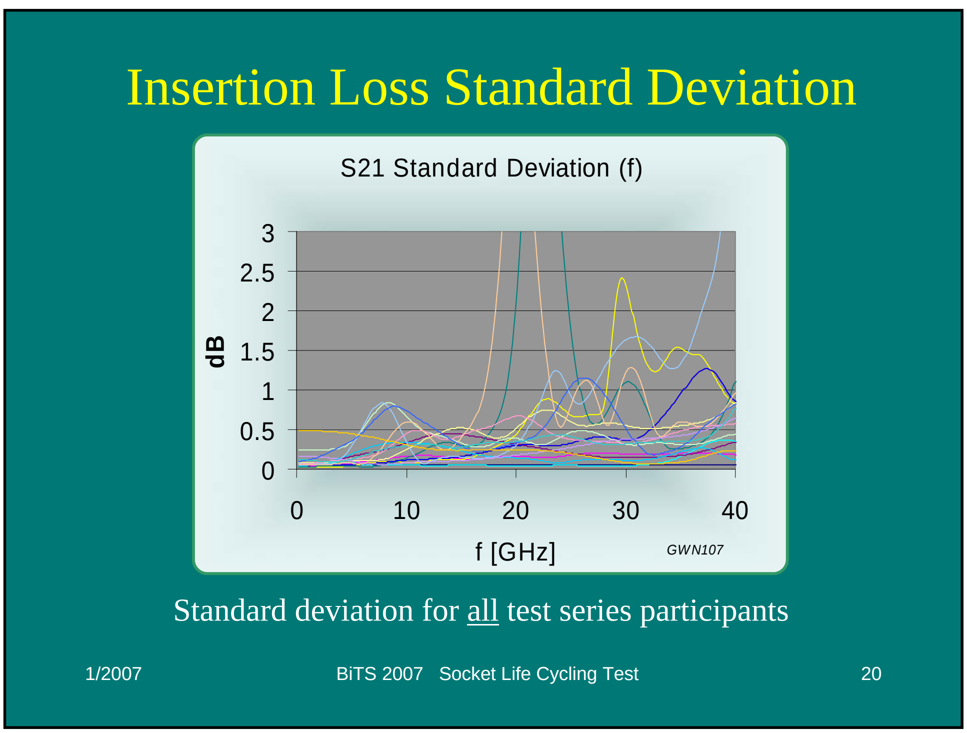
Insertion Loss Standard Deviation
S21 Standard Deviation (f)
dB
3
2.5
2
1.5
1
0.5
0
0
10
20
30
40
f [GHz]
GWN107
Standard deviation for all test series participants
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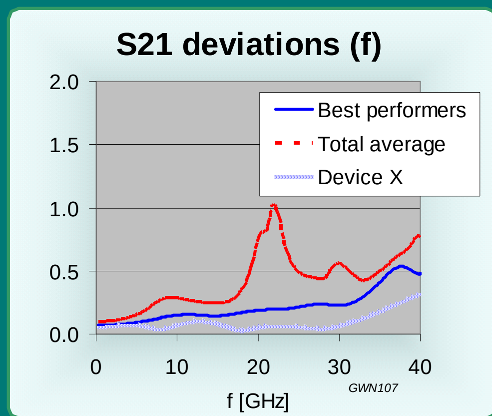
Insertion Loss Standard Deviation (averages, sample 'Device X' plus all participants)



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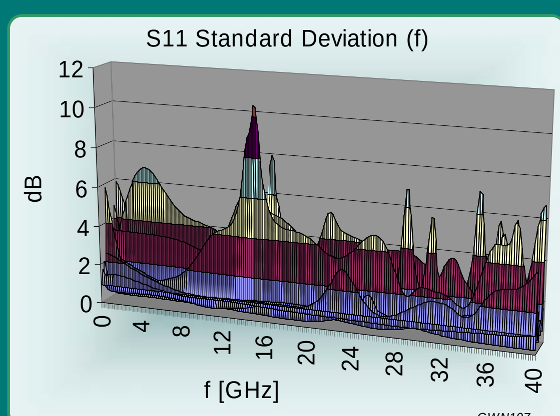
Return Loss Standard Deviation (averages, all participants)



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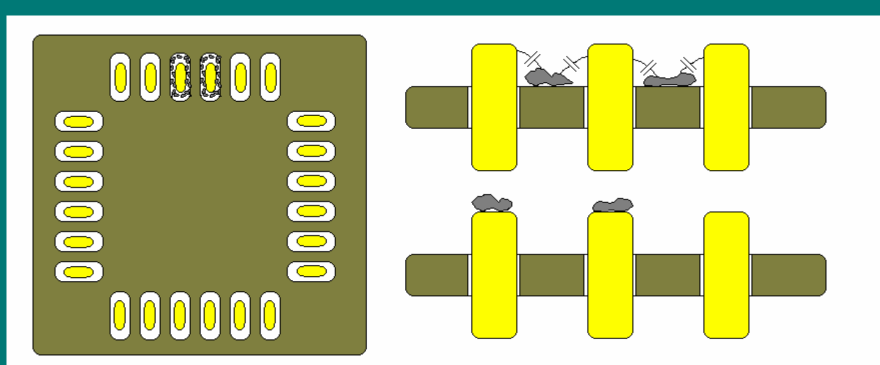
Example Causes for Performance Changes

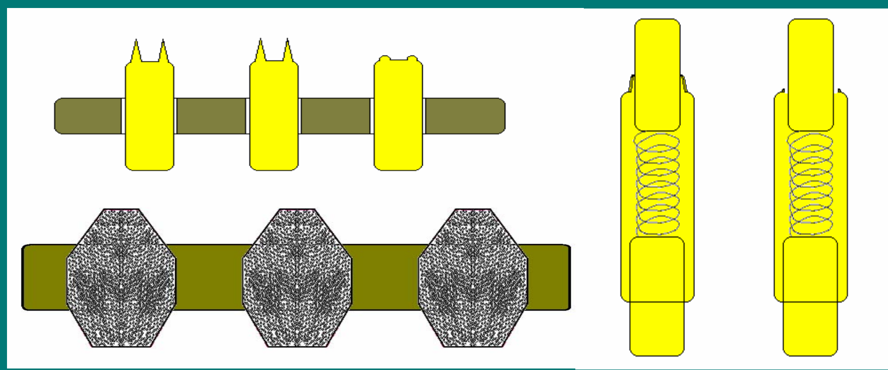
- RF characteristics are affected by
  - particle buildup
  - contactor wear
  - contact surface wear
  - distortion/damage

Particle Buildup



Abraded metal particles collect on surfaces and in gaps
Effect: Change of resistance capacitance, inductance, leakage, shorts

Contactor Wear



Wear of outer and inner contact surfaces

Effect: Change of resistance and inductance.

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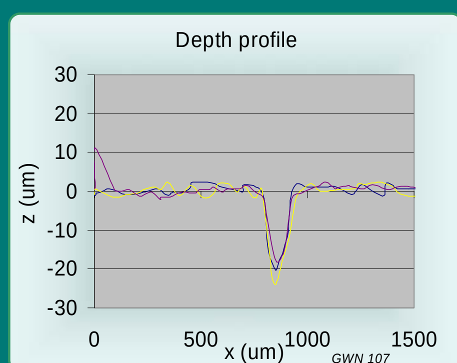
Contact Surface Wear



Wear of contact surfaces (PCB)

Effect: Change of resistance.

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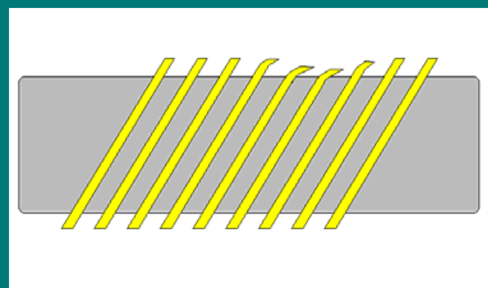
Distortion



Effect: Change of resistance, capacitance and inductance.

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Conclusion

- A test environment for cycling tests was established
- A significant number of test sockets was evaluated
- Performance changes were highlighted via data presentation
- Changes unique to RF testing were identified
- Tests are capable of pointing out weaknesses in the socket and contactor design

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Acknowledgements

Thank you to all customers who made this possible

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