IPC/IMEC/ESA Microvia TV HATS^2 Test Results

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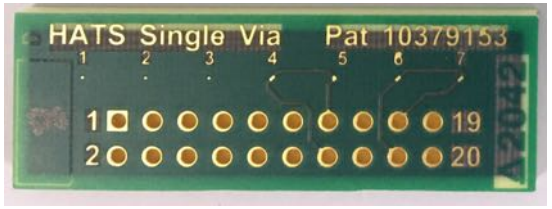
Introduction to HATS^2 Testing Technology

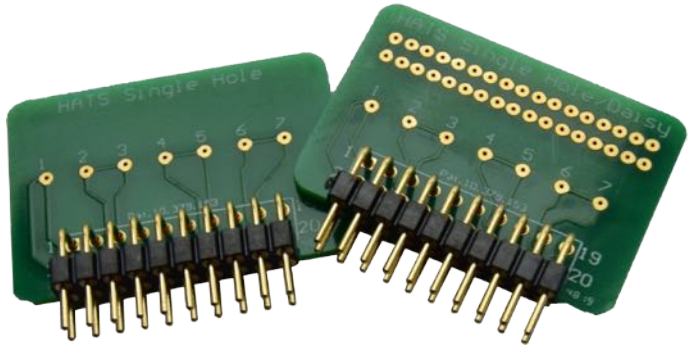
- The HATS^{2}™ Tester Can Perform Reflow Simulation & Thermal Shock/Cycling
  - Upgraded Temperature and Measurement Capability from Original HATS System (160°C → 260°C)
  - IPC-TM-650 Methods 2.6.27B & 2.6.7.2C
  - Replicate Temperature Conditions of Current Induced Heating Methodologies
  - Replicate any Convection Reflow Oven Surface Temperature Profile
  - Meet Current Automotive Reliability and Robustness Requirements
- The HATS^{2}™ Tester Uses High-Speed "Air" as the Heat Transfer (Fluid) Mechanism
  - Temperature Range from -55°C to 260°C for Reflow Simulation & Thermal Cycling/Shock
  - Thermal Capacity to Transfer Test Coupon Core Temperature in 3-6 minutes (5-10 Cycles per hour)
  - 1000-Cycle Robustness or Reliability Testing Performed Within 1 Week
- Test Coupon Nets are Measured Using a 4-Wire System
  - High Current (up to 1A) allows Accurate Measurements to Micro-ohms
  - Test up to 72 (2-net) IPC-2221B "D" Coupons, 36 (4-net) Traditional HATS™ Coupons or 36 (7-net) HATS^{2}™ Single Via Coupons*
  - Surface Temperature Measured Directly with Thermocouples

* U.S. Patent 10,379,153. German Patent 10 2019 006 553.0. Chinese Patent ZL 201922142627.1. Worldwide Patents Pending.

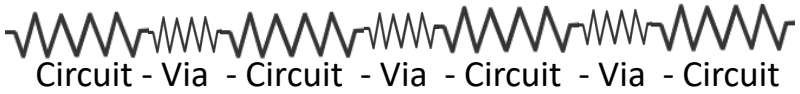
Introduction to HATS²™ Single Via Coupons*

- HATS²™ Single Via Coupon Uses Patented* Technology
  - Accurate, High Current, Micro-ohm Precision, 4-wire Resistance Measurement
  - 7 Single Vias and/or Daisy-chain Test Nets





- Why Single Vias Instead of Daisy Chains?
  - Daisy Chains can be Characterized as Resistors Connected in Series



  - 50-90% of the Daisy Chain Resistance Comes from the Circuits Connecting the Vias Together
  - A 50% Separation/Crack in a Single Via Only Increases Daisy Chain Resistance Change by ~1%
    - In a Single Via Test this Change is Measured Directly as a 50% Change
  - Daisy Chains detect the end of Via(s) Failure while Single Via Testing Detects the Beginning of Via Failure

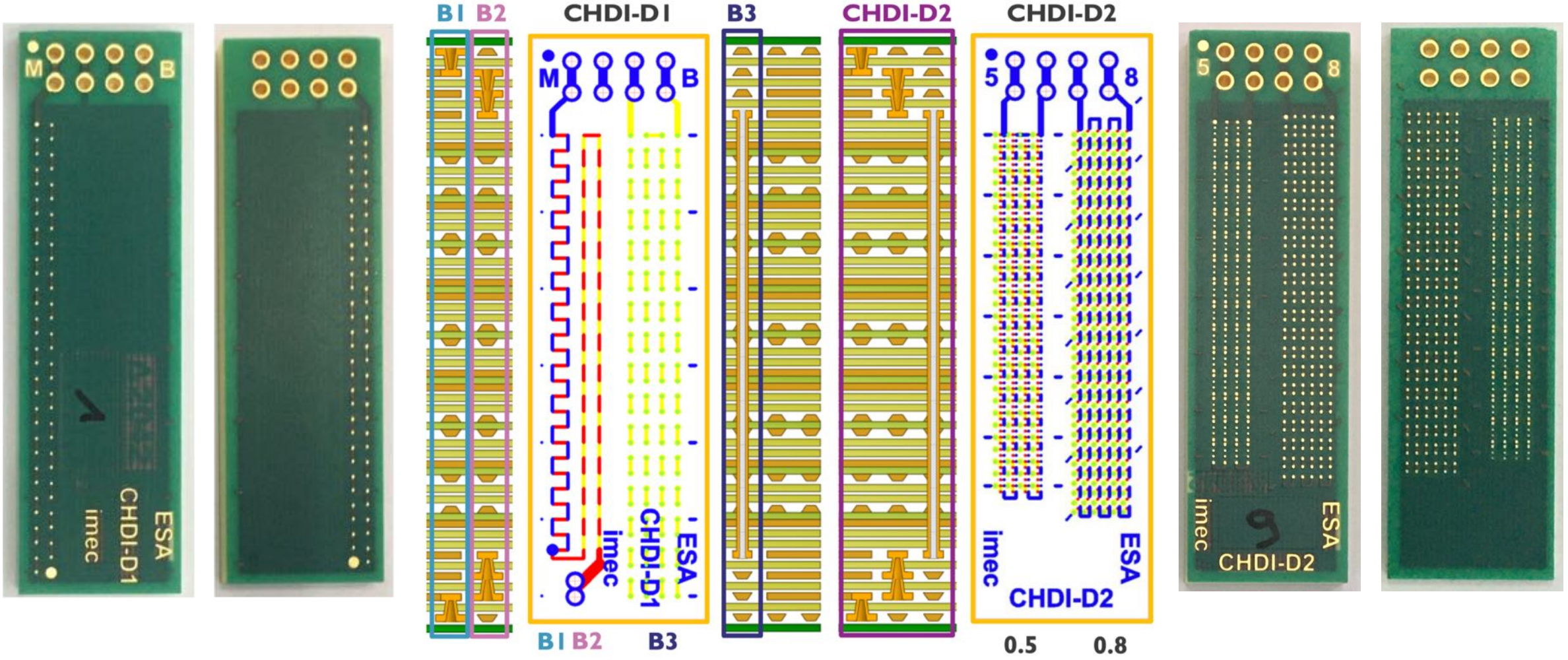
* U.S. Patent 10,379,153. German Patent 10 2019 006 553.0. Chinese Patent ZL 201922142627.1. Worldwide Patents Pending.

IPC/IMEC/ESA Microvia TV HATS^2 Test Program Goals

- Compare 6 Differing 3-Layer Stacked Microvia Structures to Each Other
  - Semi-Stacked Outside, Semi-Stacked Inside, Full Stacked, Full Staggered, Staggered Above Buried Via, Semi-Stacked Inside Above Buried Via Both on Top and Bottom of Test Coupon
  - Perform IPC-TM-650 Method 2.6.27B - 230°C 6x Cycles of Reflow Simulation
  - Perform Subsequent Thermal Cycle Reliability and Robustness Testing (20% Change in Net Resistance Calculated as "Failure")
- Compare Results of "Reliability" Test (10°C Below T_g) to "Robustness" Test (20°C Above T_g)
  - "Reliability" Testing: 1000x Cycles from -55°C to 160°C
  - "Robustness" Testing: 500x Preconditioning Cycles from 25°C to 150°C followed by 1000x Cycles from 25°C to 190°C
- Compare IPC-2221 "D" Style Daisy Chain Coupons to HATS^2 Single Via Test Structures
- Compare a 1-Second Data Capture Interval to a 7-Second Data Capture Interval During IPC-TM-650 method 2.6.27B 230°C Reflow Simulation Testing

IPC/IMEC/ESA Microvia TV Structures Tested in HATS^2 Chamber

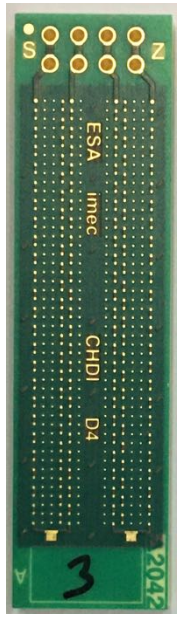
IPC "D" Coupon Structures D1 & D2

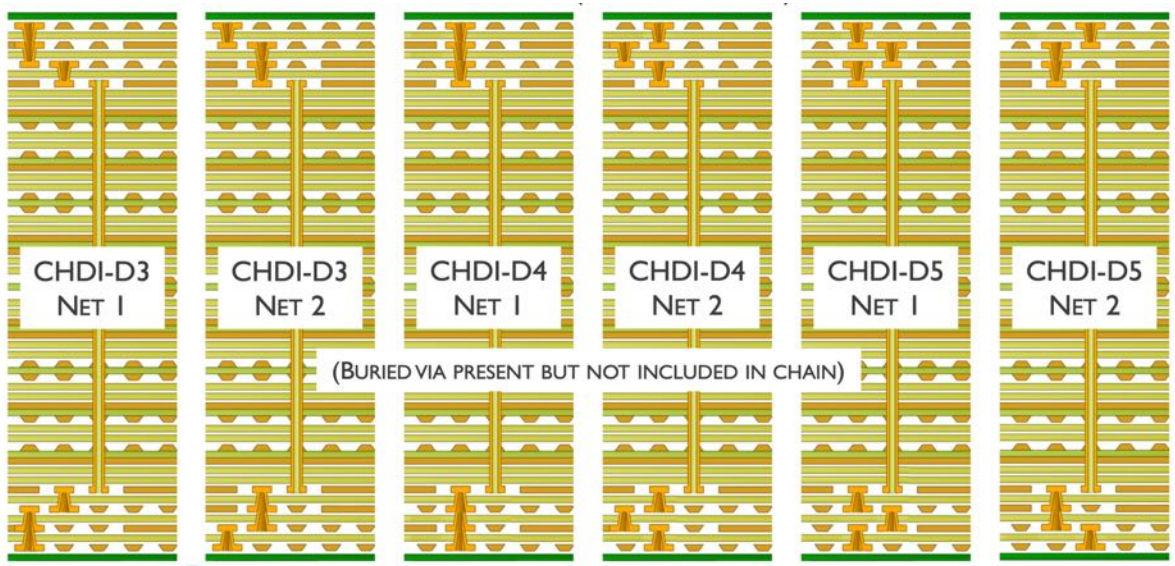


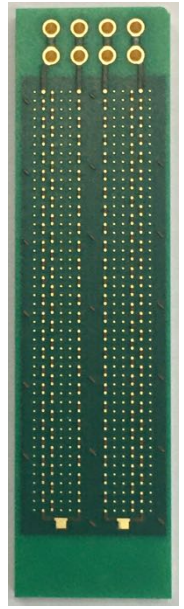
** images courtesy of imec

IPC/IMEC/ESA Microvia TV Structures Tested in HATS^2 Chamber

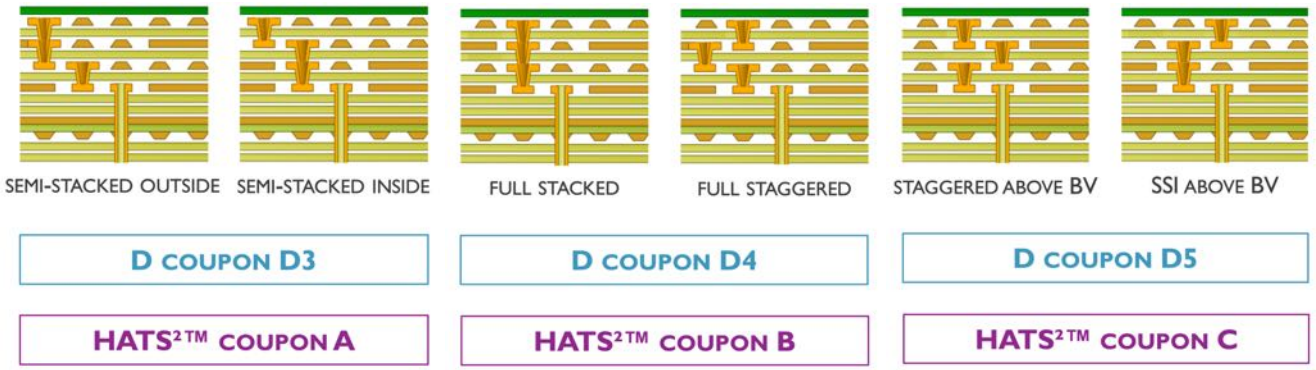
IPC "D" Coupon Structures D3, D4, D5 – Microvia Nets in Parallel on Either Side of Sample

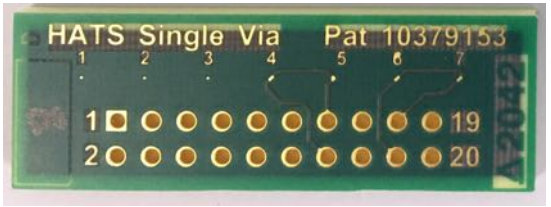






HATS^2 Single Via Coupons v.s. IPC "D" Coupons

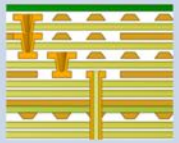
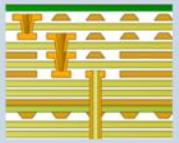
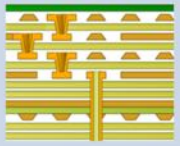
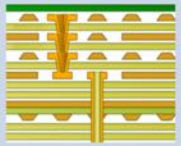
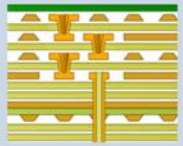
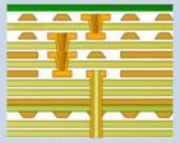


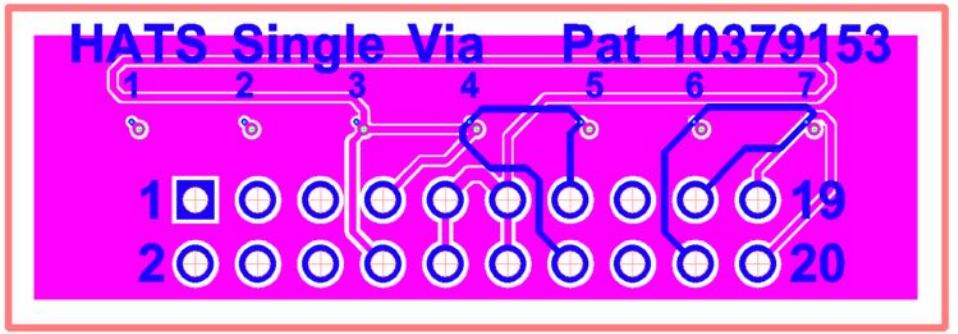


** images courtesy of imec

IPC/IMEC/ESA Microvia TV Structures Tested in HATS^2 Chamber

- HATS^2 Single Via Test Coupons* Contain 7 Test Nets that can be Single Vias or Daisy Chains
- HATS^2 Single Via Test Coupons Contain Circuitry that Allows Adjustments for Measurement and Temperature Drifts

HATS^2 COUPON A		HATS^2 COUPON B		HATS^2 COUPON C	
 SEMI-STACKED OUTSIDE	 SEMI-STACKED INSIDE	 FULL STAGGERED	 FULL STACKED	 STAGGERED ABOVE BV	 SSI ABOVE BV
	1. MVs bottom		1. MVs bottom		1. MVs bottom
2. MVs bottom		2. MVs bottom		2. MVs bottom	
3. Buried via		3. Buried via		3. Buried via	
	4. Microvias top		4. Microvias top		4. Microvias top
	5. MVs+BV+MVs		5. MVs+BV+MVs		5. MVs+BV+MVs
6. MVs+BV+MVs		6. MVs+BV+MVs		6. MVs+BV+MVs	
7. Microvias top		7. Microvias top		7. Microvias top	



Net 1 & 4 are the same structure on the Top and Bottom of the Test Coupon
Net 2 & 7 are the same structure on the Top and Bottom of Test Coupon
Nets 5 includes a connected top to bottom via structure (microvias top, buried vias microvias bottom)
Nets 6 includes a connected top to bottom via structure (microvias top, buried vias microvias bottom)

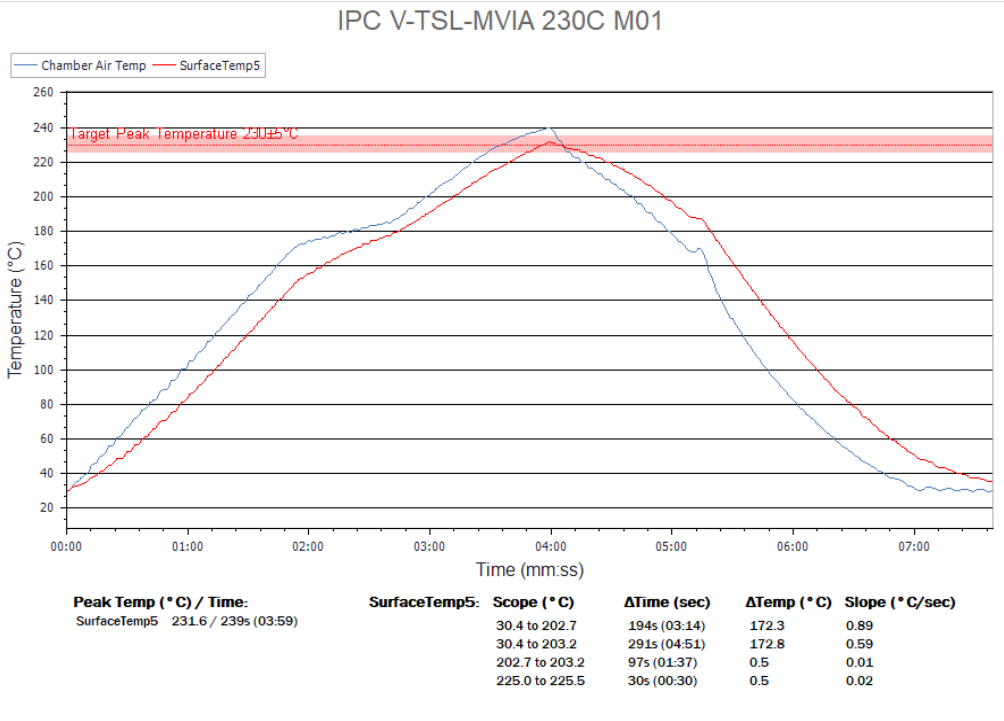
* U.S. Patent 10,379,153. German Patent 10 2019 006 553.0. Chinese Patent ZL 201922142627.1. Worldwide Patents Pending.
** images courtesy of imec

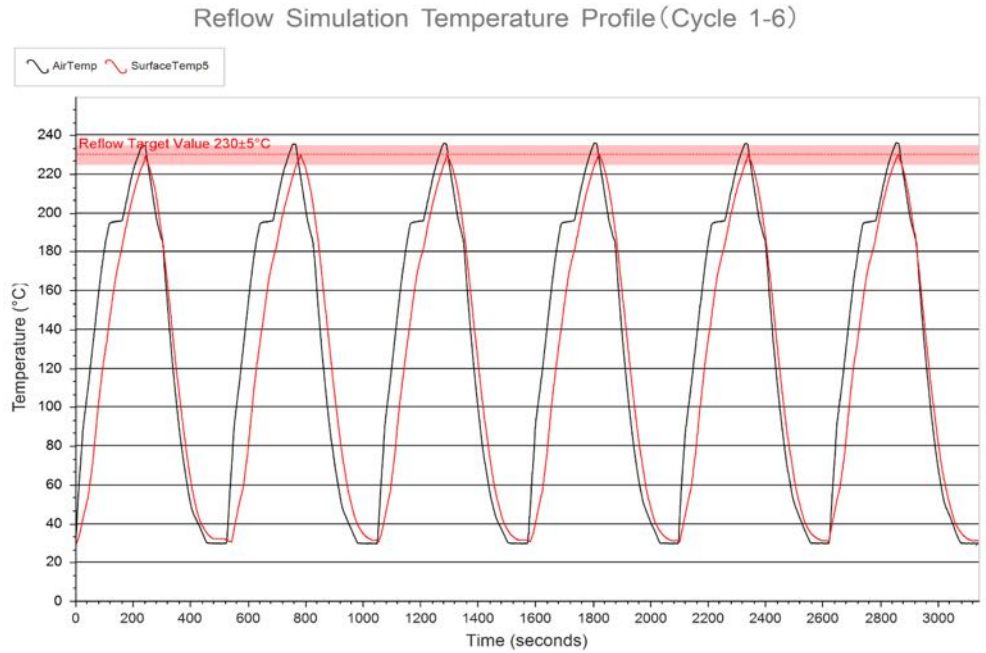
Results of Testing Program

- The Detailed Results of Testing are Contained in a 160+ Page Report
- Today I will Present a Highly Condensed Summary of the Test Results
- The Complete Test Report can be Downloaded at www.HATS-Tester.com
- The Samples were Tested in a HATS^2 Test System at Microtek Laboratories China
  - Samples were Logged In, Photographed and Labeled
  - A Small Area was Subjected to a Double TMA Test to Determine T_g (~170°C)
    - Reliability Test Temperature Range was then Set at -55°C to 160°C
  - Samples were Divided into Groups for Reliability and Robustness Exposures
  - All Samples in Test Plan were Exposed to IPC-TM-650 method 2.6.27B - 230°C 6x Cycles of Reflow Simulation in the HATS^2 Test System
  - Samples Subjected to Reflow Simulation Were Subsequently Exposed to Reliability and Robustness Testing as Detailed in the Test Plan (see Complete Test Report for Details)

IPC-TM-650 Method 2.6.27B - 230°C 6x Cycles of Reflow Simulation

All Coupons in the Test Program were Subjected to 6X Cycles of IPC-TM-650 Method 2.6.27B - 230°C Reflow Simulation In the HATS^2 Tester Prior to Reliability and Robustness Testing

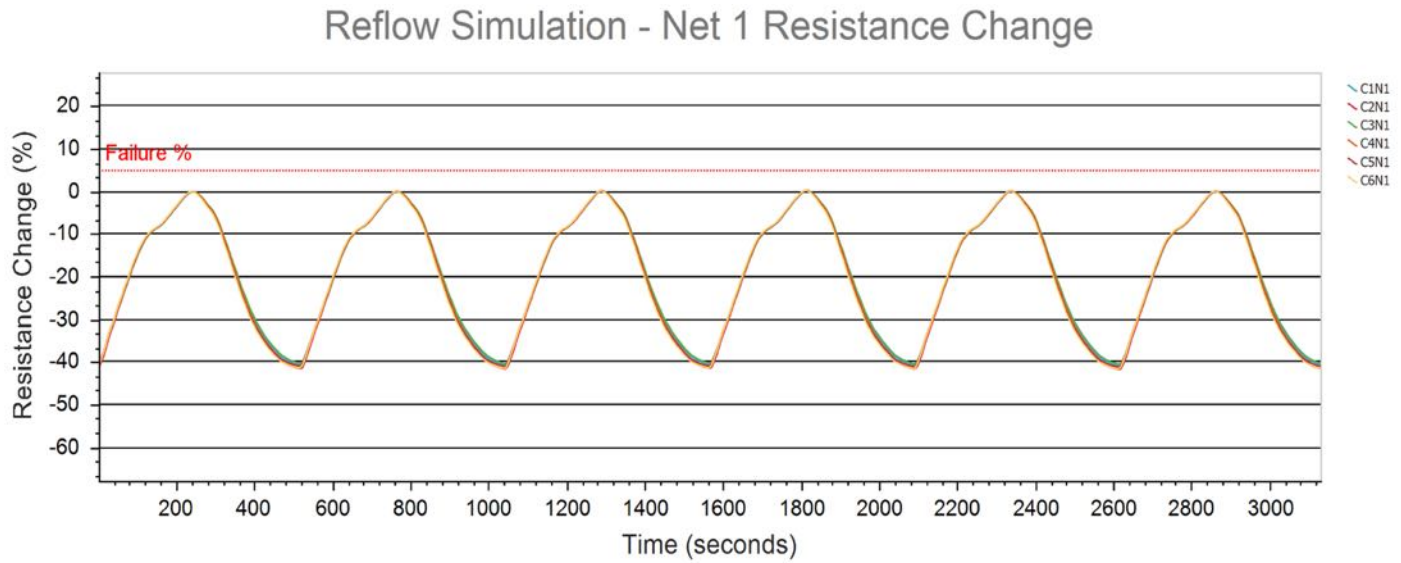




No Nets in Any of the Samples Failed During Reflow Simulation

IPC-TM-650 Method 2.6.27B - 230°C 6x Cycles of Reflow Simulation

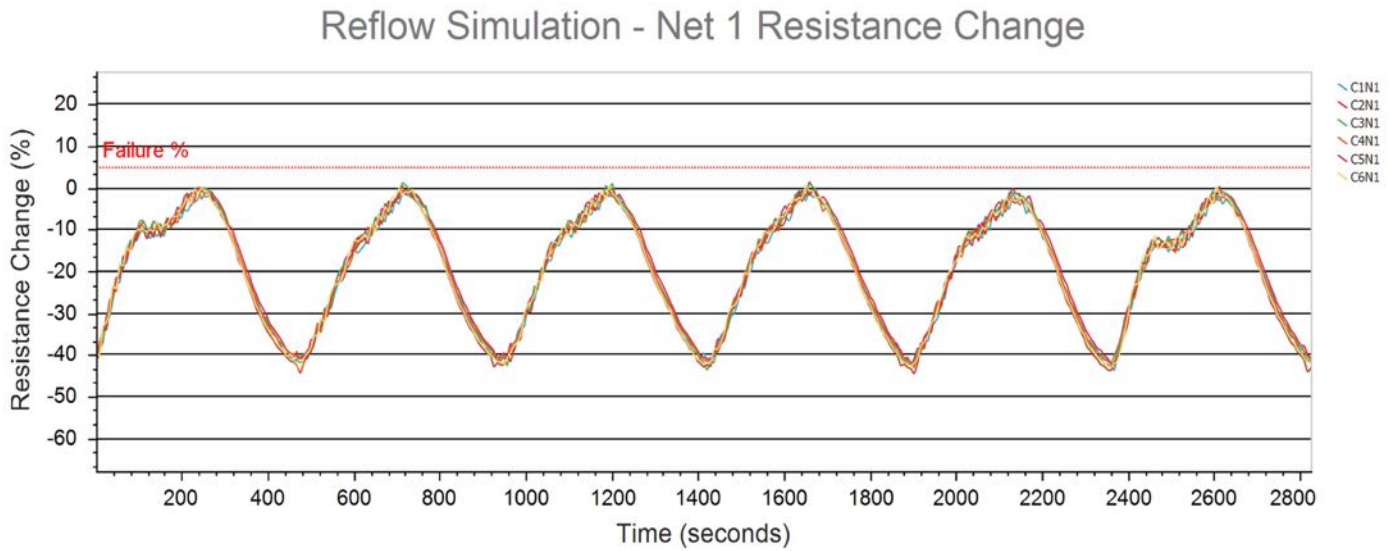
- Typical Resistance Plot of IPC “D” Coupons - 6 Coupons for Net 1
- Resistance at Reflow Peak Temperature 0.160 to .180 Ohms
- Change During 6 Cycles <0.3%



Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.16685	0.16092	0.16155	0.17019	0.17574	0.16003
Maximum Resistance % Change	0.28	0.25	0.30	0.29	0.27	0.26
Cycle Failed 5% Limit	>6	>6	>6	>6	>6	>6

IPC-TM-650 Method 2.6.27B - 230°C 6x Cycles of Reflow Simulation

- Typical Resistance Plot of HATS^2 Single Via Coupons - 6 Coupons for Net 1
- Resistance at Reflow Peak Temperature 0.0015 to .0018 Ohms
- Change During 6 Cycles <0.3%



Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.00178	0.00187	0.00184	0.00162	0.00152	0.00179
Maximum Resistance % Change	0.00	1.34	1.14	0.06	0.46	0.56
Cycle Failed 5% Limit	>6	>6	>6	>6	>6	>6

IPC “D” Coupons – Daisy Chain with Micro Vias Only (No Buried Via)

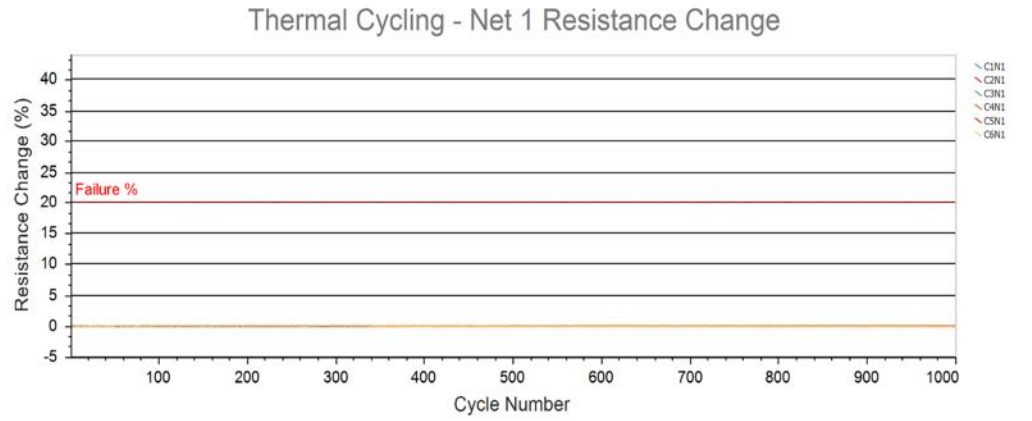
- Each IPC-2221 “D” Coupon in Groups A3-B3, A4-B4 & A5-B5 Contained 2 Daisy Chain Via Nets Consisting of 288 Micro Vias on Both the Top and Bottom of the Coupon for Each of 2 Via Structures
  - The Micro Vias on the Top and Bottom of the Coupons in these Groups were Connected in Parallel by Design Without Buried Vias Included within the Net
    - Not a Typical “D” Coupon Design
    - Sensitivity of Each Net to Via Resistance Increases is Reduced by the Parallel Design
- 3 Types of Coupons Tested with 2 Micro Via Structures Per Coupon
  - Group **“3”** (Semi-Stacked Outside, Semi-Stacked Inside)
  - Group **“4”** (Full Stacked, Full Staggered)
  - Group **“5”** (Staggered Above Buried Via, Semi-Stacked Inside Above Buried Via)

IPC "D" Coupons – Daisy Chain with Micro Vias Only (No Buried Via)

- Typical Results of Reliability and Robustness Tests – Groups A3-B3, A5-B5
  - No Discernable Difference Between the Single Stacked Inside/Outside Structures

Group A3 Net 1 after -55°C to 160°C (1000x Cycles)

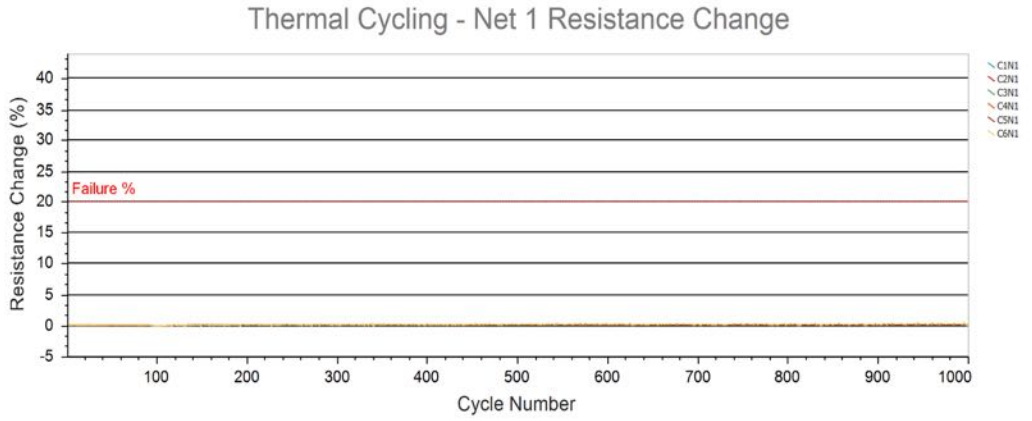
Cycle Range (°C): -55 to 160 **Quality of Cycles:** 1000 **Failure Percentage (%):** 20
Quantity of Coupons: 6 **Number of Nets:** 2 **Coupon Thickness:** 2.8 mm
Net 1 Via Type: SS Outside (Parallel) **Net 1 Quantity of Holes:** 288 **Net 1 Hole Size:** .125 mm
Net 2 Via Type: SS Inside (Parallel) **Net 2 Quantity of Holes:** 288 **Net 2 Hole Size:** .125 mm



Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.19090	0.18538	0.18567	0.19076	0.19565	0.18399
Maximum Resistance % Change	0.05	0.00	0.08	0.09	0.04	0.06
Cycle Failed 20% Limit	>1000	>1000	>1000	>1000	>1000	>1000

Group B3 Net 1 after 25°C to 150°C (500x Cycles)
Followed by Thermal Cycling 25°C to 190°C (1000x Cycles)

Cycle Range (°C): 25 to 150 / 25 - 190 **Quality of Cycles:** 500/1000 **Failure Percentage (%):** 20
Quantity of Coupons: 6 **Number of Nets:** 2 **Coupon Thickness:** 2.8 mm
Net 1 Via Type: SS Outside (Parallel) **Net 1 Quantity of Holes:** 288 **Net 1 Hole Size:** .125 mm
Net 2 Via Type: SS Inside (Parallel) **Net 2 Quantity of Holes:** 288 **Net 2 Hole Size:** .125 mm



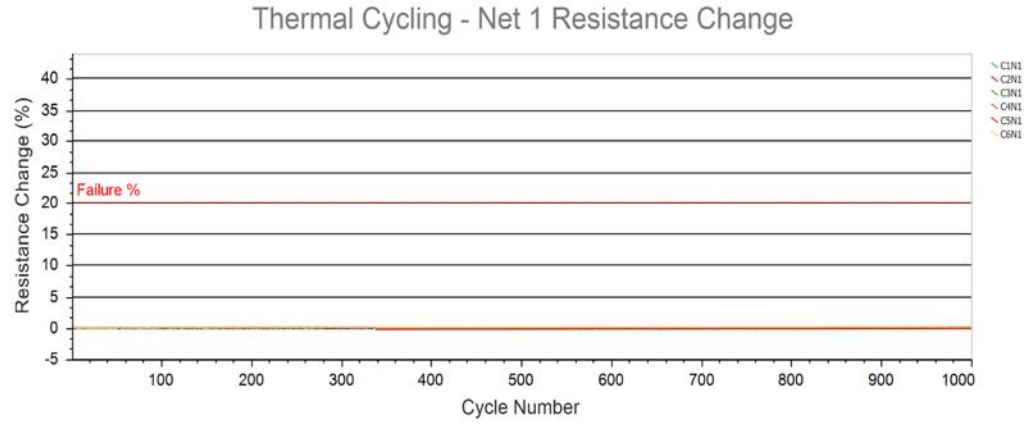
Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.20657	0.20240	0.20658	0.20071	0.22041	0.20006
Maximum Resistance % Change	0.33	0.41	0.42	0.37	0.37	0.49
Cycle Failed 20% Limit	>1000	>1000	>1000	>1000	>1000	>1000

IPC "D" Coupons – Daisy Chain with Micro Vias Only (No Buried Via)

- Typical Results of Reliability and Robustness Tests – Groups A4-B4
  - Coupon 3/6 - Net 1 (Full Stacked) Showed a Small Increase (1.5/3.5%) after Robustness Test

Group A4 Net 1 after -55°C to 160°C (1000x Cycles)

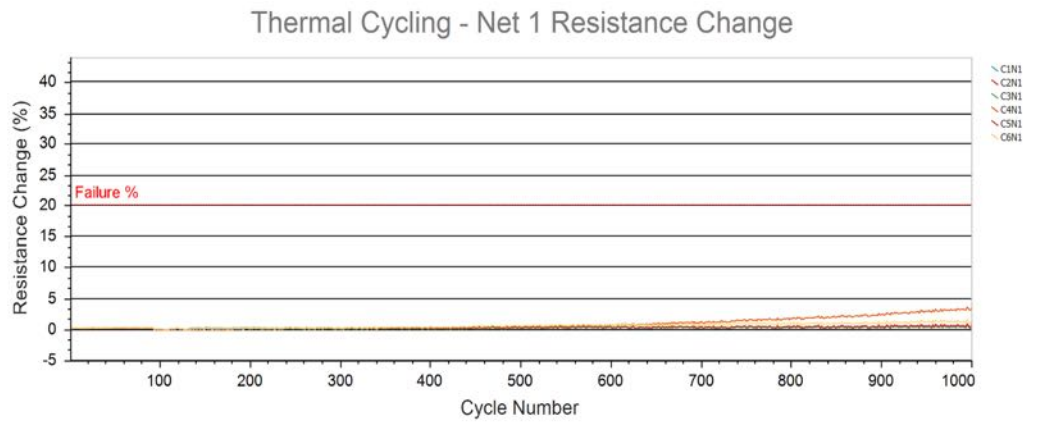
Cycle Range (°C):	-55 to 160	**Quality of Cycles:**	1000	**Failure Percentage (%):**	20
Quantity of Coupons:	6	**Number of Nets:**	2	**Coupon Thickness:**	2.8 mm
Net 1 Via Type:	Full Stacked (Parallel)	**Net 1 Quantity of Holes:**	288	**Net 1 Hole Size:**	.125 mm
Net 2 Via Type:	Full Staggered (Parallel)	**Net 2 Quantity of Holes:**	288	**Net 2 Hole Size:**	.125 mm



Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.14318	0.13763	0.13921	0.14599	0.15049	0.13701
Maximum Resistance % Change	0.20	0.12	0.14	0.10	0.11	0.23
Cycle Failed 20% Limit	>1000	>1000	>1000	>1000	>1000	>1000

Group B4 Net 1 after 25°C to 150°C (500x Cycles)
Followed by Thermal Cycling 25°C to 190°C (1000x Cycles)

Cycle Range (°C):	25 to 150 / 25 to 190	**Quality of Cycles:**	500/1000	**Failure Percentage (%):**	20
Quantity of Coupons:	6	**Number of Nets:**	2	**Coupon Thickness:**	2.8 mm
Net 1 Via Type:	Full Stacked (Parallel)	**Net 1 Quantity of Holes:**	288	**Net 1 Hole Size:**	.125 mm
Net 2 Via Type:	Full Staggered (Parallel)	**Net 2 Quantity of Holes:**	288	**Net 2 Hole Size:**	.125 mm



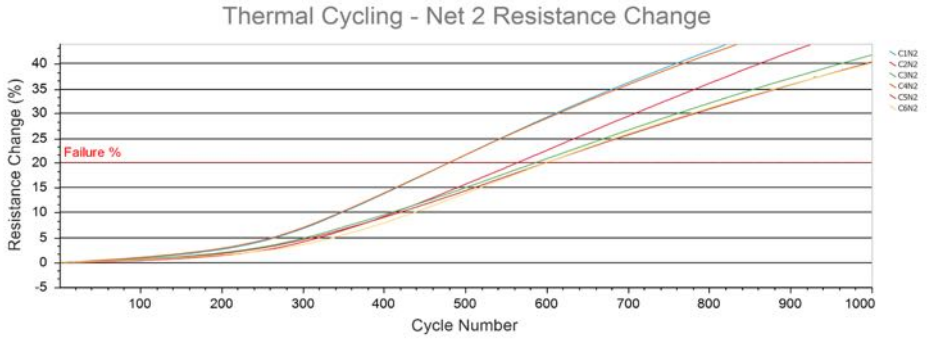
Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.16012	0.15301	0.16015	0.15333	0.15450	0.15806
Maximum Resistance % Change	0.71	0.83	0.60	3.55	0.73	1.49
Cycle Failed 20% Limit	>1000	>1000	>1000	>1000	>1000	>1000

IPC “D” Coupons – Daisy Chain with Micro & Buried Vias

- The IPC “D” Daisy Chain Coupons (Test Groups C1-D1, C2-D2) were Only Subjected to Reliability Testing (-55°C to 160°C - 1000x Cycles)
- ”Failure” Percentage was Set at 20%
- Group C1-D1 Contained 61 Buried Vias Only in Daisy Chain
- Group C2-D2 Contained 240 Single Stacked Inside, Micro Via Structures Integrated with Buried Vias in Daisy Chain
  - Net 1 was designed at 0.5 Grid
  - Net 2 was designed at 0.8 Grid
- The Results Did Not Show a Notable Difference Between the Two Grid Spacings
  - The Resistance was Higher for the 0.8 Grid Spacing as the Circuits Connecting the Via Structures were Longer Creating Increased Resistance
    - Percentage Differences Between the 2 Spacings will be Affected Differently by Similar Via Failures

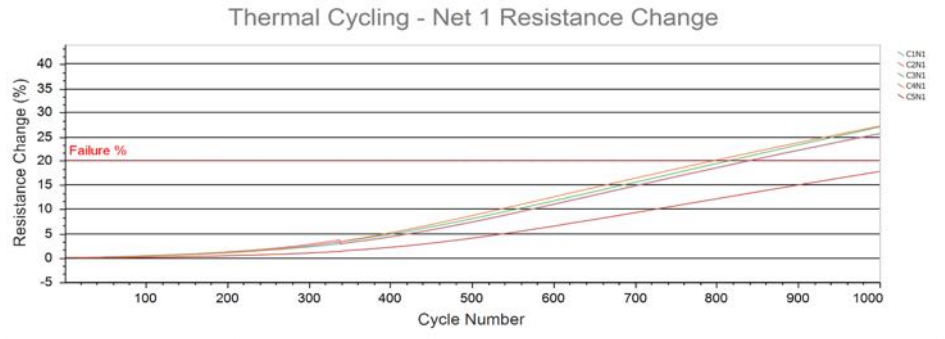
IPC “D” Coupons – Daisy Chain with Micro & Buried Vias

Group D1 Buried Via Net



Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.74950	0.74410	0.72627	0.67587	0.81358	0.67729
Maximum Resistance % Change	54.14	48.47	41.84	52.95	40.41	40.21
Cycle Failed 20% Limit	479	563	585	479	598	598

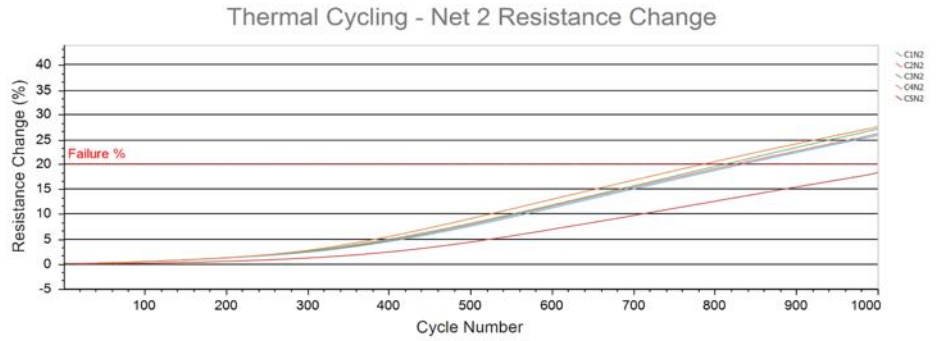
Group D2 Buried & SS Inside Via Net - 0.5 Grid



Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	1.23159	1.20632	1.30677	1.12505	1.15405	-
Maximum Resistance % Change	25.72	25.64	27.09	27.23	17.85	-
Cycle Failed 20% Limit	837	840	814	795	>1000	-

Differences in Cycles to Failure Likely Due To Differences in Daisy Chain Resistance Affecting Percentage Contribution of Via Failure(s)

Group D2 Buried & SS Inside Via Net - 0.8 Grid



Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	2.46408	2.34123	2.60184	2.27342	2.32678	-
Maximum Resistance % Change	25.83	26.23	27.17	27.58	18.36	-
Cycle Failed 20% Limit	833	825	812	785	>1000	-

HATS^2 Single Via Coupons

- Each HATS^2 Single Via Coupon contains 7 Single Via Test Nets Consisting of:
  - 1 Single Via Net on Coupon Top Consisting of 1st Via Structure
  - 1 Single Via Net on Coupon Bottom Consisting of 1st Via Structure
  - 1 Single Via Net on Coupon Top Consisting of 2nd Via Structure
  - 1 Single Via Net on Coupon Bottom Consisting of 2nd Via Structure
  - 1 Single Via Net with Top and Bottom of 1st Via Structure Connected by a Buried Via
  - 1 Single Via Net with Top and Bottom of 2nd Via Structure Connected by a Buried Via
  - 1 Single Via Net Consisting of a Buried Via
- 3 Groups of Coupons Tested with 2 Micro Via Structures per Coupon.
  - Group **“A”** (Semi-Stacked Outside, Semi-Stacked Inside)
  - Group “**B**” (Full Stacked, Full Staggered)
  - Group “**C**” (Staggered Above Buried Via, Semi-Stacked Inside Above Buried Via)

HATS^2 Single Via Coupons – Isolated Via Structures

- Reliability Testing (10°C Below T_g): (Test Groups 1**A**-2**A**, 1**B**-2**B**, 1**C**-2**C**)
  - 1000x Cycles from -55°C to 160°C
- Robustness Testing (20°C Above T_g): (Test Groups 3**A**-4**A**, 3**B**-4**B**, 3**C**-4**C**)
  - 500x Preconditioning Cycles from 25°C to 150°C
  - 1000x Cycles from 25°C to 190°C
- Micro Via Structures Without Buried Vias Showed No Failures (<2% Actual Change) During Reliability Testing and Small Changes (<8% Actual Change) During Robustness Testing
  - The Semi-Stacked Outside & Semi-Stacked Inside Structures from Group 3A/4A Showed Increases of Resistance Between 2% and 4% after Robustness Testing
  - The Full Stacked Vias Structures from Groups 3B/4B Showed Increased Percentages Over the Semi-Stacked Via Structures After Robustness Testing (4%-8% vs. 1%-2%)

HATS^2 Single Via Coupons – Buried Vias

- Nets with Buried Via Structures Showed Failures in All Nets for Both Reliability and Robustness Testing
- Nets with Micro Via Structures that Included Buried Vias Showed Testing Failures in All Nets for Both Reliability and Robustness Testing
- “Full Staggered” and “Staggered Above Buried” Via Structures Demonstrated Increased Cycles to Failure in Both Reliability and Robustness Testing over other Micro Via Structures that Included Buried Vias
- The “Staggered Above Buried” Via Structure Showed the Highest Reliability of all the Via Structures with Buried Via included

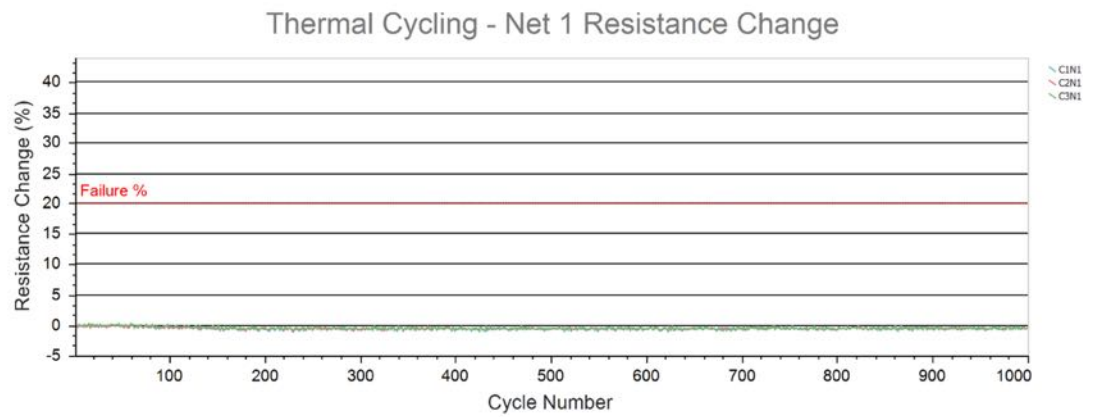
HATS^2 Single Via Coupons – Reliability Test Example

Group 2C, HATS^2 Single Via Coupons – Thermal Cycling -55°C to 160°C (1000x Cycles)

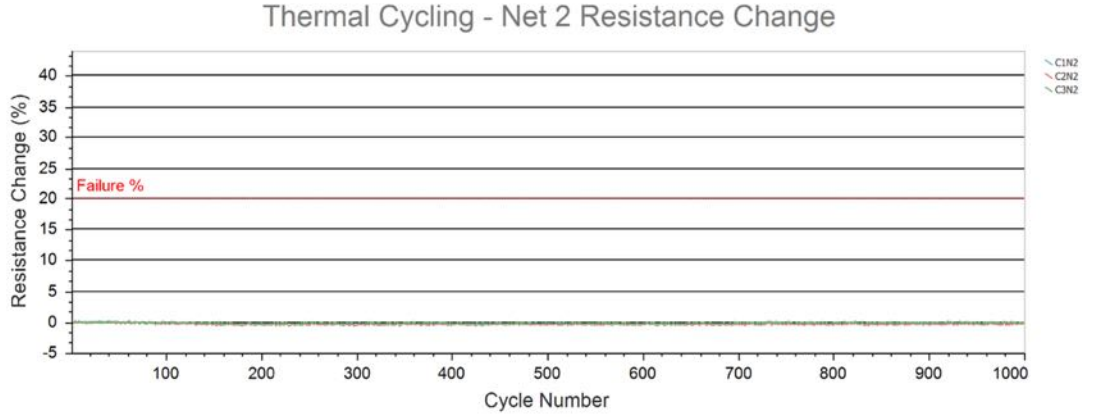
Cycle Range (°C): -55 to 160
Quantity of Coupons: 3
Net 1 Via Type: SSI Above BV MV Bottom
Net 2 Via Type: Staggered Above BV MV Bottom
Net 3 Via Type: Buried
Net 4 Via Type: SSI Above BV MV Top
Net 5 Via Type: SSI Above BV MV+BV+MV
Net 6 Via Type: Staggered Above BV MV+BV+MV
Net 7 Via Type: Staggered Above BV MV Top

Quality of Cycles: 1000
Number of Nets: 7
Net 1 Quantity of Holes: 1
Net 2 Quantity of Holes: 1
Net 3 Quantity of Holes: 1
Net 4 Quantity of Holes: 1
Net 5 Quantity of Holes: 1
Net 6 Quantity of Holes: 1
Net 7 Quantity of Holes: 1

Failure Percentage (%): 20
Coupon Thickness: 2.75 mm
Net 1 Hole Size: .125 mm
Net 2 Hole Size: .125 mm
Net 3 Hole Size: .25 mm
Net 4 Hole Size: .125 mm
Net 5 Hole Size: .125 mm
Net 6 Hole Size: .125 mm
Net 7 Hole Size: .125 mm



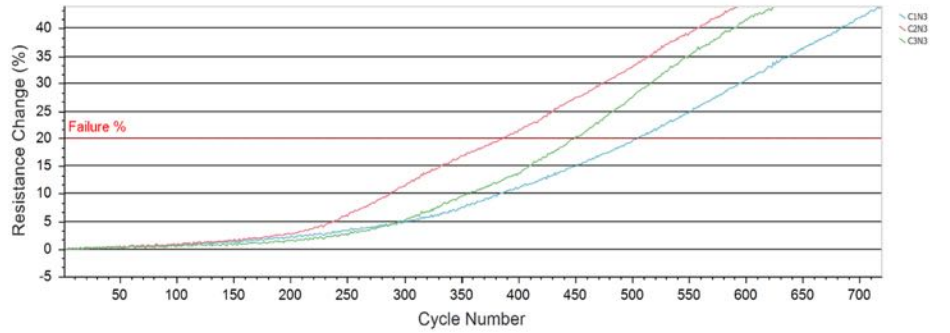
Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.00193	0.00221	0.00194	-	-	-
Maximum Resistance % Change	0.23	0.10	0.29	-	-	-
Cycle Failed 20% Limit	>1000	>1000	>1000	-	-	-



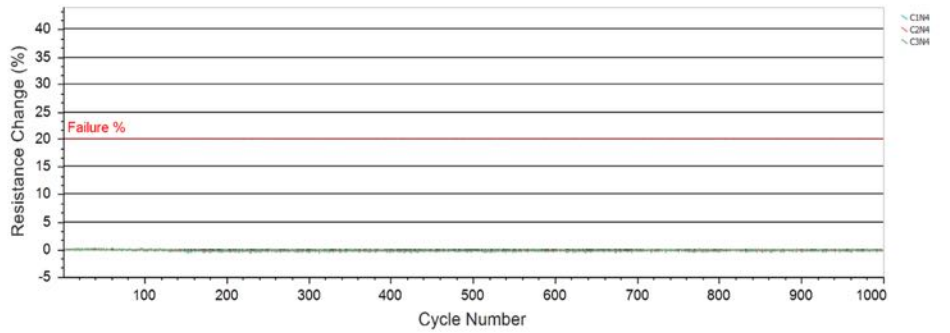
Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.00286	0.00315	0.00273	-	-	-
Maximum Resistance % Change	0.21	0.09	0.18	-	-	-
Cycle Failed 20% Limit	>1000	>1000	>1000	-	-	-

Results: HATS^2 Single Via Coupons – Reliability Test Example

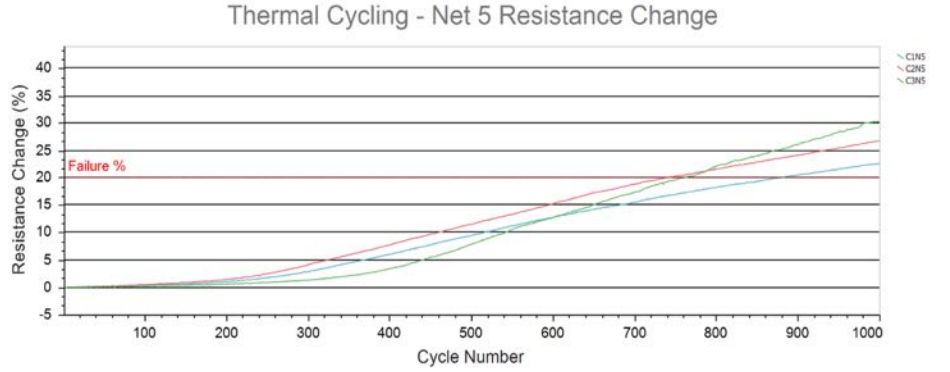
Group 2C, HATS^2 Single Via Coupons – Thermal Cycling -55°C to 160°C (1000x Cycles)



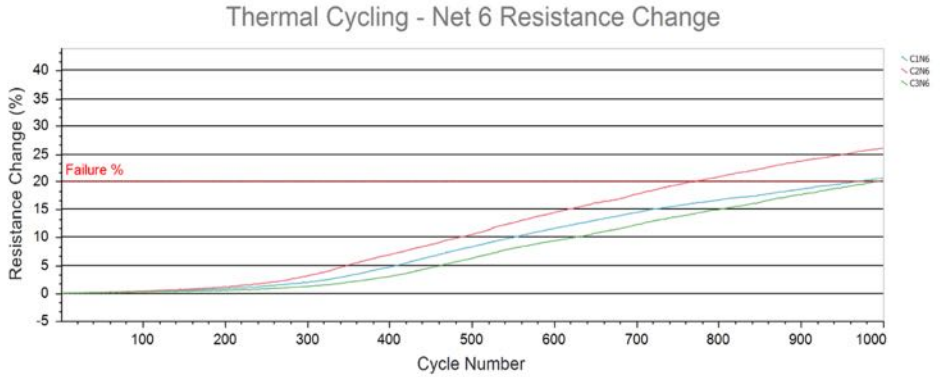
Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.00300	0.00318	0.00285	-	-	-
Maximum Resistance % Change	67.94	89.44	86.91	-	-	-
Cycle Failed 20% Limit	505	386	450	-	-	-



Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.00269	0.00297	0.00307	-	-	-
Maximum Resistance % Change	0.19	0.23	0.19	-	-	-
Cycle Failed 20% Limit	>1000	>1000	>1000	-	-	-



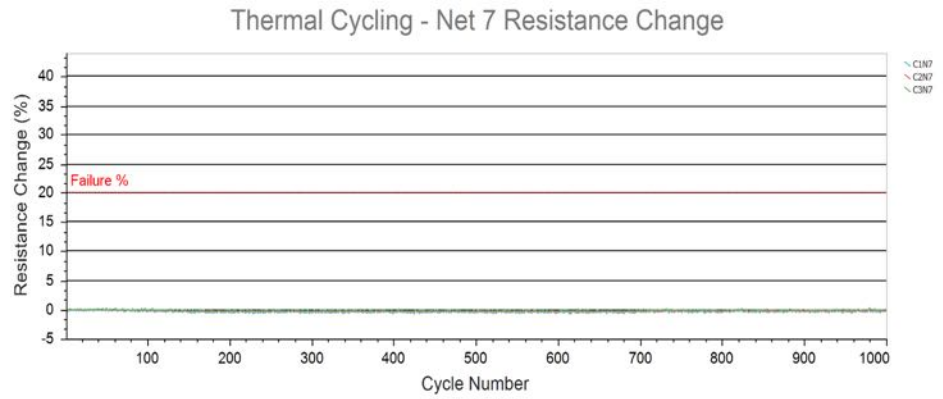
Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.00846	0.00901	0.00845	-	-	-
Maximum Resistance % Change	22.63	26.74	30.32	-	-	-
Cycle Failed 20% Limit	878	740	762	-	-	-



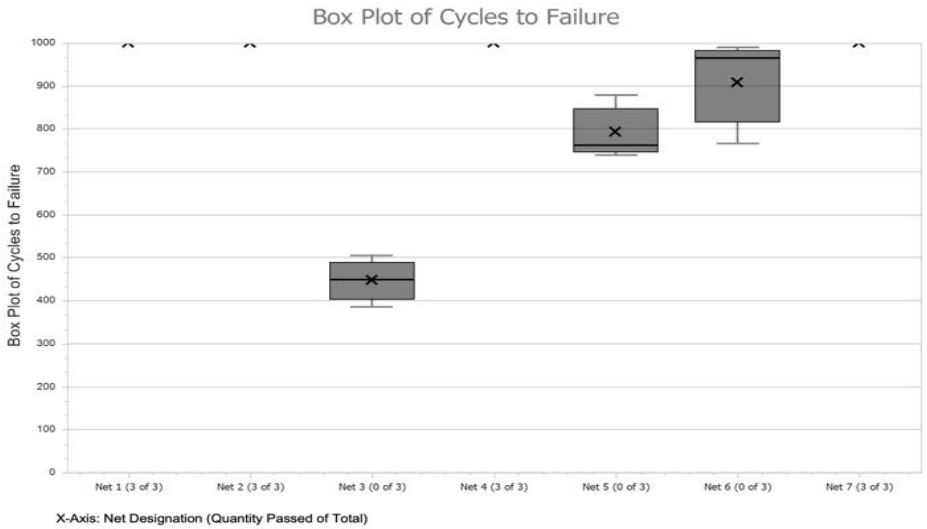
Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.01016	0.01076	0.00994	-	-	-
Maximum Resistance % Change	20.74	26.08	20.27	-	-	-
Cycle Failed 20% Limit	965	766	989	-	-	-

HATS^2 Single Via Coupons – Reliability Test Example

Group 2C, HATS^2 Single Via Coupons – Thermal Cycling -55°C to 160°C (1000x Cycles)



Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.00283	0.00309	0.00280	-	-	-
Maximum Resistance % Change	0.10	0.16	0.26	-	-	-
Cycle Failed 20% Limit	>1000	>1000	>1000	-	-	-



- Net 5 (Staggered Above Buried Via) & Net 6 (Single Staggered Inside Above Buried Via) Lasted Longer than other Micro Via Structures Containing Buried Vias
- Net 6 (Single Staggered Inside Above Buried Via) Lasted Longest of Micro Via Structures that Included Buried Vias Although the Slightly Higher Via Resistance (~0.0001 Ohms at Peak) of Net 6 May Have Influenced the Contribution of the Failure to the Resistance Percentage
- Lower Cycles to Failure of Net 3 (Buried Via) Without Micro Via Structures is Expected as Net 5 & 6 Contain The Additional Resistance of Micro Via Structures which Decreases the Percentage Effect of the Resistance Caused by Buried Via Failure

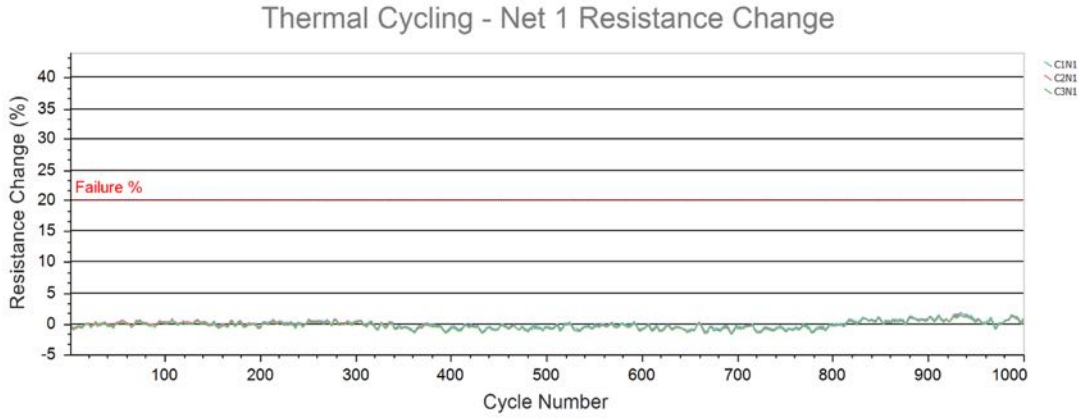
HATS^2 Single Via Coupons – Robustness Test Example

Group 4C, HATS^2 Single Via Coupons – Thermal Cycling Preconditioning, 25°C to 150°C (500x Cycles); Followed by Thermal Cycling 25°C to 190°C (1000x Cycles)

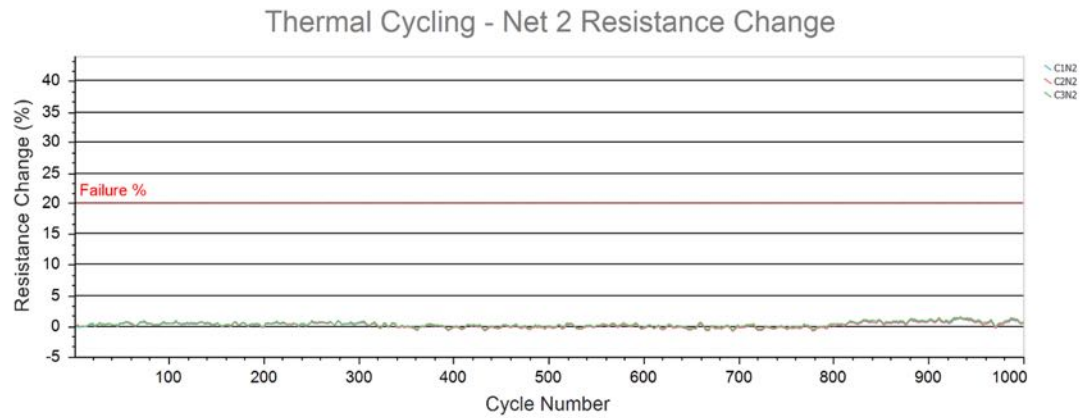
Cycle Range (°C): 25 to 150 / 25 to 190
Quantity of Coupons: 3
Net 1 Via Type: SSI Above BV MV Bottom
Net 2 Via Type: Staggered Above BV MV Bottom
Net 3 Via Type: Buried
Net 4 Via Type: SSI Above BV MV Top
Net 5 Via Type: SSI Above BV MV+BV+MV
Net 6 Via Type: Staggered Above BV MV+BV+MV
Net 7 Via Type: Staggered Above BV MV Top

Quality of Cycles: 500/1000
Number of Nets: 7
Net 1 Quantity of Holes: 1
Net 2 Quantity of Holes: 1
Net 3 Quantity of Holes: 1
Net 4 Quantity of Holes: 1
Net 5 Quantity of Holes: 1
Net 6 Quantity of Holes: 1
Net 7 Quantity of Holes: 1

Failure Percentage (%): 20
Coupon Thickness: 2.75 mm
Net 1 Hole Size: .125 mm
Net 2 Hole Size: .125 mm
Net 3 Hole Size: .25 mm
Net 4 Hole Size: .125 mm
Net 5 Hole Size: .125 mm
Net 6 Hole Size: .125 mm
Net 7 Hole Size: .125 mm



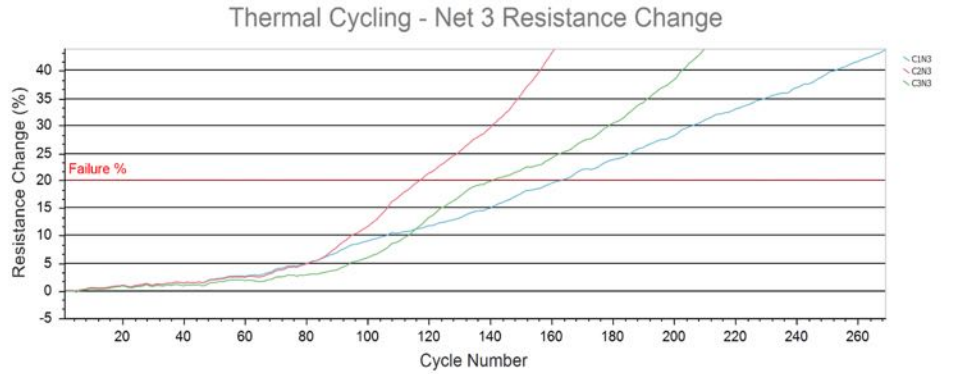
Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.00214	0.00204	0.00218	-	-	-
Maximum Resistance % Change	1.79	1.46	1.37	-	-	-
Cycle Failed 20% Limit	>1000	>1000	>1000	-	-	-



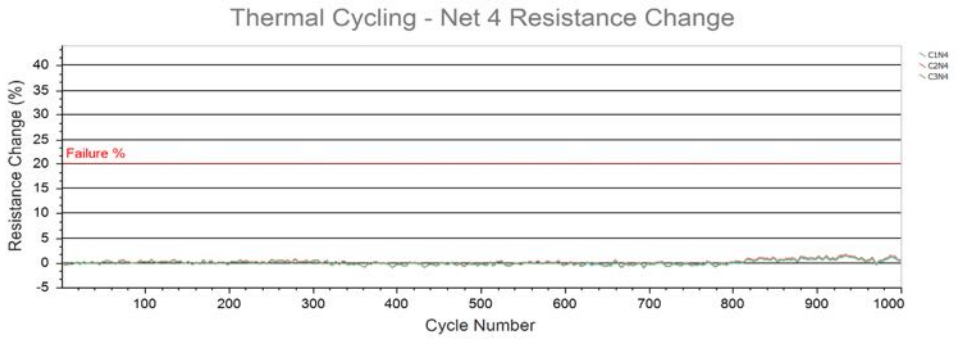
Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.00329	0.00299	0.00314	-	-	-
Maximum Resistance % Change	1.25	1.32	1.49	-	-	-
Cycle Failed 20% Limit	>1000	>1000	>1000	-	-	-

HATS^2 Single Via Coupons – Robustness Test Example

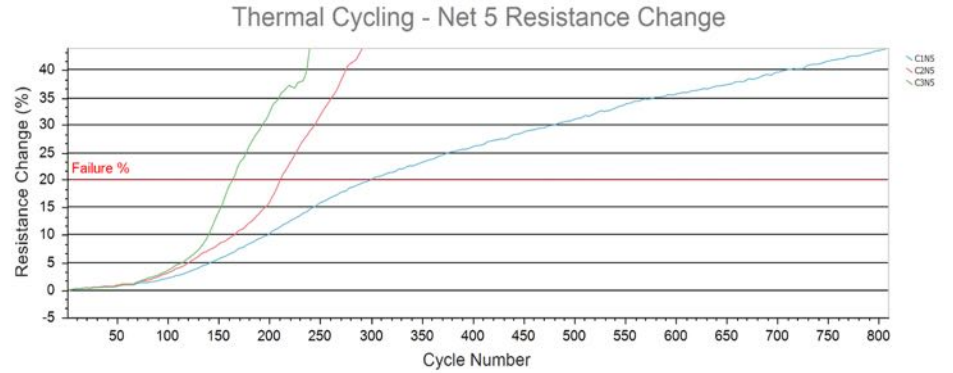
Group 4C, HATS^2 Single Via Coupons – Thermal Cycling Preconditioning, 25°C to 150°C (500x Cycles); Followed by Thermal Cycling 25°C to 190°C (1000x Cycles)



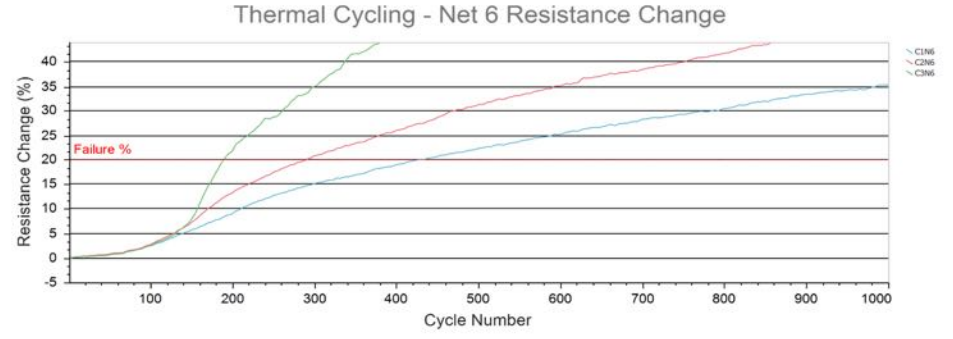
Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.00346	0.00324	0.00301	-	-	-
Maximum Resistance % Change	131.72	418.53	287.45	-	-	-
Cycle Failed 20% Limit	162	117	141	-	-	-



Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.00284	0.00264	0.00294	-	-	-
Maximum Resistance % Change	1.41	1.73	1.42	-	-	-
Cycle Failed 20% Limit	>1000	>1000	>1000	-	-	-



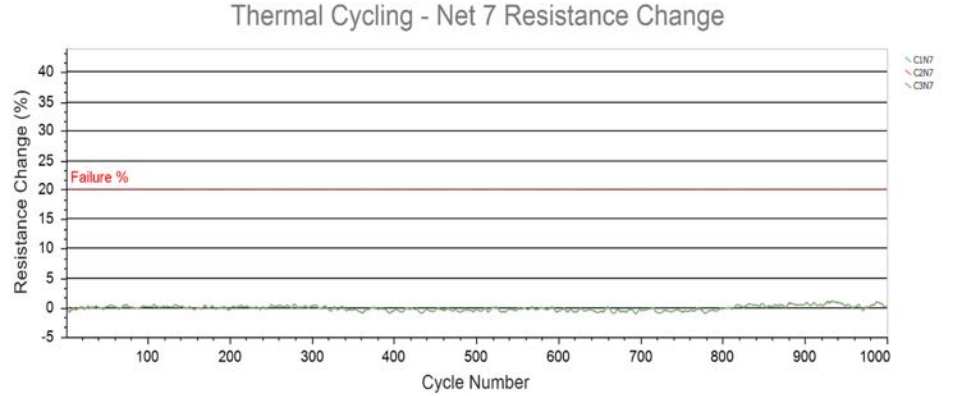
Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.00916	0.00861	0.00879	-	-	-
Maximum Resistance % Change	50.29	119.15	90.69	-	-	-
Cycle Failed 20% Limit	300	211	164	-	-	-



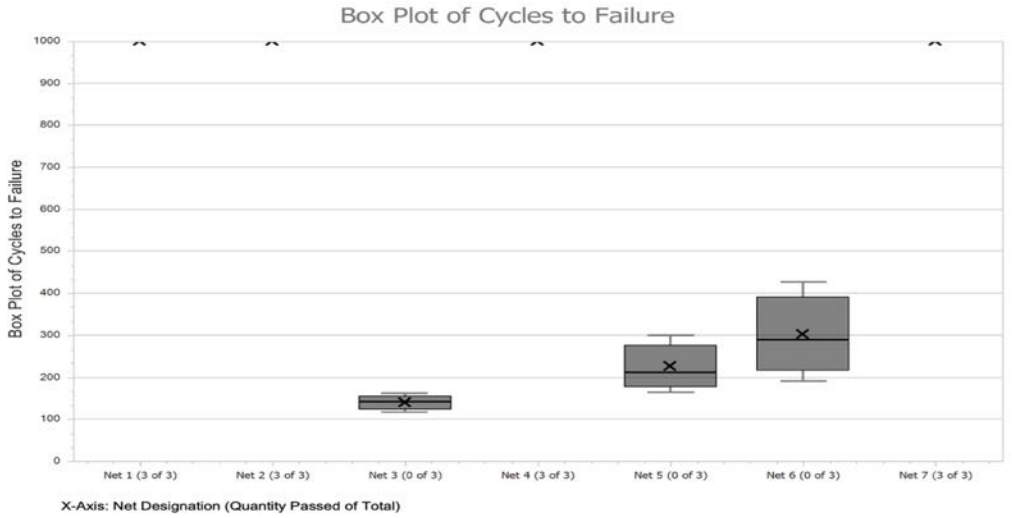
Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.01137	0.01067	0.01081	-	-	-
Maximum Resistance % Change	35.41	50.03	72.03	-	-	-
Cycle Failed 20% Limit	427	290	190	-	-	-

HATS^2 Single Via Coupons – Robustness Test Example

Group 4C, HATS^2 Single Via Coupons – Thermal Cycling Preconditioning, 25°C to 150°C (500x Cycles);
Followed by Thermal Cycling 25°C to 190°C (1000x Cycles)



Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.00306	0.00307	0.00307	-	-	-
Maximum Resistance % Change	1.08	1.03	1.12	-	-	-
Cycle Failed 20% Limit	>1000	>1000	>1000	-	-	-



- Net 5 (Staggered Above Buried Via) & Net 6 (Single Staggered Inside Above Buried Via) Lasted Longer than other Micro Via Structures Containing Buried Vias
- Net 6 (Single Staggered Inside Above Buried Via) Lasted Longest of Micro Via Structures that Included Buried Vias
- Lower Cycles to Failure of Net 3 (Buried Via) Without Micro Via Structures is Expected as Net 5 & 6 Contain The Additional Resistance of Micro Via Structures which Decreases the Percentage Effect of the Resistance Caused by Buried Via Failure

Comparison of 1s to 7s Data Capture Interval During Reflow Simulation

- IPC-TM-650 Method 2.6.27B Currently Requires Data to be Acquired at 1-Second Intervals
- Periodic Monitoring is Intended to Capture Failure Events at or Near Peak Temperature
  - Via Structures Can Fail at or Near Peak Temperature Then Reconnect as They Cool
- How Long of a Delay Between Data Points is Acceptable
  - 1s, 0.5s, 2s, 5s, 7s, 10s….. What's the Right Number?
  - 1s was Chosen Using Data and Capability from 1 System During Test Method Development
  - The HATS^2 System Became Available Late in the Method Development Process
    - We Submitted Data with 10-Second Data Acquisition Width and the Majority of Committee Members Voted to Keep 1-Second as the Test Method Requirement Based Upon Their Experience
  - Testing on the HATS^2 System has Shown that a 7-Second Data Acquisition Width is Adequate to Capture Failures at or Near Peak Reflow Temperature
    - 3-4 Data Points are Captured Within 5°C of Peak Reflow Temperature

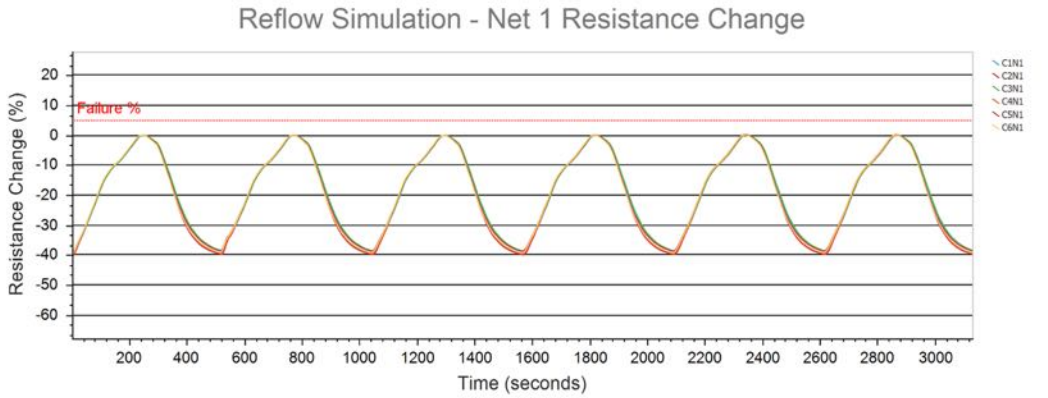
Comparison of 1s to 7s Data Capture Interval During Reflow Simulation

- Why Does a 7-Second Data Capture Interval Make Sense?
  - Capacity of Samples for Simultaneous Testing
    - Measuring 24x IPC “D” Coupons Simultaneously Requires a Measurement System Capable of >50 Measurements / Second and can only be Accomplished with Digital Switches
    - Mechanical Switching Systems are Capable of Facillitating Accurate Low Resistance Values at ~20 Measurements Per Second (10x IPC “D” Coupons at One Time)
    - 7 Second Data Capture Intervals Would Allow Systems with High Current Mechanical Switching to Test as Many as 65 IPC “D” Coupons Simultaneously
  - Measurement Current – Low Resistance
    - Digital Switching Systems are Capable of Very Fast Switching but Must Limit the Current of Measurement to <=10mA which in Turn Limits the Minimum Resolution of Resistance Measured to the 10s of Milliohms
    - The Low Resistances of Single Via Testing (0.5 to 3 Milliohms) Require High Current in Order to Obtain Precise and Accurate Measurements
      - 0.1A for 0.010 to 0.100 ohm
      - 1A for resistances below 0.010 ohm
    - Mechanical Switching Systems are Necessary for Measurement Current Above 10mA

Comparison of 1s to 7s Data Capture Interval During Reflow Simulation

IPC 230°C Reflow Simulation Testing on “D” coupons

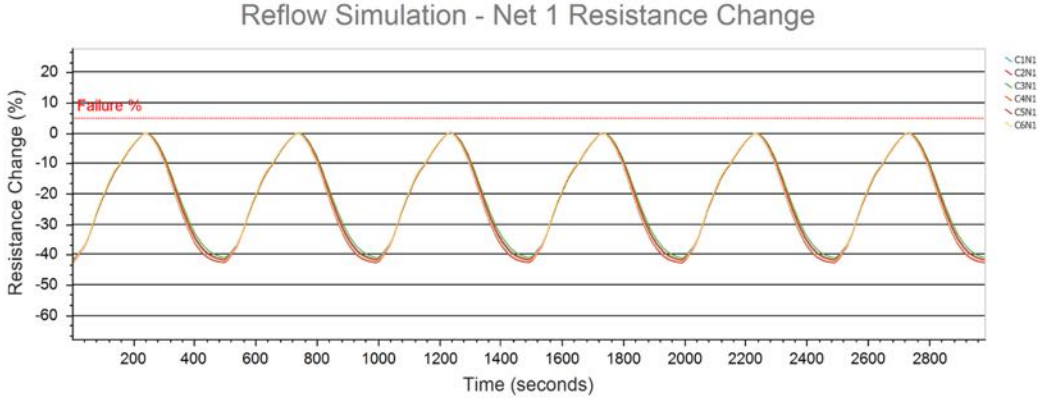
7 Second Between Measurements (Group C1)



Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.24124	0.24260	0.27108	0.24459	0.23265	0.23811
Maximum Resistance % Change	0.12	0.12	0.04	0.06	0.22	0.06
Cycle Failed 5% Limit	>6	>6	>6	>6	>6	>6

4 Measurements within 5°C of Peak Temperature

1 Seconds Between Measurements (Group D1)



Coupon Number	1	2	3	4	5	6
Reference Resistance (Ohms)	0.24991	0.24259	0.23995	0.22123	0.24740	0.24548
Maximum Resistance % Change	0.22	0.21	0.26	0.20	0.21	0.22
Cycle Failed 5% Limit	>6	>6	>6	>6	>6	>6

29 Measurements within 5°C of Peak Temperature

Acknowledgements

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